The Ship Timbers from the Islamic Site of al-Balid: A Case Study of Sewn-Plank Technology in the Indian Ocean

Submitted by **Alessandro Ghidoni** to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Arab and Islamic Studies in December 2020.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature: ………………………………………………………………..

Abstract

The sewn-plank ships that sailed the Indian Ocean during the medieval Islamic period (10th-15th centuries) carried people, goods, and ideas between East Africa, Arabia, India, and China. Yet, despite the crucial role such vessels played in the history of this remarkably disparate and expansive region, we know relatively little about them. To date, the archaeological work related to sewn boats in the region has been relatively limited, while the few textual references to sewn-plank vessels generally lack crucial details regarding their design, structure, and operation. Thus, archaeological evidence such as the ship timbers recently discovered at al-Balid, southern Oman, provides us with an invaluable opportunity to deepen our understanding of these watercraft and the material culture they represent. In this thesis, I undertake the most comprehensive and interdisciplinary analysis of Islamic era sewn-boat technology in the Indian Ocean to date, with a particular emphasis on the sewn-planks of al-Balid

This study provides a technical analysis of the al-Balid timbers in a comparative context. First, the pieces are examined from a material perspective by analyzing the technical details of each plank and identifying their material composition. Second, the timbers are then compared with extant textual, iconographic, ethnographic, archaeological, and experimental archaeological evidence. Finally, this study contextualizes the al-Balid timbers within the broader material networks in the Indian Ocean during the medieval Islamic period. In doing so, it increases our knowledge of Indian Ocean maritime technology and of the people who built these historically important vessels.

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Along with this main thesis document there is also a folder containing the orthophotos of the timbers based on the photogrammetry surveys conducted by the author between 2017 and 2019.

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Abbreviations

Weight and Measures

cm	centimetre(s)
g	gram(s)
kg	kilogramme(s)
km	kilometre(s)
m	metre(s)

Literary

AH	*Anno Hegirae* (Hijri Year)
BCE	Before Common Era
c.	circa
CE	Common Era
cf.	*confer/conferatur* (compare)
d.	died in
d.c.	died circa
E	East
ed(s)	editor(s); edited by
et al.	*et alii* (and others)
fl.	*flourit* (flourished)
N	North
NE	North east
NMoQ	National Museum of Qatar

NW	North west
pl.	plural
QM	Qatar Museums
sing.	singular
S	South
SE	South east
trans.	translated by; translator
vol(s).	volume(s)
W	West

Linguistic

Ar.	Arabic

Notes on transliteration

For the transliteration of Arabic text, in this study, I have adopted the Library of Congress Arabic Transliteration System, which is outlined below. For places names, such as al-Balid and Dhofar, I have retained their common English spellings according to gazetteer to facilitate the readability.

Arabic Transliteration

Consonants

ء	ʾ	س	s	ل	l
ب	b	ش	sh	م	m
ت	t	ص	ṣ	ن	n
ث	th	ض	ḍ	ه	h
ج	j	ط	ṭ	و	w
ح	ḥ	ظ	ẓ	ي	y
خ	kh	ع	ʿ		
د	d	غ	gh		
ذ	dh	ف	f		
ر	r	ق	q		
ز	z	ك	k		

Vowels

Long vowels		Short vowels	
ا	ā	ـَ	a
و	ū	ـُ	u
يّ	ī	ـِ	i
	õ		o
	ē		e

Doubled

شَّ iyy (final form =/ī/)

وُّ uww (final form =/ū/

Diphthongs

َيْ ay

َوْ aw

1 Introduction

Strings, cordage, or something that ties things together is such a fundamental part of everyday life that it is completely taken for granted. (Hardy 2007: 271)

Making cordage is one of the greatest and earliest achievements of modern human development.[1] Archaeological evidence, both direct and indirect, suggests that people have exploited fibre or animal fur to make strings since the beginning of the Upper Palaeolithic (Adovasio et al. 1996: 531; Stannard and Langley 2020: 2).

Plant technology involving the twisting of fibres to make cordage produced the “unseen weapons that allowed the human race to conquer the earth” (Barber 1994: 45), enabling people to tie things together and boosting the development of composite technology (Hardy 2008: 272).

Strings and cordage have played a crucial role in many maritime activities, including fishing, boatbuilding and seafaring, and would have been essential in early migrations and the colonisation of islands (Balme 2013: 72; O’Connor et al. 2011). Ancient fishermen and colonisers could not have assembled and held together the buoyant elements, such as reeds, bamboo or wooden logs, that were required to make rafts without some sort of string or cordage. When maritime communities developed more complex vessels, they would have transferred this technology to more complex boats and ships, tying their planks together with cordage of various materials. Hence, it is

[1] The discovery of perforated objects dated to 300,000 BP might suggest the use of strings associated with Neanderthals (Bednarik 1995; Hardy et al. 2013).

no surprise that sewn-plank construction has been practiced throughout history and is found worldwide.

Sewn technology was predominant in the western Indian Ocean during the medieval period (Agius 2007a: 161; Bowen 1952: 202; Casson 1989: 63; Hornell 1970 (1946): 234; Hourani 1963: 92–97; Johnstone and Muir 1962: 59; McGrail 2001: 71–72; Mookerji 1912: 31; Moreland 1939a: 76–74, Prins 1986: 66–67). Sewn-plank ships that sailed in this region during the Premodern Islamic period (622–1500) were agents of trade, religion and culture. They connected the Indian Ocean and littoral Islamic world in significant ways, carrying people, goods and ideas back and forth between East Africa and China. Yet relatively little is known about them. The few textual references to sewn-plank boats in the region, for the most part, lack any technical detail or specificity. Instead, archaeological evidence provides the best information for us to deepen our understanding of these ships and the material culture they represent. This thesis undertakes a comprehensive and interdisciplinary analysis of Islamic-era sewn-boat technology in the Indian Ocean to date, with a particular emphasis on a collection of sewn planks from al-Balid, Oman (Belfioretti and Vosmer 2010; Pavan et al 2018: 226–229; Pavan et al. 2020: 190–194).

In this thesis, I provide a technical analysis of the al-Balid timbers within a comparative context. I have approached the study of these maritime findings from a material perspective, analysing the technical details of each plank and identifying their material composition. To achieve this goal I have employed modern documentation techniques such as photogrammetry to create detailed technical drawings of each timber. These timbers are then compared with the broader textual, iconographic, ethnographic, archaeological and experimental archaeological evidence of sewn boats in the region.

Collectively, this process contextualises these timbers within broader material networks in the Indian Ocean during the Premodern Islamic period.

1.1 Aims of the Thesis and Research Questions

This study contributes to the knowledge of maritime technology in the Indian Ocean in the Premodern Islamic period by providing a detailed and comparative analysis of sewn-plank ship timbers discovered on the Islamic site of al-Balid with relevant archaeological, textual, iconographic and ethnographic data. Collectively, this places these timbers within the broader picture of material networks in the Indian Ocean during this period and deepens our understanding of the fundamental seaborne/maritime connections that the Islamic world enjoyed with the rest of the Indian Ocean.

The main focus of the research is, therefore, to provide the most comprehensive interpretation for this set of evidence, and to achieve this purpose I formulated two leading research questions, which will be addressed throughout the thesis:

1. What can the al-Balid ship timbers tell us about the nature and development of sewn construction technology in the western Indian Ocean?
2. What can the materials of the al-Balid assemblage tell us about broader material networks in the western Indian Ocean?

In order to answer my leading questions, I formulated a series of subordinate questions:

a. Do the timbers indicate a single boatbuilding method or do they show any differences in technical patterns?

b. Are any technical features and changes over time evident through a comparative chronological analysis of the timbers?

c. What can the comparison of the al-Balid timbers with other timbers of the western Indian Ocean tell us about the emergence of a wider regional tradition?

d. What are the boatbuilding materials used in the Indian Ocean during the medieval period, and where did they come from?

1.2 Theoretical Framework

My analysis of the al-Balid timbers relies on a multidisciplinary approach. Although the emphasis is on maritime archaeology, this discipline is used in conjunction with textual, iconographic and ethnographic data.

The study of the material culture is the main focus of my research. Keddie (1992) remarks on the importance of this approach to deepen our knowledge about the cultural, social and political development of Middle Eastern (Islamic) societies. Gould (2011: 9) reminds us of the importance of adopting a rigorous scientific method to make archaeology a suitable discipline for the study of the human past.

Studying material culture reveals the relationship between objects and the socio-economic factors influencing the societies that produced them, providing different views with the potential to enable “the silent masses to speak” (Keddie 1992: 34). These silent masses are the people that left very little written evidence (Keddie 1992: 55) and this is particularly true in the case of Indian Ocean boatbuilding and seafaring in the Middle Islamic period, where textual documents are often vague in regard to many aspects of watercraft techniques, materials and technology.

1.2.1 The importance of Direct Observation and Involvement

Between 2008 and 2019, I was privileged to work on several ship reconstruction projects and to conduct maritime ethnographic research in the western Indian Ocean, including the documentation of vernacular vessels from Oman, the UAE, Iran, Zanzibar and southern India (Cooper et al. 2020; Blue et al. 2014; Weismann et al. 2014; Cooper et al. 2021 forthcoming).

Some of the experimental archaeology projects involved the reconstruction of sewn-plank vessels dating from the 9th to the 20th century. These reconstructions, which will be discussed more deeply in Chapter 2, were the *Jewel of Muscat* (Vosmer et al. 2011; Vosmer 2010), the al-Hariri Boat (Staples 2019), and the *Beden Seyad* (Ghidoni 2019). Each vessel was built and sewn entirely with traditional materials and tools by skilled sewn-boat shipwrights from Kerala, southern India.

My role in these projects consisted of documenting every aspect of a given vessel's construction. This involved photographing and measuring each component, precisely recording the various boatbuilding processes and techniques, and conducting detailed interviews with Omani and Indian boatbuilders.

These experiences provided me with the essential knowledge and technical skills to undertake this study. Additionally, they made me familiar with the traditional tools, materials, and techniques used in building sewn vessels, and with the most common technical challenges encountered in their construction. Observing the activities of shipwrights and ropeworkers trained my eyes to recognize the subtle details of the al-

Balid timbers and helped me to posit reasonable interpretations of the features I observed. But my experience is not limited to constructing sewn boats. In 2010 I sailed aboard the *Jewel of Muscat* on a five-month voyage that gave me a much deeper understanding of the advantages and disadvantages of sewn-plank construction technology. Therefore, the many comments about technical details that I express in this thesis are rooted not just in my careful examination of the al-Balid timbers, but in my long and intimate association with sewn-plank vessels.

Finally, I believe that direct engagement with boatbuilders and their activities is crucial if we wish to gain a more accurate and detailed understanding of the design, construction, and operation of traditional sewn-plank vessels, and that maritime archaeologists should be encouraged to seek out this direct engagement whenever possible.

1.2.2 The Study of Boats and Ships

Why should we study sewn ships? One fundamental reason is their crucial role in the economic, social and cultural history of the Indian Ocean. Ships carried cargoes and people along numerous maritime routes intertwining throughout the Indian Ocean, bridging the various communities located along its coasts.

Boats and ships also prove to be perfect candidates for revealing technological aspects of a society. Muckelroy underlines this (1978: 3) in his book *Maritime Archaeology* by stating that “in any pre-industrial society, from the upper palaeolithic to the nineteenth century A.D., a boat or (later) a ship was the largest and most complex machine produced.” Muckelroy warns us that boats are just elaborate artefacts, which should not be studied for themselves but rather because they retain the imprint of the people who made them and their activities on the sea (1978: 4).

Because of their complexity, boats are also good cultural indicators (Hasslöf et al. 1972: 164; Prins 1986: 14-15), and the study of their technical details has the potential to provide insights into the "mind of *homo faber*" more than other archaeological artefacts (Maarleveld 1995: 4). Shipwrecks and maritime assemblages yield information about their original shape and size, how shipwrights built them and with what materials, how sailors propelled and steered them, what cargo and passengers they carried, their functions and economic activities and, lastly, crews and their belongings.

1.2.3 The Study of Ship timbers

The study of the collections of timbers from al-Balid might raise a few questions regarding reliability since these pieces of evidence are very different from those of a shipwreck. The main difference is that these timbers are only small fragments of the hulls of numerous ships, which are scattered around in a secondary and terrestrial context.

Some might argue that a secondary context is not as significant as that of a shipwreck, but various studies of ship timbers have shown their potential in providing cultural information (Belfioretti and Vosmer 2010; Creasman 2010; 2014; Haldane 1988; Pomey 2012; Vosmer 2017: 200; Ward 2000: 107-128; Ward and Zazzaro 2010). One of the most significant advantages of shipwrecks is that they represent a time capsule (Gould 2011: 12) and thus the association of their assemblage is the consequence of the same event (Gibbins 1990: 377). The al-Balid timbers are precisely the opposite, having been removed from their original context and recycled multiple times. Moreover, they belonged to the hulls of different vessels that sailed in different periods, stretching over almost five hundred years. This represents an advantage because these pieces of material culture allow both synchronic and diachronic analysis. These timbers can hardly indicate how the vessels looked, and they provide limited information regarding the cargo or the route of the ships. However, by displaying a variety of techniques and materials, they provide invaluable information about different sewn boats and boatbuilding technologies over a considerable period of time, allowing speculation about changing trends and cultural influences in construction techniques and technology. The advantage of a collection of planks from different vessels covering such an extended period also provide various materials, which, in turn, provides information about possible connections between the material used and construction techniques, boat size or typology; variations in wood species used for boat construction over time can offer interesting insights regarding material trade in the Indian Ocean during different periods.

1.2.4 A Multidisciplinary Approach

Unfortunately, as reminded by McGrail (2014: 133), no matter how well preserved a shipwreck is, archaeological evidence is always incomplete. This is particularly true in the case of the al-Balid timbers. Unlike other disciplines, such as ethnography, geography, sociology and economics, for example, archaeology cannot provide direct information about human behaviour but can only make speculations based on the artefacts created and utilised by the people of the past (Trigger 2009: 29). Therefore, the study of maritime archaeology should also draw upon "supplementary evidence", such as data provided by historical sources, both textual and iconographic, and ethnography (Crumlin-Pedersen and McGrail 2006: 55). This method of research has proven particularly valid for the study of the maritime Arab world, past and present, and more generally of the Indian Ocean (Agius 1999; 2002; 2005; 2007a; 2013; Belfioretti and Vosmer 2010; Vosmer 1996; 1999b; 2007; 2017; 2019). A multidisciplinary approach, such as that used in this thesis, can be a valid tool for the archaeologist to contextualise the excavated data by relating it to other sources through a comparative analysis (Hasslöf 1963: 132; Vosmer 1999b).

1.2.5 Ethnographic Analogies

Ethnography, and ethnographic analogies, have a significant role in my thesis. Although my research primarily draws upon the data from other archaeological evidence for the interpretation of the technical features of the timbers, ethnographic records of Indian Ocean sewn boats are also crucially important due to the considerable scarcity of nautical finds in the region.

Ethnography has played an essential part in maritime archaeology since the early years of its establishment as a discipline. Muckelroy (1978: 234) remarks that, because maritime ethnographic researches reveal traditions of present maritime communities, they can also provide archaeologists with insights into their past. Studies on traditional boats provide analogies that help researchers explain technical features of excavated assemblages, as well as their function (McGrail 1984: 149).

Ethnographic parallels also have the potential to yield clues for interpreting the social and economic context of the past maritime societies that built and used the boats (Gibbins 1990: 338). Moreover, experimental reconstruction projects of sewn ships in the region, such as *Sohar* (Severin 1982; 1985), *Jewel of Muscat* (Vosmer 2010;

Vosmer et al. 2011) and the al-Hariri boat (Staples 2019) owe a great deal to ethnography. Experimental archaeology has often borrowed information from ethnographic studies, such as the case of *Jewel of Muscat*, a reconstruction of a sewn vessel based on evidence from the Belitung shipwreck (Vosmer 2010; Vosmer et al. 2011). The wreck was not completely preserved and information from Omani traditional watercraft with similar shapes and construction techniques helped to fill in the gaps of the archaeological excavation (2011: 414). Moreover, ethnographic records, along with a team of boatbuilders from Kerala, southern India, where sewn boats are still used, built and repaired (Ransley 2009), proved to be essential during the construction of *Jewel of Muscat*, providing a wealth of information about the fastening process, materials employed and socio-economic context (Vosmer et al. 2011: 417).

However, Gould (2011: 15) warns us about the use of analogies, stating that the present cannot be a definitive model of the human past. Indeed, an approach that is too focused on ethnographic observation can generate theories of social reductionism. These "pitfalls of presentism" are well exemplified by theories such as *unilineal cultural evolution* and *cultural diffusion*, which create a misleading and derogatory view of both the present and past societies studied. Gould (2000: 18-20) uses the initial settlement of Australia as an example of the dangers of applying ethnographic data directly to explain the archaeological record. The latter clearly indicates that the ancestors of modern Australian Aborigines sailed there from Southeast Asia. At the same time, the former shows no evidence of recent or historical seagoing watercraft capable of making that passage.

McGrail (2014: 133) also calls for caution when using ethnographic analogies, because similarities between present and past artefacts and assemblages do not always indicate the same interpretations and functions but instead offer a range of possible explanations, which should be tested within a comparative analysis with other sources. One should avoid using this approach cross-culturally as its validity works better in areas showing cultural continuity throughout history, such as Scandinavia (2014: 133). The Indian Ocean, with its rich maritime ethnographic resource and relative cultural unity, is also an appropriate candidate for the application of this procedure in the study of the al-Balid timbers.

However, British maritime archaeologist Lucy Blue (2003: 334) reminds us that extracting information from present maritime communities and applying it directly and uncritically to the past can be misleading, as is the case even within the small coastal area of Tamil Nadu, southern India. For example, in her research in Tamil Nadu, she highlights the numerous variables influencing the shape of a boat, which reveals the complexity of this topic that cannot be expressed simply in terms of functionality (2003: 333-335). Hence, the validity of present analogies to explain the past strongly depends on the quality of ethnographic researches methodology, which should focus on the people that built and used the boats, and their social and economic context, instead of approaching the object in isolation (2003: 335).

This thesis is on relatively secure ground with regard to the use of ethnographic parallels. In order to avoid the “pitfalls of presentism” (Gould 2000: 15), Interpreting the al-Balid timbers’ technical features, such as the sewing-hole patterns, is relatively straightforward and accurate because of their striking similarities with modern sewn boats. As the efficacy of ethnographic parallels considerably decreases as we try to venture into the economic, social, political and religious spheres, the data from similar contexts in contemporary maritime cultures can only provide suggestions or ranges of possibilities rather than definitive explanations. As British archaeologist Tim Insoll remarked (2004: 113–116; 2006: 223), ethnographic analogies are crucial in broadening “interpretative horizons” rather than pursue direct similarities, or “indiscriminate projections of the present onto the past” (Wylie 1985: 105). For example, a study of the Tallensi, an ethnic group of northern Ghana, provides invaluable insights into the religion and rituality of the British Isles during the Neolithic (Insoll 2006).

The range of interpretations provided by the ethnographic analogies can be then examined and refined in a comparative analysis with other sources. Scholars have remarked about the value of multiple sources (Hasslöf 1966; Vosmer 1999b; Wylie 1985: 105–106), and how both archaeological and ethnographic observations can often make historical sources more comprehensible (Hasslöf 1963: 169). Likewise, medieval textual documents, in concert with the study of the material culture of present maritime societies and technology, can help to further shed light on archaeological assemblages.

To conclude, I believe that the “alliance” between maritime archaeology, experimental archaeology, ethnography and history (Vosmer 1999b) provides the most effective research tool for the study of the al-Balid ship timbers.

1.3 Methodology

In order to complete my research and answer my related questions I have used a methodology that consists of different phases. The first consisted of rigorous documentation of the timbers. Various scholars remark that recording is the most vital step in the process of research and reconstruction of past maritime assemblages (Coates et al*.* 1995: 294; Crumlin-Pedersen 1977: 165; McGrail 1992: 354; Steffy

1994: 191). Therefore, my method follows Richard Steffy's guidelines for documenting ship remains (Steffy 1994: 191-213), with some minor alterations and additions.

The al-Balid ship remains are currently stored in the Museum of the Land of Frankincense Museum in Salalah, Oman. I selected forty-six of these timbers according to their size and features, and I measured, documented and photographed them during four field trips carried out between April 2017 and April 2019. During the same period, I also documented three ship timbers from the Islamic port of Qalhat on the eastern coast of Oman. It is not the intention of this thesis to provide a comprehensive study of the material culture from Qalhat, but rather provide a preliminary analysis. The dataset is still very limited compared to that of al-Balid and, at the time of writing this thesis, only comprises a few timbers, although a further brief survey at the Qalhat site in April 2018 showed a considerable number of timbers, allegedly from boats, still in situ within the masonry of the buildings.

Documentation of the al-Balid timbers has aimed to extract as much information from every relevant piece and place it within a comparative context with the available textual, iconographic, archaeological, ethnographic and experimental archaeological evidence on sewn boats.

To this end, I created two different recording pro formas (see Appendix A):

1. a timber documentation form.
2. a timber sewing form.

The first served to record the context and location of the timbers; their dimensions; their various features such as stitching holes, plugs, recesses, presence of fibres, ropes or wadding, dowels and tool marks; and substances on their surfaces (Figure 1.1).

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 30/10/17**

TIMBER ID:	Wo86	**LOCATION:**	Citadel, 17 MI59
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	1443	**WIDTH:**	120-82-121	**THICKNESS:**	35-37-36

			TOP	**BOTTOM**	**FRAME**
HOLES			9	31 (4 on diagonal edge)	
OVERALL NUMBER:		40			
DIAMETER (Average):			10	10	
PLUGS	**WOOD**		4	18	
REBATES				26	
DOWELS				4	
DOWEL DIAMETER				10-12-12-9	
DOWEL SPACING				326-837-281	
SCARFS					
WADDING					
BEVEL				84-80-81˚	

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN		Bitumen		Bitumen

COMMENTS: Thick and heavy timber with regularly spaced holes. One edge of the timber is preserved, hand has a bevel of between 80 and 84˚. The upper edge is not preserved and the timber broke along the grain of the wood. A few holes are visible near the broken edge, but it is difficult to determine whether they are part of a frame lashing. The diameter of the sewing holes is relatively consistent and these were drilled with an angle following that of the edge's bevel.

The timber displays a diagonal end, and it is difficult to determine whether it is a scarf joining two planks of the same strake, or a hood end connecting the plank to either the stern or stem post. The end of the plank was fastened with cordage in single-wadding technique and two dowels.

Traces of bitumen are visible on the inner side of the plank, between the sewing holes and the edge, indicating the presence of luting under the wadding and between the planks seam. Impressions on the bitumen reveal the material used for the wadding, such as reeds, thin strips of palm leaves and grass.

Figure 1.1: The documentation form used to record the al-Balid timbers, completed for timber Wo68.

This form also included a comment section allowing a brief preliminary description of each timber and its details. The timber sewing form was specifically created to facilitate the documentation of fastening patterns. It is a stylised drawing of an ideal plank with sewing holes and frame-lashing patterns arranged in the western Indian Ocean sewn-plank technique. This form served to record hole diameters and their spacing, the size of rebates and the distance from holes to the edge of planks. Frame-lashing arrangements, the spacing between them and their thickness were also included in this form (Figure 1.2)

The data collected were then incorporated into a database created in Excel to carry out a quantitative analysis of the timbers' main features with the aim to answer my research questions (1 and 2) regarding a possible classification of the timbers. This method allowed identification of similarities and differences in the timbers' main features and, possibly, determination of correlations between the overall measurements of the planks and the size of their other elements, such as hole diameters, dowels and frame lashings, as well as their arrangement. The database also served to compare the timbers with other relevant archaeological finds, such as the sewn timbers from Quseir al-Qadim and the shipwrecks of Belitung and Phanom-Surin, as well as with more recent ethnographic records from the western Indian Ocean, and data from experimental reconstruction projects such as *Sohar* (Severin 1982; 1985), *Jewel of Muscat* (Staples 2013; 2019; Vosmer 2010; Vosmer et al. 2011), the al-Hariri boat (Staples 2019) and the *beden seyad* replica (Ghidoni 2019).

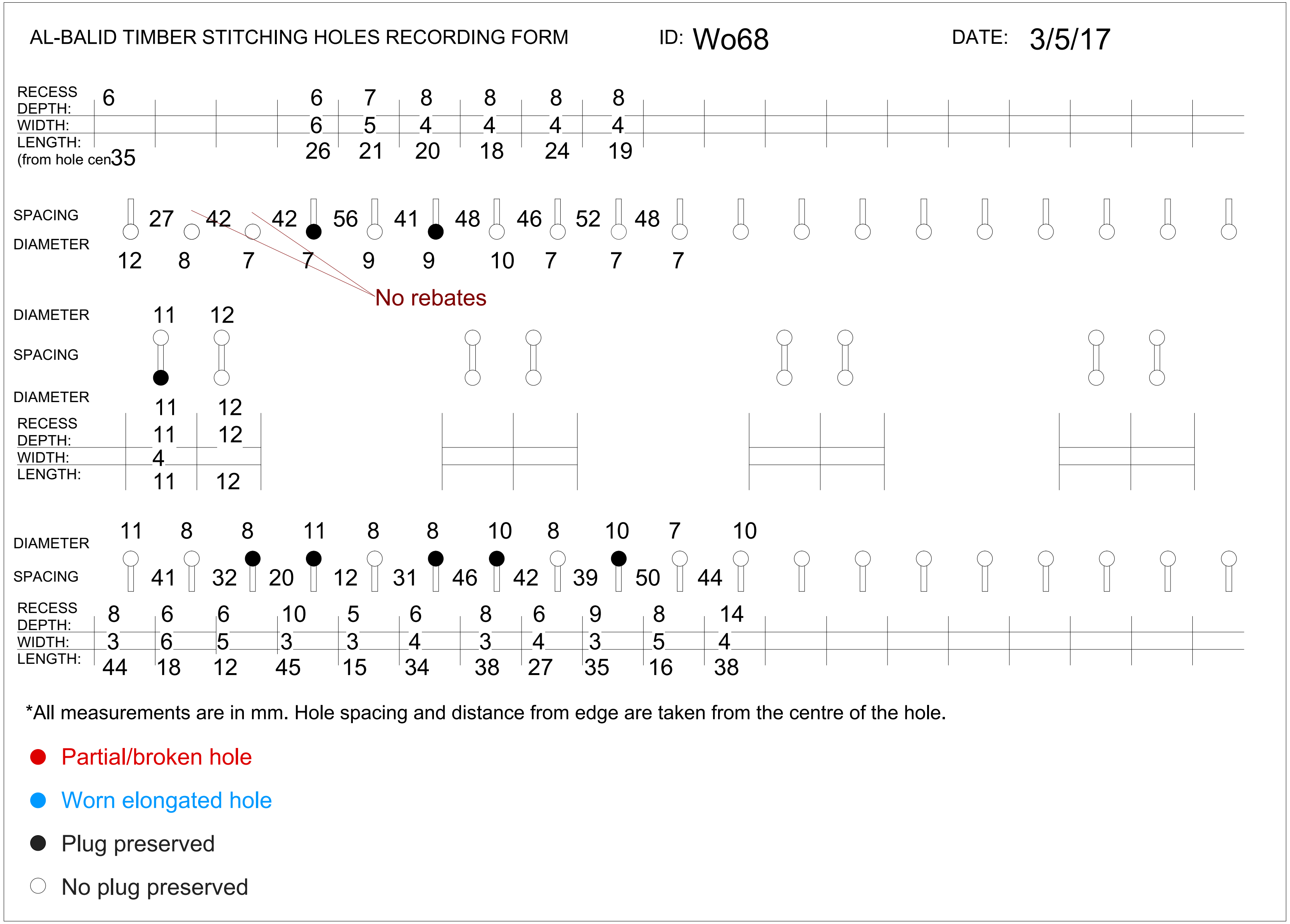

Figure 1.2: The stitching recording form created to document the sewing pattern of the timbers.

1.3.1 Photographic Documentation

Each timber was extensively photographed in order to create an archive of high-resolution images that may be useful for the recording process and in reconstruction, as well as being a crucial tool for further studies. This phase consisted in taking several photographs of each timber's surface, including close-ups of particular features, such as the fibre cordage, bitumen, sewing and dowel holes, cracks, etc. Timbers that were not excavated but remain set in the stone walls of buildings were measured and photographed in situ.

A more detailed photographic documentation of the timbers was carried out using multi-image photogrammetry, a documentation technique that has proved to be particularly suitable in the maritime field (Cooper et al. 2020; Martorelli et al. 2014). For example, in recording of a 5th-century sewn shipwreck discovered in Comacchio, Italy, Beltrame and Costa experimented with both digital photogrammetry and laser scanning. The comparison between the methods revealed that the two techniques are comparable in terms of accuracy (Beltrame and Costa 2016; Costa et al. 2016: 238). A series of close-up photographs of the wooden remains were taken from a fixed distance with a Nikon D3100 digital SLR camera placed on a tripod. The photos, numbering between thirty and sixty depending on the size of the timber, overlapped each other by at least 30%. Agisoft Photoscan[2] was used to process and align the images to create 3D point clouds, which were converted into large, high-quality, two-dimensional images (orthomosaics) of the surfaces of the timbers (Figure 1.3). The files obtained can be scaled and measured with a high degree of accuracy, and used as if they were full-scale drawings (Yamafune et al. 2016). The orthomosaics are

[2] The name of the software changed to Agisoft Metashape in 2019.

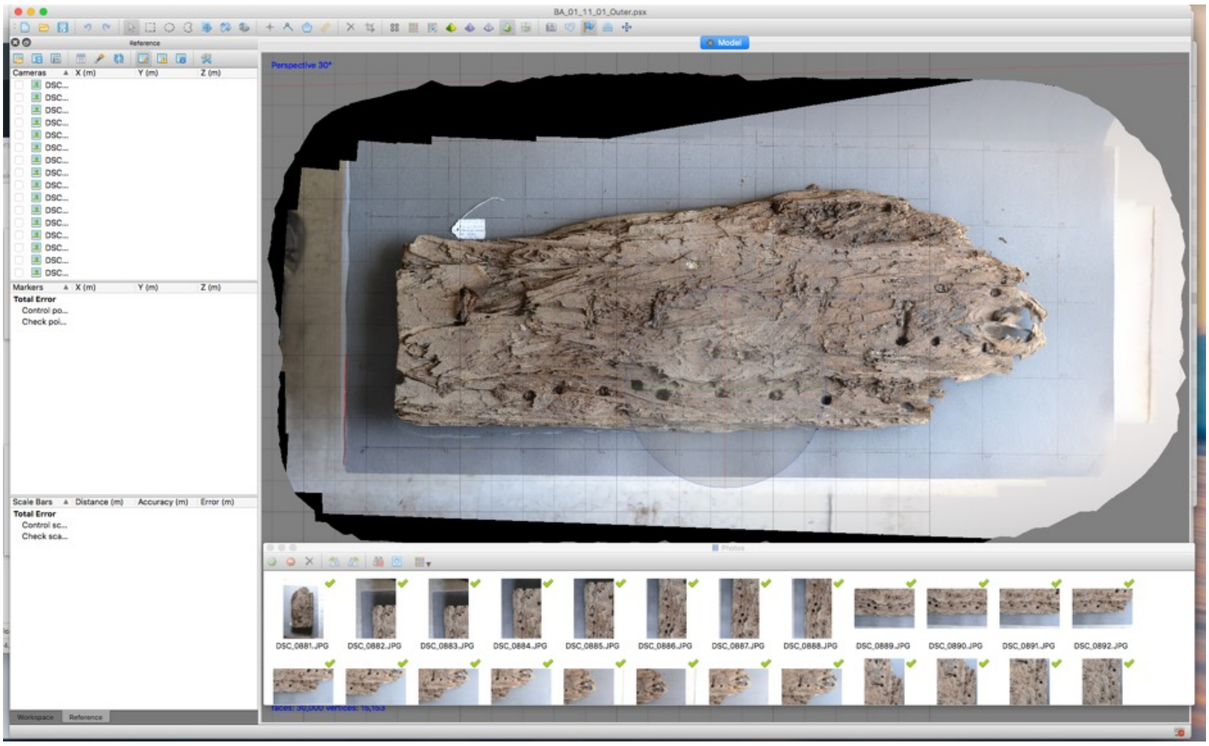

Figure 1.3: A screenshot of Agisoft Photoscan in the process of creating an orthomosaic of plank BA.01.11.01. (Photo: Author)

particularly useful to verify measuring carried out on the timbers in situ and can be analysed again by future scholars. A grid of squares measuring 100x100 mm placed below the planks during the photographic session served as a reference to verify that the size and proportions of the resultant image matched those of the actual timbers.

The main advantages of this method are:

- to create a very detailed high-resolution image of the timbers, which is impossible with a single photograph;
- to avoid any distortion of the image caused by the camera lens;
- to create a scaled and undistorted image that can be used exactly as a drawing, retaining all the features of the timber;
- to generate highly detailed 3D models, similar to those created with a laser scanner, by simply using a camera and tripod;

- a significant decrease in the recording time.

I have limited the use of photogrammetry to two-dimensional images, instead of creating 3D models of the timbers because the latter is a more complicated process and requires a considerably longer time, while adding no particular further data to my research. The timbers would have had to have all their surfaces exposed at the same time to allow photography for 3D photogrammetry, and this could only be achieved by using stands specifically created for each timber or by suspending them with a cable. Both methods would have likely caused damage to the timbers, some of which are already in a poor state of preservation. While 3D photogrammetry, or even better 3D laser scanning, remains important for the overall documentation of the timbers, in order to minimise any damage it should be completed once they have been through extensive conservation.

1.3.2 Archaeometric and Botanical Analysis

The next phase of the work consisted of the extraction of wood, fibres and bitumen samples from the most relevant timbers for archaeometric and species identification analyses. The former includes radiocarbon dating analysis (^{14}C) carried out by Beta Analytic on a selection of timbers (see Appendix B), which provides an approximate age for organic materials based on the radioactive decay of the carbon-14 isotope. Radiocarbon dating enables a comparative chronological analysis of the timbers, which assists in answering my research question about possible changes in sewing techniques and materials through time.

This procedure also provides a chronological context for the timbers, the date of which cannot be estimated with diagnostic artefacts since the timbers have been recycled multiple times. At the same time, it can more accurately pinpoint the age of the citadel at al-Balid.

Archaeometric analyses, such as Gas Chromatography-Mass Spectrometry (GM-MS) and diffractometric (X-Ray diffraction) were also carried out on substances adhering to the surface of the timbers, such as bitumen. These analyses have proved to be vital tools for the study of archaeological bitumen in the Persian/Arabian Gulf[3] and Oman, from the Neolithic to the medieval period (Connan 1999; Connan et al. 1998; 2005; Connan and Carter 2007; Connan and de Velde 2010; Stern et al. 2008). GM-MS helps identify the chemical signature and gross composition of the bituminous material, which can offer clues to its source. This analysis is particularly important to answer my questions regarding the material trade in the Indian Ocean and the general relationships between the various Indian Ocean entities of the period. The bitumen samples from the al-Balid timbers also underwent diffractometric analysis (X-Ray diffraction) with the aim of revealing their mineralogical composition in order to determine whether the bitumen was pure or intentionally mixed with other inclusions.

Finally, species identification analysis on a selection of timbers (see Appendix C) also proved to be another essential tool for my study, and in answering my research questions about the material trade and fundamental connections in the Indian Ocean. This method is an essential stage in the study of wooden artefacts and is widely employed in maritime archaeology (Belfioretti and Vosmer 2010: 111-112; Flecker 2000: 215-216; 2008; Gale and der Veen 2011; Tomalin et al. 2004: 257; Vosmer 2019: 311). In this thesis, botanical analysis was not limited to determining the wood species of the timbers themselves, but also of other components such as plugs,

[3] Hereafter called the Gulf.

dowels and fibre cordage. These analyses can give an insight into which materials boatbuilders used in construction and into geographical areas involved in the material network, as well as a range of possible places where they repaired or built vessels.

The data obtained through the documentation and analyses of the timbers are then compared with the available evidence of sewn boats in the Indian Ocean, including archaeological data from ship timbers from Quseir al-Qadim, Qalhat and the Belitung and Phanom-Surin shipwrecks, as well as information from historical sources, ethnographic and boat reconstruction projects. This comparative analysis provides a broader context for these pieces of material culture.

1.3.3 Tool marks analysis

One of the aims of my research is to recognize and interpret any marks left on the al-Balid timbers by the shipwrights' tools during the building or repairing of the vessels. Needless to say, these tools are an essential part of boatbuilding, and the evidence they leave behind tells us not only about the technological level of society at the time of a boat's construction, but it also reveals information about the individual men who wielded the tools during the building process.

Maritime ethnographic studies and experimental reconstruction projects in the western Indian Ocean reveal a certain uniformity of boatbuilding practices and tools (Agius 2002: 139-144; Agius 2007a: 144; Johnstone and Muir 1964; Salimi and Staples 2019; Severin 1985: 281-285; Vosmer 2007: 360-365; Vosmer et al. 2011: 422; Vosmer 2017: 185-186). Shipbuilders used a few simple but effective tools to transform rough logs into finely shaped vessels capable of sailing across the ocean. Their typical "tool kit" includes:

- *Saws* of different sizes to cut timbers into general shapes.
- *Adze* to rough- and fine-shape various components of the vessel, particularly curved members such as frames.
- *Chisels* of different sizes for fine-shaping boat parts such as plank seams and complicated joineries. Chisels are always used with a *hammer*.
- *Bow drill* to bore either the sewing- or nail-holes into the hull planking.

Although none of these tools survived in the archaeological record from the medieval period, they nevertheless left specific marks on the surfaces of the al-Balid timbers, and these marks provide information about the type and, in a few cases, the size of tools used by the shipwright (Figure 1.4).

Sewn boats also require specific tools to carry out the sewing activity, but, unfortunately, these tools leave no visible marks on the timbers. Consequently, stitching tools, which I will discuss in Chapter 6, have been scarcely documented in ethnographic records and are rarely mentioned in sewn boats studies in the region. However, like those used for woodworking, they are simple and highly effective in the hands of a skilled shipwright.

Figure 1.4: Boatbuilding tools and their marks on timber: (A-B) saw, (C-D) adze and (E-F) chisel. (Photo D: J. Cooper; All the other photos: Author).

1.4 Thesis Structure

Following Chapter One, which introduced the topic, aims of my research, questions shaping my investigation and my theoretical framework and methodology, this section provides an overview of my thesis organised by chapters.

Chapter Two introduces a review of the literature of sewn-boat studies in the Indian Ocean, critically analysing the main issues and identifying gaps within these works. The chapter is organised into three main sections reflecting the disciplines revolving around this topic: history, archaeology and ethnography. After a brief introduction underlining the universality of sewn-plank construction through time and space, the first section explores medieval historical sources, consisting of textual records and iconography mentioning and depicting sewn watercraft in the Indian Ocean. The second section provides a synthesis of archaeological work undertaken in the region, including experimental projects, and the third section examines the ethnographic researches on the last sewn vessels used in the Indian Ocean.

Chapter Three presents the case study, providing a technical study of the al-Balid timbers and detailed documentation of their features. The aim of the chapter is to introduce the dataset and distinguish the timbers according to their characteristics in hull planks and other boat parts, such as beams and sheaves. Within this first classification, planks are further grouped into different types according to their sewing patterns and hole arrangements. This chapter provides a quantitative study of the main features of the timbers, seeking correlations between the timbers and identifying similarities and differences within the dataset. It also presents the results of botanical and archaeometric studies, such as radiocarbon dating and chemical analyses carried out on a selection of timbers and the substances on their surfaces. Overall, this chapter provides the raw data for use in their interpretation in Chapters Five, Six and Seven.

Chapter Four introduces the timbers discovered at Qalhat, another important Middle Islamic site in Oman. As with Chapter Three, this chapter aims to provide a technical description of these ship timbers. This chapter is brief because the number of artefacts discovered is, at present, limited but future excavations have the potential to provide more data. Rather, this preliminary study offers the opportunity to investigate similarities and differences between the vessels sailing to and from Qalhat and al-Balid.

Chapters Five, **Six and Seven** provide an interpretation of the data extracted from the al-Balid timbers detailed in Chapters Three and Four. This is achieved by comparing the timbers with the relevant textual, iconographic, ethnographic, archaeological and experimental archaeological evidence to identify the main features of these finds. The aim is to provide a broader context for this material culture and define the main features of sewn-plank construction in the Indian Ocean during the medieval period.

Chapter Five explores the forms and structures of Indian Ocean sewn boats, describing the structural components of vessels, of which the al-Balid timbers provide both direct and indirect evidence. It also details the tools and methods of construction used in medieval sewn boats. Lastly, the chapter focuses on the size, shape and function of the boats as suggested by the al-Balid timbers.

Chapter Six describes fastening methods of medieval sewn boats of the western Indian Ocean as suggested by the al-Balid timbers. It provides a technical analysis of the various sewing techniques and their main elements, such as dowels, hole plugs, luting and caulking. The chapter also provides a range of possibilities to explain differences in sewing methods, and discusses a possible development in fastening techniques hinted by the timbers.

Lastly, the chapter discusses the evidence of nail fastening in the al-Balid timbers and its importance within the context of Indian Ocean boatbuilding during medieval times.

Chapter Seven explores what maritime material culture can tell us about the boatbuilders and societies that produced and relied on the vessels. The study of the materials of the al-Balid timbers provides insights into the material trade and origin of the boats, and sheds some light onto the fundamental relationships between the Arab world and the broader Indian Ocean during the Middle Islamic period.

Chapter Eight presents the final analysis and discusses the conclusions of the research, emphasising the importance of the timbers in yielding technical and cultural information. It also underlines the success of a multidisciplinary approach for answering my research questions and deepening our understanding of past maritime technology. The Indian Ocean maritime world is undoubtedly one of the best fields to carry out this study thanks to the longevity of vernacular boatbuilding practices, which enable archaeologists to use ethnographic analogies confidentially. The chapter continues highlighting the gaps and complexity of this topic, and concludes by providing guidelines and advice for future studies.

2 Literature Review

2.1 What is a Sewn Boat?

Before beginning this discussion of the al-Balid timbers, it's important to familiarize ourselves with the main features and terminology concerning sewn plank construction. "Sewn boats" are vessels with their hull planking joined edge to edge with fibre cordage in a continuous line of sewing.[4] This technique is different from an isolated single stitch or a cluster of stitches in a wooden hull. It is also different from the "lashing" technique used to fasten frames to the hull (Prins 1986: 24).

This thesis focuses primarily on the sewn-plank technology of the western Indian Ocean, which, through various forms and materials, shared common characteristics throughout this region despite its vastness (Prins 1986: 100-109; Facey 1991: 107; Vosmer 2019; Pomey 2011: 138; Varadarajan 1993: 554) (Figure 2.1).

Listed below are the main features of western Indian Ocean sewn watercraft—all of which I will discuss in depth in the thesis:

- *Continuous sewing* with fibre cordage through holes regularly spaced apart near the edge of the planks;
- *Wadding:* a caulking roll, firmly compressed by the sewing cordage above the planks seams, generally inboard;
- *Rebates*: grooves carved outboard between matching holes of adjacent planks to accommodate the sewing cordage;

[4] Sewing is also referred to as 'stitching' (Prins 1986: 25) or 'tying' (Ransley 2009: 5, 18).

- *Dowels*: wooden pins connecting and aligning adjacent planks;
- *Luting:* a substance, usually resin, smeared on the edge and seams of the planks to watertight the hull;
- *Frames* secured to the hull by lashings through sets of holes along the centre of the plank;
- *Through-beams* penetrating the hull on either side and either sewn or pegged;
- *Double-ended hull shape*: pointy bow and stern;
- *Shell-first or hybrid shell/frame built*: the hull is either entirely or partially assembled by sewing the planking before fitting the frames.

2.2 The Ubiquity of Sewn Boats

Studies on sewn boats have revealed the ubiquity of this fastening method worldwide and throughout history. Researchers have documented vessels assembled and held together with fibre cordage in America, Europe, Russia, Africa, Arabia, India, Southeast Asia and China, with the only exception being Australia (McGrail 1996: 227-231; McGrail and Kentley 1985; Prins 1986). Moreover, this boatbuilding technology occurred through a broad chronological period stretching from the Bronze Age to the Modern era in both riverine and maritime contexts. However, sewn boats have now almost disappeared everywhere except in southern India. Although forms of sewn-plank construction can vary considerably in vessels from different geographical areas and temporal range, they all use similar materials, such as fibrous cordage, to achieve the same purpose.

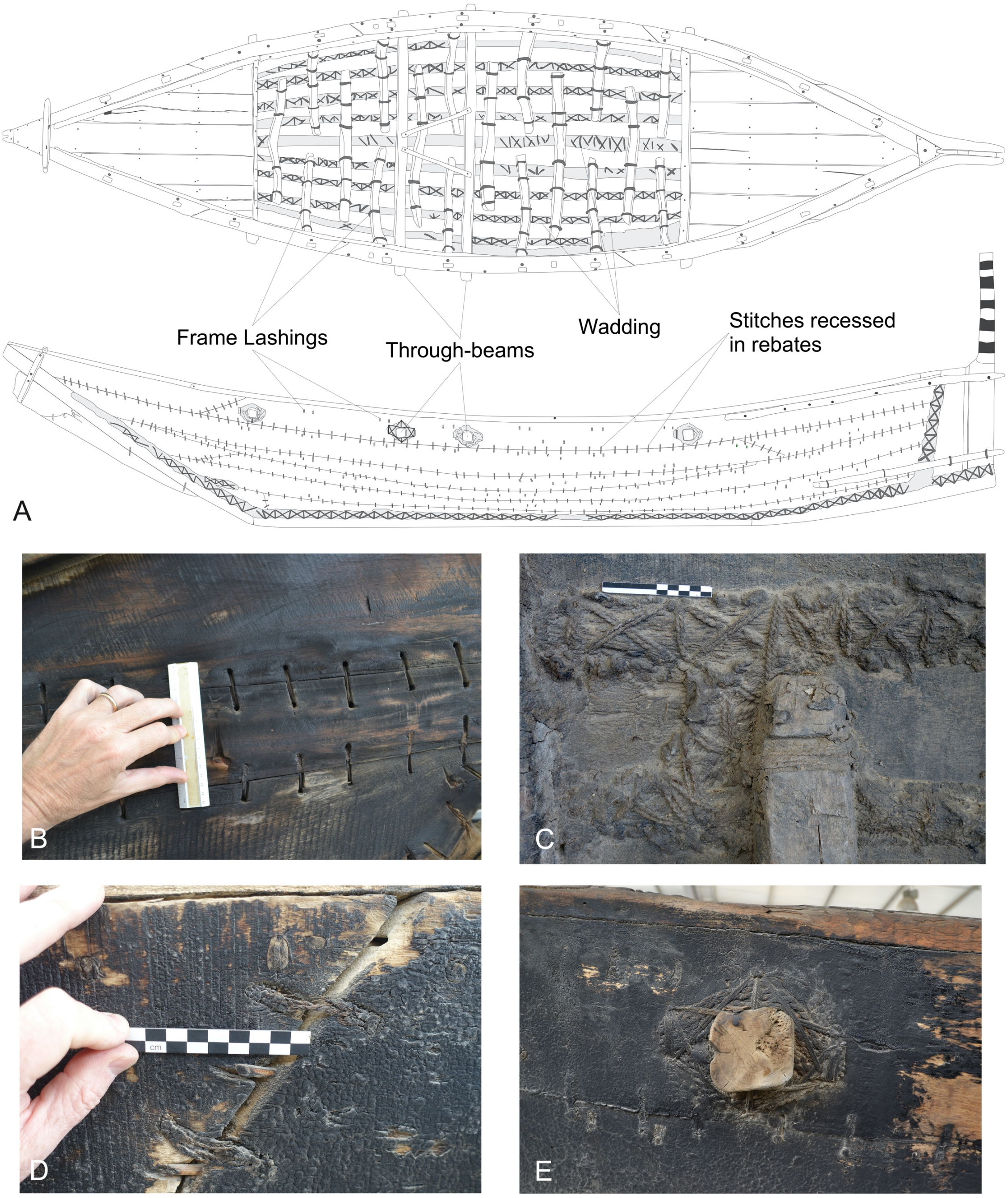

Figure 2.1: Construction drawing of *baggāra* 3 from Qatar Museum (QM), illustrating the main features of western Indian Ocean sewn-plank construction technique (A) (Image: Author). Detailed images showing: (B) sewing ropes recessed in rebates outboard an Indian *kettuvallam* from Qatar Museum (Image: Author); (C) wadding covering the plank seams inboard QM *baggāra* 2 (Image C. Zazzaro); (D) dowels connecting the planks ends on QM *baggāra* 1 (Image: J. Cooper); (E) a through-beam sewn to the hull of QM *baggāra* 3 (Image: Author).

Although numerous scholars have carried out studies on sewn watercraft from specific regions, the universality of the sewn-plank construction method is emphasised by three academic works that focused specifically on the topic. Two volumes were published in the mid-1980s, one year apart. The first, *Sewn Plank Boats* edited by McGrail and Kentley and published in 1985, consists of proceedings of a conference held at the National Maritime Museum, Greenwich, UK, in 1984. It includes papers by leading scholars who discuss different forms of sewn-plank techniques and technology worldwide. However, the Indian Ocean is represented in only a few papers, despite being the only place where, at that time, sewn boats were still built and used: Yemen (Prados 1996), Oman (Donaldson 1979: 453; Vosmer 1997), Sri Lanka (Kentley and Gunaratne 1987), India (Shaikh et al. 2012), Somalia (Chittick 1980) and Lakshadweep (Varadarajan 1998). Christensen (1988: 191) remarks on the heterogeneity of this work, questioning whether it is appropriate to use a particular fastening technique to classify watercraft from such a wide geographical area. Despite acknowledging the importance of these studies and their different approaches, he argues against the use of sewn construction as a tool for classifying watercraft. The range of vessels presented stretches from Pharaonic Egypt (Lipke 1985) to the Modern era, with a variety of different craft, functions and contexts. However, McGrail (1996) re-asserts that it is precisely the widespread nature of this fastening method, both geographical and chronological, and the variety of approaches applied by scholars focusing on this topic, that makes the study of stitched-plank boats so valuable, particularly in the Indian Ocean region (1996: 227).

Prins published the other academic work focusing on the topic, *A Handbook of Sewn Boats*, a year later, which further remarks on the universality of sewn boats (1986: 11). His work provides an up-to-date study while underlining the extent of the spread of sewn boats in both space and time. He also recommends the terminology for the study of sewn boats and proposes a classification system for these vessels based on construction features. Prins' main goal is the creation of a schema that allows a comparative study between boats showing similar traits. This classification explores the differences and similarities of the various technological styles and forms of sewn craft. Stitches and other fastening elements, such as dowels or hole plugs, constitute the basis of a permutation table, which is used to arrange the evidence presented by Prins to identify the different classes of sewn-plank traditions, their distribution and origin (1986: 23).

Since the above-mentioned publications, scholars continued to record sewn boats from different parts of the world and historical periods, particularly in the Indian Ocean. The results of some of these studies were presented in the workshop 'Fibre and Wood: Sewn Boat Construction Techniques Through Time', held at the German University of Technology, Oman, in 2015 (Staples and Blue 2019: 270). As with the 1985 Greenwich conference, the researchers presented on a wide range of sewn-plank vessels using a variety of approaches including archaeology, ethnography, history, iconography and experimental archaeology. While the chronological context was vast, ranging from the 1st millennium BCE to the present day (Pomey and Poveda 2019), the geographical scope was mostly focused on the Indian Ocean — only one presentation was on a Mediterranean vessel — with studies on sewn boats from East Africa, Oman, India and Southeast Asia.

The workshop presentations, plus a few others not presented at the event, have been collected in a special section of the *International Journal of Nautical Archaeology*[5]

[5] Hereafter referred to as Fibre and Wood 2019, as indicated by the editor of the *International Journal of Nautical Archaeology*, Miranda Morris.

(*IJNA*) (Burningham 2019a; Dixon 2019; Fenwick 2019; Ghidoni 2019; Manguin 2019; Pomey and Poveda 2019; Shaikh 2019; Staples 2019; Staples and Blue 2019; Vosmer 2019; Weismann et al. 2019). Overall, this publication aimed to update the topic of sewn boats, particularly for the Indian Ocean. It introduces information regarding the latest archaeological discoveries in the region, such as the al-Balid ship timbers in Oman, and the Belitung and Phanom-Surin shipwrecks (Vosmer 2019) found respectively in Indonesia and Thailand. It also highlights the importance of the experimental approach, with reconstruction projects such as *Jewel of Muscat*, the al-Hariri boat (Staples 2019) and the *beden seyad* (Ghidoni 2019). The data from ethnographic research also play a crucial role in the volume, with evidence from India (Fenwick 2019; Shaikh 2019) and Oman (Weismann et al. 2019), as well as introducing the value of scaled models for the study of this topic (Dixon 2019).

In their introductory paper to the *IJNA* special section (Fibre and Wood 2019), Staples and Blue (2019: 281-282) emphasise the workshop's achievement in regard to the additional knowledge of the sewn-construction method gained since the works of Kentley and McGrail (1985) and Prins (1986), and suggest a strategy for future research. The establishment of a centre dedicated to the study of sewn boats proposed by the authors would undoubtedly be a valuable opportunity to promote an interdisciplinary dialogue between scholars, outline a scientific "protocol" for experimental reconstruction projects and, overall, further deepen knowledge about sewn watercraft in the Indian Ocean and beyond.

2.3 Archaeological Evidence of Sewn Boats in the Indian Ocean

One striking aspect arising from the study of ancient watercraft in the western Indian Ocean is the paucity of archaeological evidence, and it is only over the past two decades that archaeologists' knowledge has benefited from the remains of ships from the 8th–15th centuries. As Vosmer pointed out (2007: 172), "compared to the Bronze Age, the Islamic Period has not yielded as much information about ships as might be expected, given its closer chronological and cultural proximity to modern time." The picture of Islamic shipping from its early period to the arrival of the Portuguese also appears rather scarce when compared to that of the Mediterranean world or ancient Egypt.

One of the main reasons for the scarcity of boat remains is that the Indian Ocean is not a good environment for the conservation of wooden vessels due to the presence of shipworm (*Teredo navalis*), a marine organism that infests the waters of tropical regions and destroys wooden artefacts (Agius 1999: 194). Moreover, the cargo of medieval trading ships sailing in the Indian Ocean often consisted of perishable materials such as textiles, spices and dates, which are even more vulnerable than wood when submerged and leave no evidence (Vosmer 1999b: 296). In addition, maritime and underwater archaeological investigations have been exiguous along the Indian Ocean coastline. In light of the scarcity of archaeological data available, early studies on Islamic shipping in the Indian Ocean mainly rely on ethnographical studies of indigenous craft in conjunction with historical sources and iconographic representations (Bowen 1952; Hornell 1942; 1970; Hourani 1963; Mookerji 1912; Moreland 1939a; Prins 1986).

2.3.1 Pre-Islamic Evidence: Ancient Egypt

The earliest archaeological evidence for boats fastened with cordage and, in general, the richest collection of archaeological watercraft in this region, comes from ancient Egypt. The Nile played a vital role in all spheres of ancient Egyptian society, to the extent that Egyptians relied almost exclusively on water transport. The richness of iconographic evidence and remarkable archaeological discoveries, such as the Khufu ship (Landström 1970; Lipke and Moustafa 1984), Abydos hulls, Dashur boats (Ward 2000), and the more recent boat remains at Wadi Gawasis (Ward and Zazzaro 2010) and Ayn Sukhna (Pomey 2012) have indicated the longevity of rope-fastening methods that spanned, in different forms, five millennia. The most renowned example is the Khufu boat, which dates to the Old Kingdom (c. 2560 BCE) and was found dismantled in a pit in Gizeh in 1954. The discovery revealed the main traits of a unique fastening method found in Egyptian sewn boats. Lipke and Moustafa (1984) describe, ex post facto, the colossal reassembly process and provide a technical analysis of the main features of the construction method, which relies on transverse hull lashings (Figure 2.2) reminiscent of the pattern used on earlier reed and papyrus watercraft (Vosmer 1996: 228; Ward 2004: 13). If Lipke provides a valuable technical approach to the study of the ship, marine archaeologist Cheryl Ward, who had "the luxury of comparing" (2000: 68) the Khufu boat with all the other archaeological evidence, is the first to produce a comprehensive study of the archaeology of ancient Egyptian watercraft.

Ward (2000) took three main sets of data into account with regard to sewn-plank technology: the Khufu ship, the Early Dynastic hulls found in the boat–grave cemetery of Abydos (ca. 3050 BCE) and the boat timbers from Lisht. Comparative analyses of archaeological and iconographic evidence, combined with the study of materials used

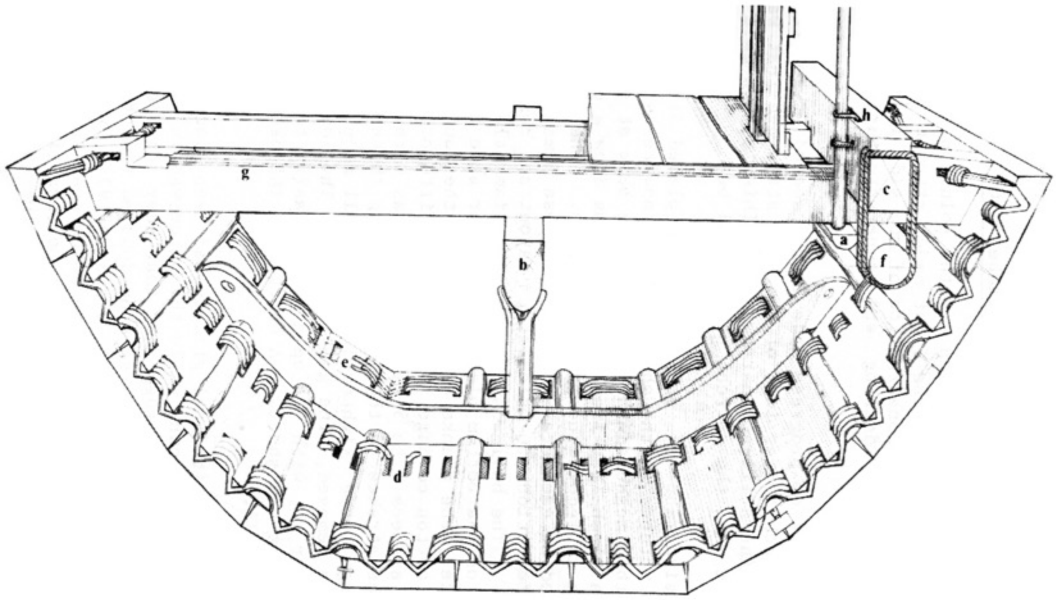

Figure 2.2: Midship section of the Khufu boat showing the transverse lashing. (Image: Lipke 1984: 75).

and the archaeological context of the discoveries, allowed Ward to define the primary traits and forms of Egyptian boatbuilding technology and provided information concerning different aspects of the society, economy and culture of ancient Egypt.

2.3.2 Early Seafaring in the Gulf and Arabian Sea

We cannot count on the same richness of ship remains in the other areas of the western Indian Ocean and the Gulf. However, this region provides direct evidence of watercraft as far back as the sixth millennium BCE (Carter 2002: 20) and demonstrates the establishment of a long-distance exchange network that, in the third millennium BCE, linked Mesopotamia, the Gulf, the eastern part of the Arabian Peninsula and the Indus Valley (Cleuziou and Tosi 1994: 745).

One possible piece of evidence attesting to the use of rope to fasten boats outside Egypt, and suggesting an early tradition of lashed-plank technology in the Indian Ocean, comes from Ra’s al-Jinz, Oman, in the form of impressions on the surface of bitumen fragments[6] dated to the first half of third millennium BCE (Cleuziou and Tosi 1994; 2000; Vosmer 1996). Two fragments bearing the impressions of planks associated with a series of ropes converging to a rectangular slot and closed by a wooden plug (Figure 2.3) suggest individual lashings holding planks together, rather than continuous sewing (2000: 748-754). Australian maritime archaeologist Tom Vosmer, who has produced a comprehensive study on the development of watercraft in the Indian Ocean (1996; 1997; 2007; 2017), considers the evidence of lashed planks as an early stage of what would develop into a fully sewn-plank technology (Vosmer 1996: 231). The presence of material from both Mesopotamia and the Indus Valley indicates that the settlement was involved in an exchange network connecting these

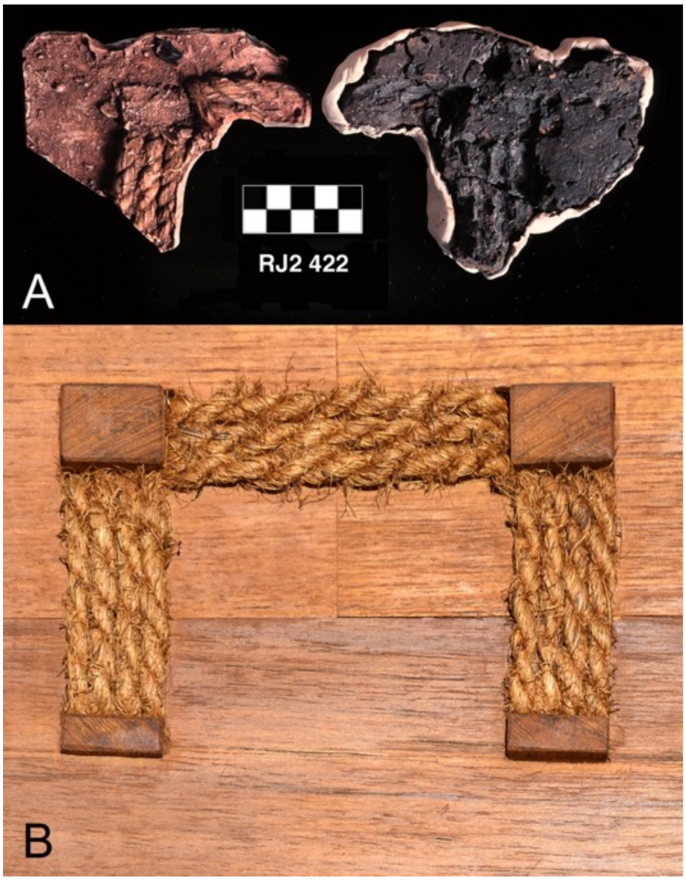

Figure 2.3: Bitumen from RJ-2, Ra's al-Jinz, Oman, showing impressions of wood and ropes converging into a rectangular slot locked with a wooden plug (A) (Photo courtesy of Tom Vosmer). A hypothetical reconstruction of the impression (B). (Photo: Author)

[6] The bitumen, stored in mud-brick buildings, was discovered during the excavation of the Bronze Age coastal settlement site of RJ–2 by the French–Italian Archaeological Mission, The Joint Hadd Project, in 1994. Cleuziou and Tosi provide a description of impressions of woven mats, bundled reeds and wooden planks lashed with ropes, interpreting them as hull parts of reed and wooden boats that were coated with bitumen and involved in a trading system established in the Indian Ocean and Gulf during the Bronze Age. Traces of barnacles on the opposite surface of the impressions in some samples suggest long immersion in sea water, reinforcing the hypothesis that bitumen was used as a waterproofing agent on the hulls of vessels from this time.

two civilisations (Cleuziou and Tosi 2000: 26). Unfortunately, the information that can be extracted from the bitumen fragments is limited to a small section of the outer surface of the hull, and so the main traits of this construction method belong to the field of hypotheses. However, it suggests a use of cordage that was common for fastening the planks of vessels in the Bronze Age and indicates an advanced degree of technology mastered by ancient craftsmen that allowed them to build boats that were able to sail over long distances, connecting the Gulf, eastern Arabia and the Indus Valley during the third millennium BCE.

2.3.3 The Islamic Period

This section presents the archaeological evidence for sewn ships in the Indian Ocean in the Early and Middle Islamic period, ordered by the date of discovery. Chronologically, there is a gap of almost three millennia until the next sewn-ship finds in the region, while the archaeological evidence of Pre-Islamic watercraft indicates a different fastening method.[7]

Before the discovery of the first Islamic shipwreck in the Indian Ocean, studies of stone anchors (Figure 2.4), including those found at the Islamic ports of al-Balid and Qalhat (Agius 1999: 187-194; Newton and Zarins 2010: 259-260; Vosmer 2004: 399-401; Zarins and Newton 2017b: 64; 2017a: 104-107) have provided insights into maritime

[7] The Red Sea provides the only archaeological evidence for boatbuilding in the Pre-Islamic period (2nd–4th centuries). Ship timbers from Myos Hormos (the Roman name of Quseir al-Qadim), recycled in buildings dated to the 2nd century, reveal a mortise-and-tenon fastening method (Blue et al. 2011: 179-181). This boatbuilding practice is typical of the Mediterranean world, where it persisted until late antiquity (Pomey 2004; Steffy 1994: 23-78), and these ships where probably sailing in the Red Sea when Myos Hormos was under Roman control. Archaeological work in Berenike, Egypt, also provided similar evidence from 4th-century buildings (Sidebotham 2008: 310-311).

Figure 2.4: Large stone anchors discovered at al-Balid, on display at the Museum of the Frankincense Land, Salalah, Oman. (Photo: Author)

trade and technology in the Indian Ocean and allowed speculation about the size of Islamic ships (Vosmer 1999a; Agius 1999: 189). However, most of the anchors were discovered in a context not associated with any diagnostic artefacts, making their dating uncertain (Vosmer 1999: 253). These anchors had been used widely in the region since the Bronze Age (2500 BCE) (Newton and Zarins 2010: 260) and were employed in Oman and the Gulf until recently (Bowen 1957: 290), which is a considerable time span. Kapitän (1994) has argued that these anchors are, in fact, buoy/mooring anchors and were not carried on board, and perhaps not associated with any one particular vessel. Ships used them to moor in the sheltered bays of the Indian Ocean when the sea was rough, especially during the monsoon season (Zarins and Newton 2017: 104).

The information provided by these stone anchors is limited and cannot tell us what vessels looked like or whether they were sewn. Nevertheless, their number in the archaeological record from Qalhat and al-Balid provides information about the extent of shipping and the active role of these Islamic sites in the Indian Ocean trade network.

2.3.3.1 The Belitung Shipwreck

Discoveries of ship remains in the Indian Ocean in more recent years have provided a glimpse of maritime technology in the region between the 9th and 15th centuries. The most relevant archaeological evidence is the Belitung shipwreck (Figure 2.5), an entirely sewn vessel dated to the 9th century that was salvaged in Indonesian waters in 1999 (Flecker 2000; 2010). According to Flecker (2000: 200), the wreck indicates strong evidence for direct trade between the western Indian Ocean and China in the

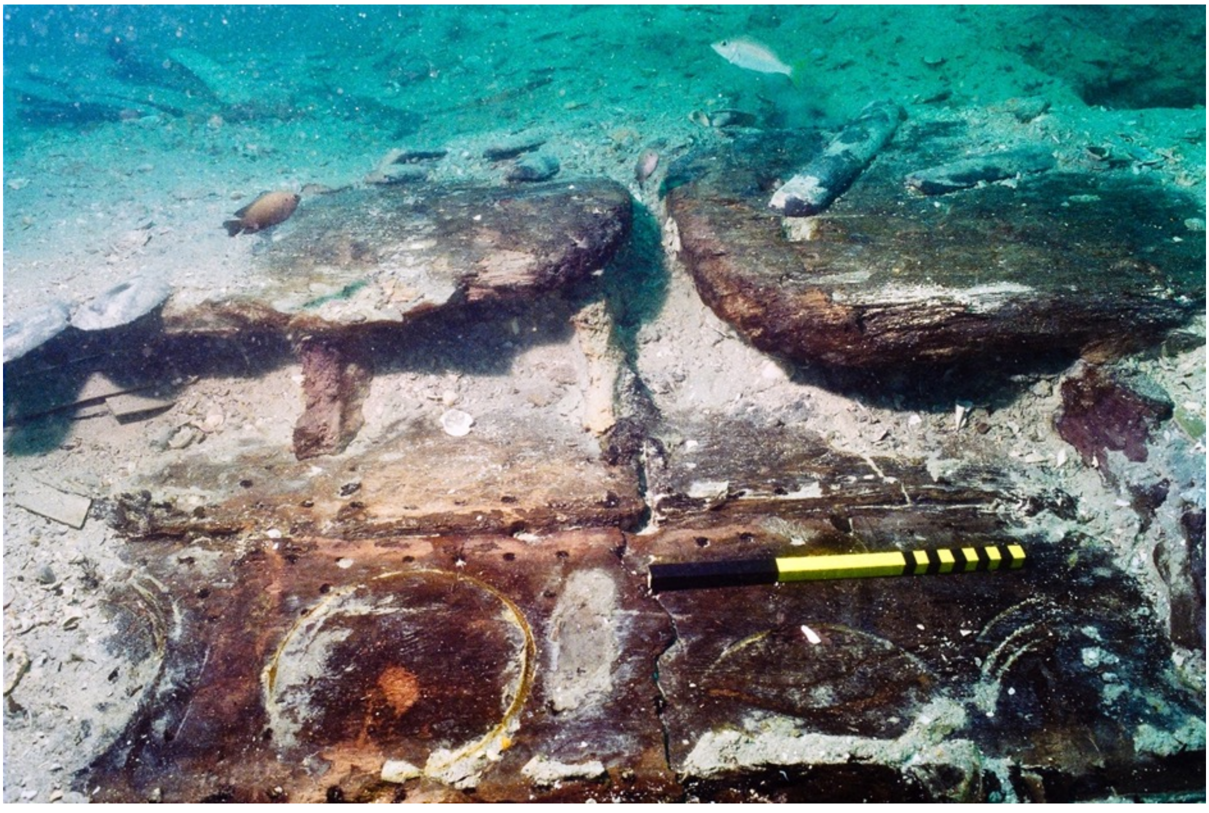

Figure 2.5: Belitung shipwreck showing the planking, frames and ceiling planks. (Photo courtesy of Michael Flecker).

9th century through the ship's probable Arab/Persian origin, a cargo that originates almost entirely in China and the location of the shipwreck in Southeast Asian waters. The cargo of the Belitung wreck included the largest collection of glazed ceramics produced in the Changsha kilns of Hunan province during the Tang Dynasty (618–907), green-glazed ware, white-glazed ware and white- and green-splashed ware, along with other luxury goods such as gold and silver bowls and cups, and bronze mirrors (Guy 2010: 20). Some items bear Arabic inscriptions, suggesting that the cargo was produced for an Islamic market (Guy 2010: 26). According to Flecker (2001), the ship sank near the Belitung Island, while sailing along the Maritime Silk Route, which Hourani describes as "the longest sea route regularly used by mankind before the European expansion in the 16th century", connecting the two largest empires at that time: the Abbasid in Baghdad and the Tang in China (1963: 61).

2.3.3.2 The Ship Timbers of Quseir al-Qadim

Other archaeological artefacts indicating sewn construction are the remains of planks found on archaeological sites in Egypt and Oman. Ship timbers (Figure 2.6) dated between the 12th and 15th centuries were found during the excavation of the Islamic port of Quseir al-Qadim (Blue 2002: 608), which is located on Egypt's Red Sea coast and was excavated by the Oriental Institute of the University of Chicago between 1978 and 1982 (Whitcomb 1983) and, more recently, by the University of Southampton in 1999–2003 (Blue 2002; Peacock and Blue 2006; 2011). Quseir al-Qadim was an important trading centre involved in the Indian Ocean maritime network during Roman (1st century BCE–3rd century CE) and Islamic (12th–15th centuries) periods (Blue 2002: 139). The planks, some showing sewn construction and others with traces of nails, were discovered in a terrestrial context, where they had been recycled as the ceilings of two graves in the site's Islamic necropolis (Blue 2002; 2006; Blue et al. 2011).

Figure 2.6: A plank showing sewing holes and remains of stitching in situ, from Tomb 1, Quseir al-Qadim. (Photo courtesy of Lucy Blue).

2.3.3.3 The al-Balid Timbers

One of the most exciting and relevant collections in Oman, and one that has previously received little attention, is a number of sewn timbers at the site of al-Balid (Belfioretti and Vosmer 2010; Vosmer 2017; 2019). Belfioretti and Vosmer only carried out a limited study on the timbers, only providing a preliminary analysis on a fraction of the al-Balid timbers after the 2016–20 excavations there (Pavan *et al.* 2018). A total of fifty specimens were discovered between 2004 and 2009, consisting of sewn planks and beams reused as structural components in the walls of buildings (Belfioretti and Vosmer 2010: 111). They carried out radiocarbon dating analyses on three samples, and identified the wood and cordage species for five timbers (2010: 111-112), which revealed that the timbers were hull parts from different vessels from a period ranging between the 10th and 15th centuries (Belfioretti and Vosmer 2010: 111-112, 114). The study of the timbers provided interesting insights into Indian Ocean sewn-plank technology in the medieval period, revealing striking similarities between their fastening techniques and materials, and the construction methods of today's Indian Ocean sewn vessels (2010: 111, 116). In their paper, Belfioretti and Vosmer describe the timbers very briefly, and many technical details, such as the size and spacing of the sewing holes, frame lashings and dowel spacings, among other features, are not presented. Moreover, the identification of wood species was successful on only two timbers, and it could only provide either family or genus for the others. With this thesis, I draw upon the information provided by the preliminary study on the timbers, but extend my analysis to a much larger number of samples, with different research questions and approaches.

2.3.3.4 Thaikkal-Kadakkarappally Boat

This boat was discovered in a paddy field at Kadakkarappally, Kerala, southern India, and excavated in 2002–2003 (Tomalin et al. 2004). The absence of cargo or ballast associated with the boat's remains seems to suggest that it was abandoned rather than wrecked. Tentatively dated to the 13th–15th centuries, this flat-bottomed, double-masted vessel measured 18 m in length and 4 m wide amidships, and probably carried people and goods from the coast to the interior. Its construction method is unique, relying on a wide range of fastening techniques including nails, lashings and dowels (2004: 256). Various elements, such as a double-planked hull, lack of a keel, bulkheads, a probable transom stern and the use of diagonal iron spikes, makes the vessel very different from those from southern India, and more generally in the western Indian Ocean, pointing instead to a strong Chinese influence (2004: 259). However, most of the timbers identified in its hull are *Artocarpus hirsutus*, a wood native to Kerala where it is known as *anjili* and widely used in boatbuilding (Agius 2007a: 148; Severin 1985: 279; Vosmer 2017: 185). The evidence from the Thaikkal-Kadakkarappally boat, deviating from the traditional notion of Indian watercraft, might appear to complicate our understanding of boat construction in the region but, in fact, is of significant interest because it reveals the complexity of this topic, as well as underlining the limits of our knowledge of boatbuilding in the Indian Ocean during the Middle Islamic period.

2.3.3.5 The Phanom-Surin Shipwreck

A second completely sewn shipwreck was recently discovered in Southeast Asia. Named after the landowners who accidentally discovered the remains in 2013, the Phanom-Surin wreck (Figure 2.7) was found buried in mud in Thailand's Samut Sakhon province a few kilometres from the modern shoreline (First Regional Office of Fine Arts 2016; Jumprom 2014; 2019). Two rescue excavation campaigns, which were carried out in 2014 and 2015 by the First Regional Office in Ratchaburi and the Underwater Division of the Fine Arts Department of Thailand, exposed planking sewn

Figure 2.7: Stitching ropes are still in place at the bow of the 8th-century Phanom-Surin shipwreck emerging from the mud in Thailand. (Photo courtesy of Abhirada Komoot)

with fibre ropes, a large keelson with notches to accommodate frames and two round posts, which have been interpreted as masts (First Regional Office of Fine Arts 2016: 55-61; Jumprom 2014: 1-2; 2019: 234-235). The cargo of the Phanom-Surin ship consisted of Chinese Guangdong glazed stoneware of the late Tang period, Mon earthenware from central Thailand and turquoise-glazed earthenware and stoneware torpedo jars of Persian origin (First Regional Office of Fine Arts 2016: 63-82; Guy 2017: 183-188; Jumprom 2014: 2-3). Studies of the ceramic typology, along with a Pahlavi inscription on a torpedo jar reporting the name of a Persian merchant suggest that the ship was involved in the maritime trading network between Persian merchants, Southeast Asia and China in the second half of the 8th century, and radiocarbon dating analyses carried out on fourteen samples from the hull confirm this date (Guy 2017: 192). The Phanom-Surin wreck promises to provide interesting results although few publications, with few details, have been forthcoming to date. Unfortunately, due to the challenging conditions of working in the mud and the lack of experienced maritime archaeologists and conservators in the Department of Fine Arts in Thailand, the excavation has been put on hold and, therefore, very little progress has been made in relation to understanding the ship's size, materials and construction features.

2.3.4 Features of Medieval Indian Ocean Vessels

All the above discoveries have deepened our understanding of maritime technology in the Indian Ocean during the Early and Middle Islamic periods, but information regarding the origins of vessels, materials, construction techniques, sizes and shapes is still limited, especially in the case of the Belitung shipwreck, where a wealth of potential data was lost due to the salvaging nature of the excavation.

2.3.4.1 Sewing Techniques

The above archaeological evidence suggests that the practice of fastening planks with continuous sewing, in a way observed in recent sewn vessels found in the western Indian Ocean, had already been clearly established in the 8th century. The use of continuous sewing through regularly spaced holes over wadding is indicated by analyses of the construction technique of timbers collected from Quseir al-Qadim and al-Balid, and the Belitung and Phanom-Surin shipwrecks. Two main distinctive forms occur, one using a double- and the other a single-wadding method (Figure 2.8). Wadding is a roll made of different materials, such as fibre, leaves and ropes, which is placed over the seam of two planks and firmly tightened by the sewing cordage. The

Figure 2.8: Single-wadding technique on the outside of the al-Hariri boat reconstruction (A). *Jewel of Muscat* reconstruction showing the double-wadding method (B). Both methods have wadding on the inside of the hull (C). (Photos: Author)

double-wadding technique employs this padding on both the inside and outside of the hull, with a pattern of alternating vertical and diagonal stitches (IXIXIXIXI). The Belitung and Phanom-Surin shipwrecks are examples of the double-wadding method (Flecker 2000: 206; Vosmer 2017: 200). In the single-wadding technique the wadding is found only inside the hull, while the outside shows unconnected vertical stitches recessed in rebates, as in the case of the timbers from Quseir al-Qadim (Blue 2006: 607).

Vosmer (2017: 200) offered hypotheses for the two different sewing patterns, stating that they could represent various stages of a chronological development of the technique. Radiocarbon dating analyses carried out by Vosmer on some of the al-Balid timbers appear to strengthen this hypothesis by showing that samples without rebates, suggesting a double-wadding technique, are older than those with single wadding (Vosmer 2017: 200). However, Vosmer acknowledges that the data is not sufficient to prove a definite interpretation and the difference between the timbers' sewing patterns might also be explained by other factors, such as culture, geographical area, environment and the function of the boat. It could even depend on the wood species used.

2.3.4.2 Nailed Construction Method

The geographical extent of the sewn-construction method in the Indian Ocean in the Middle Islamic period is still not clear. One interesting aspect emerging in the archaeological record is the presence of other methods, apart from sewn-plank construction. For example, the use of nails in boatbuilding is attested in Quseir al-Qadim between the 12th and 15th centuries (Blue 2002: 149; Blue et al. 2011: 182). In southern India, the discovery of the Thaikkal-Kadakkarappally boat has revealed the use of nail fastenings between the 13th and 15th centuries (Tomalin et al. 2004: 256-257). The al-Balid timbers include some examples showing a method combining nail and sewn construction, but Belfioretti and Vosmer only briefly mention this evidence, which they tentatively describe as a hybrid form combining Mediterranean and Indian Ocean sewn-plank traditions (2010: 115).

2.3.4.3 The Provenance of the Archaeological Ships

Evidence for the origin of these ships remains vague and far from conclusive. Most of the academic discourse on the topic revolves around the assumption of a strict distinction in fastening techniques between western and eastern Indian Ocean watercraft, the former being sewn while the latter is either nailed, doweled or lashed (Burningham 2019b: 178-179; Lewis 1973: 247-248; Manguin 1985a: 16-18). For example, Flecker, the Australian maritime archaeologist who directed the survey and excavation of the Belitung shipwreck, provided an identification of the ship as either Arab or Persian while excluding Indian origin due the large presence of timber native to Africa (see section below) identified in its hull (Flecker 2010: 118). Chinese or Southeast Asian origin are also excluded on the basis of the construction method (Flecker 2000: 212). The shipwreck had planks held together by continuous sewing and differed from either the lashed-lug planked boat shipbuilding tradition of Southeast Asia (3rd–4th centuries) (Manguin 1985: 333-334) or the iron-fastening method of Chinese ocean-going ships of the 2nd millennium (Manguin 1996: 184). In fact, the sewing technique of the Belitung is similar to that of the Indian *masula* (Kentley 1985: 309-310), while the fastening of its beams resembles those of the Omani *battīl,* a nailed fishing vessel used in Musandam, northern Oman, with sewn hood ends and beams (Vosmer 1997; Vosmer et al. 2011: 411).

2.3.4.4 Materials

Knowledge of the materials used for boatbuilding in the Indian Ocean during this period is also limited, but a study of wood species can provide insights concerning origin, technology and trade.

The timber of the Belitung wreck has been analysed by two different laboratories with entirely different results. In 2000, analyses carried out by Dr Jugo Illic of the Forestry and Forest Products Division of the CSIRO, Australia, showed a predominance of genus and species from India, such as teak (*Tectona grandis*), *Dalbergia* sp. and *Pterocarpus* sp. (Flecker 2000: 215-216). In contrast, Professor Nili Liphschitz of the Institute of Archaeology, Botanical Laboratories of Tel Aviv University, carried out analyses on the timbers in 2007, indicating instead that African wood (*Afzelia africana*) was predominant (Flecker 2008; 2010: 117). The discrepancy between the results of the identification analyses of the Belitung timber raises a few doubts about their reliability, which has also been recently challenged by Haw (2019). Flecker explains that the difference in identification results might be due to the different sectioning methods used by the laboratories, as well as by the fact that the CSIRO, unlike Liphschitz, is not specialised in identifying waterlogged samples (Flecker 2008: 385).

The wood species identified in the Belitung shipwreck by Liphschitz, comprising a variety of species such as *Afzelia africana*, *Afzelia bipidensis,* teak (*Tectona grandis*) and *Juniperus procera*, which are endemic to Africa, India, Sri Lanka and Southeast Asia, allowed Flecker to further speculate about the origin of the ship (Flecker 2010:

117). All these regions have plentiful sources of good quality wood for boatbuilding and it is unlikely that they would have imported timber from elsewhere (Flecker 2000: 215; Vosmer et al. 2011: 412-413). According to Flecker, the variety of timber indigenous to different regions and historical references mentioning the import of wood from India to Arabia and the Gulf is likely to suggest an Arab/Persian origin for the shipwreck (Flecker 2010: 117).

The ropes used to sew the hull, and the wadding, had deteriorated too far for definitive identification; hibiscus for the cordage and paperbark for the wadding were the closest match. The presence of Southeast Asian materials, both hibiscus and paperbark, which were largely used in Malaysian and Indonesian boatbuilding[8], raises a few doubts about an Arab/Persian origin of the boat and Flecker suggests that this evidence might indicate that the vessel underwent maintenance in that region and that the original stitches were replaced with material found locally (Flecker 2010: 118). While the resewing of the Belitung hull with Southeast Asian materials certainly sounds plausible, it remains just a hypothesis. The discovery of the Phanom-Surin shipwreck, which shares some similar features with the Belitung wreck, particularly the double-wadding sewing technique and the presence of Southeast Asian wood and cordage, point instead to the building of these vessels in this region, perhaps by Arab or Indian settlers (Vosmer 2017: 198). However, evidence from the two shipwrecks also tells us that we cannot necessarily consider the sewn-plank method as exclusive to the western Indian Ocean and that the vessels could have been built in Southeast Asia by local boatbuilders.

[8] However, experiments with paperbark suggested it was not suitable, as the cordage damaged it (Tom Vosmer, personal communication, December 2020).

Analyses of the wood species of the Quseir al-Qadim timbers, meanwhile, provided very little information in regard to the sewn timbers, and only one plank was identified as cf. *Afzelia*, a species indigenous to the tropical regions of Africa, India and Southeast Asia. The remaining timbers were too degraded to allow a definite identification. Rowena Gale and Marijke van der Veen, who carried out the analyses, were only able to determine that the wood is not local, but they excluded teak (*Tectona* sp.) and *Dalbergia* sp. as possibilities. Interestingly, the planks showing nailed construction are all from wood available locally (*Acacia nilotica* and *Ficus sycomorus*), which could suggest that nailed-plank vessels were built locally while sewn ships made of exotic timber were built outside Egypt (Gale and van der Veen 2011: 223-224).

2.3.4.5 The Appearance of the Ships

Although the Belitung shipwreck was of invaluable importance, its discovery provided only limited information regarding its shape and size. The salvage operation took only six weeks, an extremely short period in which to document such an extraordinary archaeological assemblage,[9] and vital information, for example concerning the stern of the ship, was lost.

Flecker states that no accurate theoretical reconstruction of the vessel was possible because the hull lay flat on the seabed after the stitching had rotted away and the stern had been covered by coral concretion (Flecker 2000: 200, 208). The length of the keel and the cargo dispersion of the Belitung suggest an overall length of 18m for the vessel (Flecker 2010: 106) but there is some confusion about the interpretation of

[9] By comparison, as maritime archaeologist Jeremy Green pointed out (2011: 450), the excavation of the Uluburun shipwreck, dated to the 14th century, took almost ten years.

the hull shape. Flecker (2000: 205, 208) deduces that the wreck was probably double-ended, as indicated by iconographic studies of Arab and Persian ships before the arrival of the Portuguese. The forefoot of the keel and the stem joinery were visible, indicating that the bow was raked and making it possible to determine its angle. Flecker (2000: 208) first states that the sternpost probably had the same angle as the stem post but later he concludes (2010: 106) that the stern had probably been vertical.

Very little is currently known about the shape of the other sewn shipwreck, the Phanom-Surin. The hull is believed to be double-ended and the massive size of the keelson, measuring over 17 m, suggests that the ship may be 30 m long (Vosmer 2017: 198).

Figures regarding the size of the two shipwrecks are particularly useful to my research because they provide analogies for interpreting evidence from al-Balid. Timbers from this site, which have been cut and modified for reuse, cannot tell us much about the shape of the vessels, but their thickness and width, compared to those of the Belitung and Phanom-Surin wrecks, can offer interesting insights regarding the size of the boats from which these planks came.

2.3.4.6 Date of the Shipwrecks

Studies of archaeological sewn-boat evidence from the western Indian Ocean also highlight the limits of knowledge concerning the date of abovementioned vessels.

Belitung has been dated to the 9th century on the basis of radiocarbon dating and the interpretation of an inscription found on one of the Changsha bowls discovered on the wreck (Wilson and Flecker 2010: 26). However, only three samples were radiocarbon dated, and only one was timber from the hull of the ship. The attempt to scientifically date the cargo through radiocarbon dating has produced rather uncertain results with a large time span.[10] The results were refined to the first half of the 9th century on the basis of the date inscribed on one of the abovementioned Changsha bowls included in the cargo, indicating a specific day of the year 826 and representing a terminus post quem for at least the time of the voyage, but not for the ship (Wilson and Flecker 2010: 36). Although it is plausible that the objects constituting the cargo could have been produced shortly before being loaded onto the ship, it is also possible that artefacts could have been manufactured years before their export.

Dating of the ship remains from Quseir al-Qadim is even more problematic. The tombs had no diagnostic artefacts and the date of the timbers is based on stratigraphic analyses of the site buildings, which range between the end of the 12th–15th century. Moreover, the planks are not in their original context, and this might indicate that the vessel (or vessels) could be earlier than the Islamic necropolis (Blue 2006: 610).

2.4 Textual Sources

Until the recent discoveries of the Belitung (Flecker 2000, 2010) and Phanom-Surin (First Regional Office of Fine Arts 2016; Jumprom 2014; 2019) wrecks, and the ship timbers from Quseir al-Qadim (Blue 2002; 2006; Blue et al. 2011) and al-Balid (Belfioretti and Vosmer 2010), knowledge of sewn boats in the Indian Ocean during the Middle Islamic period relied almost exclusively on textual sources; accounts of Europeans and Arabs from the Mediterranean, and Chinese who ventured into the

[10] By admission of Flecker himself, two samples taken from the cargo — a piece of star anise and a lump of resin — were not a good choice. The star anise disintegrated during analysis and the resin, of Southeast Asian origin, could have already been a hundred years older than the other samples when it was harvested (Wilson and Flecker 2010: 36).

Indian Ocean and provided descriptions of the technology, culture and traditions of the places they visited. Scholars have collected, translated and studied these texts, focusing on different sources, periods and regions with the aim of expanding knowledge regarding the maritime history, trade and technology of that vast area identified as the western Indian Ocean (Mookerji 1912; Yule 1914; Moreland 1939b; Hornell 1942, 1970; Johnstone and Muir 1962; Hourani 1963; Lewis 1973; Tibbetts 1981; Prins 1986; Agius 1999, 2007a).

The information provided by these texts involves a large geographical area that stretches from the Gulf to India and as far as Southeast Asia and China, and includes the Red Sea and the coast of East Africa. It also covers a vast period of time ranging from the Early Islamic period to the time of European expansion in the Indian Ocean in the late 15th century. Scholars have argued that the texts should be studied collectively in light of the cultural unity of the western Indian Ocean where techniques and technology were not restrained by geographical boundaries (Hourani 1963: 88). This has led to the identification of general features of the so-called "Arabo–Indian tradition" (Manguin 1985: 19). Textual sources, taken as a whole, might create a misleading view of watercraft in the Indian Ocean because they refer to ships from various periods and geographical areas which, despite being connected by a vibrant trade network, had different cultures, traditions and technologies.

The authors of the accounts were historians, geographers, missionaries, pilgrims, traders and explorers who travelled in this region from the Mediterranean world and, in part, from China, and were intrigued by the absence of nails in the boats and ships of the western Indian Ocean. Unfortunately, their curiosity was not passionate enough for them to provide detailed descriptions of these vessels, which rarely go beyond the simple statement that they were structurally fastened with ropes. Agius has provided the most comprehensive linguistic examination of the variety of watercraft used in the Islamic world to date, including the few historical references to sewn-plank craft (Agius 2002, 2005, 2007a). He states that "the history of the development of ships can only be studied with concrete examples of the past, such as the eye-witness accounts of historians, geographers, and travellers" (Agius 2007a: 33). These texts are undoubtedly an invaluable source for the study of the maritime past of the Indian Ocean but they are often vague about shipping technology. Information on the appearance of ships, their size and construction technique is very limited. Literary sources are also rather confusing about the ownership and origins of these vessels.

2.4.1 Ubiquity of Sewn Boats in the Western Indian Ocean

One of the striking aspects of medieval vessels emerging from a study of the sources is the ubiquity of the sewn-plank method in the western Indian Ocean. One of the earliest studies of watercraft from this area was carried out by Moreland in the first half of the 20th century (1939a, 1939b). His approach, which aimed to identify the general features of vessels of the Arabian Sea, was simply based on the interpretation of accounts of Western travellers in the 13th–14th centuries and of the Portuguese. It must be acknowledged that at the time Moreland writes there was no archaeological or iconographic evidence,[11] and ethnographic studies were scarce. The only evidence he was able to use came from two scale models built in Oman in the 19th century (1939a: 65). According to Moreland, the ubiquity of references to sewn boats in historical sources clearly indicated that sewn-plank construction was the distinctive

[11] Moreland mentions the boat illustrations of the *Maqāmāt* of al-Ḥarīrī only in the postscript at the end of the paper (1939b: 192).

feature of Arab vessels until the 16th century, in contrast to the nail-built Mediterranean ships and Chinese junks (Moreland 1939a: 74).

Other scholars, such as Hornell (1970: 236-237) and Hourani (1963: 88) used a similar approach and came to similar conclusions. In his work *Arab Seafaring in the Indian Ocean in Ancient and Early Medieval Times*, Hourani presents accounts from Mediterranean Arab travellers and iconographic data, in addition to sources mentioned by Moreland, in order to explore the history of trade routes and the Arab vessels of the Indian Ocean until the arrival of the Portuguese in the 16th century. He provides a comprehensive study of the features and techniques of the vessels reported in sources, including hull shape, materials, structural elements such as rudders and sails, and claims that the distinctive traits of Arab vessels are their continuous-sewing pattern, double-ended shape and, erroneously, their lateen sails (Hourani 1963: 88, 92). Hornell focuses on the origin, evolution and diffusion of watercraft in the Indian Ocean, and combines a study of the sources with the results of his ethnographic studies of boats and ships of the Indian Ocean, which aims to classify vessels by type. Within a comparative approach to recent Indian Ocean vessels, he defines the main traits of sewn boats in the medieval period as their distinctive steering system, double-ended shape and sewn construction. He remarks that no changes or improvements took place in Indian Ocean vessels until the Portuguese or European "revolution", which gradually changed the design and construction technique (Hornell 1970: 236-237).

2.4.2 Pre-Islamic Period

References to rope fastening for ships in the region occur before the Islamic period. Pedersen examines the eleventh tablet of the Epic of Gilgamesh (second millennium BCE) and argues that it provides evidence of sewn-plank technology, including a description of shell-first construction and the plugging of stitching holes (2004: 234). Mookerji (1912: 31) reports a reference to a sewn vessel sailing to Ceylon in the *Dāthā dhāthu wanso* (also known as *Dantadhātuvaṇṇanā*), a work of Pali literature possibly dated to the 3rd–4th centuries. Sewn boats, called *rhapta*, were recorded in the 1st century by the anonymous author of the *Periplus Maris Erythraei* in Azania (East Africa), in a port in the Zanzibar archipelago (Casson 1989: 141) and again in Omana along the Makran coast, where they were known as *madarate*[12] (1989: 63). In the 6th century, the boats sailing in the Gulf and Indian Ocean were all sewn with ropes according to the Byzantine historian Procopius (d. c. 570) (1914: 183). Islamic, European and Chinese sources of a later period (9th–14th centuries) provide a picture of the geographical distribution of this fastening method in the region by reporting similar observations. According to Agius (2007a: 162), the earliest Islamic reference to the use of sewn-plank construction is found in the *Holy Qur'an*, in the Sūrat al-Qamar (The Moon), which deals with the construction of Noah's ark saying it was "made of broad planks and cord of palm fibre".[13]

[12] The term has been interpreted by Hornell (Hornell 1970: 234) as indicative of sewn-plank construction, but Casson (1989: 181) argues that the correct translation should be "to be armed". McGrail suggests that the term may refer to the wadding made of fibre and ropes placed on the seams of the planks on the inside of the hull, thus the hull seams were "armed" or protected (McGrail 2001: 72).

[13] However, the term *dusur* (sing. *disār*), translated in the text as "cord of fibres", could also mean wooden dowel (Agius 2007a: 162; Al-Salimi and Staples 2019: 152).

2.4.3 Early and Middle Islamic Period

Mentions of sewn boats in the Indian Ocean occur throughout the 9th–12th centuries, indicating the predominance of this fastening method. Muslim historians and geographers al-Masʿūdi (d. 345/956–957[14]) (Agius 2007a: 163) and Ibn Jubayr (d. 614 /1217–1218) (Hourani 1963: 92) recorded sewn boats in the Red Sea, and in the Maldives and Lakshadweep by Abū Zayd al-Ḥasan al-Sīrāfį (4th /10th century) (Al-Sīrafī and Ibn Faḍlān 2014: 121). In the 9th century, a statement made by geographer al-Yaʿqūbī (d. 278/891)(Agius 2007a: 162) that ships that sailed from the Gulf to China were sewn finds confirmation in the Late Tang reference of Liu Xan, who describes the merchant ships as "built without nails, and … only bound with leaves of the gomuti palm" (Ming-liang 2010: 139).

Later, in the 13th and 14th centuries, accounts of European missionaries, merchants and travellers in the Indian Ocean joined those of Muslims, and provide additional references to the sewn-plank technique in the region. References to ships "sewn like clothes" in the Arabian Sea are mentioned by the missionary Friar John of Montecorvino (d. c. 1328) (Yule 1914: 66), in Yemen by Ibn Bāṭṭūṭa (d. 770/1368–9 or 779/1377) and by the Egyptian historian al-Nuwayrī l-Iskandarānī (fl. 8th/14th century) (Agius 2007a: 163). Sewn vessels are reported in Malabar by the Dominican missionary Friar Jordanus (d. 1330) (Jordanus 1863: 53), in the Maldives by Ma Huan (d. 1460), Secretary to Admiral Zheng He (Manguin 2012: 615), and in the Red Sea by al-Maqrīzī (d. 846/1442 CE) (Hornell 1970: 235). Marco Polo (d. 1324) (Moule and Pelliot 1938: 36) gives one of the most detailed, and derogatory, descriptions of the sewn boats of the merchants of Hormuz. Friar Odoric of Pordenone (d. 1331)

[14] Hijri Year/Gregorian Calendar

(Moreland 1939: 67), who sailed on one from Hormuz to Bombay in the early 14th century, calls them *jase*.

2.4.4 Portuguese Sources

With Portuguese expansion in the Indian Ocean at the end of the 15th century, there are useful descriptions by the explorers and missionaries who took part in expeditions in the region. Arab-owned ships built without nails are noted by the crew of Vasco Da Gama's (d. 1524) fleet in Mozambique, the first port visited by the Portuguese after entering the Indian Ocean (Velho 1898: 128-129). In East Africa, Portuguese sources mention sewn boats in Kilwa, from where D'Almeida (d. 1510) saw several sailing to Sofala (Prins 1986: 67), in Melinde, where Gujarati ships are described by Cabral (d. 1520) as "well built of good wood, tied together with cord" (Greenlee 1938: 65), and in Pemba and Zanzibar by Duarte Barbosa (d. 1521) in 1517–18, who informs us that these islands traded with the mainland with small sewn boats (Dames 1918, I: 27).

Similar accounts are provided about watercraft along the coasts of India. The Portuguese historian Correa (d. 1563), who reached India in the second decade of the 16th century, provides a detailed description of these vessels, the planking of which "is joined and sewn together with coir thread" (Stanley 1869: 240). Sewn vessels were documented by the Portuguese armadas in Malabar (Velho 1898: 128), in Gujarat, where Castanheda (d. 1559) states that the ships are "stitched with coir, like those of Malabar" (1833, III: 437) and in the Maldives, where Duarte Barbosa and Correa report sewn boats made of the coconut tree (Dames 1918, II: 103-104; Manguin 2012: 615). References to rope-fastened vessels in the Indian Ocean are also found in later accounts by British travellers, traders and officers. James Lancaster (d. 1618), who took part in the first English maritime expedition to India, writes of sewn boats used in

Zanzibar at the end of the 16th century, and William Daniel, who travelled from London to Surat during the 17th century, records them in Mocha, Yemen (Foster 1949: 73).

2.4.5 Perception of Sewn Boats in the Western World

Collectively, these texts provide a picture of the ubiquity of sewn-plank techniques in the western Indian Ocean and its survival for centuries. However, it is possible that some travellers could have limited their descriptions only to sewn boats, which they probably considered uncommon and exotic, rather than mentioning vessels built in a way similar to those of the Mediterranean that were more familiar to them. These accounts also promoted, among the majority of the scholars who studied them, a view of Indian Ocean vessels as immutable in terms of shape, technique, materials and technology until the arrival of the Portuguese in the 16th century. Early scholars have assumed that the nailed-construction method of recent Arab boats was the result of European influences (Hourani 1963: 88; Johnstone and Muir 1962: 59). Johnston and Muir (1962) studied the sewn vessels of the Indian Ocean through an approach that combined ethnographic data and the etymology of the words used in shipbuilding. Their linguistic approach enabled them to identify various nautical terms with Portuguese roots, the most significant ones referring to the use of nails and shape of the vessels. According to them, these words indicated from where these terms, and consequently the technology, were borrowed, confirming that the use of iron fastenings was introduced by the Portuguese (Johnstone and Muir 1962: 61). However, we have at least four references indicating the use of nails in Indian boatbuilding from the very early years of the 16th century, such as those by Ludovico de Varthema (d. 1517) (De Varthema et al. 1833: 152), Castanheda (Castanheda 1833, III: 21), Padre José (d. 1600) (Greenlee 1938: 101) and Correa (Stanley 1869:

240), but these are simply explained by early scholars as the evidence that Indian shipwrights quickly emulated European boatbuilding practice (Moreland 1939b: 180–183). However, French maritime archaeologist Pierre-Yves Manguin, who has produced extensive studies about the maritime technology of the Indian Ocean, argues that the references to the use of nails in boatbuilding are from just a few years after the Portuguese arrival in the Indian Ocean, and therefore too early to be simply considered as indicative of a quick imitation of European construction methods (2012: 608) as Moreland claimed (1939b: 182). Rather, those references strongly suggests that nailed-plank technology was known and practiced before the Portuguese expansion in the region. Chinese and South Asian junks, which were involved in the trading network of the Indian Ocean, could similarly have influenced the boatbuilding techniques of Arab and Indian vessels (Agius 2007a: 166).

2.4.6 Sewing Technique

A crucial piece of information that is missing from historical sources is how medieval boatbuilders sewed their vessels. In fact, textual descriptions are limited to statements that the planking was held together with fibre ropes. This lack of detail further contributes to strengthening the notion that these sewn vessels remained unaltered through time and space (Hornell 1970: 236-237). Ethnographic studies on the watercraft of the Indian Ocean, such as those conducted by Pâris in the 19th century (1843), have revealed that sewn boats had different forms and were often linked to the geographical areas where they developed, where the availability of materials and the vessel function played an important role.

Thanks to ethnographic studies, as well as recent archaeological evidence, the main features of sewn-plank technology in the western Indian Ocean are that they were carvel built with continuous sewing through holes drilled along the edges of the planks (Hourani 1963: 92; Pâris 1843: 15, Pl. 8). Perhaps a hint at continuous-sewing patterns can be found in two medieval accounts: in the 13th century Jordanus describes the vessels of the coast of Malabar as stitched with a needle (Jordanus 1863: 54), while John of Montecorvino, when referring to ships of the Arabian Sea in the 14th century, states that they are sewn like clothes (Yule 1914: 66).

2.4.7 Materials

2.4.7.1 Cordage

Medieval accounts frequently refer to the use of coir (coconut husk) as the material for the fastening cordage. Products from the coconut tree (*Cocus nucifera*) were widely traded and highly valued in the Indian Ocean region. In the 10th century, Abū Zayd reports that Omanis travelled to islands off the coast of India to purchase this material for their boats, and provides a detailed description of the maritime applications of the coconut tree (Al-Sīrafī and Ibn Faḍlān 2014: 121). Abū Zayd does not specify the name of the islands, but he is likely to refer to the Lakshadweep archipelago off the southwest coast of India, renowned for its high-quality coconut palms and for being one of the primary suppliers of coir (Agius 2007a: 148). Fibres from the husks of the coconut were used to make the stitching ropes and rigging, the trunk provided the timber for almost every part of the hull of the boat and, lastly, leaves were cut into strips and woven together to make sails. The plant is indigenous to south India and Southeast Asia but by the 11th century it had already been introduced into Oman, and in the 14th century Ibn Baṭṭūṭa describes coconut palms in Dhofar (Hourani 1963: 91).

2.4.7.2 Timber

Our understanding of the wood used to build medieval sewn vessels in the Indian Ocean region is very limited and relies on just a few references. Teak (*Tectona grandis*) and the wood from coconut trees are the only timbers mentioned in historical sources being used for boatbuilding (Hourani 1963: 90; Lewis 1973: 250; Moreland 1939b: 145). The main source of teak was India, where it flourished on the hills behind the coast of Malabar. A lack of suitable boatbuilding timber in the arid regions of the Gulf and Arabia had promoted a teak trade from India from early times (Mookerji 1912: 85). The fact that no other wood species is reported in sources is rather surprising, especially considering that the tropical region of southern India is the source of a variety of good quality timber such as mango wood (*Mangifera indica*), *aini* (*Artocarpus hirsuta*) or *poon* (*Calophyllum inophyllum*), which were used for the building of Arab and Indian vessels until recently (Agius 2007a: 80, 103-104; Vosmer 1997a: 218). Moreover, archaeological evidence, such as that of the Belitung shipwreck (Flecker 2000: 215), the timbers from Quseir al-Qadim (Gale and van der Veen 2011: 224) and al-Balid (Belfioretti and Vosmer 2010: 111-112), provides a picture of materials employed in the construction of sewn vessels in medieval times, when teak represents only a portion of identified wood species.

2.4.8 Shipyards and Origins of Boats

Apart from references to the presence of sewn boats in the Indian Ocean, knowledge of shipbuilding and shipyards in the Early and Middle Islamic periods is scarce (Agius 2007a: 142). The material used for the construction of these vessels is often insufficient for determining where they were actually built, for timber was extensively traded in the Indian Ocean region and wood was imported from India, Africa and Southeast Asia to Arabia and the Gulf. Moreover, sources are rather generic regarding the origin of boats and often can be misleading. Statements such as “ships from India” or “from China” could indicate ships coming from or going to a place and carrying goods from that place (Agius 2007a: 67) or vessels built elsewhere or by a merchant community of different origin based in that place (Manguin 2012: 600). Similarly, references to “Muslim” or “Moorish” ships might not necessarily indicate Arabs because of the spread of Islam along the coasts of the Indian Ocean (Agius 2007a: 8-12). Ubulla and Siraf were the main boatyards during the Early Islamic period and Aden in the Middle Islamic period (Agius 2007a: 142; Margariti 2007: 56-60) while later, in the 15th century, sources appear to suggest that boats were built outside the Arab world, probably commissioned by Arab merchants from boatbuilding centres on the Malabar coast. Southern India was indeed a strategic place along Indian Ocean trade routes and a necessary stop for ships on their way to the Far East while waiting for the shift of the monsoon (2007a: 142). Here the availability of highest-quality timber for boatbuilding, such as teak, as well as the coconut palm for the fastening cordage, might have played an important role in making India a regular source of ships (Moreland 1939a: 70, 174). For the same reason, the Maldives and Lakshadweep were also important boatbuilding centres due to the quality of their coconut trees, the products of which were used to make every part of the boat, including the cordage for fastening the planks, rigging and sails (Hourani 1963: 91).

2.4.9 The Appearance of Boats

According to Hornell (1942: 22), double-ended vessels represented archetypal ancient and “primitive” forms of Indian Ocean sewn ships before the arrival of the Portuguese. However, little information is found in literary sources regarding the appearance of ships’ hulls and it is generally assumed by scholars that the vessels of the Indian Ocean were double-ended until the 16th century (Hornell 1942: 22; Hourani 1963: 89; Johnstone and Muir 1962: 62). Textual sources only detail the names of vessels in use at the time but not their shape (Hourani 1963: 98). Agius points out that the root of the words used to describe these vessels in these sources could provide hints about their general shape (2007a: 156). Moreover, he sees a strong link between the form of the hull and the fastening method, stating that vessels with pointed bows and sterns (double-ended) are easier to sew than those with transom sterns (2007a: 156; Vosmer 2007: 224; Vosmer 2019: 305).

No transom is mentioned in early accounts and scholars generally believe that its introduction was the result of foreign influence, either by Portuguese caravel (Hourani 1963: 89; Johnstone and Muir 1962: 60) or perhaps by Chinese junks (Agius 2007a: 156). One interesting observation in the textual sources comes from Cabral, who notices the presence of a castle in the sterns of three sewn vessels from Cambay, Gujarat, (in Moreland 1939b: 177). Rather than indicating a transom, Cabral’s description might allude to a raised poop deck built above cabins (Manguin 2012: 602), similar to those on Arab boats depicted in the Lopo Homem-Reinéis *Atlas de 1519.*

2.4.10 The Size of Ships

The size of vessels is barely mentioned in sources. As Agius (2007a: 218) points out, early historical sources are generic in regard to the dimension of Indian Ocean boats, usually describing them in contrast to Mediterranean or Chinese ships. Descriptions by travellers such as Ibn Baṭṭūṭa or Marco Polo (Yule 1871, III: 195), which compared the junks of China or Southeast Asia with the sewn vessels of the western Indian Ocean, report Arab, Persian and Indian boats were generally smaller.

Portuguese accounts give little information about the size and capacity of the sewn boats that they encountered in East Africa and India. Vasco da Gama in 1498, describing the sewn vessels of Mozambique, reports that the largest was 50 tons[15], while Cabral, a few years later, notes ships in Malindi of 60 tons (Greenlee 1938: 66; Prins 1986: 67). Other sources mention a trading ship with a 200-ton cargo capacity loading horses in Qalhat in 1507 (Agius 1999: 185). According to Agius (2007a: 225), the largest Arabian, Persian and Indian sewn cargo ships would most probably not have exceeded 100 ft (approx. 30.5m) in length and 300 tons in weight, while cargo vessels employed along the coast would have been about around 50 tons (1999: 185). However, the figures regarding the size of the ships provided by Agius (2007a: 225) are just estimates based on textual sources mentioning cargo capacity and number of people carried, without distinguishing between passengers and crew.

[15] The term 'tons' in a weight sense is problematical because of the many different tonnage systems for measuring capacity. Tons may be related to volume, weight or cargo capacity. Hence, these figures cannot be taken as arising from one system, but only indicate very relative sizes.

2.4.11 Other Structural Elements

2.4.11.1 Frames

Not much more is provided by textual sources regarding the hulls of sewn craft. With the exception of Correa's statement about Indian sewn boats having just a few ribs sewn to the hull (Stanley 1869: 240), mentions of frames are never found in textual sources. Two models of sewn boats from the British Museum, which were built in Oman in the 19th century, led Moreland to argue that Indian Ocean medieval sewn boats were frameless. However, archaeological evidence, such as that from the Belitung wreck (Flecker 2000: 206) and from the Quseir Al-Qadim (Blue et al. 2011: 182), and the al-Balid timbers (Belfioretti and Vosmer 2010: 111), have shown that frames were used in large seagoing vessels in order to provide sufficient structural integrity to the hull.

2.4.11.2 Deck

Hourani (1963: 98) argues that references to decks are vague. Boats are reported to be either undecked, with decks or with partial decks (Agius 2007a: 160). Vessels without decks would have had their cargo covered with hides, as noted in the 13th century by Marco Polo in Hormuz and by Jordanus in Malabar, or with a removable deck made of palm ribs lashed together, as observed in the boats of Cananor (Kannur, southwest India) by Correa (Stanley 1869: 240). Once again, both archaeological and iconographic data is scarce in this regard, but it is difficult to imagine large seagoing ships, such as those carrying four hundred people that are mentioned by Buzurg, without a deck (Hourani 1963: 98). The absence of a deck in some ships may have facilitated the loading and accessibility of cargo (Agius 2007a: 191) and, perhaps, it would have made it easy to access the bilge to bail out water. Illustrations from the *Maqāmāt* suggest the presence of a deck on which sailors stand while controlling the ship and, perhaps, even cabins to accommodate important passengers, such as those with turbans, visible through portholes in the hull.

2.4.11.3 Steering System

The nature of other structural features, such as steering systems or sails, can be extracted from literary sources. References to a single rudder appear very early in texts and iconography. John of Montecorvino (1247–1328) states that the rudder of a sewn boat he observed in the Arabian Sea was narrow, frail and flimsy and placed in the middle of the stern (Yule 1914: 66), and Marco Polo provides a similar description for the boats of Hormuz (Moule and Pelliot 1938: 36). Iconography provides perhaps the earliest depiction of an axial rudder with illustrations from the *Kitāb Ṣuwar al-kawākib al-thābita (The Book of the Constellations of Fixed Stars)* of al-Ṣūfī (d. 376AH/986CE) dating to the 12th century (Agius 2007a: 205; Nicolle 1989: 175-176). Curiously, the illustrations show both the steering systems, with axial rudders mounted and connected to the sterns, together with two steering oars (quarter rudders). However, an even earlier indication of the introduction of the axial rudder in Indian Ocean vessels can be seen in al-Muqaddasī's (fl. second half of the 4th AH/10th century CE) description of a steering system that is controlled with ropes by the helmsman (Agius 2007a: 206). The description is similar to the reverse-tiller system illustrated by Hornell (1942: 26), where the rudder is operated by two ropes, one on either side of

Figure 2.9: The reverse-tiller steering method on a traditional *battīl* sailing off the coast of Muscat, Oman. (Photo: Author)

the vessel (Figure 2.9);[16] there is a mention of a similar system in the 16th-century account of the Portuguese historian Correa (Johnstone and Muir 1962: 62).

2.4.11.4 Mast and Rigging

Textual sources generally describe sewn vessels as single-masted, although some accounts and iconography indicate two or three masts (Lewis 1973: 247). There is general agreement in the texts concerning materials used for the sail, namely woven palm mats, a feature that survived until the early 20th century in the East African *mtepe* (Hornell 1941: 57). Despite the assumptions of early scholars (Hourani 1963: 100;

[16] The same method, according to Tibbets, is illustrated in the *Maqāmāt* (1981: 54-55), but McGrail argues that there is no evidence of a seated helmsman using lines connecting the rudder to steering toggles ("outrigger sticks") in the drawings (2001: 75). However, there are two drawings in the *Maqāmāt* and one clearly shows a tiller (or perhaps two) attached to the aft side of the rudder, suggesting this particular steering system.

Johnstone and Muir 1962: 63), which are based on the study of recent Arab boats, sails of medieval craft were not triangular (lateen) but square or, perhaps, slightly trapezoidal, with the luff shorter than the leech. Historical sources provide no information about the shape of sails prior to the 15th century, but boat illustrations, such those of the *Maqāmāt*, appear to suggest square rigging. Tibbets reports the description of Ibn Mājid (d. after 906/1500) who compares the sails of 15th-century boats to the square of Pegasus constellation (Figure 2.10), providing a picture of a trapezoidal sail (1981: 52). Similar comments have been made by Correa about the Indian vessels, the sail of which "is longer abaft than forward by one-third". He continues reporting the complicated task of wearing by describing how the yard was set vertically and passed around the mast (Stanley 1869: 241). The manoeuvre described by Correa is identical to that used in more recent Indian Ocean boats with triangular sails, and would not have been necessary if the sail was square.

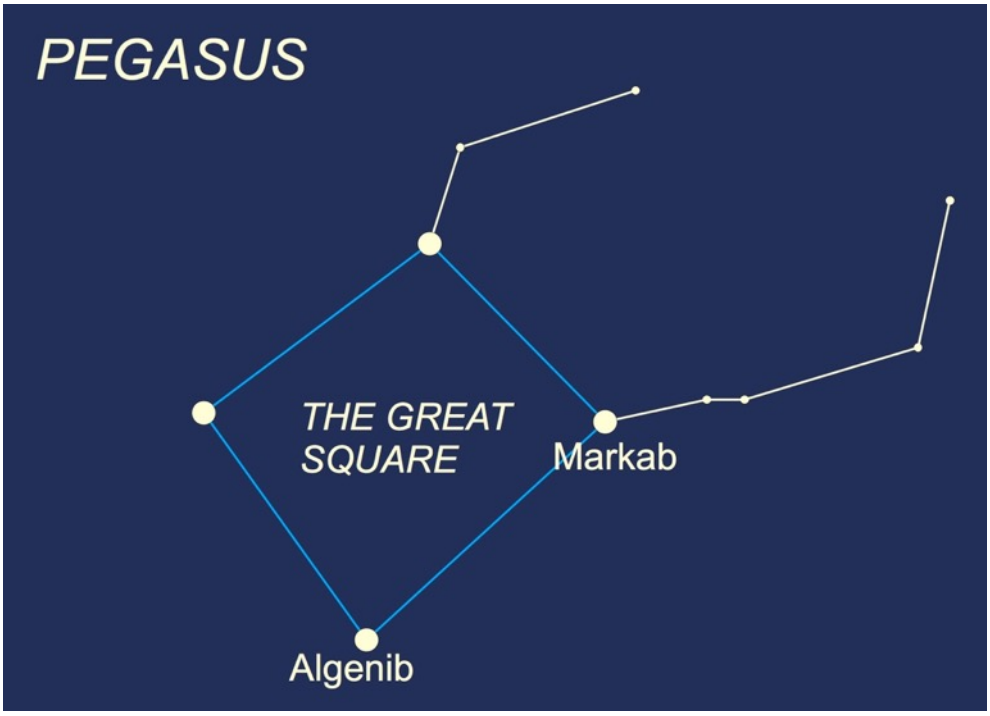

Figure 2.10: The Pegasus constellation with the Great Square highlighted in blue. (Image: Author).

2.4.12 Derogatory View of Sewn Boats in Historical Studies

Textual sources have produced a rather derogatory picture of the sewn-construction method. Early 20th-century scholars described sewn vessels of the western Indian Ocean as weak and primitive on the basis of accounts of early travellers who thus commented, in contrast to the heavily built, sturdy, large Chinese and Southeast Asian junks. According to Moreland, these descriptions are sufficient to claim that these vessels, due to their construction method, were capable of sailing only in fair weather (1939b: 190). Similarly, Hourani remarks that sewn-plank technology made the Arab and Indian vessels inferior to those of Greeks and Romans and unsuitable for sailing during the southwest monsoon between May and October (1960: 135-136). He further states that rough conditions of the sea during this period were too dangerous for sewn vessels, and even for recent nailed dhows, which rather used the winds of the northeast monsoon for their journeys between East Africa, Arabia and India (1960: 136). However, Van Beek (1960: 138) argued with this view, considering it an assumption based only on the derogatory descriptions of some medieval travellers. Tibbets (1981: 366), summarising the sailing date for the Indian Ocean ports reported by 15th–16th century navigators and commanders, such as Ibn Mājid, Sulaymān al-Mahrī (d. 917/1511) and Sidi Çelebi (d. 1562), shows that voyages continued during the southwest monsoon, stopping only in July. However, in addition to accounts mentioning the dangers of sewn boats, travellers also noted the advantages of this construction method. Agius (2007a: 164) acknowledged the benefits of using coir ropes by pointing out literary sources that mentioned the flexibility, strength and reliability of sewn vessels.

A term that often recurs in early studies of Indian Ocean sewn boats is “primitive” (Hornell 1942: 22; Johnstone and Muir 1962: 63). Scholars have used it to connote sewn boats in contrast to European vessels and assert the lack of development of maritime technology in this region until the coming of the Portuguese. However, more recent works (McGrail 1996: 228-229; McGrail and Kentley 1985; Prins 1986) have provided a picture of the distribution of sewn boats through time and space, showing the ubiquity of this method, which has been used in every part of the world except Australia. Evidence of boats fastened with cordage was found in the Adriatic seas until the 7th century (Pomey and Boetto 2019: 15-16) and their characteristics are still visible in recent watercraft (Pomey 1985: 35).

Scholars such as Hornell (1942: 22), and Johnston and Muir (1962: 63) apply the term "primitive" to various features of vessels, such as shape, construction method and the steering system, stating that it is only due to the influence of European technology that these vessels developed toward, what they consider, more "modern" forms. It is likely that the Portuguese and the other European powers had an impact on Indian Ocean shipbuilding when they ventured into the region at the end of the 15th century. However, lack of detail in literary sources concerning construction techniques, materials and boat shapes does not provide any knowledge of what exactly happened before that date, and textual sources provide no evidence for this "European revolution" that, supposedly, affected maritime technology of the Indian Ocean, where sewn boats continued to exist until recent times despite European influence. On the contrary, the survival of these vessels in the region indicates the extent of success of the sewn-construction method, for which scholars have attempted to provide different explanations. Moreland sees it in the high cost of iron (1939b: 190), while Hourani adds that the conservative nature of Indian Ocean boatbuilders could also have played an important role (1963: 97). Lewis (1973: 264) identifies it with the generally peaceful character of the peoples of the Indian Ocean region, which rendered the development of a naval force unnecessary and the main reason for a lack of technological development in shipbuilding before the coming of the Portuguese. All these factors could have contributed to the survival of the sewn-plank method, but the strongest explanation may be that sewn vessels simply fulfilled the needs of the various maritime communities involved in the Indian Ocean trade network during this period.

After the 16th century, this context changes in many ways with the appearance of European naval power, and Indian Ocean boatbuilders had to gradually adapt to a new scenario in order to compete with the stronger and heavily armed ships of foreign invaders. One of the main consequences of this change is the gradual transition from a sewn- to nailed-construction method, but the dynamics and forms of this transition are still unknown. However, the use of nail fastenings cannot be merely considered a Portuguese introduction, as stated by Johnston and Muir (1962: 63), but perhaps the adoption of a system that, as previously noted, was already known in the Indian Ocean and was not employed because it was not advantageous until things changed.

2.5 Iconography

The study of iconographic evidence of boats and ships, such as graffiti, miniatures, sculptures and stone reliefs found scattered throughout the western Indian Ocean region, proved to be an essential tool for the study of Indian Ocean shipbuilding. Together with written accounts of travellers and historians, they are the primary sources for the depiction of medieval shipping in the region. Despite their crudeness and stylised nature, they yield information about the general forms of the vessels, as well as insights into various boatbuilding elements and construction techniques.

Various scholars have focused on the collection, study and interpretation of iconographic sources of medieval Indian Ocean boats. Although appearing in the works of many scholars since the early 20th century (Bowen 1952; Eastman 1950; Hourani 1963; Mookerji 1912), these boat depictions were not deeply investigated. Probably because of the crudeness of the illustrations, their description and interpretation are often brief and straightforward, while the authors' approach is predominantly based on textual sources.

One of the most relevant publications on the subject is that of Nicolle (1989). In his paper, he collects most of the boat representations from Islamic art, between the 7th and 16th centuries from both the Indian Ocean and Mediterranean Sea. The author's aim is the creation of a 'catalogue' of pictorial evidence — many depictions were unpublished at that time — that would serve as a tool for the researchers studying the fields of boatbuilding and seafaring.

Nicolle acknowledges the stylised nature of the evidence and its scarcity, particularly compared to the Mediterranean or Chinese maritime worlds. His merit lies in the monumental gathering of these illustrations from multiple sources and attempting a description and interpretation of their general features. However, his study lacks a broader context. Nicolle is a historian focusing on Islamic arms and armour, and nautical archaeology, by his own admission, is not his field of specialisation (1989: 168). Hence, these boat illustrations are examined individually and briefly described within a technical approach, instead of being contrasted and compared to find common features and hints of developmental trends. Moreover, these ship depictions have been re-drawn as black-and-white sketches by the author, which means that many features, such as the original colours and small details, have been omitted. Moreover, one of the main issues of these illustrations is that it is practically impossible to determine whether the boats were sewn or nailed, except in a few notable exceptions. Nevertheless, Nicolle's paper represents an essential tool for the study of medieval boatbuilding and seafaring in the Indian Ocean.

2.5.1 *The* Maqāmāt *of al-Ḥarīrī*

Illustrations from the *Maqāmāt* of al-Ḥarīrī are undoubtedly the most famous depictions of Premodern western Indian Ocean sewn trading ships. The most renowned of the drawings (Figure 2.11), which is widely used by maritime historians and archaeologists, is the vessel in the *Maqāmāt* illustrated by Yaḥyā bin Maḥmūd al-Wāsiṭī (d. before 706/1300) in 1237 (Bibliothéque Nationale, Ms. Arabe 5847, Folio 119v, Paris) (Bowen 1952: 213, fig. 12; Hourani 1963: next to page 99). The ship is depicted sailing from Iraq to Oman carrying passengers and a number of crew members. Its hull is double-ended with a high, sharp bow and stern decorated with elaborate carvings. The ship has two masts: the forward one rigged with what looks like a square sail, while the one aft has a crow's nest. Two series of portholes on the side of the hull suggest the presence of multiple decks and points to a relatively large vessel. The ship appears to be governed by two steering systems consisting in an axial rudder attached to the sternpost and a steering oar. A series of vertical stitches grouped in pairs along the plank seams reveal that the hull is sewn. Vosmer (2007: 182-189) provides a detailed examination of the *Maqāmāt* illustrations in his unpublished thesis, remarking that this iconographic evidence, along with that of the *Kitāb Ṣuwar al-kawākib al-thābita (The Book of Fixed Stars)* (Nicolle 1989: 171-177, figs. 14-15, 19-20) defines the general traits of Arab/Persian medieval vessels. He also notes that these features echo those of the Bronze-Age watercraft of the Gulf and persisted in Arab traditional boatbuilding until the 20th century (2007: 189).

Figure 2.11: Miniature from the *Maqāmāt* of al-Ḥarīrī, illustrated by Yaḥyā bin Maḥmūd al-Wāsiṭī showing a 13th-century sewn vessel. (Image: Bibliothéque Nationale, Paris, MS Arabe 5847)

2.5.2 East African Graffiti

A number of engravings in the buildings of East African sites of the 13th–16th centuries provide pictorial evidence for watercraft on the Swahili coast. Maritime communities living in Kilwa and Songo Mnara in Tanzania, Gedi and Ungwara in Kenya (Garlake and Garlake 1964: 197) and Kilepwa, Mida Creek, also in Kenya (Pollard and Bita 2017), incised ship graffiti on the plaster of mosque and house walls scattered along the coast (Figure 2.12). These graffiti allude to the importance of watercraft in the life of the coastal communities of East Africa, representing the direct evidence of “the one thing on which the survival and prosperity of the settlements depended: the vessels” (Garlake and Garlake 1964: 197).

A significant aspect emerging from these engravings is their similarity to an early 20th-century sewn watercraft from East Africa, the *mtepe* (1964: 200). The vessels depicted in the buildings of Songo Mnara and Kilwa (1964: 198, fig. 1) reveal the distinctive feature of the *mtepe*, such as the upright mast with flying pennants, overhanging bow

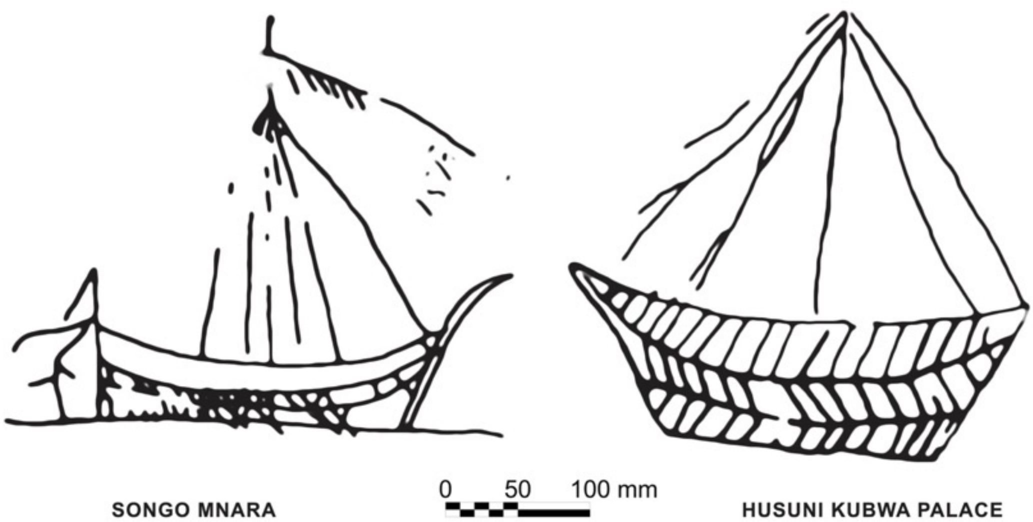

Figure 2.12: Engravings incised in the wall plaster of mosques and houses from Kilwa, Tanzania. (Image: Garlake and Garlake 1964: 198).

with a long swan-neck stem decorated with oculi and pendants, and square sail, which is suggested by the stylised rigging.

The limit of these engravings, as the authors admit (1964: 201), is their crude nature. While their sketchy features enable us to recognise various hull types, it is impossible to determine whether they were sewn or nailed. The authors remark that it is likely that the vessels depicted were sewn, but only because they are from a period before Portuguese expansion in the Indian Ocean. However, despite being crude and stylised, these engravings provide strong evidence of the importance of vessels for coastal trading communities, offering insights into their involvement in the maritime trade networks of the Indian Ocean during this period (1964: 205).

2.5.3 Indian Vessels

French historian Jean Deloche published several works focusing on iconographic evidence for Indian watercraft (1983; 1987; 2009; 2010). His 1996 paper collects all the relevant pictorial sources of Indian vessels from the 2nd century BCE to the 15th century CE (1996: 199). The focus of his research is the study of the development of Indian shipbuilding. Since the absence of archaeological data of Indian Ocean ships at the time he writes, he states that the only available evidence for achieving his aim is the study of iconography (1996: 201). His approach is technical and focused on the shape, types and rigging of these vessels, and how these features change through time. Deloche interprets these iconographic sources by comparing them with 19th–20th century ethnographic records from the western Indian Ocean, providing information about Indian nautical technology before the arrival of Portuguese.

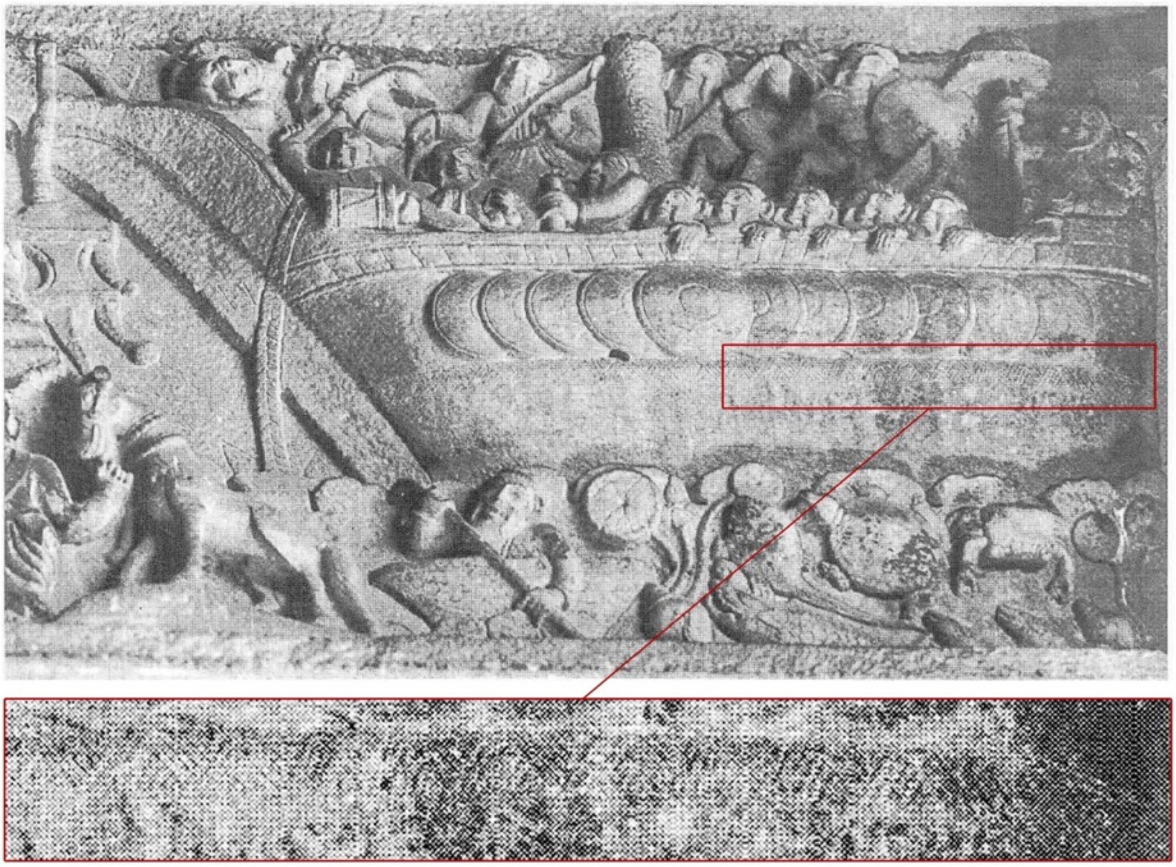

Figure 2.13: The sewing pattern (below the series of discs) of the boat relief of the Sri Alakiyanampirayar temple, Tirukkurunkudi, India, suggesting the presence of wadding outside the hull. (Photo: Institut Française d'Indologie, Pondicherry, after Deloche 1987).

Analysis of pictorial sources highlights similarities with recent vessels, such as the presence of a raked bow, while the first appearance of the transom stern and axial rudder suggests a development in boatbuilding during the medieval period (11^{th}–15^{th} centuries) (Deloche 1987: 167-169; 1996: 207-209).

These iconographic sources also provide significant information about the fastening method of these vessels. The long horizontal battens laid over the seams of some vessel reliefs in the Goa Museum resemble wadding used in sewn boats, and might indicate that these vessels were sewn with wadding outboard (Deloche 1987: 168), suggesting a double-wadding method such as that observed in the Belitung and Phanom-Surin wrecks and, more recently, in one type of the south-east Indian *masula*

(Kentley 1985; 2003b) and in vessels from Orissa (Colin Palmer, personal communication, December 2019). The boat relief from the Sri Alakiyanampirayar temple of Thirukkurunkudi (ca. 15th–16th centuries) (Figure 2.13), Tamil Nadu, also shows a vessel with a similar sewing pattern visible on the outside carrying people and animals (Deloche 1987: 170; 2009: 562, 563).

In the revised and translated version of his 1983 and 1987 papers, Deloche (2009) draws on pictorial evidence for information about the function of some of these vessels. For example, the painted panel at the Narumpunatasami temple of Tiruppudaimarudur, Tamil Nadu, and the relief in the Sri Alagiya Nambirayar temple of Thirukkurungudi are unique representations of stable ships carrying horses from the Arab world to India (Deloche 2009: 564).

2.5.4 Indian Ocean Vessels during the Portuguese Expansion

Weismann (2002) carried out a study of the vessels depicted on the early 16th-century maps of Lopo Homem in the Miller Atlas (Figure 2.14). He defines the features of the 16th-century Indian Ocean vessels, immediately after the Portuguese arrived, through a multidisciplinary approach combining iconographic evidence from different sources along with textual documents and ethnographic records. Weismann (2002: 140) notices that most of the vessels depicted during this period have recurrent features, such as long, raked stems, round sterns with an overhanging poop decks, one to two masts, square sails gradually developing into a traditional settee and steering systems consisting of a median rudder manoeuvred with ropes. Although it cannot be determined from sources whether the vessels are sewn or nailed (2002: 140), this

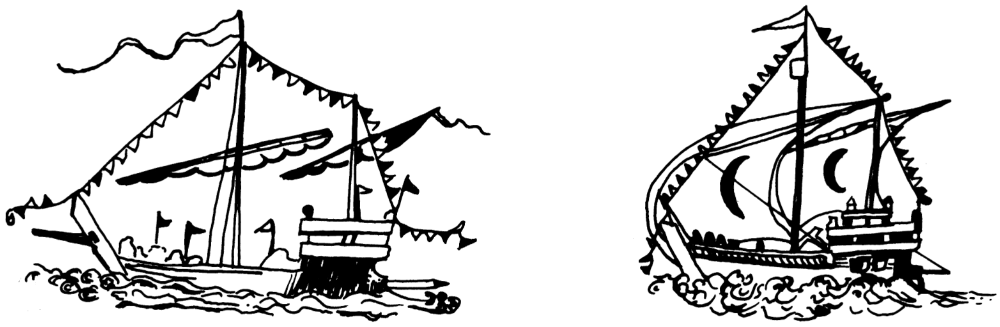

Figure 2.14: Vessels depicted in the maps of Lopo Homem in the Miller Atlas, c. 1519. (Images: Weismann 2002: 133).

pictorial evidence is particularly significant in providing insights into the hull shape and size, and rigging.

2.5.5 Limits of Iconographic Sources

Overall, the various abovementioned research shows the significance of iconographic evidence for the study of Indian Ocean boatbuilding and seafaring during the Premodern Islamic period, but also underlines its limits. On one hand these representations offer invaluable insight into the general features of medieval vessels, which can be briefly summarised in:

- A predominance of a double-ended hull with high raked stem and stern, which gradually sees the emergence of a transom;
- square rigging;
- two different steering systems consisting of steering oars and axial rudder.

On the other hand, since most of these drawings were not intended to be accurate representations of naval architecture, they lack many details. One crucial limit for the objectives of this thesis is that the fastening system is not apparent in the vast majority of the vessels, and scholars assume they are sewn because this was the predominant shipbuilding method in Indian Ocean vessels before European expansion. In the few illustrations where the sewing is visible on the hull, this is often stylised and difficult to interpret. However, other sources, such as those from India, have a more detailed representation of the sewing elements, such as wadding, pointing to the use of different techniques.

A further significant aspect revealed by the study of the iconography is the similarity between many features of medieval shipbuilding and those of the 20th-century western Indian Ocean. This evidence indicates a continuity in construction technique that persisted in the region with various forms until the last century. At the same time, it tells us that ethnographic studies are critical, as discussed more deeply in the next section.

2.6 Experimental Reconstruction Projects

Archaeologists use experimental approaches in the building and reproduction of artefacts, assemblages and techniques, and their subsequent testing, to deepen their understanding of the relationship between people and the material culture they create (Carrell 1992; Coates et al. 1995; Coles 1973; 1977; 1979). Since experimentation is the distinctive feature of scientific research, it is also a tool widely used in archaeology to test hypothesis and theories, rebut assumptions and ideas, and suggests modifications (Hurcombe 2005: 84). By combining experimental archaeology with ethnographic records, this approach offers archaeologists the invaluable opportunity to observe “cause and effect, and affordance and possibilities” in reality, enabling them with a range of possible interpretations rather than complete proofs (Hurcombe 2008:

84). In her review of experimental archaeology, British archaeologist Linda Hurcombe (2005) defines its methodology, remarking that it should have specific research questions and archaeological issues to test and verify; use materials and tools similar to those available in the past; and be rigorously documented and published to provide other scholars with the chance to verify and replicate it. She proves the potential of the experimental approach when investigating perishable artefacts, such as cordage and fibres and plants, which she calls the "missing majority" of the archaeological record (2008: 84).

Experimental archaeology and boat reconstruction projects provide scholars with a chance to test materials and experiment with boatbuilding techniques (Crumlin-Pedersen 1995: 303). The reconstruction and replication of a complex assemblage, such as a vessel, is an essential step in archaeological research and enables archaeologists to test the reliability of hypothesis and theories (Carrell 1992: 4-5; McGrail 1992: 355). This experimental approach can also be useful when speculating about aspects such as the time and technology required to build a boat, or the number of people involved in various stages of the construction, as well as providing a comprehensive insight into the people that produced and used these vessels.

Five sewn-boat reconstructions have been carried out in the Indian Ocean, with Oman supporting four of them. Of these, only one, *Jewel of Muscat*, can be considered an experimental archaeological project because it relies primarily on excavated evidence (McGrail 1992: 354). The other projects, although using a multidisciplinary approach partly involving archaeological data, are predominantly based on ethnographic records and iconography, and more accurately belong to the category of historical "reconstructions or simulations" (McGrail 1992: 354). The following sections describe these experimental projects and their outcomes and implications, underlining their crucial role in offering insights into the study of sewn-plank technology in the Indian Ocean.

2.6.1 Sohar

Sohar is the earliest sewn-boat reconstruction in the region (Figure 2.15) and was carried out in Oman in 1980 (Severin 1982; 1985; Severin and Awad 1985). The project, directed by British explorer Tim Severin and financed by the Ministry of National Heritage and Culture of Oman, consisted of a hypothetical reconstruction of a 8th–12th century Arab trading ship, and its passage to China demonstrated that sewn boats were capable of such voyages, thus reviving the myth of Sindbad. *Sohar* was built in Sur, on the eastern coast of Oman, and measured 80ft in length (approximately 24m) with a maximum beam of 20ft (approximately 6m). The international construction team included boatbuilders and rope workers from Agatti on the Lakshadweep Islands in India. The materials also came from south India: *anjili* (*Artocarpus hirsutus*) from Kerala was used for the hull planking and framing timber, while the rope workers used the best quality coir from the Lakshadweep islands for their sewing cordage and wadding (Severin 1985: 279-280).

Due to the lack of archaeological evidence of Indian Ocean medieval watercraft, the design and construction method of *Sohar* was largely based on historical sources and ethnographic records. Since iconography, such as illustrations from the *Maqāmāt* of al-Ḥarīrī and the vessels depicted in the early 26th-century Lopo Homem map in the Miller Atlas, indicated that the shape of the hull was double-ended, Severin decided to build a sewn version of a *būm*, the last double-ended trade vessel popular in the Gulf and Indian Ocean between the 19th and 20th centuries (Severin 1982: 18-20). *Sohar's*

Figure 2.15: *Sohar* careening in Beypore, southern India, after twenty-eight days at sea. (Photo courtesy of Bruce Foster)

rigging was also heavily influenced by ethnographic data and consisted in two masts rigged with traditional Indian Ocean settee sails, despite iconographic sources appearing to indicate that this sail arrangement developed in a later period.

Sohar sailed from Muscat to Guanzhou, China, a journey of seven-and-a-half-months, stopping in India, Sri Lanka, Indonesia and Singapore. During the passage it endured different weather conditions, ranging from a lack of wind in the doldrums between Sri Lanka and Indonesia to several storms in the South China Sea. It arrived safely at its destination showing the strength and durability of sewn-plank construction.

Although it cannot be considered an experimental archaeological project, *Sohar* nevertheless provides invaluable information regarding Indian Ocean sewn boats, and shows various aspects behind their construction. Severin's experimentation with materials, building processes and sailing performance has undoubtedly deepened our knowledge of this construction method while establishing the bases for the reconstructions that came three decades later, such as *Jewel of Muscat*, the al-Hariri boat and the *beden seyad* (Staples and Blue 2019: 317).

2.6.2 Shungwaya

Shungwaya is a reconstruction of a *mtepe* (Figure 2.16), a sewn cargo vessel used along the coast of East Africa until the 1930s (Sheriff et al. 2006). The boat was built in Zanzibar in 2003 as the centrepiece of the Dhow Culture of the Indian Ocean exhibition and displayed in the House of Wonders Museum. Zanzibari historian Abdul Sheriff, who directed the project, determined its design and construction technique mainly by studying illustrations and models of the *mtepe*, as well as early 20th-century recordings, such as that of Lydekker (1919). The size of the reconstruction was initially supposed to be based on a *mtepe* recorded in 1877, which measured over 96 ft (29.5 m) in length and over 24 ft (7.4 m) in width, but it was scaled down to nearly 46 x over 11.5 ft (14x3.5 m) (Sheriff et al*.* 2006: 39) due to museum requirements.

The shipwright (*fundi* in Swahili) who built the boat was from Lamu, the archipelago off the coast of Kenya known to be where the *mtepe* were built. However, since he was not familiar with sewn construction, the *fundi* built the vessel using a frame-first technique, instead of shell first. Another "departure" from the evidence of the *mtepe* was the choice of timber — *mtondoo* (*Calophyllum inophyllum*) for planking and frames, and teak for the mast instead of the original mangrove, because the latter was not sufficiently wide and long (Sheriff et al. 2006: 40-41; Staples and Blue 2019: 277). The sewing material, caulking and cordage was coir, as used in the *mtepe*, luting was a mangrove bark paste and wadding was stripped *doum* palm (*Hyphaene thebaica)*

Figure 2.16: The *mtepe Shungwaya* in the House of Wonders, Zanzibar. (Photo courtesy of John Cooper)

leaves (2006: 40-41). *Doum* palm leaves were used for the traditional square, woven mat sail. *Shungwaya* was launched in February 2004 and undertook a sea trial, during which it sailed fast covering a mile (1,609 m) in just ten minutes, meaning a speed of 5.2 knots (2006: 43).

The *Shungwaya* project was primarily an iconographic reconstruction rather than an archaeological project. By the admission of Sheriff himself, the construction did not follow the sewn "traditional method to the letter" (2006: 44) but he remarked that its appearance is very similar to depictions and photographs of the *mtepe*. Unfortunately, the project team did not record the building of *Shungwaya* in detail, providing just one publication with a vague description of the sewing method, no drawings of individual elements and limited photographic documentation.

2.6.3 Jewel of Muscat

In 2008–10, an international team of experts, under the direction of Tom Vosmer, undertook the construction of *Jewel of Muscat*, the only archaeological reconstruction of a sewn vessel in the Indian Ocean to date. The vessel (Figure 2.17) was a full-scale reconstruction of an Early Islamic sewn ship based on the interpretation of data from the Belitung shipwreck (Vosmer 2010; Vosmer et al*.* 2011).

The ship was built in Oman, measured 18 m in length and 6.5 m amidships, and was sewn entirely with coir rope (2010: 412). The project team experimented with a double-wadding sewing pattern by employing skilled boatbuilders from Kerala, southern India. It used the same wood that was identified in the shipwreck by Liphschitz, such as *Afzelia africana* for the planking, keel and posts, and teak for the beams, while locally sourced *Ziziphus spina-christi* was used for the frames.

Every part of the ship and every step of its construction was rigorously documented with photographs, videos and reports, with particular focus on the sewing process of the planking, frames and beams. The documentation team created stitching history forms specifically designed to record every stitch of the vessel, including the location of the wadding, the sewing team working on that section, the starting and finishing hole of the sequence and the time required (Staples 2019: 324-325).

Jewel of Muscat also constituted an invaluable opportunity to observe and record the assumed sailing performance of ancient ships. After it was launched, it was fitted with two masts and rigged with square canvas sails. By relying only on its two sails, *Jewel of Muscat* undertook a successful five-month journey in 2010, sailing 3,800 nautical miles from Oman to Singapore following the ancient maritime trade route that connected the Arab world with Southeast Asia in the 9th century (Hourani 1963: 61).

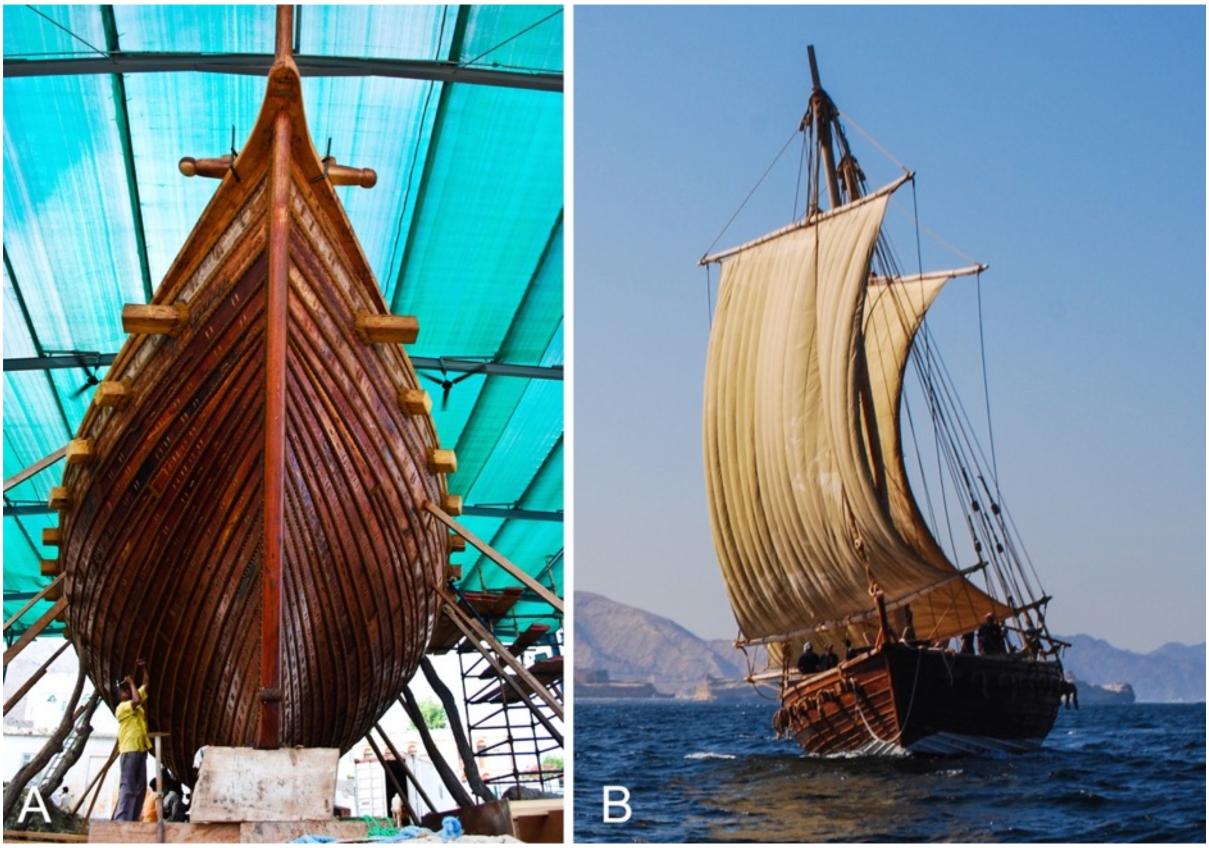

Figure 2.17: *Jewel* of *Muscat* has her stitching holes plugged before the launch (A); and sailing off Muscat, Oman, during the sea trials (B). (Photos: Author)

The sewn hull of the ship proved to be strong and reliable, even during the rough weather conditions of the southwest monsoon in the Bay of Bengal, where she experienced winds up to fifty knots, as she sailed along the edge of Cyclone Laila.

The passage also provided an excellent opportunity to experiment with celestial navigation using a *kamāl*, the traditional star-measuring instrument of the Indian Ocean (Staples 2013). Due to safety concerns, the sailing and route of *Jewel of Muscat* relied entirely on modern sailing instruments, which recorded every aspect of sailing, including speed, direction and heading, which enabled the archaeologists on board to evaluate the data obtained with star altitude measurements while showing that square rigging and hull shape made the vessel capable of sailing close to the wind with limited leeway (Vosmer 2010: 422).

2.6.4 Al-Hariri Boat

The team involved in the *Jewel of Muscat* project built a second experimental reconstruction of a sewn-plank vessel, the al-Hariri boat (Figure 2.18), for the Museum of History of Islamic Science at the German University of Technology (GuTech), Oman, in 2012–13 (Staples 2019: 329-331). The construction was based on the sewn-plank boat of the *Maqāmāt* of al-Ḥarīrī illustrated by al-Wāsiṭī (Figure 2.11). Due to the stylised nature of the drawing, the project relied on supplementary evidence sources such as the timbers found in al-Balid, data collected during the excavation of the Belitung wreck, deduced construction techniques and details from the *Jewel of Muscat* reconstruction, and data from the documentation of the sewn *sanbūq* (*kambārī)* of Dhofar, southern Oman.

The team used the same documentation method to record every aspect of the construction of the vessel. The goal of the project was to thoroughly document an alternate single-wadding, sewn-plank construction process based on all the historical

Figure 2.18: The al-Hariri Boat on display at the GuTech Institute, Oman. (Photo: Author).

evidence available. The project also provided an opportunity to compare the data from the al-Hariri boat to that of *Jewel of Muscat* to determine the main differences between single- and double-wadding sewing techniques (Staples 2019: 329). The single-wadding method was faster than the latter, providing strong evidence for its persistence in the western Indian Ocean (2019: 330-331), as opposed to double-wadding that only survived on the eastern coast of India.

2.6.5 The Beden Seyad

The *beden seyad* (Figure 2.19) was the third sewn-boat reconstruction carried out by the *Jewel of Muscat* team (Ghidoni 2019). It is a slightly scaled-down reconstruction[17] of a sewn fishing watercraft documented by Admiral Pâris in Muscat in the 19th century (Pâris 1843: 15-16, Pl. 8-9), and was built for display in the Maritime History Gallery of the National Museum of Oman. This simple yet elegant Omani vessel, measuring 9.34 m in length and 1.54 m at its maximum beam, has a flat-planked bottom and sleek profile. Its main feature is that the hull has no frames but is simply held together by sewing in a single-wadding pattern.

The project was an iconographic reconstruction based on technical drawings included in Pâris' *Essai sur la Construction Navale* (1843) and on his original manuscript of the drawings (Inv: 3 EX 8) preserved at the Musée National de la Marine, Paris. However, it also relied on a multidisciplinary approach that combined data from ethnographic research in the region with historical sources and emerging archaeological evidence from al-Balid.

[17] The length of the vessel was reduced by 17% to fit into the Maritime History Gallery of the National Museum of Oman.

Figure 2.19: The *beden seyad* in the National Museum of Oman. (Photo: Author)

The aim of the *beden seyad* reconstruction, apart from having an educational scope, was to test the accuracy of Pâris' drawings and to compare their different versions. The project also provided a chance to experiment with various aspects of sewn-plank construction, such as the use of the single-wadding stitching technique, the materials and the shell-first building method, particularly in a frameless boat (Ghidoni 2019: 371-375).

2.7 Ethnographic Studies

A significant advantage of the Indian Ocean maritime world is the persistence, until recently, of traditional boatbuilding and sailing practices in many of its regions. The scarcity of archaeological, textual and iconographic evidence for the medieval period is somehow compensated for by the presence of sewn-plank watercraft along the coasts of the western Indian Ocean. Ethnographic studies in the last two centuries have revealed the presence of sewn boats with similar characteristics from East Africa to Arabia and from India to Sri Lanka and the Lakshadweep.[18]

Scholars have stressed the importance of ethnographic studies in understanding ancient boats (Blue 2003; Crumlin-Pedersen and McGrail 2006; Gibbins 1990: 338; McGrail 1984; 1996; 2014; Muckelroy 1978: 234; Prins 1986). As expressed by Greenhill (1976: 14), since people have dealt with similar problems and have found similar solutions whenever and wherever they have built wooden craft, the study of more recent traditional boats is crucial to interpreting ancient techniques and technology that reflect the thinking and concepts of the past. For example, finds like those of Quseir al-Qadim (Blue 2006: 598) and al-Balid (Belfioretti and Vosmer 2010:

[18] In Dhofar, southwest Oman, *sanbūq* (locally called *kambārī*) fastened with coir ropes were still used for cargo lightering and fishing until the 1970s (Facey 1979: 146) and could still be seen abandoned on the beach in the late nineties (Vosmer 1997: 231; Agius 2002: 78). Partially sewn boats, like the *battīl* of Musandam and the *badan* of the Batinah coast, were used in the north of Oman (Vosmer 1997; Weismann et al. 2014). Sewn *baggarā*s recently acquired by the Qatar Museums show that this fastening technique was also used in the northern shores of the Gulf (Cooper et al. 2020). In Somalia, the fishing communities of the northeast coast still built sewn boats (locally known as *beden*s) in the 1980s (Chittick 1980). Large sewn seagoing vessels (*mtepe* and *dau la mtepe*), built in the Lamu archipelago, East Africa, disappeared around the 1930s (Hornell 1941; Prins 1982). On the other side of the western Indian Ocean, sewn boats have been widely recorded on the Indian subcontinent in both riverine and maritime contexts. Sewn vessels have been observed in Goa (Shaikh, Tripati and Shinde 2012; Fenwick 2015), Kerala (Edye 1834; Hornell 1941; Pâris 1843; Rajamanickam 2004; Ransley 2009), Coromandel (Kentley 1985, 2003), Sri Lanka (Kentley and Gunaratne 1987; Kentley, 2003a) and the Lakshadweep (Varadarajan 1998).

111) have been identified as planks from sewn boats because of the sewing-pattern similarities with traditional vessels of the western Indian Ocean. Similarly, the stitching arrangement of modern sewn boats was key in identifying the Belitung shipwreck as a possible Arab, Persian or Indian vessel (Flecker 2000: 211-212; Flecker 2010: 118).

The earliest proto-ethnographic studies on Indian Ocean watercraft, comprising a few sewn vessels, are those of Edye and Pâris, and date to the first half of the 19th century. Edye spent five years in Sri Lanka working at His Majesty's Dockyard, and due to his background as a master shipwright, he uses a purely technical approach combining brief descriptions of the features of Indian boats, including sewn craft such as the *pattamar*, reporting their size, materials and construction method, with accurate lines and construction plans (1834: 8-10). Similarly, Admiral François-Edmond Pâris, during his exploratory voyage around the world aboard the *Artémise* (1837–40), documented a large variety of watercraft in the Indian Ocean. Considered one of the first nautical ethnographic studies in the history of sailing, his *Essai sur la Construction Navale des Peuples Extra-européens* (Pâris 1843) provides detailed lines plans, watercolour paintings and descriptions of sewn vessels from Oman, India and Sri Lanka.

A century later, but with a very similar approach, James Hornell published *Water Transport*, which is a summary of his studies on traditional vessels around the world (1970 [1946]). As a marine biologist in Sri Lanka and, later, Director of Fisheries in Madras, he had the opportunity to directly observe the technical aspects of Indian Ocean boats, focusing on the construction and classification of vessels, including sewn-plank boats from Arabia, East Africa and India, within an evolutionary perspective (Hornell 1920; 1930; 1941; 1942). As with the early works of Pâris and Edye, Hornell's view is still flawed by the principles of the Enlightenment, which considered human history as dominated by cultural progress, and where cultural and technological changes are universal to all societies and structured in a series of predictable stages from the simple to the advanced (Trigger 2009: 101). In this perspective, traditional boats are seen as different branches of the progression of watercraft in an unfailing model of development from the primitive to complex/technological advanced forms, which is applicable worldwide. Hence, the sewn boats of the Indian Ocean, such as the East African *mtepe* and *dau,* or the southwest Indian *masula,* are presented as the latest stage of a development that originated with the dugout canoe (Hornell 1970: 193). Hornell's primarily focus is the construction and classification of watercraft, while very little emerges from his work about the people behind these vessels. Thus, boats are destitute of their social and economic context and are merely considered as functional objects to record and arrange in classes with the aim of establishing various forms of the evolution of watercraft and their diffusion. Nevertheless, Hornell's technical description of the features of sewn vessels, such as the East African *mtepe* and *dau*, is still an essential source for maritime studies in the Indian Ocean (1941).

2.7.1 Arabia and the Gulf

Diffusion and origin are also the primary concern of Richard LeBaron Bowen. A chemical engineer, Arabist and nautical researcher, Bowen was the technical and engineering advisor to the American Foundation for the Study of Man Arabian Expedition in 1950 (1952). He published a study of Arabian watercraft focused on the sewn vessels of coastal fishing communities of southeast Arabia, where isolation from foreign influence had preserved the traits of what he saw as "primitive" indigenous forms of boatbuilding (1952: 186). Interviews with local fishermen carried out by Bowen pointed out the advantages of sewn-plank construction along the coast between Aden and Mukalla; these boats were used for lightering and fishing. Due to the surf generated by the monsoons and the scarce presence of sheltered bays, these vessels had to be hauled in and out every day, and their durability and pliability made them preferable to those of nailed construction (1952: 201). By comparing various sewn boats of the western Indian Ocean, such as the *mtepe*, the Omani *beden seyad*, the *masula* of the southeast Indian coast and sewn craft of the Lake Victoria with Yemeni sewn boats, Bowen identifies a distinctive boatbuilding tradition ranging from central Africa to India (1952: 204) and describes continuous sewing, rebates, oblique dowels and carvel style as the main traits of this tradition. He traces the practice of continuous sewing to Indonesia or India, while he proposes that the oblique-dowel method could have developed from tenons used to fasten the planks of ancient Egyptian Dashur boats (1952: 209).

Prados, who conducted a coastal survey in Yemen in 1993–94, provides a more comprehensive study of the sewn vessels mentioned by Bowen, which were locally called *sanbūq*, by illustrating the changes, development and adaptability of Yemeni maritime culture and technology in recent times (1996). In his study, he documented the construction phases of watercraft, highlighting the diverse sewing and fastening techniques used by Yemeni boatbuilders (1996: 103). Interviews with local shipwrights and fishermen emphasise the views and role of the people behind these sewn boats, providing information regarding their use, material and history. Prados also challenges the general assumption of sewn-plank construction as a relic of the past, static and immutable through time, by showing how economics have led local boatbuilders to modify the *sanbūq* by fitting outboard engines (1996: 105). This adaptation required a difficult and time-consuming process, reflecting the will of these maritime communities to keep up with the times and compete with modern motorised boats. Finally, Prados explains that if this modernisation had, on one hand, triggered new forms of adaptation, in the long run it was nevertheless responsible for the disappearance of sewn vessels and, more generally, traditional maritime culture in the region (1996: 110).

Ethnographic research, such as that carried out by Agius (1999; 2002; 2005) and Vosmer (1992; 1996; 1997b; 2007) have illustrated the boatbuilding traditions of the maritime cultures of southeast Arabia, the Red Sea and the Gulf, including studies on sewn watercraft, such as the *kambārī* of Dhofar, southern Oman (Figure 2.20); partially sewn boats, such as the *battīl* of Musandam, northern Oman; and the *badan* of the Batinah coast. Through a linguistic approach, based on interviews with local boatbuilders, captains and fishermen, Agius reveals the links between the maritime culture and traditions of the Arabian coastal communities and the past revealed by historical sources.

Meanwhile, Vosmer opts for a multidisciplinary approach in the study of traditional Omani watercraft (1999) to reach similar conclusions to those expressed by Agius. Along with history and archaeology, ethnography becomes one fundamental tool with which to investigate the past (1999: 302), deepen knowledge on the development of maritime technology in the Indian Ocean and help explain cultural expressions in the region. Vosmer's research method relies on a technical approach based on a rigorous documentation of boatbuilding techniques and materials, naval architecture construction drawings and hydrostatic analysis of vessels (Vosmer 1992: 50; 1997a: 233).

Figure 2.20: Sewn and partially sewn vessels of Oman: a *kambārī* beached in Taqa, Dhofar (A) (Photo courtesy of David Willis); a *battīl* (B) and a *badan* (C) in the Oman Maritime boatyard in Qantab, Muscat (Photos: Author).

The sewn *kambārī* is presented as particularly suited to the coastal topography of Dhofar because its fastening techniques enables it to cope with constant surf (Vosmer 1996: 228). The boat shape and its construction method are likely to suggest, according to Vosmer, a deep connection with ancient boatbuilding practices (1997: 234). Omanis ceased to use the *kambārī* in the 1980s (Alian 2006; Facey 2005: 146), and at present there are only five known examples, all in Oman[19] (Author personal observation, Oman 2018). Weismann has recently documented the *kambārī* at the Museum of Frankincense Land in Salalah, producing technical and naval lines drawings (2019). Although the boat is one of three vessels built in 1980 for display and has never been used in the water, it nevertheless provides valuable information about this type of vessel that was once widely used in the south of Oman.

Similar boats to those used in southern Arabia were recorded in north-eastern Somalia by Chittick (1980) during an archaeological survey in the region in 1975. These fishing vessels, locally called *beden*, share the same shape, size and use as Yemeni sewn boats and the *kambārī* of Dhofar, Oman. Vosmer remarks that the strong similarities between these vessels is due to the proximity of the regions where they were used (1997: 234). Chittick, who observed a *beden* being rebuilt in al-Hafun, provides a technical description of its construction features, such as plank thickness, sewing technique, materials, luting and caulking material, and decorations (1980: 301-303). The study of Somali watercraft provides Chittick with the opportunity to examine the historical, iconographic and ethnographic references to sewn boats in the Indian Ocean with the aim of supplementing Hourani's work (1963) on medieval Islamic

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[19] One *kambārī* is on display outside the Museum of Frankincense Land in Salalah; two are on display at the Fatah al-Khair Museum in Sur; one was part of the EISCA Collection at the Eyemouth Maritime Centre, Scotland, and has been recently acquired by the Oman Across the Ages Museum (OAAM), Manah; and the last *kambārī* is displayed on a roundabout in Taqa, southern Oman.

watercraft (Chittick 1980: 297). Although not a maritime archaeologist, Chittick produced a particularly relevant work for the study of sewn-construction techniques in the region since the *beden* was perhaps the last sewn craft of the western shores of the Indian Ocean. His research also addresses significant themes such as the reasons for the persistence of sewn vessels in the Indian Ocean until the Modern era (1980: 303).

Sewn *baggarā*s recently acquired by Qatar Museums (QM) indicate that a sewn-plank technique was also common in the Gulf until recently (Cooper et al. 2020). These small fishing vessels from Hormuzgan province in southern Iran are the only evidence of sewn boats in the region; they show a unique fastening method used to join the keel and garboards, and are entirely coated with bitumen. The presence of modern synthetic materials for the sewing cordage and wadding, as well as metal fastenings above the waterline, suggests that Iranian boatbuilders valued this fastening technique until relatively recently.

2.7.2 East Africa

In East Africa, one sewn vessel that has been the object of numerous studies is the *mtepe* (Figure 2.21) (Adams 1985; Gilbert 1998; Hornell 1941; Lydekker 1919; Prins 1982; 1986; Sentance 1981). Dutch maritime anthropologist Prins conducted research on the East African coast, with particular focus on the *mtepe* of the Lamu archipelago, Kenya, (1965; 1982; 1986). The last large seagoing sewn vessel of the Indian Ocean, the *mtepe* was used as a cargo ship along the coast of East Africa until the 1930s (Hornell 1941: 62). Prins researched the technical features of the vessel by studying a number of scaled models of the *mtepe* made by boatbuilders in Lamu and displayed

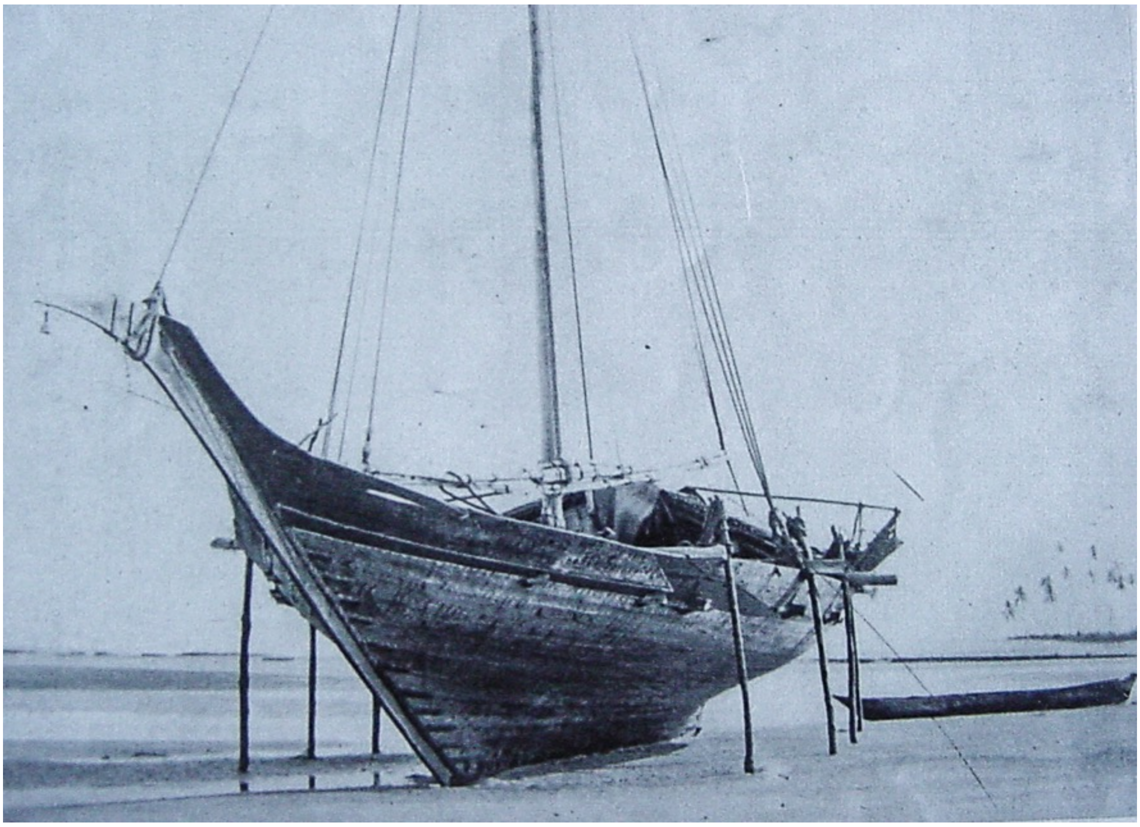


Figure 2.21: A rare photo of a *mtepe* (photographer unknown). The image looks identical to the drawing in Waller (1874: 12), depicting vessels that transported Livingston's supplies from Zanzibar to Bagamoyo (source: https://www.rafikiproductions.com/films/)

in various museums.[20] Sixteenth-century Portuguese accounts of the boats observed in East Africa offered Prins the opportunity to speculate about the origin, history and development of the *mtepe,* which he considers the ultimate form of the evolution of sewn boats (Prins 1982: 100).

In 1985, Adams carried out a technical analysis of some *mtepe* construction features highlighting the benefits of the sewn-plank technique and underlining the ingenuity of the boatbuilders. He remarks that the people who built the *mtepe*, designed their structural elements to preserve their flexibility (Adams 1985: 291), which is a recurring theme in sewn-boat studies (Coates 1985). Various construction features point to the

[20] Our knowledge of the *mtepe* relies on extremely scarce evidence including about thirty models, a few photographs, stylised drawings and, possibly, a dozen hull planks recycled in the guardroom ceiling of Fort Jesus in Mombasa (Prins 1982: 98).

pliability of the *mtepe*, such as a keel made of a single timber, garboards sewn to it with diagonal stitches allowing longitudinal movements, wadding acting as shock absorbers, stempost and sternpost simply butt joined to the keel, scanty frames lightly lashed and two series of through-beams (Adams 1985: 291). Adams' study, which has recently been further expanded by Burningham (2019a), reveals that the flexibility in sewn boats is not intrinsically related to their particular fastening system but instead is the result of conscious planning and particular construction methods relying on light structural elements such as scarce framing, simple joinery and rigging arrangement (1985: 292).

Thanks to these characteristics, the *mtepe* was particularly suited to the environment and the economic conditions of the East African coast and was able to compete with nailed boats in terms of sailing performance and cargo capacity, resulting in its long survival in the region (Gilbert 1998: 43). Sentance (1981: 8) also considers the *mtepe* to be a typical product of East Africa and a probable expression of the 12th/13th–century Swahili culture that was so interlinked into the culture and tradition of the region as to persist until the early 20th century.

2.7.3 India

On the other side of the western Indian Ocean, local maritime and lake communities have continued to build, use and repair sewn boats until the present time. Kentley (1985; 1996; 2003b) provides extensive documentation of the sewn *masula* used on the eastern coast of India (Figure 2.22). These boats are frameless and flat-bottomed, which makes them particularly suited for use in the surf, a characteristic of the coast stretching from Orissa to Tamil Nadu. Kentley's technical analysis of the watercraft

Figure 2.22: A *masula*-type vessel from Orissa showing wadding on the outside of the hull. (Photo courtesy of Colin Palmer).

enable him to distinguish a variety of types of *masula* according to their geographical areas, functions, construction features and materials. Boats are generally smaller in Orissa, and their planking pattern also changes considerably from north to south (Kentley 1985: 305, 313; 2003: 164). Kentley describes the sewing pattern and sequence of the *masula* in detail, revealing two different methods: in boats from the northern and central sectors this technique relies on vertical and diagonal crisscross stitches over wadding both inside and outside the hull (method 1), while on the southern coast the wadding is only inboard (method 2) (Kentley 1985: 311-313, 315). The sewing material also indicates a distinction between the *masula* used on the northern and central coast and those of the southern region. While the fastening cordage is coir in all cases, boatbuilders use dried grass as wadding in the former

(Kentley 2003: 137, 150), while coir is generally preferred in the latter (2003: 157). According to Kentley, this diversity might depend on the sewing pattern. Boatbuilders might prefer dried grass when sewing their boats with wadding on both sides because it is cheaper, although less effective, than coir, hence the need to use it on both sides of the hull. Wadding made of coir is more expensive but of a higher quality, meaning that it is sufficient to use it on one side only (Kentley 2003: 165).

Various scholars have focused on sewn boats of the western coast of India (Fenwick 2015; 2019; Rajamanickam 2004; Ransley 2009; 2010; Shaikh 2019; Shaikh et al. 2012). Ransley carried out significant ethnographic research in the backwaters of Alleppey, Kerala (2009; 2010). Her study focused on the relationship between boats, people and the environment in the village of Munruthuruthu through interviews with boatbuilders and the recording of the construction of two vernacular boats. One is a *kettuvallam* (Ransley 2009: 18; 2010: 429; Rajamanickam 2004: 65-74; Cooper et al. 2020), translated from Malayalam as “tied boat” from the word *kettuka* meaning “tying”, a double-ended craft with a crescent-shaped profile and planked bottom, which is used in both riverine and maritime contexts. The information regarding boats fastened using this technique in Kerala is, however, still very limited, despite being widely used in its backwaters in tourist, fishing and cargo boats (Author personal observation, Alleppey 2013). Rajamanickan, in his study of Indian watercraft (2004: 67-71, 102), provides information about a variety of sewn vessels without keels used in Kerala, but his descriptions are often brief and lack details, and the photographic documentation is poor. The author of this thesis was also part of the team that recently recorded a Keralite *kettuvallam* acquired by Qatar Museums (Cooper et al. 2020). The boat measured 10.5 m in length and Indian fishermen use it for coastal fishing, propelling it with oars and steering it with a paddle (Hornell 1920: 150; Rajamanickam 2004: 69).

Researchers carried out the study of sewn boats in Goa more extensively (Fenwick 2015; 2019; Shaikh 2019; Shaikh et al. 2012). Shaik et al. (2012: 148) carried out a survey of vernacular vessels (*revenchem vodem*) used in the rivers Tiracol, Chopara and Aman, in the northern part of the region (Figure 2.23). They documented the construction and repair of these 10–11 m long vessels, focusing on their construction process and methodology (2012: 150). Goan shipwrights build their boats by laying the keel first and assembling the hull planking before inserting the frames (Shaikh et al. 2012: 150) in a shell-first process (Hasslöf 1966: 134-136) typical of sewn-plank construction, which consists of assembling and fastening the hull planking first and then fitting the frames. The shell-first technique of the *revenchem vodem* also requires a series of sequential steps, such as the pre-bending of the hull planks with controlled fire, joining their ends with a particularly strong rabbeted joint, sewing through-holes along the seams in a single-wadding method, and use of resin as a luting substance to make the hull watertight (2012: 150-152).

Figure 2.23: Unloading sand from a *revenchem vodem* in Goa's backwaters. (Photo courtesy of Zeeshan A. Shaikh)

Shaikh also focuses on the function and the economic context of Goan watercraft (2019), linking the revival of sewn boats in the area to the rise of the sand mining industry in India (2019: 378) and underlines the environmental, economic and technological factors influencing this revival. Local boatbuilders prefer to repair abandoned sewn craft to excavate and transport river sand because they last longer than nailed boats and are generally cheaper. Their flat bottoms enable them to sail in shallow waters, while their shape provides greater stability and cargo capacity, making them perfectly suited for sand excavation (2019: 384).

2.7.4 Lakshadweep Islands

The longevity of sewn-plank construction in the Indian subcontinent is also well exemplified by Varadarajan's ethnographic work in the Lakshadweep Islands (1998). Her monograph provides a detailed account of the maritime culture of the archipelago off the coast of Kerala, with particular focus on the *odam*, the vernacular watercraft used by the islanders to trade with the mainland. Varadarajan's work is an invaluable source of information about the construction process, which is accompanied by stage-by-stage photographic documentation and the materials used by boatbuilders, of which the coconut palm plays a crucial role (1998: 50). However, one of the most important contributions of this research is that it reveals the strong link between boats and society, showing how each single social group plays a different role in the boatbuilding and seafaring context (1998: 19-22): the elite classes own the boats and manage trade with the mainland, while other groups provide pilots and navigators, and collect coconuts, which are beaten and spun into sewing cordage by women (1998: 19-22).

Discussion

Ethnographic studies reveal the ubiquity of sewn boats in the western Indian Ocean until recently despite the adoption of nail-fastening techniques. The documentation of various sewn watercraft in the region provides information regarding their construction process, sequence, material and technology, and highlights the variety of activities involved in the building, repairing and sailing of these vessels. The study of the materials, in particular, indicates that these sewn boats are products of local maritime communities and their features are influenced by a number of factors, including social, economic and environmental. While coir appears to be a frequent material for the fastening cordage of the western Indian Ocean, ethnographic records show that boatbuilders also used locally available materials. Similarly, local wood was preferred even in places where timber was relatively scarce, such as Oman (Alian 2006: 7-8; Weismann et al. 2019: 349). This emphasises the fact that these boats are expressions of autochthonous traditions, a technological response to the needs of each coastal community that built and repaired them. Their longevity strongly depended on the affordability and availability of local materials and manpower (Sentance 1981: 2), which made sewn vessels competitive with nailed boats.

Moreover, research on Indian Ocean sewn boats also reveals that environmental factors and coastal topography have both played a crucial role in the persistence of sewn-plank construction methods in the region. Maritime communities often relied on sewn boats in coastal areas with heavy surf because of their flexibility and capacity to absorb shocks, and these vessels proved to be particularly suited to the shallow waters of rivers and lakes for the same reasons.

Collectively, the ethnographic studies on Indian Ocean sewn boats are essential for my research. On one hand they provide the basis on which to carry out the identification of the various features displayed on the timbers of al-Balid, while on the other they suggest a range of methodologies and approaches to use for my investigation in the following chapters.

2.8 Conclusion

The literature review has indicated that historical and visual sources contain only limited information about vessels sailing the Indian Ocean during medieval times. Data from the rare shipwrecks and boat remains discovered in the region, although revealing further insights into the topic, are relatively scarce. In light of this dearth of information provided by other archaeological evidence, study of the al-Balid timbers becomes crucial to understanding sewn-plank technology in the Indian Ocean in the medieval period. Only ten timbers have previously been analysed (Belfioretti and Vosmer 2010), but thanks to the recent excavations of al-Balid's citadel, their number has risen to over fifty samples, making it the largest collection of ships' timbers of the medieval period found in a non-maritime context.

I will provide a technical and quantitative analyses of the timbers and their features in the next chapter.

3 The al-Balid Timbers

3.1 Introduction

The excavation and restoration of the Islamic site of al-Balid (Figure 3.1) brought to light a considerable number of wooden artefacts identified as parts of watercraft (Zarins 2007; Belfioretti and Vosmer 2010; Zarins and Newton 2012; Newton and Zarins 2014; Pavan et al. 2018). These ships, which were either repaired or broken up at the site, represented a valuable source of wood in such an arid place as the Arabian Peninsula, where it is scarce and precious. Carpenters modified hull planks and beams, and converted them into structural elements, such as lintels and ceiling planks, in the walls and buildings of the citadel.

Evidence from the timbers from al-Balid is particularly significant due to scarcity of archaeological data about sewn vessels that sailed in the Indian Ocean during the medieval period. The similarities between these timbers and the more recent sewn

Figure 3.1: The location of al-Balid. (Image: Author)

boats of the western Indian Ocean are striking, and ethnographic records offer analogies for their interpretation. These artefacts can be divided into planks, beams and, perhaps, other nautical elements, such as sheaves and cleats. Planks represent the majority of the timbers with thirty-six specimens (77%), and of these thirty-five bear evidence of sewn-plank construction, which consists of sewing holes arranged longitudinally near plank edges, remains of cordage and ropes, and dowels and luting materials.

3.2 The Site of al-Balid

Al-Balid is a large, monumental site located south of the modern city of Salalah in southern Oman (Figure 3.2(A)). The site was an important trading centre known as Ẓafār in the medieval period and was actively involved in the Indian Ocean maritime trade from the 10th–18th (Pavan et al. 2018: 211). Marco Polo, in the 13th century, calls it Dufar and describes it as a great thriving port with merchants and ships trading a variety of goods, notably frankincense and horses (Moule and Pelliot 1938: 444). Ibn Baṭṭūṭa, who sailed to Ẓafār twice, from Calicut and from Kilwa, provides a similar description, confirming its involvement in various Indian Ocean maritime trade networks (1962: 382-383, 390). He also provides a more detailed account of the city, mentioning the monumental citadel (*ḥuṣn*) that dominated the site (Figure 3.2(B)) and underlining the fertility of the region, which was conducive to agriculture and coconut plantations.

In fact, the Dhofar plain is a particularly favourable environment for settlements thanks to the summer monsoon, which brings rain between June and September making the area green and supporting agriculture and farming. Moreover, its coasts, which are rich in marine life, also provide plenty of resources. These environmental and climatic

Figure 3.2: Aerial view of the archaeological site of al-Balid (A) (Photo courtesy Alexia Pavan).

conditions also made the city particularly suited for keeping horses for shipping to India, as also suggested by the presence of buildings resembling stables (Pavan et al. 2018: 212). Archaeological excavations in the eastern lagoon have unearthed possible shipping facilities likely to have been associated with horse trading. These consist of a stone quay with jetties and platforms (Newton and Zarins 2014: 269) and indicate the importance of this commercial activity for al-Balid.

The south wall of the site faces the Indian Ocean, while two branches of a lagoon form its eastern and northern limits. Evidence of an artificial channel to the west suggests that al-Balid was probably a large rectangular island initially surrounded by water (Costa 1979: 115, 140). Archaeological work at the site's citadel shows various phases of occupation (Zarins 2007: 314-316) covering a period between the 10th and 18th centuries (Pavan et al. 2018: 211).

The heyday of al-Balid (13th–15th centuries) appears to occur after the Rasūlid conquest of the city (1279–1420). The gradual shift of the political and economic pivot in the Islamic world from Iraq to Egypt, caused by the emergence and expansion of the Fāṭimids in Egypt and the Red Sea in the 10th–12th centuries, resulted in the decline of Baghdad and the establishment of the Rasūlid Dynasty in southwest Arabia. This political change turned the focus from the dominant trading centre of the Gulf and northern Oman, such as Siraf and Sohar, to the Red Sea, boosting al-Balid's involvement in the trade with India and East Africa in the 14th century (Costa 1979: 148).

The richness of this period can be seen in the archaeological record and is characterised by a monumental phase evident in the site's buildings (Pavan et al. 2018: 215). Ceramic imports from Yemen, northern Oman, the Arabian Peninsula, the Gulf, Iran, Egypt, East Africa, India, China and Southeast Asia, with the highest concentration in the 14th century, point to the various connections between al-Balid and the rest of the Indian Ocean, showing its active role in the maritime trade (2018: 219). Various archaeological excavations have brought to light a large amount of Chinese porcelain, particularly Longquan Celadon and Qinghua ware (blue and white porcelain) confirming the climax of al-Balid trading activity in the 13th–16th centuries (2018: 221-223). Numerous coins from Kilwa, Tanzania, also indicate contact with East Africa (2018: 230) in the 15th century.

A drastic decrease in imported goods in the archaeological record indicates that the demise of the city began in the 16th century and was probably due to a number of factors. The Portuguese and Ottoman expansion in the Indian Ocean certainly played crucial roles in its decline (Zarins 2007: 321) and the trade ban introduced by Sultan Badr bin Abdullāh al-Kathīrī (1516–69) on the most valuable exported goods, such as horses, frankincense and sardines, would have had a devastating impact on the city's economy (Costa 1979: 149). Lastly, the silting up of the harbour and lagoon may have also contributed to the fall of al-Balid during this period, or been symptomatic of it.

However, as indicated by the increasing number of Chinese porcelain and Iranian glazed stone paste vessels, the site appears to have had a new flourish of activity in the 17th–18th centuries (Pavan et al*.* 2018: 219).

3.2.1 The Archaeological Context of the Timbers

All but one of the ship timbers came from the citadel area of the al-Balid site, the sole exception having been discovered in the Friday Mosque (Belfioretti and Vosmer 2010: 115; Costa 1979: 146). However, little basic contextual information was available to me on the secondary archaeology contexts of the timbers beyond these broad indications. This is largely due to the nature of the work conducted at the site: most focussed on the restoration of the citadel, rather than stratigraphic excavation *per se*. Unpublished excavation reports by previous archaeological teams either barely mention the timbers—without providing their stratigraphic context—or do not mention them at all (Lewis 2013; 2014; Zarins and Newton 2012). Only a few can be located more precisely within the citadel area, these being timbers discovered between 2016 and 2019, all of which have an identification code with the prefix ‘Wo’. The other timbers, mostly with the prefix ‘BA’, were discovered in earlier excavations carried out between 2000 and 2016 (Table 3.1). These were subsequently moved to a storage facility next to the site without being extensively recorded.

Timber ID	Location	Stratigraphic context	Date (context)
823.B-3.98.1235	N/A	N/A	N/A
BA.01.11.01	N/A	N/A	N/A
BA0301–106	N/A	N/A	N/A
BA0604128.73	Discovered in 2006. Northeast Area?	N/A	N/A
BA0604128.74	Discovered in 2006. Northeast Area?	N/A	N/A
BA0604145.175	Discovered in 2006. Northeast Area?	N/A	N/A
BA0604148.70	Discovered in 2006. Northeast Area?	N/A	N/A
BA0604159.263-BA0604172.69	Discovered in 2006. Northeast Area?	N/A	N/A
BA0704156.1477	N/A	N/A	N/A
BA090458.1010	N/A	N/A	N/A
BA1104065.449	N/A	N/A	N/A
BA1104065.450	N/A	N/A	N/A
BA1104065.453	N/A	N/A	N/A
BA1104065.454	N/A	N/A	N/A
Jansen Husn.99.01	N/A	N/A	N/A
Wo37	Room A2	SU22 (intentional filling with debris and sandy matrix)	16^{th} century
Wo44	Room A2	SU22 (intentional filling with debris and sandy matrix)	16^{th} century
Wo54	Room A2	SU18 = SU19 = SU22	16^{th} century
Wo56–Wo60	Room A2	SU18	16^{th} century
Wo73	Rooms A1-A2	SU1 (top layer covering the filling above the rooms)	16^{th} century
Wo62	Rooms A1-A2	SU1	16^{th} century
Wo63	Rooms A1-A2	SU1	16^{th} century
Wo64	Rooms A1-A2	SU1	16^{th} century
Wo65	Rooms A1-A2	SU1	16^{th} century
Wo68	Rooms A1-A2	SU1	16^{th} century
Wo69	Rooms A1-A2	SU1	16^{th} century
Wo70	Rooms A1-A2	SU1	16^{th} century
Wo71–Wo72	Rooms A1-A2	SU1	16^{th} century
Wo82	Room A1	SU24 (intentional filling with debris and sandy matrix)	16^{th} century
Wo83	Room A1	SU24	16^{th} century
Wo84	N/A	Surface	N/A
Wo85	M123-M122	US66: inside masonry/ Wall 89	Post 16^{th} century (?)
Wo86	M60: northeast corner, near the tower.	Inside the masonry	16^{th} century
Wo94	M148S: Eastern Wall	Inside the masonry	N/A
Wo98A	M182: Southern Gate	lining the locking system of the Southern Gate	13-16th century
Wo98B	M182: Southern Gate	lining the locking system of the Southern Gate	13-16th century
Wo98C	M182: Southern Gate	lining the locking system of the Southern Gate	13-16th century
Wo1 (Cleat?)	Rooms A1-A2?	SU1	16^{th} century
Wo40 (Cleat?)	Room A2	SU18	16^{th} century
Wo48 (Sheave?)	Room A2	SU19	16^{th} century
Wo81 (Stone object)	Square 111	SU40: collapse of wall(?)	Post 17^{th} century
Wo105 (Beam)	Northern fortification collapse	SU171: layer formed after cyclone Mekonu in 2018 (surface)	N/A
Wo122 (Cleat?)	A12	SU200	16-17^{th} century

Table 3.1: Location and dating of the timber's archaeological context.

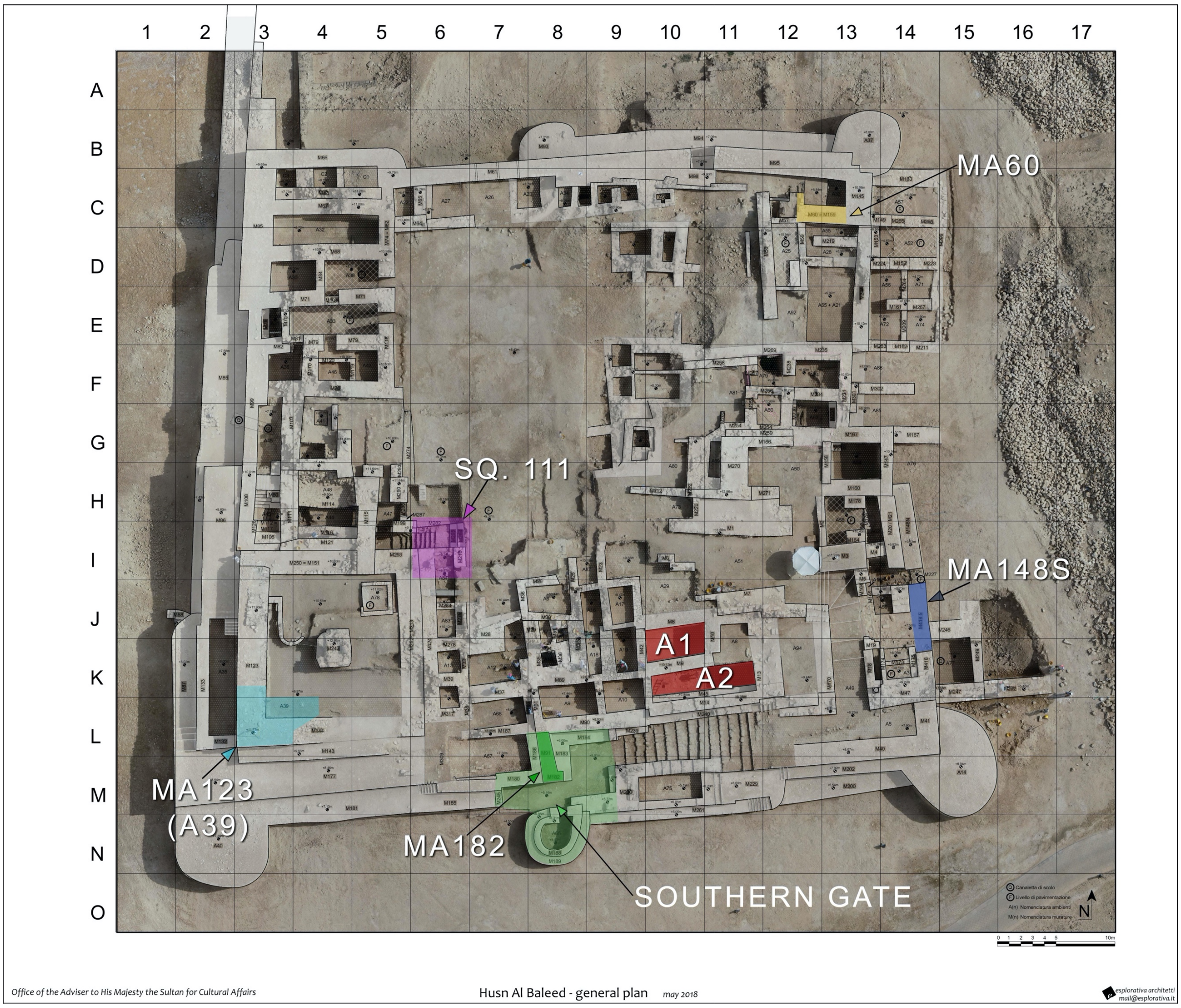


Figure 3.3: Orthophoto of al-Balid's citadel showing the main locations for the timbers discovered between 2016 and 2019 (Photo: M. Massa).

The vast majority of the timbers discovered during the 2016-2019 excavations, which were directed by Dr Alexia Pavan, came from Rooms A1 and A2 in the southern perimetral wall and the north-east corner, near the tower, of the citadel (Figure 3.3), where they were included in layers of debris filling or covering the buildings. This was an intentional intervention by the al-Balid builders to fortify the citadel's walls against naval attacks from the Portuguese from the early 16th century, and later Ottomans (Pavan et. al 2020: 177). However, diagnostic material associated with the same stratigraphic layer of timbers, such as Yemeni yellow ware, of the citadel of the citadel show a date between the 13 and 15th centuries. Only one of the timbers discovered between 2016-2019, Wo54, has been radiocarbon dated, showing an earlier date ranging from the mid-11th to the early 13th century (see Section 3.10). This evidence, although still limited, appears to indicate no chronological correspondence between the dating of the timbers themselves, the other material in the same stratigraphic context and the structures of the citadel, pointing to a secondary deposition for the materials included in the filling of the buildings.

One explanation for this disjoint in the dating might be that the timbers were recycled multiple times within the structures of al-Balid before ending up there, or even that they had been simply stored to be used for boat repairs at the site. However, radiocarbon dating analysis on more timbers is required for more definitive information about the timber's terrestrial context and their relationship with the citadel's buildings.

The limited information on the archaeological contexts of the timbers has not prevented me from making useful interpretations of them, however. I have been able to draw conclusions instead by focusing my interpretation on the from the artefacts themselves. This is primarily because my research focusses on the previous maritime life of the timbers, and hence the information that they provide about medieval sewn-plank vessels. The study of their subsequent terrestrial application, although important to understanding the entire biography of these artefacts, goes beyond the aims of this thesis, and is a problem that can be left to another researcher.

3.3 The Planks

One of the advantages of the Indian Ocean's maritime world is the persistence of traditional boatbuilding and sailing practices in many of its regions until recent times. Despite a lack of archaeological evidence, ethnographic data has provided valuable information about sewn-plank construction, and more recent sewn boats offer analogies and similarities with the remains from al-Balid and provide insights into their interpretation.

The features displayed on the surface of the timbers found at al-Balid suggest a variety of typologies and fastening techniques. The most relevant distinction emerges between the planks with rebates, parallel channels cut between the holes and the plank's edge, and those with flat surfaces. Thirty-one of the timbers discovered have rebates, which were used to recess stitching cords, while four have a flush surface without rebates. Another distinction emerges within the fastening method of the timbers. Along with the sewn-plank techniques, which are represented in the vast majority of the planks, there are two timbers displaying stitching cords and nails, and one with mortise-and-tenon joinery.

3.3.1 Physical Characteristics of the Planks

The timbers differ in condition, ranging from heavily degraded, such as BA0604148.70 and Jansen Husn.99.01, to very well preserved, as exemplified by Wo68. Most of the planks have slightly eroded surfaces and several timbers exhibit large knots and cracks on their surfaces and edges. The author measured the thickness, width and length of the most diagnostic planks of the al-Balid collection, where their conservation conditions allowed, and entered them into a database (Table 3.2).

PLANK ID	THICKNESS (mm)	WIDTH (mm)	LENGTH (mm)
823.B-3.98.1235	45	143	464
BA.01.11.01	55	296	828
BA0301–106	40	68	405
BA0604128.73	28	119 (98)*	642
BA0604128.74	27	112 (89)*	318
BA0604145.175	39	149	461
BA0604148.70	42	220	1206
BA0604159.263–BA0604172.69	51	207	1116
BA0704156.1477	30	136	652
BA090458.1010	49	198	703
BA1104065.449	27	124	684
BA1104065.450	31	97	679
BA1104065.453	43	70	646
BA1104065.454	31	72	719
Jansen Husn.99.01	22	154	851
Wo37	38	61	228
Wo44	50	124	470
Wo54	58	234	738
Wo56–Wo60–Wo73	40	216	865
Wo62	40	67	455
Wo63	52	188	538
Wo64	49	132	535
Wo65	45	285	530
Wo68	30	153	565
Wo69	45	60	288
Wo70	40	97	520
Wo71–Wo72	46	130	2506
Wo82	23	163	480
Wo83	25	139	417
Wo84	36	189	525
Wo85	52	138	783
Wo86	37	121	1443
Wo94	56	312	889
Wo98A	30	215	>3500
Wo98B	46	243	>3500
Wo98C	29	200	>3500
*** The timbers are composed of two planks sewn together. The first value refers to the overall width including both planks, while the number in brackets is the width of one plank with both edges preserved.**			

Table 3.2: Table showing the measurements of the planks recorded in al-Balid.

Length

No planks in the al-Balid collection are entirely preserved, which makes it impossible to determine their actual length. Their surviving lengths range between 230–2,500 mm and 79% of them are between 500–800 mm. Planks Wo98A, Wo98B and Wo98C, which are located in the east wall of the citadel where they were re-used in the locking system of the gate, are the longest. Unfortunately, no accurate measurement was possible due to limited access, but the estimated length of the recess in the wall is 3.4 m (Belfioretti and Vosmer 2010: 115). The other longest timbers are Wo71 and Wo72, which are broken fragments of the same plank and measure 2.5 m in length (Figure 3.4), and Wo86, which was recently discovered in the excavation of the citadel and exceeds 1.4 m. Other timbers in the dataset rarely exceed 1 m in length and their ends have either been cut or broken due to reuse, thus providing no information about the average lengths of the planks forming each strake of the hull and the way they were joined together. Only two timbers have been preserved one of their original ends, entirely in the case of BA0604128.73 and partially in Wo86.

BA0604128.73 (Figure 3.5) is a portion of a composite assemblage of three planks that were sewn together (Belfioretti and Vosmer 2010: 114). The planks, two on the same strake and one from an adjacent strake, have their edges connected with a joggled scarf at an angle of 167˚. The scarf is sewn in the same way as that used for

Figure 3.4: Wo86 (top) and Wo71-72 (below) are among the longest planks of the collection. (Photo: Author)

Figure 3.5: Scarf joint on BA0604128.73. (Photo: Author)

the seams with holes placed along the edges and ropes recessed in shallow rebates. The seam and the scarf stitching share the same hole near the vertex of the scarf where the plank tapers towards the end, making its width too narrow to have separate holes spaced closely apart without the risk of cracking or splitting the timber. Apart from the stitching, the scarf fastening is reinforced by oblique wooden dowels connecting the three planks together through their edges.

Timber Wo86 displays one end with an angle. Only one edge of the plank is partially preserved but provides no information about its original width. The end forms an angle of 152˚ with the plank's edge, which has stitching holes and rebates spaced along it. Two dowels, spaced closely apart, are visible on the edge of the angled end of the plank. These were driven obliquely from each side of the plank and, similarly to BA0604128.73, provided additional strength to the fastening of the plank's end. Unfortunately, Wo86 has no preserved portion of stitching or fragments of adjacent timbers.

Thickness

Establishing the thickness of the planks is easier than establishing either the width or the length. Most planks have retained their original thickness, though a few show some variation depending on the extent of their surface degradation. Thickness measurements were taken at the two extremities and centre of each plank, and the highest values were selected for analysis. As previously mentioned, the surface of planks, such as BA0604148.70 and Jansen_Husn.99.01, is very degraded and their thickness could only be estimated.

The overall thickness range of the al-Balid planks is between 22–58 mm, and is regularly distributed within the range. Planks between 22–30 mm are the most common, with ten samples (29%) (Figure 3.6). Plank Jansen_Husn.99.01 is the

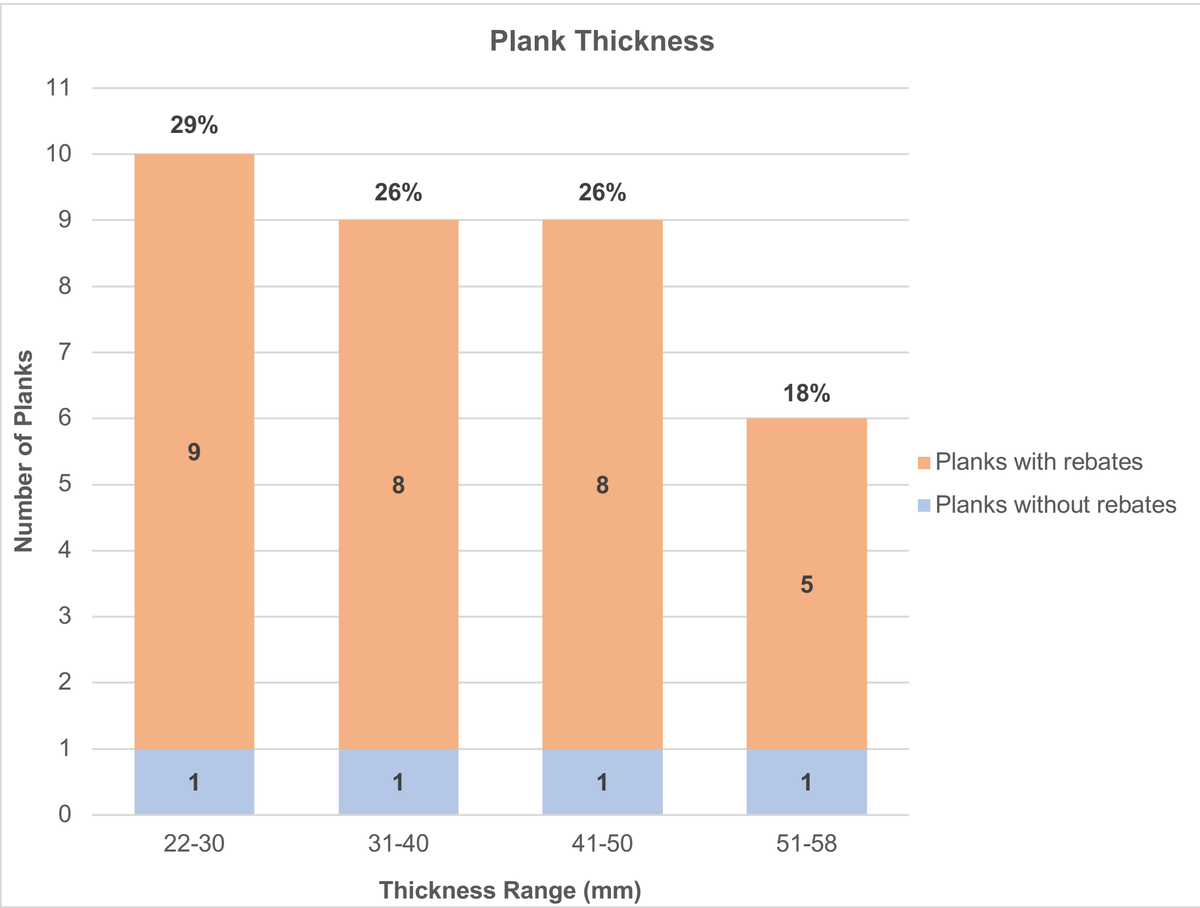


Figure 3.6: Thickness frequency of the al-Balid planks. (Chart: Author)

thinnest at just 22 mm, while the thickest are Wo54 and Wo94, at almost 60 mm (Figure 3.7). Plank Wo54 also displays the largest variation in thickness, which decreases from 58–45 mm towards one extremity, where a portion of the surface has been removed to create a chamfer. The four timbers without rebates have a thickness ranging between 27–55 mm. The remaining planks with rebates have a thickness range similar to the general figure for the timbers, with 38–40 mm being the most common and occurring in five planks (15%).

Width

In order to measure the width of the timbers accurately, it is necessary to determine whether the edges of the remaining timbers are original. Generally, the edges are cut perpendicularly to the plank's surface. Four planks have one edge that is bevelled, with angles ranging from 104˚ to 139˚, but it is difficult to determine whether the bevel was an original feature or was added at a later date. In the case of plank Wo54, it appears to have been present on the plank before its reuse.

One can determine whether the original width of a plank has been preserved by examining its edge surfaces, with those that are flat, smooth and relatively straight usually being a strong indication of being original. Further evidence that can help to identify the original width of a plank is the presence of stitching holes at a regular distance from the edge, and of substances such as bitumen or resin used as luting material to seal the plank seams and waterproof the hull of a vessel.

Only ten planks in the al-Balid collection have both edges preserved, and they have a width of between 90–303 mm. The smaller planks are BA0604128.74 and BA0604128.73, measuring 89–98 mm respectively; these are the only ones with

Figure 3.7: Planks Wo54 and Wo94 are the thickest of all the timbers found at al-Balid, with both the edges preserved. (Photo: Author)

wadding and stitching still in place and Belfioretti and Vosmer have suggested that they may come from the same vessel due to their many similarities, such as their width, thickness, sewing pattern and the substances visible on the inside (2010: 114). The two widest timbers are BA01.11.01 and Wo94 measuring 296 mm and 303 mm respectively.

The remaining planks have either only one edge preserved, a portion of it or no preserved edges at all, which makes it difficult to determine their original width; they range between 60 mm and 285 mm, and had either probably been cut before their reuse in the citadel or had simply deteriorated.

3.3.2 Hole Arrangements

In documenting the holes in the planks, these were organised according to their pattern and distinguished between those drilled along the edge, employed in plank-to-plank sewing, and those drilled in the centre of the plank, generally indicating frame lashings.

3.3.2.1 Plank-to-Plank Stitching Holes

Planks that retained their edges preserved offer an easy identification of stitching holes but this becomes more complicated when only one or neither edge is preserved. For each hole, the diameter, spacing and distance of the centre of the hole from the edge of the plank was measured. Holes are generally drilled perpendicularly to a plank's surface, and their distance to the plank's edge is similar on both sides of the timber. Wo54 is the only timber in the collection that has holes drilled at an angle and these match the bevelled edge of the plank.

Although in some timbers plank-to-plank stitching holes are typically found at a set distance from the edge and are spaced regularly apart, in others their arrangement is more confusing, with holes scattered on the surface of the timber.

3.3.2.2 Hole Diameter

Hole size often varies both between planks and within the same plank. Their diameter can vary on one edge of a plank relative to the other, and even along the same edge. For example, timber BA0604128.73 has holes with a diameter ranging between 8 mm and 15 mm, with an average diameter of 12 mm on one edge and 9 mm on the other. Similarly, Wo73 shows an even greater difference, with a 4 mm variation of holes' average diameter on the two edges.

Identification of the holes and the sewing pattern is often challenging due to the state of preservation of the planks. After 500–1000 years, some planks have degraded and are poorly preserved. Their surfaces are worn and holes have become stretched longitudinally to the plank length, along the wood grain, showing an elongated shape. In cases where the longitudinal diameter of the hole (aligned with the plank's edge) was too stretched and not indicative of the actual size of the hole, the diameter transverse to the plank length was taken, since it showed less stretch, and was therefore closer to its original diameter. For example, BA0604148.70 is one of the most degraded planks and its hole sizes were estimated by measuring vertical diameters, which were also considerably elongated (Figure 3.8).

One way to determine size with a degree of accuracy is to consider holes where a plug is still in situ. While a hole can still expand and change shape due to degradation, it is unlikely that the shape and size of the wooden plugs used to close it would change much. In order to create a database that allowed a frequency analysis and a correlation between stitching holes, and due to the variations of the size of the holes between planks and within the same planks, it was necessary to calculate and use average values. Some holes with large diameters were excluded from the database, especially if they considerably exceeded the size of others within the same plank. Holes that were visibly degraded and impossible to measure with accuracy were also excluded. Some holes also appeared to have been added after sewing as a repair or to strengthen a fastening, or perhaps as temporary lashings that were plugged afterwards.

Figure 3.8: The damaged surface of BA0604148.70 with elongated holes. (Photo: Author)

The diameter of stitching holes in the al-Balid planks ranges between 6 mm and 15 mm (Figure 3.9) with the majority (75%: twenty-five planks) having holes between 10 mm and 13 mm, with 12 mm being the most common (21%: seven planks). Only two planks (6%) had holes measuring between 6 mm and 9 mm. Four planks had a 14 mm average diameter hole, while just two (Wo70 and BA0604148.70) had the largest holes in the collection.

Since the planks can be categorised into two distinct types, based on the presence/absence of rebates between the holes and the edge of the planks, additional analysis was carried out on each type. Because only four planks were without rebates — a statistically insignificant number — the data should be approached with caution. The average hole size ranges between 11 mm and 14 mm, with the majority (50%: two planks) having holes with a diameter of 12 mm. The remaining two planks have holes with an average diameter of 11 mm (25%) and 14 mm (25%). The range of hole sizes in the planks with rebates appears greater than those that are flush: between 6

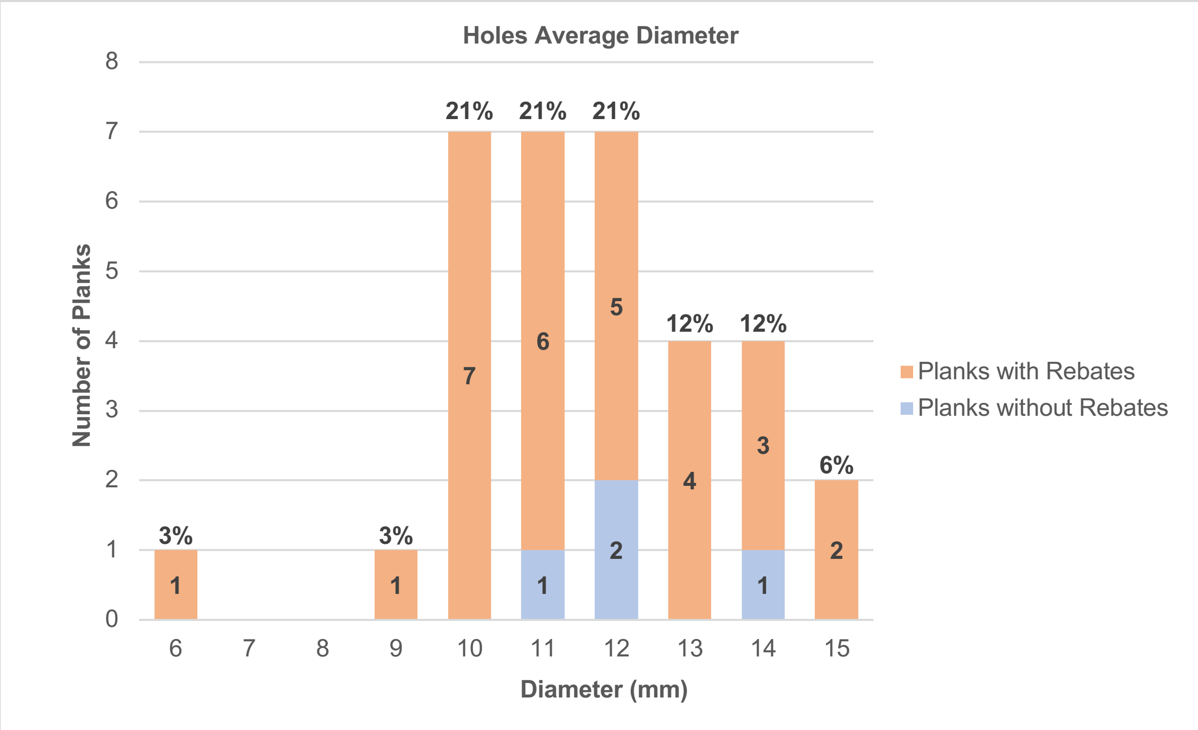


Figure 3.9: Average diameter of the stitching holes of the al-Balid planks. (Chart: Author)

mm and 15 mm. The most significant number of planks (76%: twenty-two planks) have holes with an average size of between 10 mm and 13 mm, while 10-mm holes are predominant on seven planks, representing 23% of the timbers with rebates.

There seems to be no relationship between the thickness of the plank and hole diameter. For example, planks that are relatively thin, such as BA1104065.449 and BA0704156.1477 that are 30 mm thick, have stitching holes with a diameter of 14 mm. Meanwhile, much thicker planks, such as Wo64 and Wo85, which are 49 mm and 52 mm thick respectively, have holes of 11 mm.

The correlation between hole size and plank width is more complicated to analyse. Timbers that have both edges preserved are very rare in the al-Balid collection and planks that had either one or both edges cut, probably once they had been removed from the hull of the boats for their new purpose, had just small sections of what was the original edge remaining. Only ten planks have both their original edges preserved,

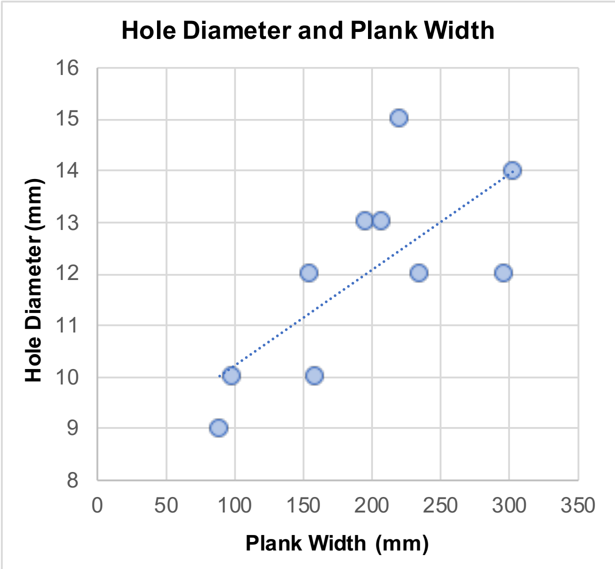


Figure 3.10: Correlation between the size of the holes and the width of the planks. (Chart: Author)

and if their width is compared with the average hole size, a medium-strong uphill (positive) correlation coefficient of 0.72[21] is obtained, which suggests that hole size increases in wider planks (Figure 3.10). However, analysis only involved ten planks, which is, statistically, a low number for definitive results.

One can estimate the width of the planks that have portions of the original edges preserved, where it is possible to establish the probable original edge of a plank. When comparing these estimates with hole size, however, the correlation appears weaker. Planks such as BA01.11.01, one of the largest of the collection with a width of 296 mm, and the much narrower Jansen Husn 99.01 (154 mm), both display holes with a diameter of 12 mm. Plank assemblage Wo56-Wo60-Wo73, measuring 204 mm in width, has considerably larger holes with a diameter of 15 mm.

3.3.2.3 Hole Spacing

As we have seen with respect to the diameter, hole spacing can also vary significantly between planks and even within the same plank. While there are a few planks that have regularly spaced holes, the majority show a variety ranging between 36 mm and

[21] A correlation coefficient is a statistical figure expressing the strength of a relationship between two variables. The value of the coefficient is between +1, indicating the strongest possible positive relationship, and -1, which is the strongest possible negative relationship.

105 mm. Due to this variation, it was necessary to calculate the average hole spacing for each plank and each of its edges.

Overall, the hole spacing displayed on the timbers of al-Balid ranges between 32 mm and 113 mm. Fourteen planks, representing the 42% of the collection, have holes 71–80 mm apart (average) (Figure 3.11). The distance between the stitching holes is between 30 mm and 70 mm in eight samples (24%), and between 80 mm and 110 mm in thirteen samples (33%). Planks Wo84 and Wo82 display the largest figure with an average hole spacing of 105 mm and 102 mm respectively. A smaller distance between holes is observed in planks BA1104065.454 at 3 mm apart, and Wo68, with an average spacing of 41 mm. The most regularly spaced holes are those from planks 823.B3.98.1235 that range between 72 mm and 74 mm, and BA1104065.450 at between 74 mm and 81 mm.

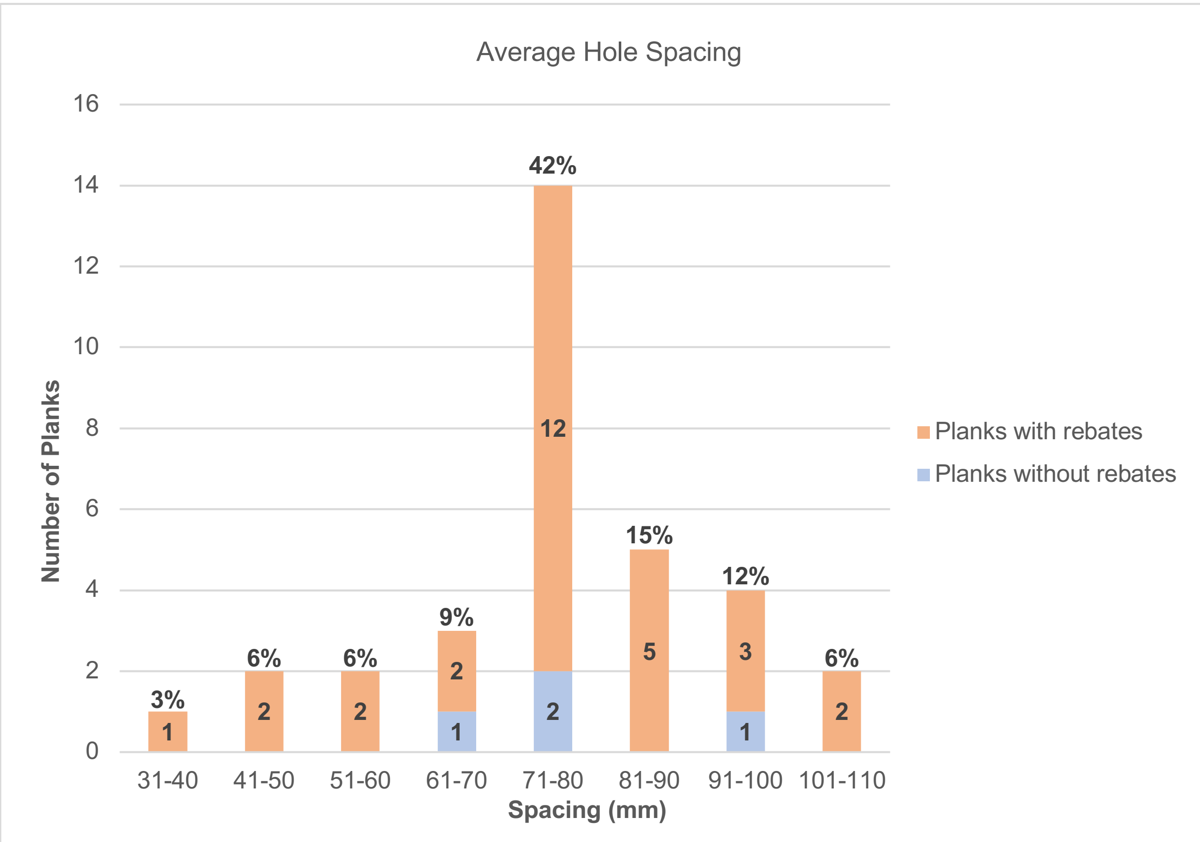


Figure 3.11: Average spacing of the stitching holes on the al-Balid planks. (Chart: Author)

The results are similar when comparing the hole spacing of the two typologies of sewn timbers, with and without rebates. Planks with rebates have an average spacing between 32 mm and 105 mm, with the majority of planks (58%: seventeen) showing holes spaced 70–90 mm apart. Holes on planks without rebates have an overall spacing range of between 69 mm and 99 mm, with the most frequent figures of between 70 mm and 80 mm observed in two planks (50%).

Four planks exhibit notable differences in hole spacing. For example, timber BA0604128.73 has holes that are 20–74 mm apart (Figure 3.12), while the range in BA0704156.1477 is between 59 mm and 98 mm. In four planks, the stitching holes are evenly spaced but their distance differs between one edge and the other. For example, BA0604145.175 has holes that are regularly spaced but the average spacing is 98 mm on one edge and 64 mm on the other (Figure 3.12). Similarly, Wo98B shows a 27-mm difference in the spacing between the top, where holes were drilled 50 mm apart, and the bottom edge, with an average distance of 77 mm apart.

Other examples show very similar figures in the spacing between the two edges of the planks, such as in the case of timbers Wo94, where the top and bottom edges share the same spacing (88 mm) and Wo98B, where holes are placed 74 mm apart along each edge. While there seems to be no relationship between hole spacing and their distance to the edge, one interesting aspect emerges by comparing the spacing of the holes and their size. In the planks with rebates, the correlation coefficient obtained is 0.6, while in those without rebates the relationship is stronger, reaching a coefficient of 0.79, suggesting that larger holes were spaced further apart (Figure 3.13).

Figure 3.12: Discrepancy in the hole spacing highlighted in blue circles on timber BA0604128.73 (top). Difference in the hole spacing between the upper and lower edge in plank BA0604145.175 (below). (Photo: Author)

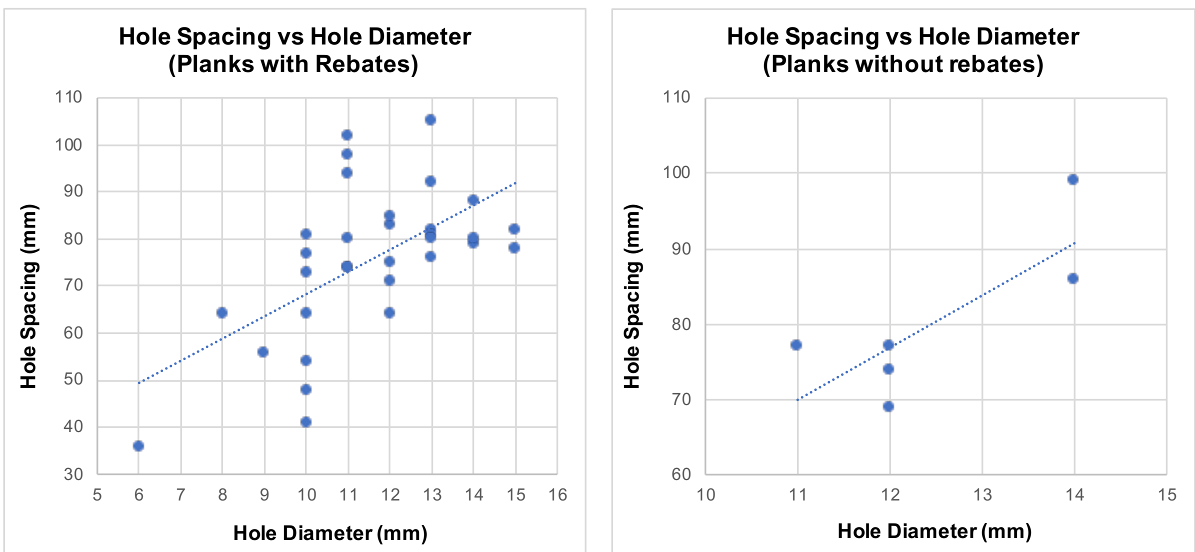


Figure 3.13: The correlation between the hole spacing and size in planks with rebates (left) and without rebates (right). (Charts: Author)

3.3.2.4 Hole Distance from the Edge

The distance between holes and the edge of a plank was measured from the hole's centre and the figures obtained correspond to the average distance calculated on planks that have at least one of their original edges preserved (thirty timbers).

Overall, holes are placed at between 14 mm and 70 mm from the edge of the planks. Wo82 displays the longest distance, at around 70 mm, while the closest holes to the edges are those from BA1104065.450 and BA1104065.454 with a 14 mm average (Figure 3.14). Thirteen planks (46%), all of which display rebates (Figure 3.15), have holes placed at 21–30 mm from the edge. The distance between the holes appears larger in the few without rebates, where two out of three have stitching holes drilled at between 31 mm and 47 mm from the edge of the plank.

Planks that have their width preserved provide an opportunity to examine whether the distance between the holes and the edge is consistent on both edges. For example, it

Figure 3.14: Planks Wo82 (top) and BA1104065.450 (below) display the longest and shortest average distance from the stitching holes to the edge of the plank. (Photo: Author)

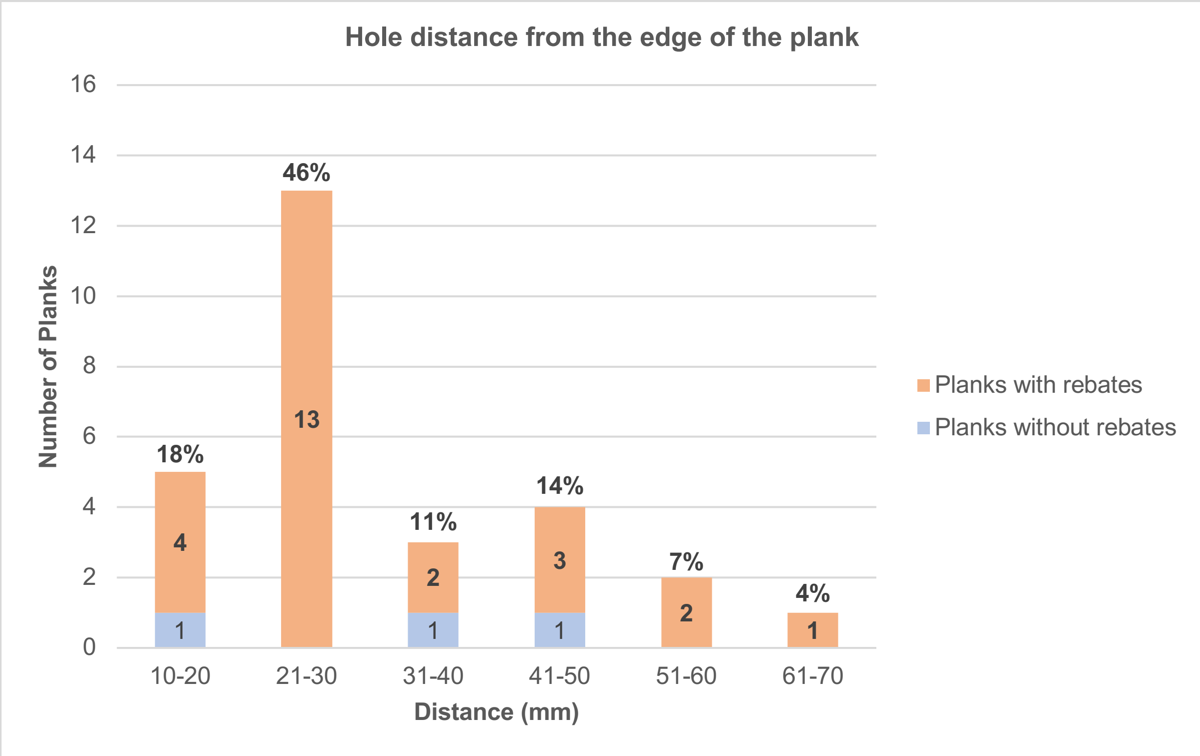


Figure 3.15: Frequency distribution of the distance between the sewing holes and the edge of the plank. (Chart: author)

is the same in planks Wo54 and Wo94, while others, such as BA0604128.73, BA0604128.74 and Wo68, show up to a 10-mm difference between the two edges.

In one case, Wo68, two additional holes appear to have been drilled below the stitching holes, halfway between them and the edge of the plank (Figure 3.16). They differ, with those closest to the edge being the smallest.

Rebates

Thirty-one planks (86%) have preserved rebates, small channels extending from the stitching holes to the plank's edge. Ethnographic records of recent sewn boats from the Arabian Peninsula and southern India indicate that these are generally located outboard, providing protection against chafing to sewing cordage recessed into them (Severin 1985: 283; Weismann et al. 2019: 357). Therefore, the side of the planks at

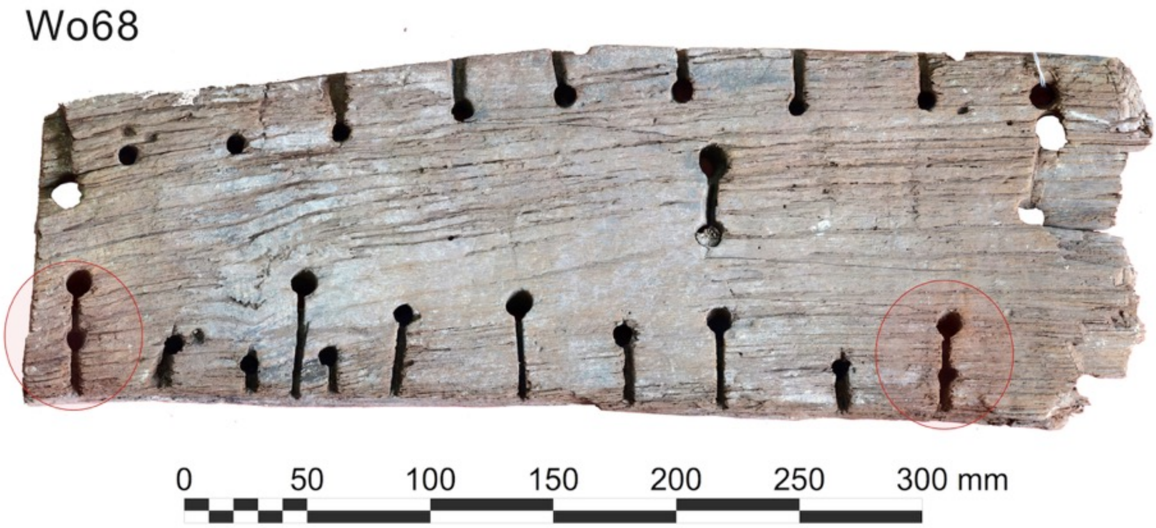
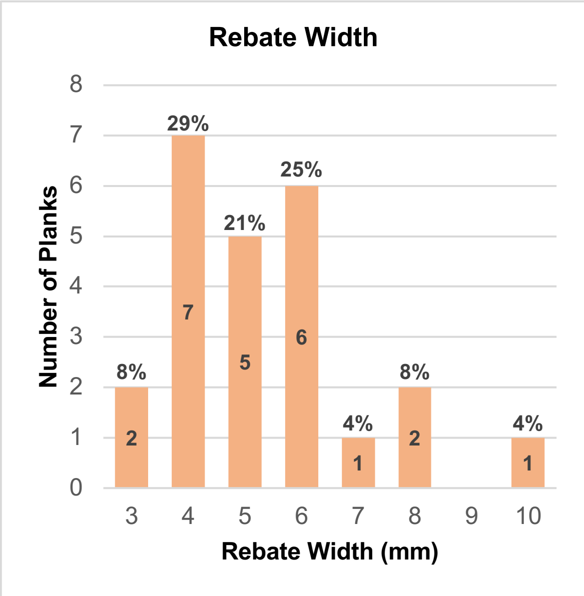


Figure 3.16: Additional holes drilled between the sewing holes and the edge of Wo68, highlighted in red ovals. (Photo: Author)

al-Balid that display rebates almost certainly correspond to the outside of the hull. Stitching ropes and fibre, some resembling coir, are still visible recessed in the rebates.

Rebates are carved perpendicularly from the holes to the edge of the planks. The only exception is plank Wo44, where the recesses are angled between 73˚ and 79˚. Their average width ranges between 3 mm and 10 mm. Planks BA1104065.454 and Wo64 have the narrowest rebates, measuring 3 mm in width, while the largest (14mm) are displayed on plank Wo94. Eighteen planks (75%) have rebates between 4 mm and 6 mm wide (Figure 3.17).

The width of the rebates is always smaller than the hole diameter. BA0604128.74 is the only plank where the rebate width (7 mm) almost matches the size of the holes (8 mm). In other planks this difference can be considerable, as in the case of Wo70, where the holes are 15 mm in diameter and the width of the rebates is 5 mm. Overall



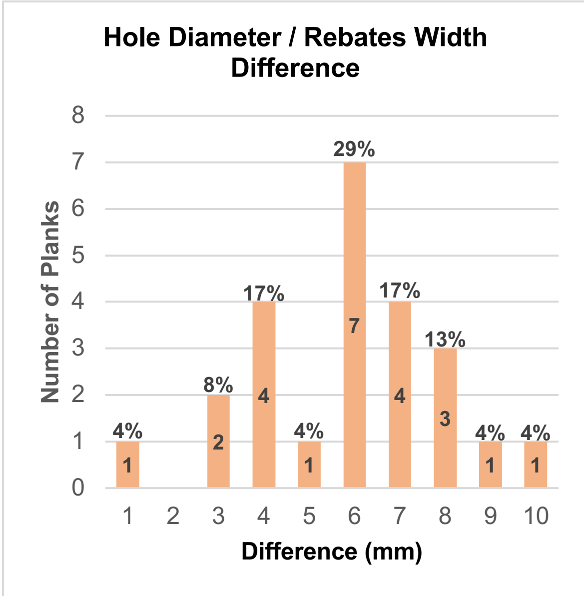


Figure 3.17: Frequency distribution of the rebate width (left) and the difference between their width and hole diameters (right). (Charts: Author)

the difference between the hole size and the rebate width is 6–7 mm in eleven planks (46%).

The average depth of the rebates can also vary significantly within the timbers, measuring between 4 mm and 19 mm. Planks BA0604128.74 and Wo86 have the shallowest rebates (4 mm), while in Wo73 and Wo94 they reach 17 mm and 19 mm in depth. The depth of the rebates ranges between 5 mm and 10 mm in eleven planks (52%), with the most frequent figure being between 7 mm and 10 mm, displayed on eight planks (38%) (Figure 3.17). A comparative analysis between rebate depth and the thickness of timbers does not provide evidence of correlation — these channels can be very deep despite a relatively thin plank. For example, Wo82, which is one of the thinnest planks of the collection, measures 23 mm yet has 14-mm-deep rebates carved through 65% of its thickness (Figure 3.18). A similar case is observed in plank Wo83, where the depth of the rebate is 14 mm and its thickness 25 mm.

Four planks (Wo62, Wo71, BA0604172.69 and BA0604159.263) have rebates that continue beyond the hole towards the centre of the plank. Wo62 and Wo71 have only one edge preserved, making it impossible to determine to what the holes are connected and the purpose of the stitches. The rebates extending from the stitching holes of Wo71 gradually disappear towards the centre of the plank, probably due to a later (intentional) reduction of the timber's thickness (Figure 3.19). In planks BA0604172.69 and BA0604159.263, the rebates connect matching holes in the centre of the plank in a pattern similar to that used for frame lashing.

Figure 3.18: Plank Wo82 displaying very deep and long rebates. (Photo: Author).

There are four planks where some of the stitching holes have no rebates. On one edge of timber Wo98B the last six holes at one end have no rebates, and Wo64 has one hole at one end of the plank that is not recessed but aligned with other sewing holes, and has the same diameter. Similarly, Wo68 has three holes without recesses, two at one end and one at the opposite end. Their spacing is comparable to that of other sewing holes, as is their diameter. One of the most interesting planks of the dataset is Wo54, which has one edge with recessed holes, while the opposite edge is flat. This evidence, which will be discussed more in Chapter 5, indicates the use of two different sewing patterns within the same vessel.

3.3.2.5 Holes in the Centre of the Plank

Twenty-three of the al-Balid timbers display patterns of holes at the centre of the planks, which are placed between the two rows of plank-to-plank sewing holes. In most cases, they were used to fasten frames to the planking, as indicated by the

Figure 3.19: Rebates extending beyond the stitching holes on plank Wo71. (Photo: Author).

analogies with recent sewn boats of the Indian Ocean (Figure 3.20). The holes are drilled perpendicularly to the planks' surface and arranged in pairs aligned vertically. Generally, the holes are connected by vertical rebates, always sharing the same surface with the recesses of the sewing holes along the edge and occasionally displaying ropes and fibres in situ.

As seen in planks' sewing holes, those located in the centre can vary in size within the same plank and overall range between 6 mm and 20 mm. Thirteen planks, more than half the dataset (57%), have an average diameter of between 11 mm and 12 mm. The largest holes, measuring 15 mm, are displayed on plank Wo63, while those from BA1104065.454 are the smallest with an average size of 6 mm (Figure 3.21).

A comparative analysis between the holes drilled in the centre of planks and those along the edges reveals that their size often differs. The analysis also suggests that their diameter is directly proportional. The holes in only seven planks (29%) are the same size. In the largest group, consisting of eleven timbers (46%), the holes in the centre are smaller than those along the edge. The largest difference is in Wo70, with 4 mm between the two types of holes.

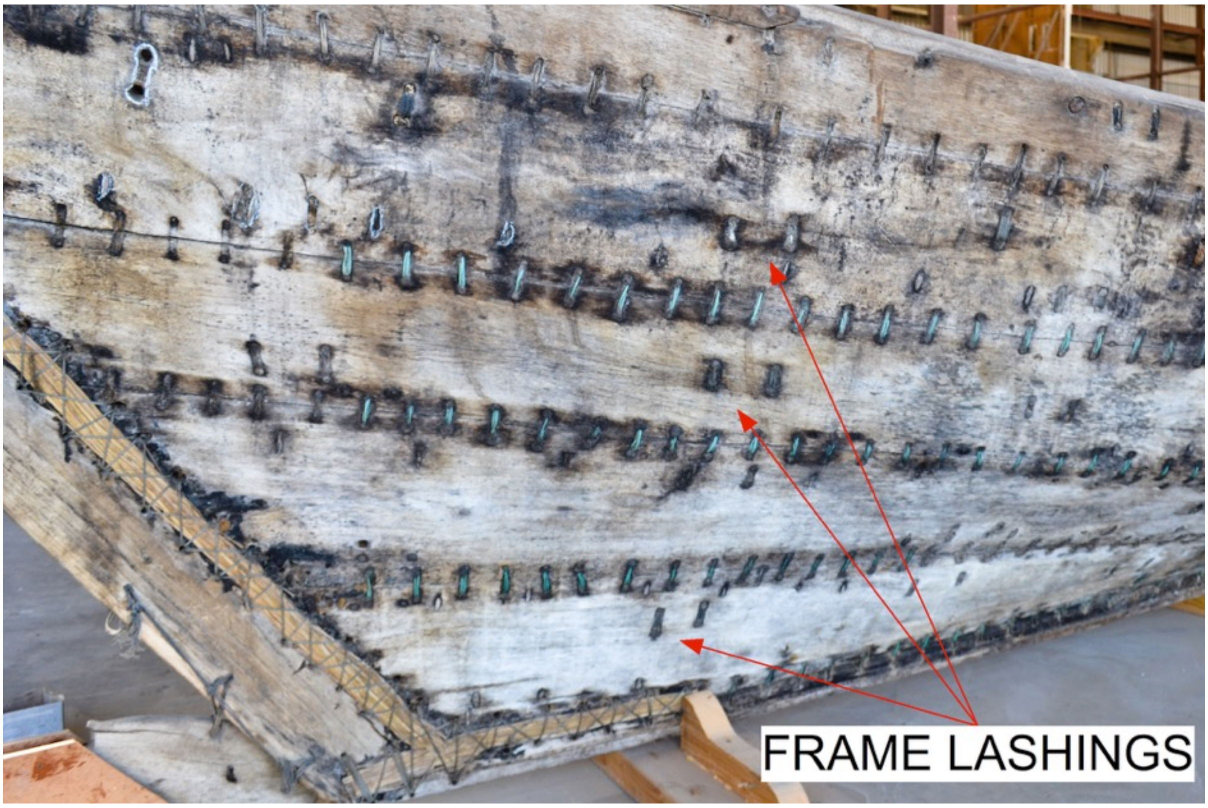


Figure 3.20: Frame lashing on the outside of the hull of a sewn *kambārī*, Oman. (Photo: Author)

By observing hole patterns, it is obvious that their horizontal distance can vary considerably and are rarely uniform within the same plank. Frequency analyses were carried out on both absolute values, comprising all the measured distances between holes, and their average lengths calculated for each plank.

The distance between all the closest pairs of holes measured ranges between 36 mm, recorded in BA1104065.454, and 215 mm displayed on Wo63. The most common distance is between 81 mm and 100 mm (26%: ten specimens), while the average distance, observed in eight planks (40%) ranges between 101 mm and 123 mm (Figure 3.22). Fifteen planks exhibiting rebates have pairs of holes spaced between 36 mm and 215 mm apart, the majority of which (17%) are 100–110 mm. Only two planks without rebates display holes at their centre. The distance between the pairs of stitches ranges from 55–221 mm.

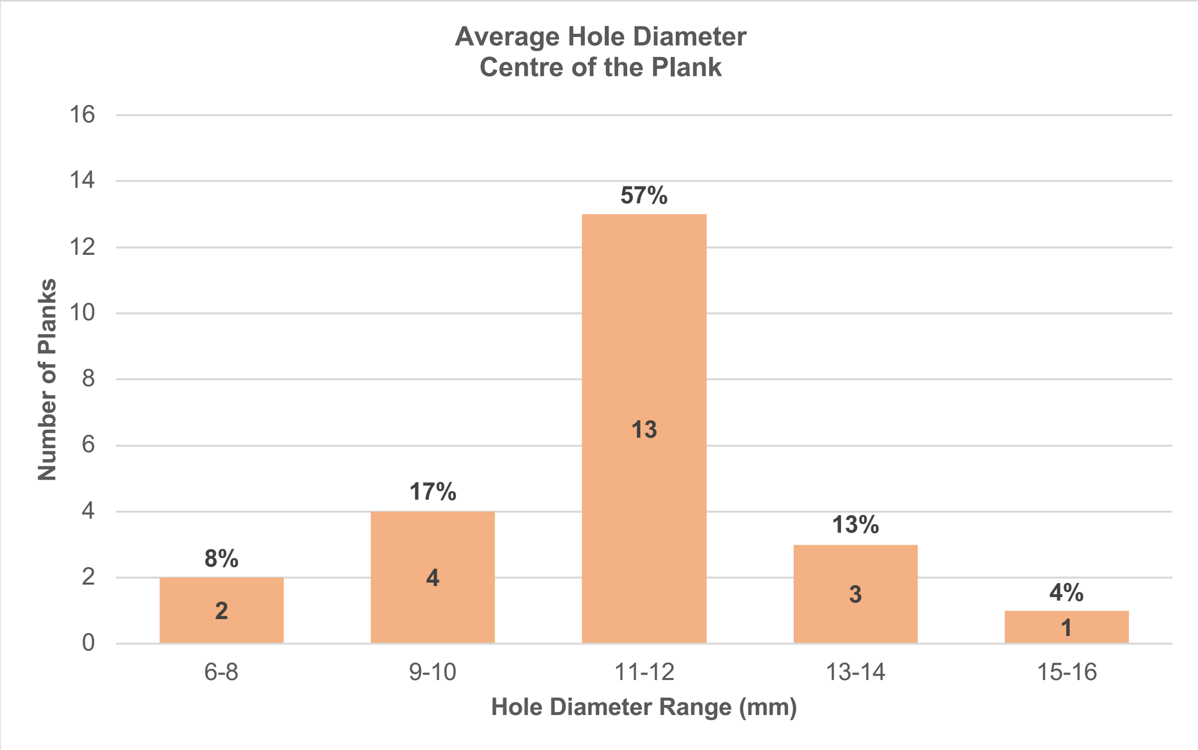
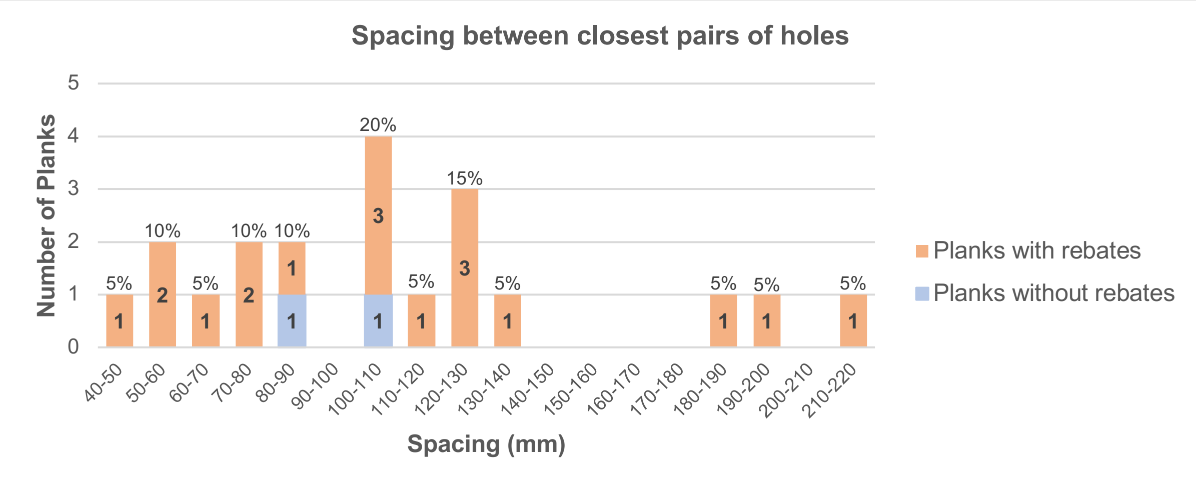


Figure 3.21: Frequency distribution of the average diameter of the holes located in the centre of the plank. (Chart: Author)

In all the timbers, except for BA0604128.73 and BA0604128.74, holes are connected by rebates on one side of the plank. Timber Jansen.Husn.99.01 has the shortest recess, measuring 16 mm, while the longest is displayed in Wo94, with a length of 90 mm. The majority of the rebates (30%) have a length of 29–30 mm.

As previously mentioned, these figures can differ within the same piece of timber. Two planks in particular exhibit significant variation, ranging between 52 mm and 100 mm in plank BA0604148.70, and between 72 mm and 141 mm in Wo98C.

Planks Wo85, Wo54 and Wo94 are among the thickest of the al-Balid collection, all exceeding 50 mm and displaying at least two sets of vertical pairs of holes each (Figure 3.23). Their hole diameters range between 10 mm and 13 mm, while the average space between the closest pairs of holes is significantly large, measuring 120–123 mm. However, a comparison of plank thickness with these hole spacings,



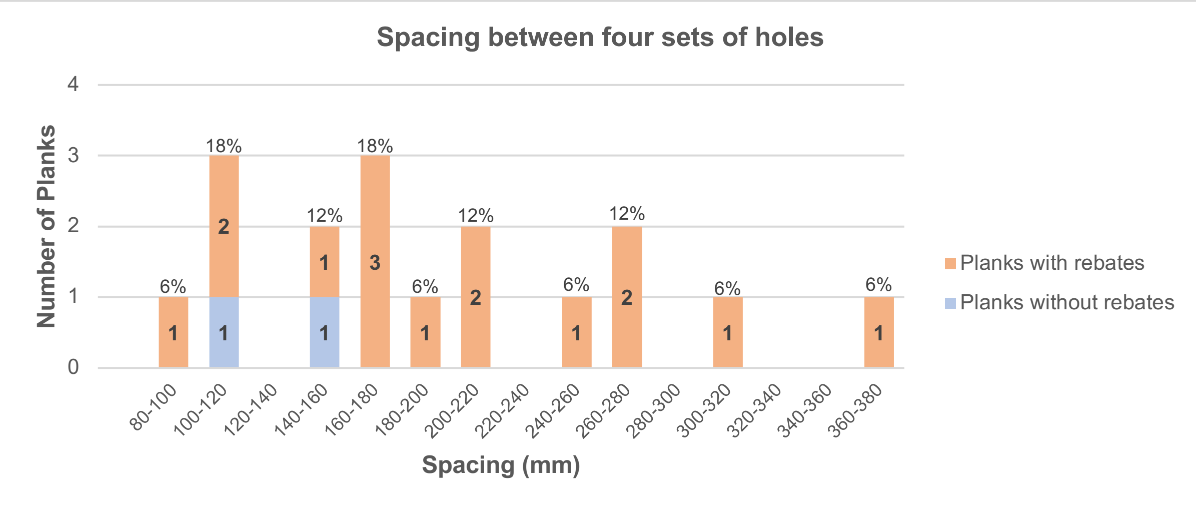


Figure 3.22: The range of spacing between the closest pairs of holes (top) and sets of four holes (below) in the centre of the plank. (Charts: Author)

across all the al-Balid timbers, shows no correlation. For example, pairs of holes spaced 118 mm apart are associated with a plank thickness of 30 mm in the case of Wo98A. The fact that this evidence is present on just twenty-three planks poses limitations on the outcome of analysis and calls for caution when interpreting data.

The distance between these sets of holes ranges between 373 mm in Wo83 and 55 mm in BA01.11.01, with the largest number (30%) included between 143 mm and 171 mm. The average distance is between 110 mm and 116 mm in three planks (18%), between 143 mm and 180 mm in five planks (30%) and exceeding 200 mm in seven

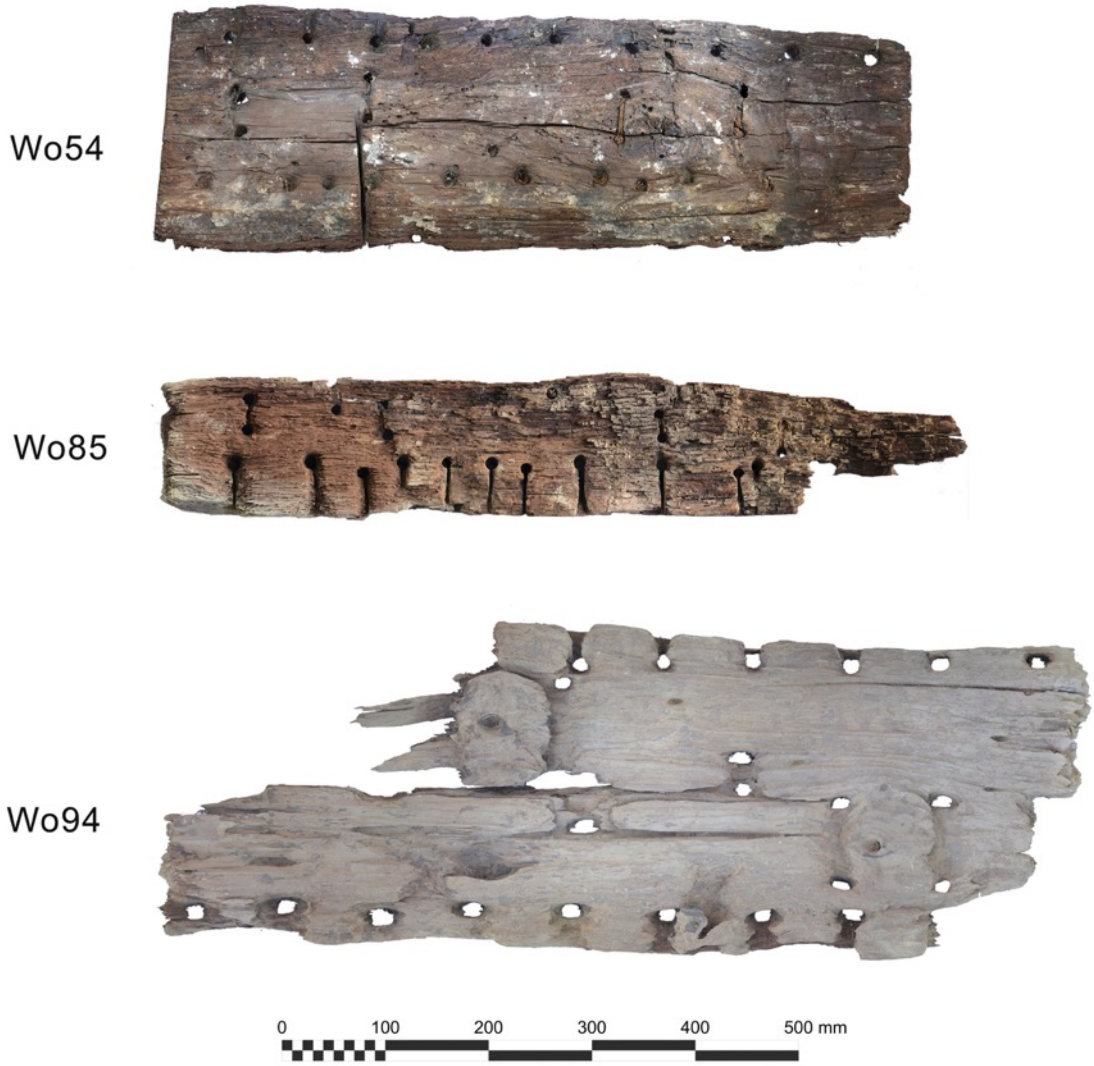


Figure 3.23: Sets of four holes displayed long the centre of the outside of planks Wo54, Wo85 and Wo94. (Photos: Author).

timbers (42%). This distance ranges between 63 mm and 373 mm in the planks with rebates, with the majority (18%) being between 163 mm and 171 mm (Figure 3.22).

Two planks display series of matching holes in their centre arranged in a sewing pattern that resembles plank-to-plank stitching. For example, timbers Wo56, Wo60 and Wo73, which are fragments of the same plank, show a series of regularly spaced vertical stitches recessed in rebates (Figure 3.24). The stitches are spaced between 66 mm and 107 mm apart and located across a large longitudinal crack. A similar arrangement can be observed on BA0604159.263, but in this case the timber does

Figure 3.24: Vertical stitches displayed along the centre of planks Wo56-Wo60-Wo73 (top) and BA0604159.263 (below). (Photos: Author)

not appear to have split (Figure 3.24). Unfortunately, this evidence reveals what the stitching looked like on one side of the planking, but provides no indication of the sewing pattern on the other side.

3.3.3 Sewing Cordage

A significant number of the timbers (50%: eighteen planks) show the preserved remains of stitching cords. Five planks (28%) bear plank-to-plank stitching cords, while another five have preserved lashing ropes associated with holes drilled in the centre of the plank. Both these types of cordage are visible on eight planks (44%). This evidence provides information about the material used for making the ropes, their thickness and the way in which they were made.

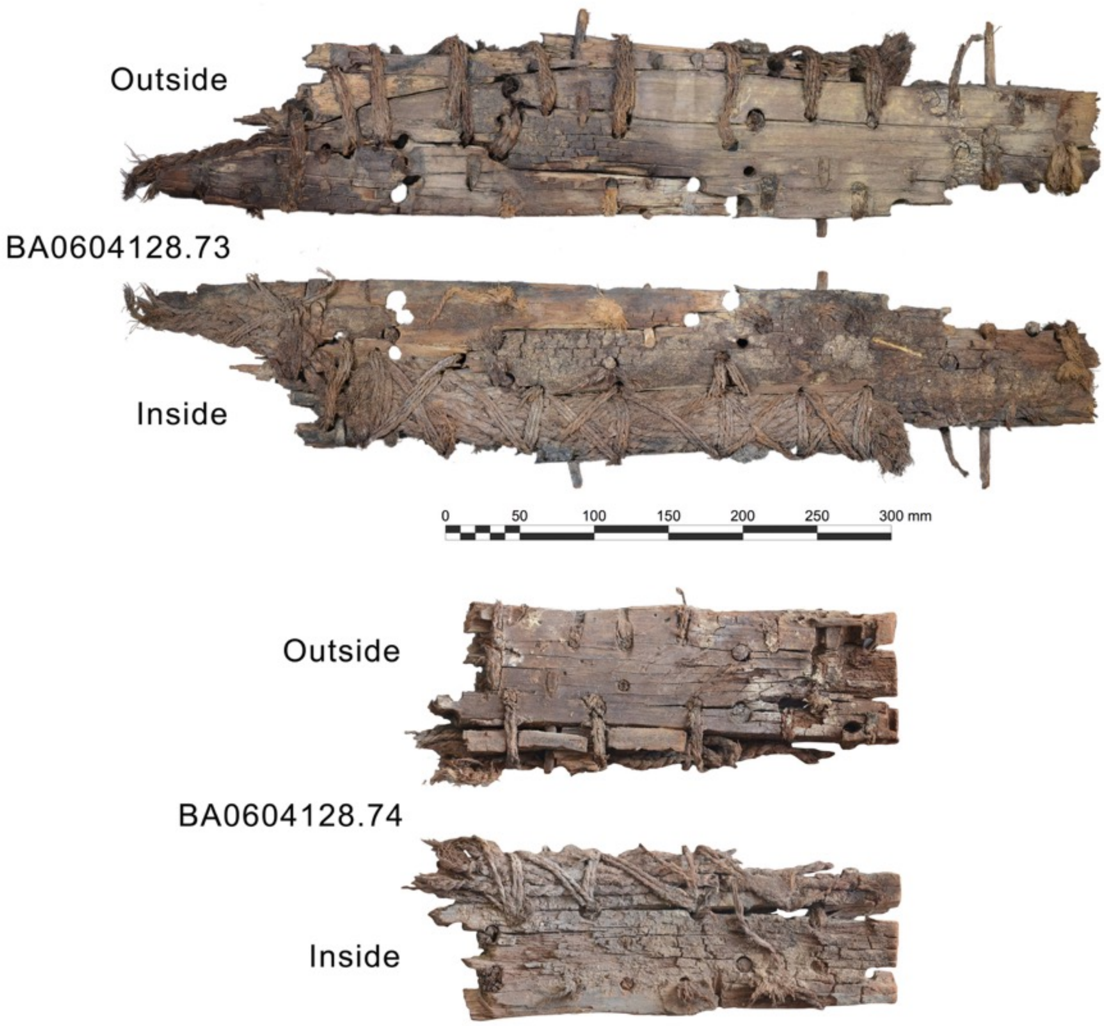


Figure 3.25: Portion of the sewing preserved on planks BA0604128.73 (top) and BA0604128.74 (below). (Photos: Author)

Timbers BA0604128.73 and BA0604128.74 have considerable portions of the actual stitching preserved, providing valuable information about the sewing technique, technology and materials (Figure 3.25). Both planks share similarities in terms of size, with a thickness of 28 mm and a width of 90 mm and 98 mm respectively. Even the timber texture and general features displayed on their surfaces, such as hole size and spacing, rebate and dowel size appear to match, as well as their state of preservation. Both timbers consist of fragments of adjacent planks sewn together. Due to their similarity, Vosmer and Belfioretti suggest that they may belong to the planking of the same hull (2010: 114).

The ropes are very degraded in BA0604128.74, and often cut, making it difficult to interpret the sewing arrangement. The stitching is relatively well preserved on BA0604128.73, providing an opportunity to understand not only the sewn pattern but also the stitching sequence. The surface of the plank displaying the wadding, which is generally on the inside of the hull, is the most useful to determine the sewing pattern. On the outer surface, the stitching cords inside the rebates are too compressed and bundled together to offer any clues about their number. Moreover, the ropes look like disconnected vertical stitches on the outside of the hull, providing no indication of the arrangement on the inside.

The stitching cord used in plank BA0604128.73 consists of three ropes bundled together passing through matching holes drilled along the edge of the plank in a continuous sewing pattern. On one side the cordage is recessed in rebates between the holes and the edge of the plank in a pattern consisting of vertical disconnected stitches (I I I I). On the opposite side a thick caulking roll (wadding) covers the seam of the plank between the stitching holes and is firmly compressed by vertical and crisscross stitching (IXIXIXI). The wadding is made of approximately twenty ropes arranged in a semi-cylindrical cushion running longitudinally to the plank, and measuring 43–54 mm wide and 12–16 mm thick. The wadding ropes are larger than those used for sewing, with a diameter ranging between 4 mm and 8 mm.

The sewing preserved on timber BA0604128.73 consists of a complete section, with a starting and finishing point. Interestingly, the sewing did not start from one end of the section but approximately from the centre. The stitching rope was threaded through the matching holes inside and outside the plank in a vertical arrangement and then taken diagonally across the wadding to the next pair of holes in a zigzag pattern (I \ I \ I). Once the cord reached one end of the section, the same pattern was repeated

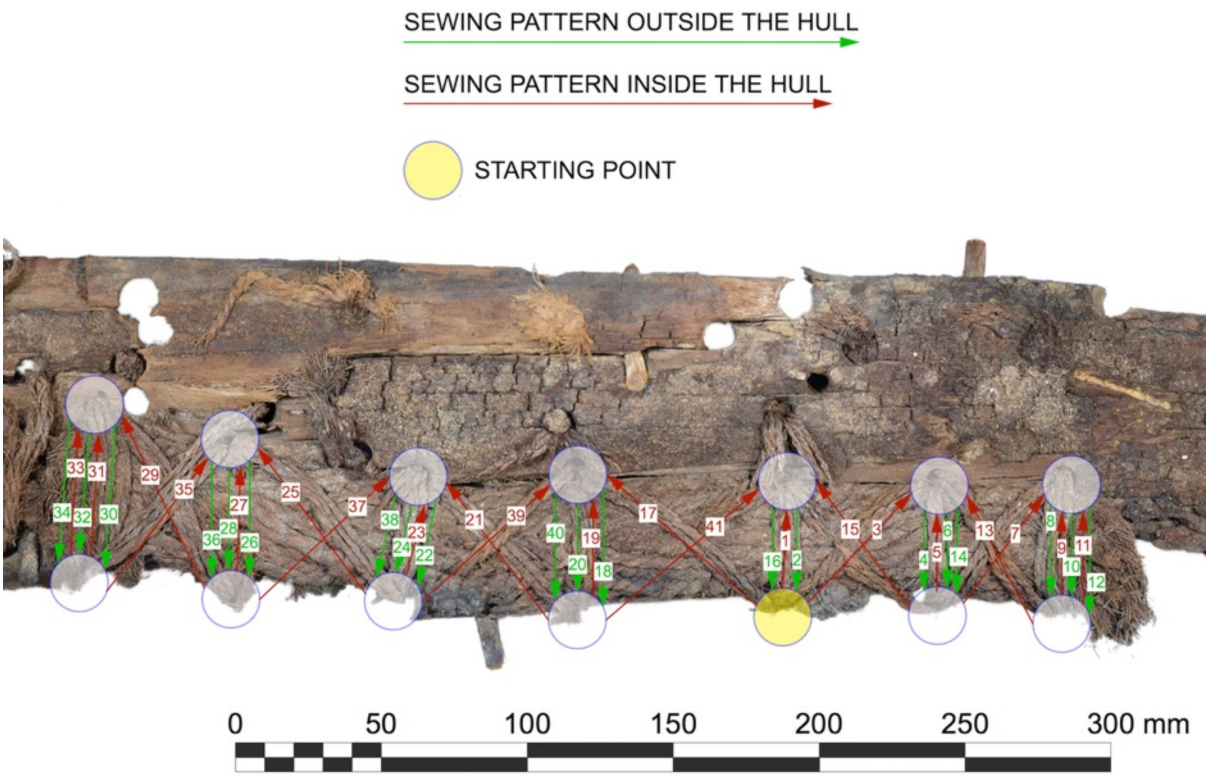


Figure 3.26: The sewing sequence on plank BA0604128.73. (Photo: Author)

back in the opposite direction to the other end, and then back again to the starting point (Figure 3.26).

Although no other timber of the dataset displays portions of stitching, some have preserved fragments of sewing cords recessed in the rebates. Although this evidence cannot tell us with definite certainty how the plank was stitched, it does provide information about the number of ropes used. For example, a comparison between the planks exhibiting partial cordage indicates that most of them (70%) consisted of two ropes, while three-rope stitching cordage is recorded on just 20%. Overall, the ropes appear to be made of two strands twisted in a left-handed direction ("S" twist). Other timbers, such as BA0604172.69 and BA0604172.263, have ropes made of three strands and the thickness of the cordage ranges between 2 mm and 5 mm for plank-to-plank stitching cords and between 2 mm and 7 mm for the frame-lashing ropes

Figure 3.27: Ropes of various thickness used in the sewing and wadding of BA0604128.74. (Photo: Author)

(Figure 3.27). However, due to the state of degradation of some of the planks, and to the fact that the ropes have probably stretched either during sewing or through time, these figures may not necessarily indicate their original thickness. The most frequent average thickness for plank-to-plank stitching cords is 4 mm, which is displayed in seven planks (54%).

As previously observed for other features such as hole size and spacing, the al-Balid timbers also display significant differences in rope thickness within the same plank. Plank BA0604128.73, for example, exhibits both the maximum and minimum rope thickness, with an average of 2 mm on one edge and 5 mm on the opposite side. The plank also has the thickest cordage for the holes in the centre of the plank, measuring 7 mm.

The frequency distribution of the thickness of cordage preserved in the centre of the plank provide results similar to those of plank-to-plank stitching cords with six planks (55%) having ropes measuring an average of 4 mm in diameter. Thinner frame ropes are found in BA1104065.454, with a thickness of 2 mm. Generally, in the planks where both types of cordage are preserved, the ones in the centre of planks appear to be thicker, in two cases, and in three cases, equal to those used in plank-to-plank sewing.

Rope thickness does not seem to have any correlation with other sewn-plank construction elements displayed on the timbers. Thin ropes can be easily observed in thick planks and vice versa. For example, Wo64 is among the thickest planks of the dataset (49 mm) and has stitching ropes measuring 3 mm. Similarly, the thickest ropes (5–6 mm) are displayed on BA0604128.73 and BA0604128.74, which are the thinnest planks, measuring 27 mm and 28 mm respectively. Moreover, the depth and width of rebates, where the ropes are recessed, does not appear to be in any way related to rope diameter. A medium/weak correlation emerges when comparing rope thickness with the size and spacing of stitching holes, suggesting that the thickest ropes are associated with holes that are larger and spaced further apart. However, the number of planks with plank-to-plank stitching ropes preserved (thirteen samples) is statistically limited and more data are necessary to confirm definitive results.

3.3.3.1 Hole Plugs

Wooden pegs are preserved in many of the holes of the al-Balid timbers (72%: twenty-six planks). They are cylindrical timbers slightly tapered towards one end and hammered into the holes from the outside of the hull after completion of sewing. Their protruding ends were then cut flush with the surface of the plank. From a preliminary observation, it appears that the plugs are made of a different wood from that used in the planks. For example, some are very fibrous and spongy, as in the case of plank Wo72, resembling either reeds, bamboo or palm wood (Figure 3.28).

Figure 3.28: Wooden pegs still inset in the sewing holes of plank Wo72. (Photo: Author).

3.3.4 Dowels

The vast majority of the al-Balid planks (83%: thirty specimens) display evidence of dowels. These are found on twenty-eight planks with rebates and two with flat surfaces. Although not all the planks still have preserved dowels, most of them have the channels through which dowels were driven. Two dowels are entirely preserved in the case of BA0604128.73, and measure 81 mm and 85 mm in length. Despite its relatively small size, this timber also has the highest number of dowels, with nine examples. In most of planks, due to degradation, dowels have disintegrated, leaving only their channels, which, however, still provide information regarding their size and spacing being the negative of the dowels that were inset into them.

Dowels visible on the timbers are wooden pins with a circular section and constant diameter. They were driven obliquely from the outside of one plank into the faying edge of the adjacent one. Their ends, protruding from each side of the hull, were then

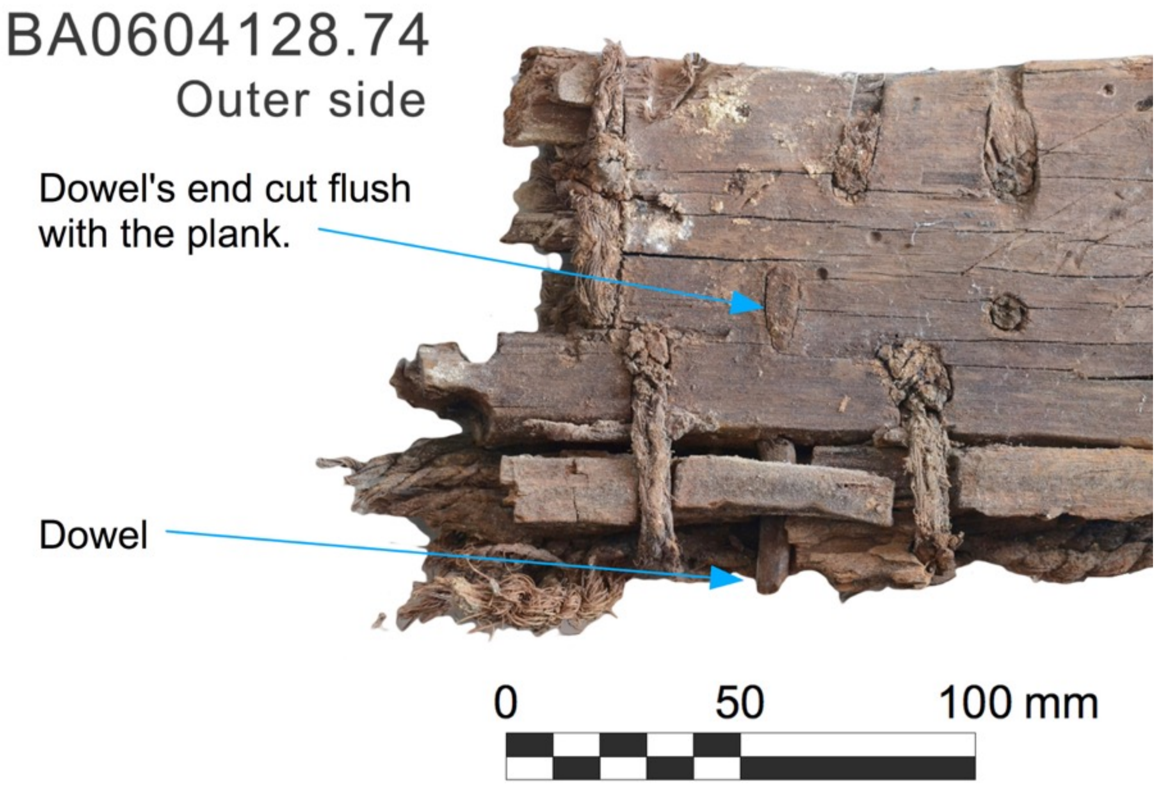
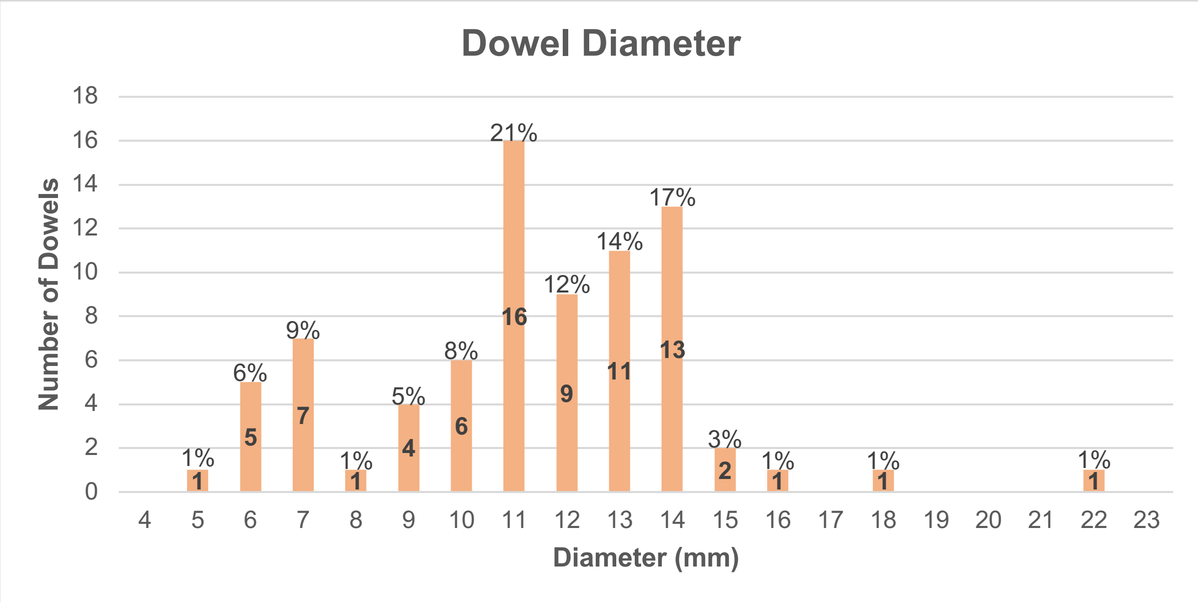


Figure 3.29: A dowel preserved on BA0604128.73. (Photo: Author).

cut flush with the plank's surface resulting in the presence of ovoidal cross shapes on each side of the planking, indicating the extremities of the dowels (Figure 3.29).

The diameter of the seventy-eight dowels recorded in the al-Balid timbers varies between 5 mm and 22 mm. The most common measurement is 11 mm, which is observed in sixteen dowels (21%), while forty-nine dowels (63%) have a diameter of between 11 mm and 14 mm (Figure 3.30). The same results are obtained when taking into consideration the average diameter of the dowels calculated for each plank. The majority of the planks, consisting of eight examples (26%), display dowels with an average diameter of 11 mm, with 11–14 mm recorded for the dowels in twenty-one planks. Wo94, the widest and thickest plank of the dataset, exhibits the largest dowel (22 mm) and the greatest average diameter (20 mm). The relatively small-sized timber BA1104065.454 has dowels with an average smallest diameter of 6mm.



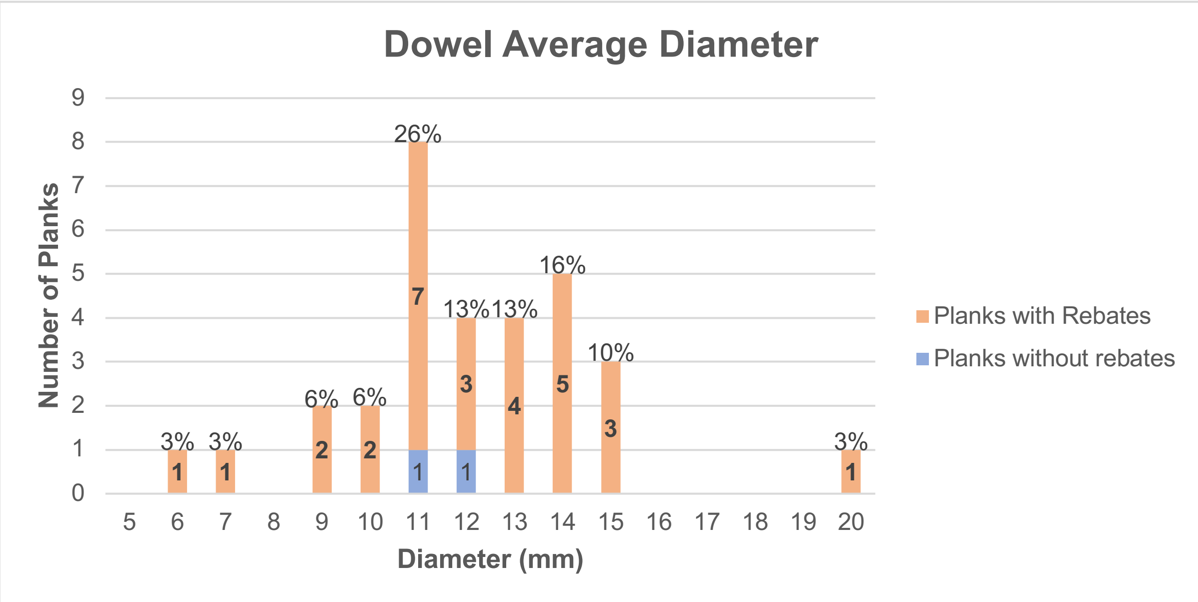


Figure 3.30: Frequency of dowel diameters (top) and their average diameter calculated for each plank (below). (Charts: Author)

The frequency distribution of the overall and average diameters of the dowels is also similar in planks with rebates, measuring 11 mm in six planks (21%) and ranging between 11 mm and 15 mm in twenty-one planks (75%). Forty-nine dowels (63%) have diameters of between 11 mm and 14 mm, with 11 mm being the most common and observed in sixteen dowels (21%). Due to their limited number — only three

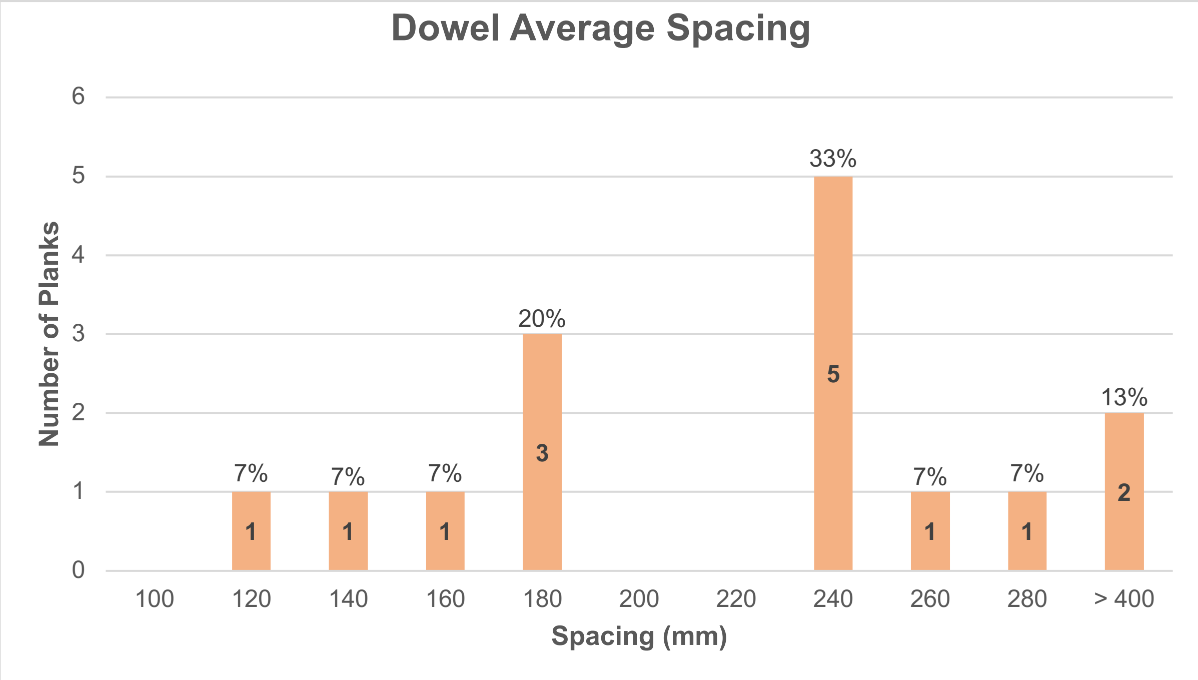


Figure 3.31: Frequency of the average dowel spacing for each plank. (Chart: Author)

planks show evidence of dowels — the range of dowels' diameters in planks without rebates is more restricted, measuring 11–12 mm.

As observed in the case of other boatbuilding features in the timbers, the thickness of a dowel can differ within the same plank. Only four planks have dowels of identical or similar diameter: Wo71 shows the most regular figures, with all the dowels measuring 14 mm, while in planks Wo72, Wo64 and Wo98C the difference is within 1 mm. The most significant variation can be observed in BA0604128.73 and BA0604128.74, where dowels range from 5–11 mm and from 7–13 mm.

The average spacing of dowels in the al-Balid timbers is between 53 mm and 837 mm, with the most common being between 225 mm and 243 mm, observed in five planks (33%) (Figure 3.31). The frequency of spacing distribution for the total number of dowels reveals a similar result, with the majority, consisting of sixteen examples (31%), being 228–257 mm apart. BA01.11.01 is the only timber without rebates that has at least two dowels, which are spaced 411 mm apart. Unfortunately, only one of the planks without rebates has more than one dowel. This makes it impossible to carry out any frequency analysis about their spacing, or determine whether there are differences in dowel placement between planks with rebates and those with flat surfaces. More data are therefore required to determine whether the dowel spacing changes according to the method used to sew the vessel.

Within the timbers that have their original width intact, only three samples (BA0604128.73, BA0604128.74 and Wo56-60-73) have dowels on both their edges. Their arrangement generally appears to be staggered but in one case, BA0604128.73, dowels on opposite edges are almost on the same line. In this particular case, two dowels are located on the opposite edges of a scarf and were used to strengthen the joint between two planks of the same strake.

Dowels, with their channels driven through a timber's section, can also represent a weak point in a plank and is the reason for their being staggered. For example, timbers Wo56 and Wo60 are fragments of the same plank displaying a large crack associated with the channel of a dowel (Figure 3.32).

Figure 3.32: A large crack caused by a dowel on Wo56-Wo60. (Photo: Author).

It appears that there is no correlation between the diameter of the dowels and the plank thickness and width. For example, a large dowel measuring 15 mm is only slightly smaller than the thickness of Wo82, which is one of the thinnest timbers of the dataset (23 mm). Wo54, the thickest plank recorded in the collection, has dowels with a diameter ranging between 11 mm and 13 mm, which appear not to be related to their average spacing but rather to a medium coefficient correlation (0.65) between their size and the distance between plank-to-plank holes, suggesting that larger dowels were employed in planks with stitches that were spaced further apart. Dowels have the same diameter as the stitching holes in fourteen planks (45%), are larger in five (16%) and smaller in twelve (39%).

Figure 3.33: The recess in the southern wall of the citadel of al-Balid lined with ship planks. (Photo: Author).

3.4 Additional Fastening Methods

3.4.1 Nailed Planks

Recent restoration work of the citadel of al-Balid has exposed four long planks, two of which display a combination of different fastening techniques. The timbers were discovered placed against each side of a square slot in the stone wall of the southern gate of the building (Figure 3.33). This recess extends for approximately 3.4 m inside

Figure 3.34: Plank Wo98C exhibiting stitches on the outer side that were exposed after a cyclone in 2018 (top) and triangular notches on the inner surface (below). (Photos: Author)

the wall and was used to accommodate the sliding square timber that locked the gate (Belfioretti and Vosmer 2010: 115).

Planks Wo98A and Wo98C, respectively at the right and left side of the slot, have one of their original edges preserved, displaying a fastening system that combines stitches, dowels and nails in triangular recesses (Figure 3.34). The sewing pattern is the same as that on the majority of the al-Balid planks, with rebates between the stitching holes and the edge of the plank on one side and the flat surface on the opposite side. The triangular recesses are located on the flat surface of the plank, which, on sewn boats, is generally outboard. Their size ranges between 30 mm and 43 mm in length and 10–17 mm in width with an approximate depth of 10 mm. They are placed along the edge of the plank at a distance of 30–35 mm and are spaced 165–212 mm apart. Holes are driven from inside these recesses through the faying edge of the planks. Traces of metal are still visible inside one of these holes, indicating the presence of a nail (Figure 3.35), and revealing timbers Wo98A and Wo98C once belonged to a vessel the planking of which was edge-joined with metal fastening.

Between the triangular recesses, more or less at the same distance from the edge of the plank, are 2 to 3 stitching holes spaced between 57–101 mm. Other distinctive features of the sewn-plank construction technique are visible on the planks, such as oblique dowels, spaced 344 mm apart, and series of central transverse pairs of holes.

Figure 3.35: Traces of metal revealing the presence of a nail inside one of the recesses on plank Wo98C. (Photo: Author).

Although they share the same principle of diagonal holes through the faying edge of adjacent planks, the triangular recesses and dowels are two distinctive fastening systems and should not be confused. While the latter are simply wooden pegs driven through oblique holes, the former indicate the presence of nails, whose head (either circular, rectangular or square) is inset in the triangular recesses. In addition, oblique dowels are driven from one side of the plank through the edge and into the opposite side of the adjacent plank, while nails housed in the recesses do not extend from the other surface.

Planks Wo98A and Wo98C are very similar, not only because they share the same curious technique, but also in terms of size; they may both be from the same vessel. Both measure 30mm in thickness and 200–215 mm in width. The presence of stitching holes in the lower edge of Wo98A indicates that its width is closer to the original; probably only a few centimetres shorter. Curiously, there is no evidence of triangular recesses in the lower edge of the plank, which raises the question as to why they are located only near one edge. A coating of a black substance approximately 5 mm thick, which has been identified as bitumen amalgam (Jacques Connan, personal communication, March 2019) covers the section between the stitching holes and the edge of the plank on both Wo98C and Wo98A. A similar substance was found inside one of the triangular recesses and was probably used to seal the hole. Traces of fibres still sticking to it reveal the presence of a wadding pad placed under the stitches and over the plank's seams.

3.4.2 Mortise-and-tenon Joinery

Timber BA1104065.453 displays a fastening system called mortise and tenon, consisting of a rectangular recess (mortise) cut into each edge of adjacent planks into which a wooden tongue (tenon) is fitted to form a joint (Figure 3.36). The plank measures 646 mm in length. Both width and thickness are consistent and measure 73 mm and 43 mm respectively. There are three mortises carved on the same edge of the plank while the opposite edge is flat with no evidence of fastenings. The two mortises are almost entirely preserved and are 45 mm wide and 40 mm deep, while one, located near a broken end of the plank, is only partially preserved, measuring 43 mm deep. The tenon that is still inside one of the mortises is 12 mm thick and broken at the edge of the plank. A wooden peg, 8 mm in diameter and driven perpendicularly to the width of the plank through the mortise and tenon, locks the latter in place.

The spacing between the mortises is not consistent and varies between 85 mm and 320 mm. A small recess carved on the edge of the plank has the same width as the mortises (12 mm) and is located between them at a distance of 87 mm and 220 mm.

The function of this recess is not clear but one possible interpretation could be that a carpenter started a mortise and then left it incomplete. There is a nail shank visible in the centre of the plank's wider side, probably resulting from reuse.

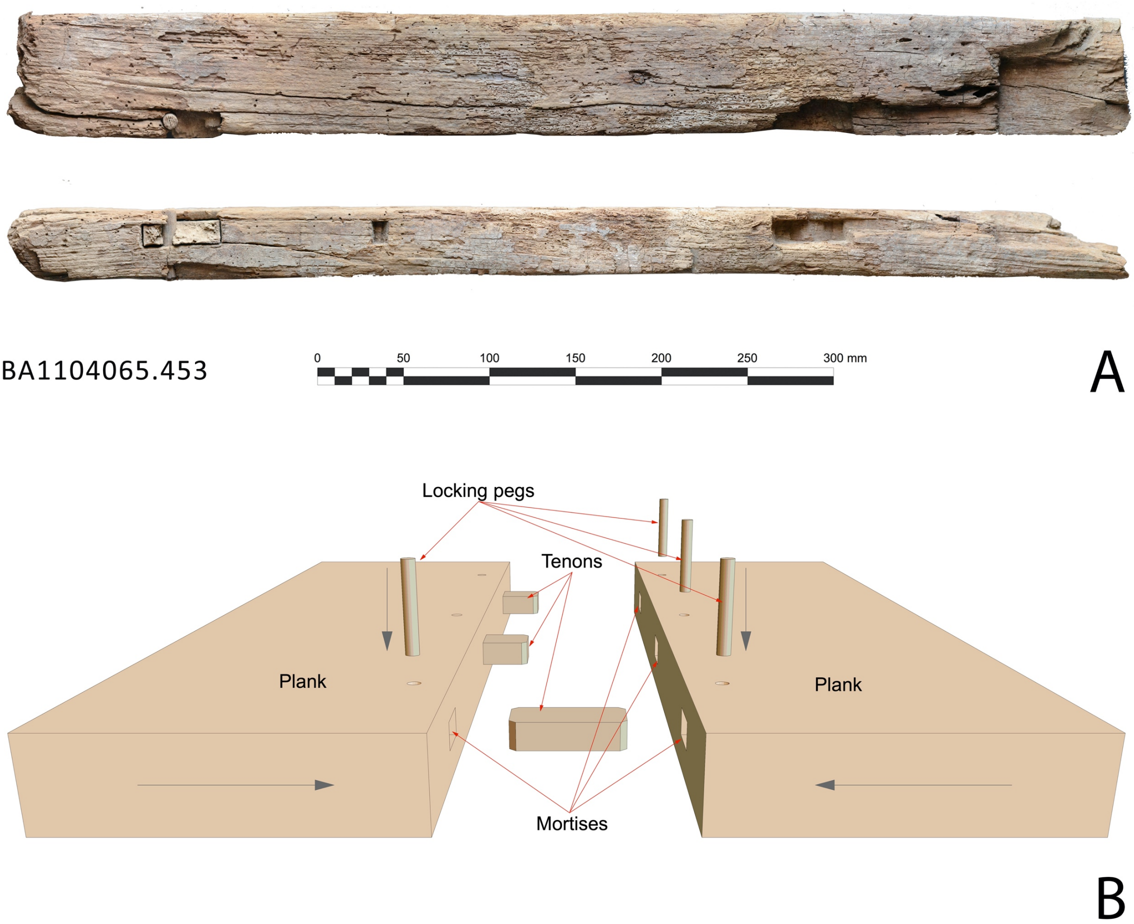


Figure 3.36: Timber BA1104065.453 displaying the mortise-and-tenon joining method (A), and graphical reconstruction of the mortise-and-tenon joinery (B). (Photos: Author).

3.5 Other Maritime Remains

3.5.1 Beams

3.5.1.1 Timber BA1104065.447

In 2011 a large beam (BA1104065.447) employed as a lintel over a small window (Figure 3.37) was discovered inset into one of the walls of the citadel of al-Balid. It measures 1.78 m in length and has a rectangular section measuring 125 x 160 mm. One end of the timber appears to be square cut, while the other is tapered and shows elaborate decorative carving. The timber has rebates on both its wider sides: two on the surface with the decoration and three on the one opposite. One rebate, located on the side of the decoration near the end of the timber, is 40 mm deep and 55 mm wide, forming an angle of 68˚ relative to the length of the timber. Two holes on each side of the rebate measure 10 mm in diameter and are drilled diagonally from the surface to each side of the beam, both at a 39˚ angle. Rope fibres resembling coir are still visible inside the holes, perhaps indicating that the beam was fastened to the hull with ropes

Figure 3.37: Timber BA1104065.447 showing rebates and notches suggesting interpretation as a through-beam. (Photo: Author).

through these holes. One transverse channel is located near the centre of the beam. Its angle with the beam is different from that of the other rebate and is almost square (88˚). Overlapping this channel, there is another rebate carved longitudinally to the beam length. There is another, almost square notch measuring 50 x 56 mm near the end with the decoration.

3.5.1.2 Timber Wo105

Two large timbers with a square section and several features on their surfaces were discovered during the excavation of the northern fortification system of the citadel in 2018 (Figure 3.38). The two fragments connect to form an almost entire beam, 3.031 m long, 135 mm sided and 90 mm moulded. One end of the beam is completely preserved, showing angled grooves carved across two opposite sides of the timber, as seen in BA1104065.447. A portion of the timber is missing on the other end of the beam, showing only a small section of the rebates. The rebates on each side and the ends of the beam have similar sided and moulded dimensions. They are 20 mm sided, between 12 mm and 16 mm moulded, and their angle relative to the length of the timber is also very similar, ranging between 76˚ and 80˚. The distance between these

Figure 3.38: Top, side and bottom views of beam Wo105. (Photo: Author).

rebates is 2.623 m. The preserved end of the timber is square (perpendicular to the beam's sides) and extends 306 mm beyond the rebate.

The beam also exhibits a series of notches (rebates) carved perpendicularly to its side along one of its edges. Two notches near the broken end of the beam are well preserved and spaced 240 mm apart. They are 53–62 mm long, 34–25 mm wide (sided face) and 40–45 mm deep (moulded face). There is a similar slot close to the angled rabbet at one extremity of the beam but since this end is damaged, only one side is visible, where the rebate measures 25 mm wide and 34 mm deep.

Other notches are visible near the other end of the beam, but they are only partially preserved. Their size is close to that of the other notches and their distance from the angled rebates appears similar, measuring 332 mm at the broken end and 375 mm at the opposite end. One notch is located approximately in the centre of the beam, 1469 mm and 1114 mm from either end.

There is a wide-angled rebate across the timber, near its preserved end, which is 117 mm long and between 20 mm and 34 mm moulded. A circular wooden peg in the centre of the rabbet, and cut flush with the beam's surface, reveals the presence of an 8-mm hole.

3.5.1.3 Beam from the Friday Mosque

A large timber interpreted as a ship's beam was found during the excavation of the Great Mosque at al-Balid (Costa 1979: 146, Plate 76a-c) (Figure 3.39). The timber has no identification number, and will be referred to as the Mosque beam. It shares similarities with BA1104065.447 and displays angled notches with a finely carved abstract design at one end (Belfioretti and Vosmer 2010: 115). Unfortunately, the author was not able to locate the beam in the storage room of the Land of Frankincense Museum in Salalah, where all the other timbers are currently housed, and the information provided here relies on a brief description and images provided by Costa, who directed excavations at al-Balid in 1977–81.

Figure 3.39: The beam discovered at the Mosque, al-Balid. (Photo from Costa 1979: pl. 76a-c)

3.5.2 Rigging Block Sheave

A flat, circular timber (Wo48) with a hole in its centre was discovered during the excavation of the citadel in 2016. The disc measures 280 x 320 mm wide and 45 mm thick, with the diameter of the central hole being 60 mm (Figure 3.40). Because of its shape and the presence of the hole, the timber can be easily identified as a sheave, which is the wheel of a pulley block over which a rope or chain is pulled to lift heavy objects. The disc rotates around a wooden pin inserted into a central hole, while the edge of a sheave is generally grooved to guide the running rope: that of Wo48 is smooth and flat with a bevelled section.

Figure 3.40: Large wooden disc Wo48, resembling a sheave. (Photo: Author).

3.5.3 Cleats

Three similar but crescent-shaped objects, Wo1, Wo40 and Wo122 discovered in the rooms of al-Balid's citadel might point to a previous use in a maritime context (Figure 3.41). They are all made of wood, of different sizes and resemble cleats (similar to pull handles). Although the artefacts could have been parts of wooden latches of doors and windows of the buildings on the site, they are also very similar in appearance to traditional boatbuilding elements of the western Indian Ocean.

Timber Wo1 is the smallest of the three objects. Although only partially preserved, its original size can easily be estimated because it is symmetric. Its estimated length is 123 mm, while its original thickness would have been 40 mm. The object has split along its longitudinal axis, exposing two holes in the section, which are driven at the two extremities of the handle perpendicular to its thickness through its base. The holes are hollow and there is no evidence of what was inset into them, but the absence of metal traces or an orange/reddish colour indicating oxidation, excludes the presence of nails. The handle was probably fastened to a wooden element, perhaps a plank or board with wooden pegs. The slot (opening) of the handle is rectangular and measures 35 x 25 mm, displaying sharp edges and indicating that a timber of similar shape and size was locked into it.

Wo40 and Wo 122 are similar in terms of shape and size, and even wood colour. They are more than twice the size of Wo1, measuring 290 mm long and 45 mm thick. Two nails, 12 mm in diameter, were used to fasten the handle and are still in situ on Wo122 while, although not present in Wo40, traces of oxidation reveal that nails were also employed to attach Wo40 to a wooden element. The slot of the two handles measures 106 x 45 mm and, in contrast to that of Wo1, the handle bars are rounded. The two objects have not been radiocarbon dated but the ceramic typology in the archaeological context of the discovery suggests dates of approximately the 14th–15th centuries for Wo40 and the 16th–17th centuries for Wo122 (Alexia Pavan, personal communication, October 2019).

Figure 3.41: Wooden handles Wo1, Wo40 and Wo122, resembling cleats (*zand*). (Photo: Author).

3.5.4 Stone Object

A small stone artefact (Wo81), recently discovered in the court of the citadel, can be interpreted as a tool used in a maritime context, such as a sounding led or a plumb bob (Figure 3.42). The object is pear-shaped with its width larger than its thickness. It measures 85 mm in height, 59 mm at its fullest part and is 46 mm thick with an overall weight of 640 g. A 7-mm-round hole, located along the longitudinal axis of the object, pierces it through its width, where it narrows. Between the hole and its closest edge, there is the evidence of a groove or a shallow channel, suggesting that the tool was tied to a rope and probably used hanging from it. The groove was either carved into the stone to facilitate the lashing of the rope or string, or perhaps resulted from the rope chafing on the rock due to continued use. The artefact is made of a hard, heavy, glittering dark stone with silver-grey shades resembling haematite (also called hematite), which is the primary ore of iron.

Figure 3.42: Wo81 with a perforating its smaller end. (Photo: Author)

3.6 Decoration

Thirteen timbers exhibit either painted or carved decorations on their surfaces and edges with BA0704156.1477 and BA1104065.450 having geometrical motifs on one side (Vosmer 2019). BA0704156.1477 displays a series of rectangles and triangles cut slightly obliquely to the wood grain along the surface of the plank (Figure 3.43). The rectangles measure approximately 55 x 14 mm and are arranged in a zigzag pattern with two series of diagonal lines incised in bands and again arranged in a zigzag pattern to form a series of triangles on either side. The decorative motifs are shallow and crudely made, and meet the edge of the plank at an angle, indicating that the decoration extended to the adjacent plank (Vosmer 2019: 311).

Similar to those exhibited on timber BA0704156.1477, the decorative motifs of BA1104065.450 are also aligned obliquely across the length of the plank (Figure 3.44).

Figure 3.43: Plank BA0704156 showing decoration carved on its outer surface (top) and a high-contrast image obtained with Agisoft Photoscan displaying the motif pattern (below). (Photos: Author)

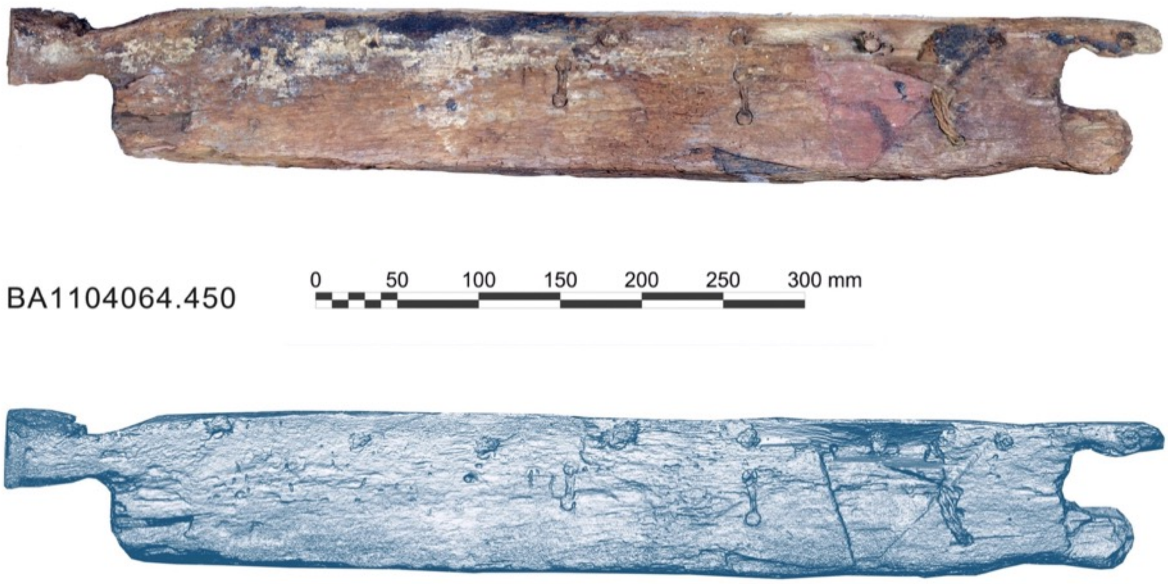


Figure 3.44: Black and red triangles carved diagonally on the outer surface of BA1104065.450 (top) and a high-contrast image of the timber showing the decorative pattern in detail (below). (Photos: Author)

They consist of series of triangles, with sides of approximately 80 mm, arranged diagonally across the length of the plank. These motifs are carved into the surface of the plank and are alternately painted with red and black pigments. They are visible on one end of the plank but the evidence of a vertex (corner) painted in black and preserved on the other extremity reveals the presence of a similar pattern carved on both ends. The ends of two large beams from al-Balid, seen in section 3.4.1 of this chapter, also feature elaborate carved incisions and decorations (Figure 3.37 and Figure 3.39).

Nine planks bear traces of paint on their surfaces and edges and all, except one, are covered with a dark grey pigment on their former inner side. The surfaces of timbers Wo56, Wo60 and Wo73, which connect to form a large plank, are decorated with Arabic text in light grey over a dark grey background (Figure 3.45). The paint has faded away in several areas of the planks with only light traces of the Arabic characters impressed on its surface, thus making translation impossible. The outer surface of the

Figure 3.45: Arabic text painted on the inside of planks Wo56-Wo60-Wo73 (top), and detail of the red motif on the outer surface (below). (Photos: Author)

plank exhibits a small arabesque ornament consisting of thin red lines resembling a flower, or perhaps a stylised animal such as a bird or turtle. Decorations are also found on timbers Wo71 and Wo72, fragments of the same plank. These consist of a pattern of repeated geometric forms painted in red, white and black on one edge of the planks (Figure 3.46).

Figure 3.46: The pattern of geometric forms on the edge of Wo72 (top), and its magnification (below). (Photos: Author)

3.7 Tool Marks

Some of the timbers from al-Balid (47%) show the marks of tools employed to shape them on their surfaces or edges. The study of these impressions provides information regarding the tools and woodworking techniques used for shaping and they offer an interesting insight regarding the boatbuilding economy.

The most obvious tool indicated by the timbers' features is the bow drill, which was used to bore holes on the surface of the planks and channels for the dowels through their edges. As previously observed, holes have a wide range of diameters, from 6–20 mm, indicating the use of different drill bits.

Nine timbers display irregular facets of different size and depth, generally located on their surfaces, indicating the use of an adze. The marks are arranged transversally to the length of the artefact and are visible on their former outer side on six of them. In most of the cases, the edges of the marks are faded, making it difficult to determine their size. One of the sides of the beam BA1104065.477 exhibits several impressions ranging from 50–100 mm in width (Figure 3.47). Similar evidence is found on Wo54, the end of which was tapered down to 62 mm wide and shows adze marks. A similar tool was most likely used to cut a diagonal notch in the edge of Wo64, as indicated by several small irregular indents (steps) on the surface.

Figure 3.47: Tool marks on BA1104065.447. (Photo: Author)

A series of thin parallel lines, pointing to the use of a saw, appear on six timbers of the dataset. They are spaced closely apart (1–2 mm) and arranged transversally to the length of the planks. In the majority of the samples (four out of the six), the impressions are located in the former inner side. In one case, these marks are also visible across the edge of connecting timbers Wo71–72, indicating that it was cut with a saw (Figure 3.48). Plank Wo54 has been partially sawn through its edge, perhaps in an attempt to split the plank, leaving a mark measuring 3 mm wide. One noteworthy aspect emerging from the observation of the growth rings in the edge of the al-Balid planks is that they were all cut parallel along the trunk in a method called plain sawn.

The presence of rebates in the planks, between the stitching holes and their edge, implies the use of chisels; the small size of the rebates is likely to exclude the use adzes or saws to shape them as the large dimension of these tools would make them impractical for carving such deep and narrow recesses. The same applies to the V-shaped notches found along the edge of planks Wo98A and Wo98C, which are fitted in the recess of the gate wall of the citadel of al-Balid. Sharp cuts are still visible near the edges in some of the rebates, left by the chisels used to carve them. These incisions are also visible on the surface of five timbers. The side of beam BA1104065.477, which displays rebates and notches, shows evidence of these marks ranging between 22 mm and 50 mm in width. Chisels of various sizes were most

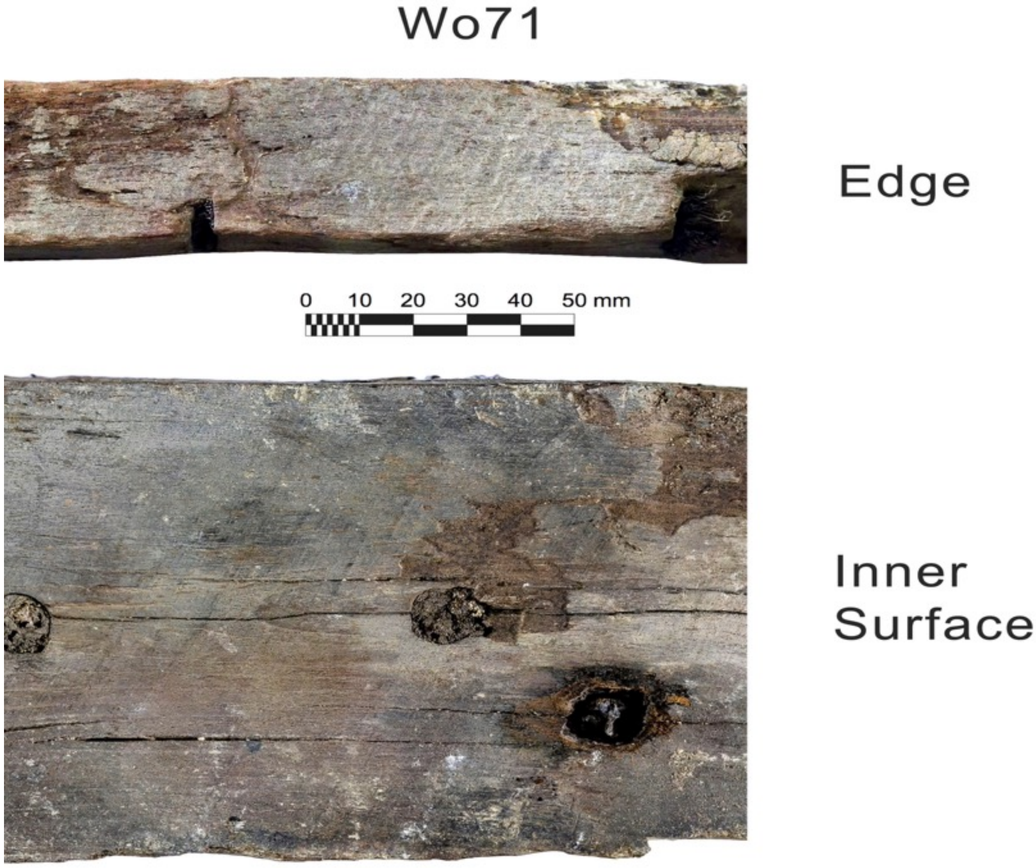


Figure 3.48: Saw marks visible on the edge and inner surface of timber Wo71. (Photos: Author)

probably used to cut these recesses into the side of the timber, as well as the decoration carved on the former outer surface of BA0704156.1477 and BA1104065.450. The width and length of their decorative motifs ranges between 14 mm, 27 mm and 50 mm.

The broken end of timber BA0604172.69 exposed the section of a hole and a rebate of a frame lashing, showing that the edges of the hole had been intentionally rounded. This suggests the use of a file or rasp to ease the angle of the stitching cord in order to prevent the risk of breaking a rope over the sharp edge (Figure 3.49).

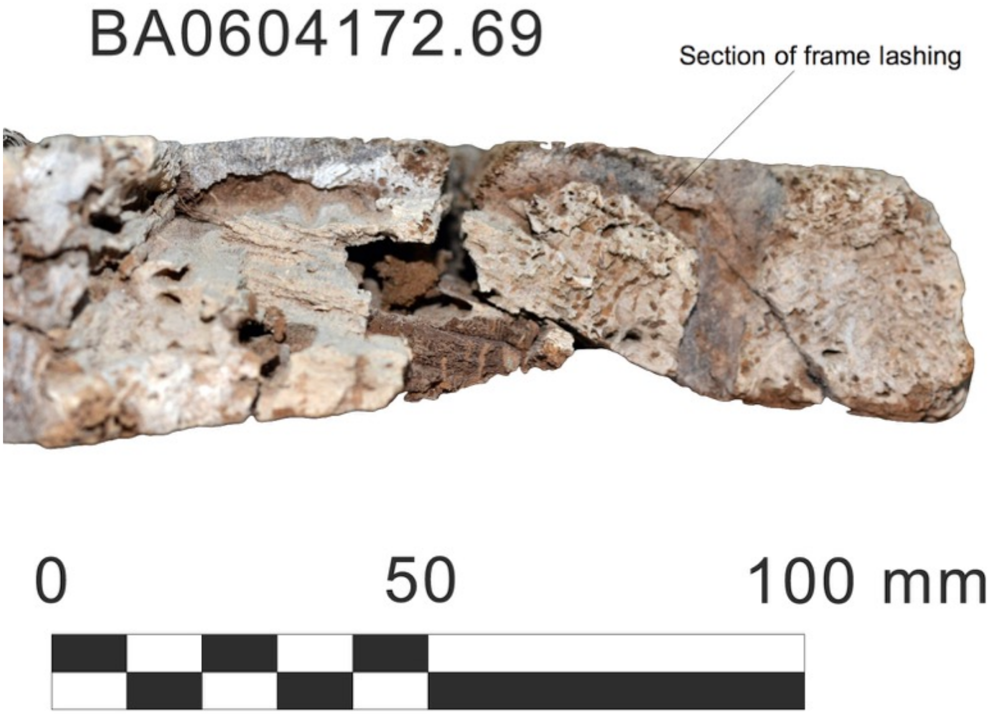


Figure 3.49: Exposed section of a frame lashing on timber BA0604172.69 showing that the sharp edge of the hole and rebate was smoothed. (Photo: Author)

3.8 Recycling and Modification

Not all the features displayed on the timbers from al-Balid are related to their maritime use. As previously noted, some of these ship remains have probably been reused multiple times and some of the characteristics visible on their surfaces are the result of their being recycled in a new terrestrial context.

These features could have been caused naturally, such as the collapse of buildings on the archaeological site. Fractured edges and ends of wooden artefacts could also indicate that the timber was damaged as a result of being buried for centuries under the ruins of the site. The people of al-Balid could also have damaged some of the timbers when they removed them from the hulls of vessels that were either repaired or broken down at the site.

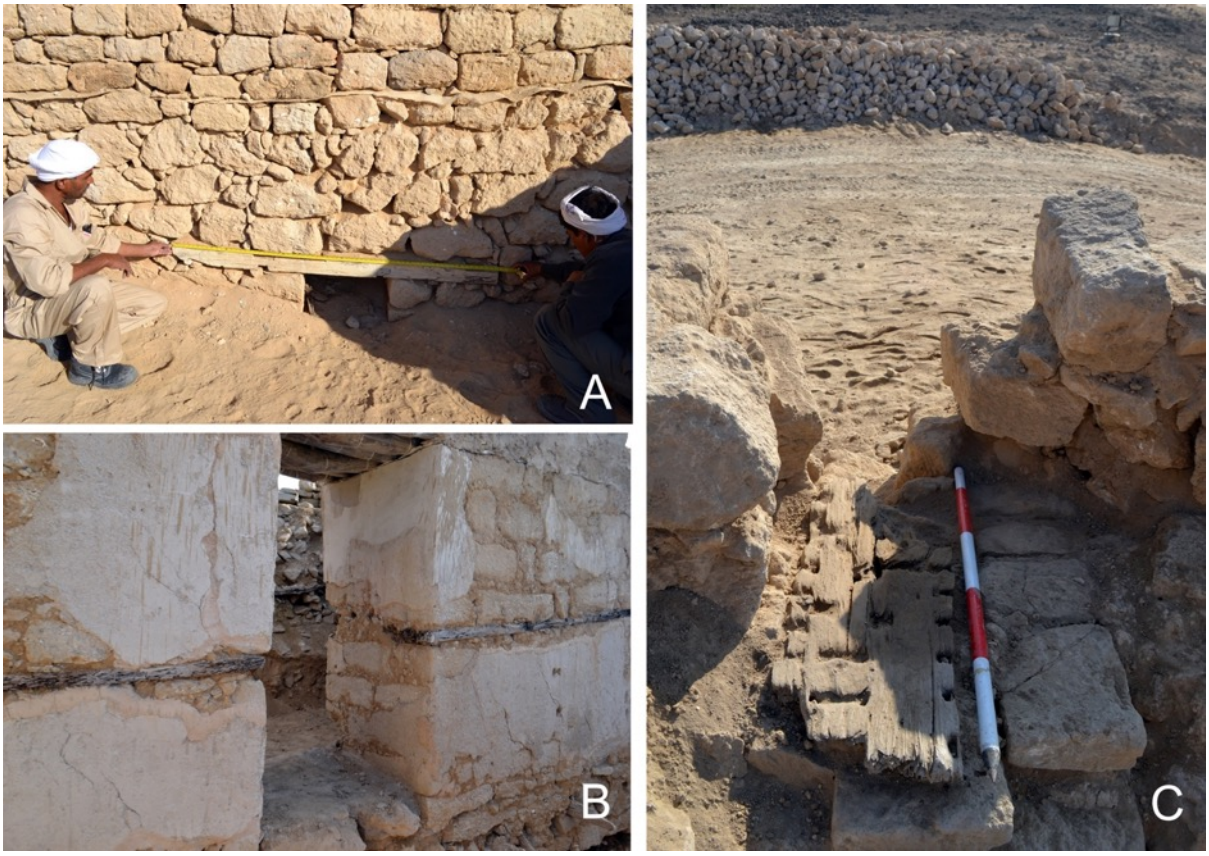


Figure 3.50: Beam BA1104065.447 used as a lintel over a small window (A). Ship planks used as a levelling course in the walls of the al-Balid citadel (B and C). (Photos: Author)

Variations in size, width and thickness within the same plank, on the other hand, hint instead towards an intentional modification by the builders al-Balid. Sharp and straight cuts at the edges and ends of the timbers suggest that carpenters reduced their length and width to make them fit for their new purpose.

These ship remains have been generally recycled in the buildings of al-Balid for different purposes. Layers of planks are found placed horizontally within the walls of the site (Figure 3.50(B-C)) to level uneven rows of stones after a certain height and help distribute their weight more equally along a wider surface (Borgese et al. 2019: 6-10).

Evidence from BA1104065.447 indicates that the people of al-Balid recycled large timbers, such as ship beam BA1104065.447, as lintels (Figure 3.50(A)). In a few cases, they attempted to reduce the thickness of the planks, as indicated by the tool marks on planks Wo71-Wo72, Wo56-60-73 and Wo54. Evidence from these examples points to the use of an adze to dub their outer surfaces, and the tool marks could also suggest the practice of removing either coating or antifouling applied on the outside of the hull or damage from marine borers attacking the vessels, such as barnacles, gribbles (*Limnoria* sp.) and Teredo worms (*Teredo navalis*).

Seven planks show evidence of nails, either partially preserved or indicated by the presence of oxidation around some of the holes (Figure 3.51). Only their shanks are retained on the timbers and they appear to be driven randomly on their surfaces and, in a few cases, on their edges. Their arrangement and location seem to indicate that they were added at a later stage.

These nails are too few and too small to be part of the fastening system of a vessel. The largest number of nails recorded in a plank from al-Balid is four, displayed on timber Wo71-72, while their shanks are relatively small, measuring 2–3 mm in

Figure 3.51: Traces of oxidation on the inner surface of plank Wo82, revealing the presence of nails. (Photo: Author).

diameter. They are located on both the surface and edge of the planks, and often not piercing the thickness of the plank completely. In the case of BA0704156.1477, the nail driven into its edge resulted in a crack, which almost split the plank. Therefore, nails were certainly used by the builders to fasten timbers while making furniture or architectonic elements such as ceiling planks, frames and beams.

3.9 Materials

3.9.1 Wood

It is relatively easy to identify some similarities and differences in the wood used in the al-Balid timbers with the naked eye. The colour of the wood in the planks varies from light grey to dark brown, suggesting different species. Meanwhile, wood grain visible on the surfaces and sections of planks ranges from straight and regular, in the case of plank Wo68, to undulating and highly interlocked in BA.01.11.01 and Wo54, providing information about the variety of timber used in boatbuilding in the Indian Ocean during the medieval period.

Jugo Ilic (Commonwealth Scientific and Industrial Research Organization [CSIRO], and Know Your Wood) (Belfioretti and Vosmer 2010: 112) and the Laboratory of Analysis of the Superintendence for Archaeological Heritage of Tuscany, Italy (Capretti et al. 2010) carried out analyses on the first selection of timbers discovered in al-Balid during excavations between 2005 and 2010 (Table 3.3). Thirteen samples were extracted from the surface of seven planks, as well as a wooden peg preserved in one of the sewing holes of plank BA0704156.1477, which is decorated with geometrical motifs carved on its outer face. The microscopic features of these samples indicate a variety of wood used in the construction of sewn watercraft that visited the site during this period. However, in several cases, due to degradation of the timber, species could not be determined and only the family and genus were identified.

Four timbers (BA0604145.175; BA0604148.70; BA0604159.263; BA0604172.69) were analysed by both laboratories. Of these, both identified BA0604145.175 and BA0604148.70 as teak (*Tectona grandis*). The anatomical features of BA0604159.263 provided information on the family and subfamily of the species only, respectively *Leguminosae caesalpiniaceae* and *Caesalpineae sensu lato*. Similarly, analysis could not provide the species for BA0604172.69, which belongs to the same family. However, it was possible to recognise the genus *Terminalia*, and since BA0604172.69 and BA0604159.263 are connecting fragments of the same plank, it can be inferred that the genus *Terminalia* can be applied to both timbers. Interestingly, timber BA0604129.176, identified as palm wood (*Palmae* sp.) by Capretti et al., connects with BA0604159.263, indicating that they are fragments of the same plank.

Two samples from BA0704156.1477 were analysed by the Italian Laboratory of Analysis of the Superintendence for Archaeological Heritage of Tuscany, one taken from the plank's surface and the other from a plug inside a stitching hole. The former belongs to the *Leguminosae caesalpiniaceae* family, while the latter is palm wood. Plank BA060418.99, which the author was not able to locate in the store room of the museum at al-Balid, was identified as *Ziziphus mauritania* (jujube). The wood structure of one sample from BA0604128.73 shared similarities with a timber native to Brazil (*Estribeiro* sp.) (Belfioretti and Vosmer 2010: 112) but the plank was too degraded to allow a definitive result and, since it was dated to the 15th century, the presence of a South American timber in the Indian Ocean before Portuguese expansion is very unlikely. Gale and Veen, who examined the sewn-boat timbers from Quseir al-Qadim, remind us that species identification analysis may provide results that are often incomplete and misleading and, therefore, should be taken with caution (Gale and der Veen 2011: 221).

Twenty-one samples of wood, mostly from new remains discovered in al Balid between 2016–18, were selected and sent by the author for species identification in 2018[22] (Table 3.3) (Cartwright 2019). Of these samples, seventeen were extracted from planks, two from dowels, two from hole plugs and one from beam BA1104065.477. Samples were taken with a scalpel and, in a few cases, a saw, from areas of the timbers showing a good state of preservation to obtain a clear view of all sections of the samples. Identification analyses were carried out by Dr Caroline Cartwright, Senior Scientific and Wood Anatomist, Department of Scientific Research, British Museum. The samples were manually cut to expose transverse, radial longitudinal and tangential longitudinal sections and examined with a scanning electron microscope (SEM) (Cartwright 2015, 2019). The images obtained were then compared with a collection of specimens and thin sections from the Arabian Peninsula, and specifically from Oman. Identifications were made according to the protocols specified by the International Association of Wood Anatomists (Wheeler et al. 1989; Wheeler 2011).

Teak is predominant, identified in eight planks and in a plug from plank Wo70. Tamarisks (*Tamarix* sp.) was identified on planks BA1104065.449, Wo85 and Wo63.

[22] Analyses were kindly supported by the Institute of Arab and Islamic Studies of the University of Exeter, the Small Research Grant of the International Association for the Study of Arabia (the former British Foundation of the Studies of Arabia) and the Ṣadaqa Jāriya Grant of the Barakat Trust.

	Timber	Type	Identification	Laboratory	Comments
1	BA0604145.175	Plank	*Tectona grandis (teak)*	CSIRO and TSAHAL	
2	BA0604148.70	Plank	*Tectona grandis (teak)*	CSIRO and TSAHAL	
3	Wo98B	Plank	*Tectona grandis (teak)*	CCBM	
4	Wo70	Hole Plug	*Tectona grandis (teak)*	CCBM	
5	Wo56-60-73	Plank	*Tectona grandis (teak)*	CCBM	
6	Wo98A	Plank	*Tectona grandis (teak)*	CCBM	
7	Wo98C	Plank	*Tectona grandis (teak)*	CCBM	
8	Wo54	Plank	*Tectona grandis (teak)*	CCBM	
9	Wo86	Plank	*Tectona grandis (teak)*	CCBM	
10	Wo94	Plank	*Tectona grandis (teak)*	CCBM	
11	BA.01.11.01	Plank	*Tectona grandis (teak)*	CCBM	
12	BA1104065.449	Plank	*Tamarix* sp. *(tamarisk)*	CSIRO	
13	Wo85	Plank	*Tamarix* sp. *(tamarisk)*	CCBM	
14	Wo63	Plank	*Tamarix* sp. *(tamarisk)*	CCBM	
15	BA1104065.447	Beam	*Acacia* sp. *(acacia)*	CCBM	
16	Wo68	Plank	*Acacia* sp. *(acacia)*	CCBM	
17	823.B-3.98.1235	Plank	*Celtis africana (hackberry)*	CCBM	
18	Wo82	Plank	*Celtis africana (hackberry)*	CCBM	
19	BA1104065.450	Plank	*Ziziphus spina-christi*	CCBM	
20	BA1104065.454	Plank	*Ziziphus spina-christi*	CCBM	
21	Wo98A	Dowel	*Avicennia marina (mangrove)*	CCBM	
22	BA0609128.73	Dowel	*Avicennia marina (mangrove)*	CCBM	
23	BA0604172.69	Plank	*Terminalia* sp.	CSIRO	The timber connects with BA0604159.263 and BA0604129.176
24	BA0604159.263	Plank	*Leguminosae caesalpiniaceae*	CSIRO and TSAHAL	The timber connects with BA0604159.69 and BA0604129.176
26	BA0704156.1477	Plank	*Leguminosae caesalpinaceae*	TSAHAL	
25	BA0604129.176	Plank	*Palmae*	TSAHAL	The timber connects with BA0604159.263 and BA0604129.69
27	BA0704156.1477	Hole Plug	*Palmae*	TSAHAL	
28	Wo72	Plank	*Albizia lebbeck (lebbeck tree)*	CCBM	
29	Wo45	Hole Plug	*Ficus* sp.	CCBM	
30	BA060418.99	Plank	*Ziziphus mauritiania (jujube)*	TSAHAL	
31	BA0604128.74	Plank	*Indeterminate*	CSIRO	
32	BA0604128.73	Plank	*Indeterminate*	CSIRO	Sample degraded; Possible species include *Tiliaceae* sp., *Sterculiaceae* sp., or even *Tamarix* sp.

CSIRO: Commonwealth Scientific and Industrial Organisation, and Know Your Wood;
TSAHAL: Tuscan Superintendence for Archaeological Heritage, Analysis Laboratory;
CCBM: Dr. Caroline R. Cartwright, Senior Scientist and Anatomist. Department of Scientific Research, British Museum

Table 3.3: Table showing the wooden species identified for the timbers of al-Balid.

Two planks, 823.B-3.98.1235 and Wo82, are made from hackberry wood (*Celtis africana*), while *Ziziphus spina-christi* was identified in timbers BA1104065.450 and BA1104065.454. *Acacia* sp. was the wood used for plank Wo68 and for the large beam

(BA1104065.447) discovered in the citadel and recycled as a lintel. Two dowels taken from timbers Wo98A and BA0609128.73 were shaped from mangrove (*Avicennia marina*). Plank Wo72, as well as Wo71, since the two timbers connect, are made from the wood of the lebbeck tree (*Albizia lebbeck*) and one of the sewing hole plugs of Wo45 has been identified as *Ficus* sp. The results of the botanical analysis confirmed the variety of wood species of different characteristics and distribution already indicated by the previous laboratories (Figure 3.52 and Figure 3.53).

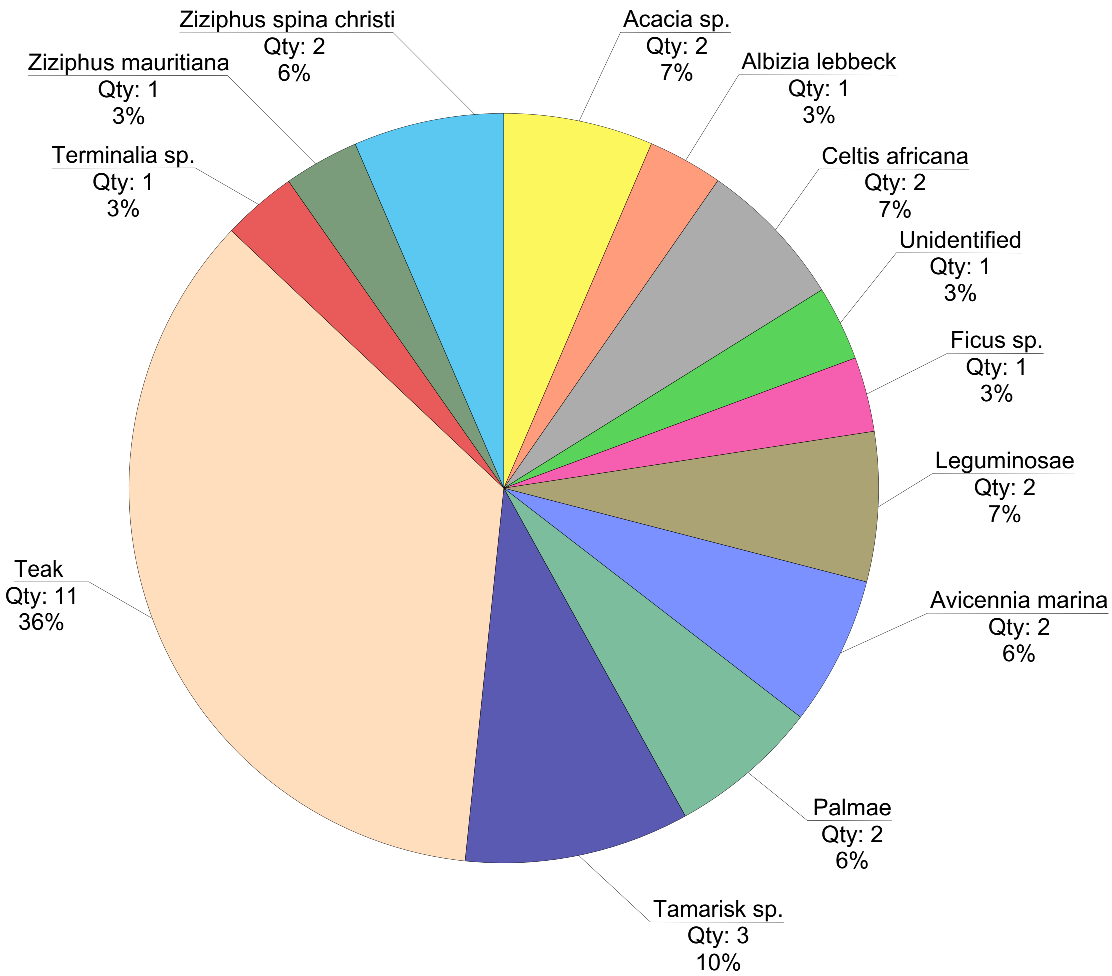


Figure 3.52: Frequency of species identified in the al-Balid timbers. (Chart: Author)

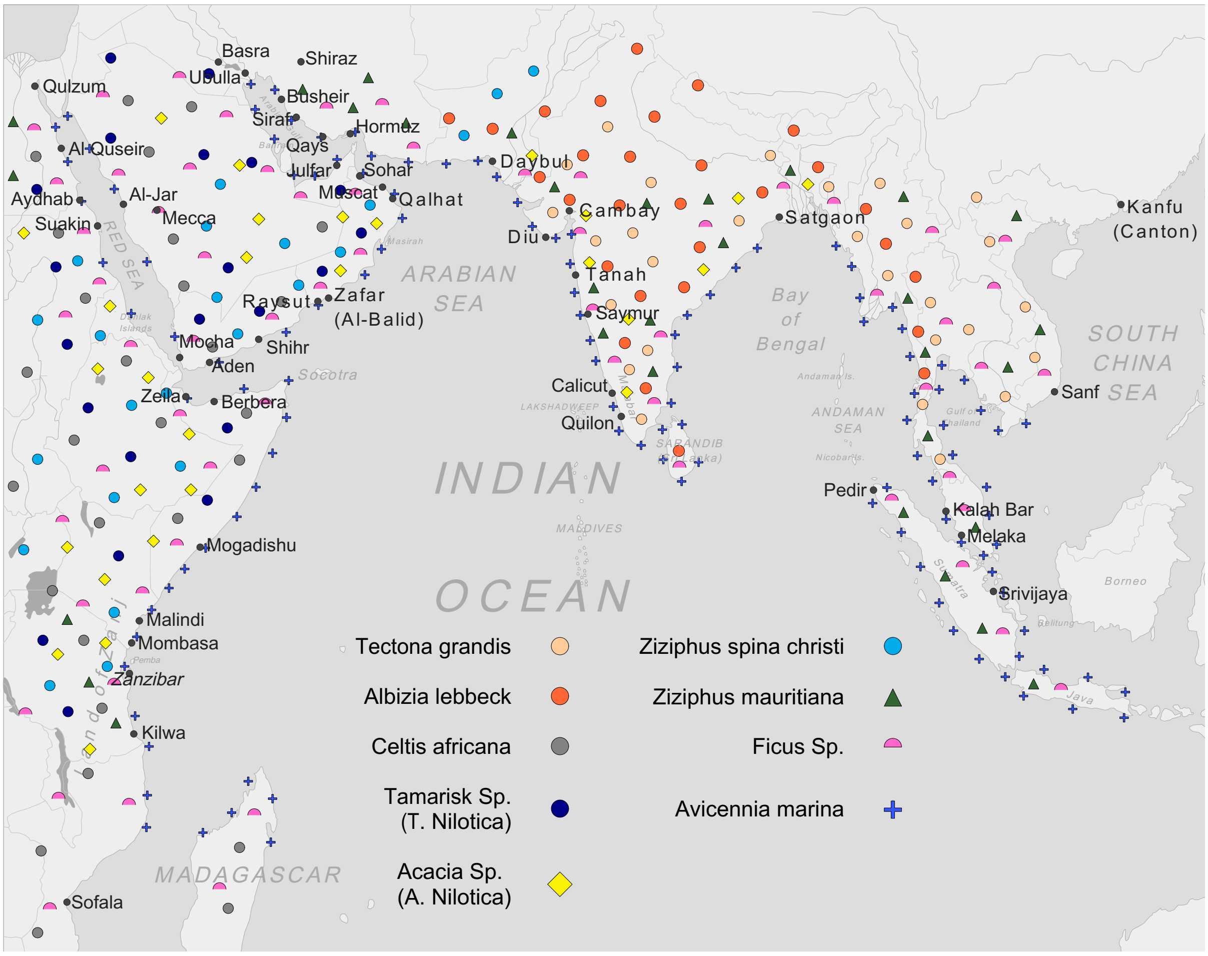


Figure 3.53: The distribution of the al-Balid timber's species (image: Author).

3.9.1.1 Distribution of Wood Species

3.9.1.2 Teak

Tectona grandis (teak) is a tree native to the tropical monsoon areas of Asia, including India, Burma, Laos, Vietnam and Thailand. The tree is tall and straight, and can reach 40 m in height (POWO 2019h). The characteristics of its wood make it one of the highest quality boatbuilding timbers in the world. It was used in Arabia, the Gulf and, more generally, in the western Indian Ocean for millennia to build watercraft, and was the predominant wood used for planking in traditional boatyards of these regions until recently (Mookerji 1912: 246; Moreland 1939: 145; Villiers 1948: 399; Hourani 1963: 90; Lewis 1973: 250). The wood grain is tight, straight and regular, making it easy to work, and because of its high oil content, it is resistant to both terrestrial and marine wood borers, and is particularly suited for hull planking. Teak from the Western Ghats region in Kerala and Karnataka, southern India, is preferred for structural purposes, such as shipbuilding and construction (Katwal 2005: 3).

3.9.1.3 Tamarix sp.

Tamarix sp. comprises numerous native species distributed in a broad geographical area stretching from West Africa to Japan (POWO 2019g). The wood is not particularly strong, has a tendency to split and is vulnerable to attack by insects but it is adaptable to different environments and climatic conditions. Some species are indigenous to Arabia and easily grow in hot, dry regions (Ghazanfar and Fisher 1998). Of the species native of Arabia, *Tamarix nilotica* is most likely to have been used in the al-Balid timbers, and its distribution includes northeastern and eastern Africa (Cartwright 2019: 19).

3.9.1.4 Celtis africana

Hackberry's (*Celtis africana*) habitat comprises a wide range of ecological conditions, from tropical and southern Africa to Somalia and Yemen (Cartwright 2019: 18). Depending on the environment, the plant's size can range from a shrub to a tree up to 40 m tall. *Celtis africana* produces a decent quality wood with a variety of uses, but is vulnerable to fungus and both terrestrial and marine borers. The grain of the wood is usually straight, sometimes interlocked, and is easy to work with hand tools. It has good bending quality but has a tendency to split (Nyemb 2019).

3.9.1.5 Ziziphus spina-christi

Ziziphus spina-christi is a plant ranging from shrubs to 10-metre trees. The wood is dense, hard and heavy, with a closed grain and a deep dark colour (POWO 2019c). The native distribution of this plant stretches from Mauritania to Pakistan, including East Africa and Arabia (Cartwright 2019: 19). *Ziziphus spina-christi* can withstand extremely arid climate conditions and is resistant to insects. It is widespread in Oman, commonly found in wadis and locally called *sidr* (Miller et al. 1988: 242). The timber has the tendency to crack and split, and is generally knotted and twisted, making it a poor choice for planking. Because of its hardness and naturally crooked branches, *sidr* was one of the timbers used for making frames in boatbuilding in the Gulf and Arabia (Al-Hijji 2001: 41; Staples 2018)

3.9.1.6 Acacia sp.

The genus *Acacia* sp. comprises several species with a wide geographical distribution. Acacia can grow as either a shrub or a tree in different environments. Its shrub form is found in arid environments, in semi-desert conditions, and produces very dense, heavy and durable wood, but is rarely straight, long or wide. In its tree form it generally grows on river banks and can be used to produce wide planks (Cartwright 2019: 19-20). Various species of acacia occur in Arabia and East Africa, and *Acacia nilotica* is one of the candidates for the timbers from al-Balid. *Acacia* is one of the most widespread species, being native to regions stretching from South Africa to Iraq and India. The tree can grow up to 5 m, producing strong, durable wood, which is not susceptible to splitting or cracking and is particularly resistant to insects. In Dhofar, southern Oman, *Acacia nilotica* is generally found on the coastal plain and used for multiple purposes (Miller et al. 1988: 178-179).

3.9.1.7 Leguminosae Caesalpinieae

*Caesalpiniea*e *sensu lato* is a subfamily of the *Leguminosae Caesalpinacea* family, and comprises forty-nine genera including a wide variety of plants ranging from shrubs to trees, commonly showing prickles and thorns. The microscopic analysis could not identify the species. While the vast part of the genera are native to South America, some are from Africa, particularly Madagascar (Capretti et al. 2010: 3).

3.9.1.8 Avicennia marina

Avicennia marina (white/dwarf mangrove) is found scattered along the whole Indian Ocean littoral, including the Red Sea and the Gulf (POWO 2019b). This plant can withstand harsh environmental conditions and high salinity in water. It is particularly common throughout the Arabian Peninsula, where it grows in the intertidal zone, colonising bays, creeks and lagoons along the coast of Arabia (Ghazanfar 1999: 25). Either a shrub or a small tree, *Avicennia marina* can reach 10–15 m in height, with a trunk measuring up to 40–50 cm in diameter. Mangrove wood displays a fine and even grain, which makes it particularly hard and durable but often difficult to work (Alvarez Cruz 2019).

3.9.1.9 Ficus sp.

Ficus sp. (fig wood) is a genus comprising several hundreds of different species. Its habitat ranges from river banks and swamps to wadis (Deil and al Gifri 1998: 166). Although being easy to work, fig wood is not considered a high-quality timber because it is relatively weak and particularly vulnerable to insects and borers. There are various species of *Ficus* native to the Arabian Peninsula, Egypt, Sudan, Somalia and East Africa (POWO 2019e).

3.9.1.10 Albizia lebbeck

The native range of *Albizia lebbeck*, (lebbeck tree) is the Indomalayan ecozone, including Pakistan, India, Sri Lanka, Bangladesh and Myanmar (Semaan 2018: 508). Lebbeck trees grow in monsoon forests, mountain slopes and on river banks. The tree is generally 20 m tall with a trunk diameter of 50 cm, but it can sometimes reach 30 m in height and 1 m in diameter. The wood has heavily interlocked grain, and is moderately hard and durable but subject to attack by wood borers (*Woodworker Source* 2015).

3.9.1.11 Palmae

The *Palmae* (*Arecaceae*) family comprises 182 genera and over two thousand species, and is widespread to tropical and subtropical regions (POWO 2019a). Although analysis provided an identification for the plant family, there are several species that are likely to have been used in the al-Balid timbers: *Cocos nucifera* (coconut palm), *Phoenix dactilyfera* (date palm) and *Hyphaene thebaica* (*doum* palm). *Cocos nucifera* (coconut palm) is native to Southeast Asia but was introduced into various regions of the Indian Ocean in early times, including India and East Africa (POWO 2019d). It is used for multiple purposes, including basketry and rope making. Although not producing an ideal boatbuilding wood, historical sources mentioned coconut palm as one of the materials for boat construction in the Lakshadweep and Maldives (Hourani 1963: 89-91). *Phoenix dactylifera (*date palm) is one of the oldest cultivated plants in North Africa and on the Arabian Peninsula, and one of the most important. Its exact origin is unknown but it probably originated from Iraq or western India (Chao and Krueger 2007: 1077). It prefers dry and semi-arid environments and is extremely common on the Arabian Peninsula, where it is widely used for a variety of purposes, from basketry to rope making (Miller et al*.* 1988: 227). Date palms can reach 30 m in height and they have a large trunk measuring up to 40–60 cm in diameter. Although used for construction, the quality of palm “wood” is moderate because its structure consists of tiny tubes (vascular bundles) running longitudinally to the trunk. However, this vascular structure makes the stem of date palm particularly resistant to tensile force, making it suitable for pillars and beams (Thomas 2013: 1).

Hyphaene thebaica, doum palm*,* has a native distribution ranging from tropical West Africa to Egypt, Arabia and India. Although it prefers river banks and oases, *doum* palm can also grow in arid rocky environments such as wadis and on hillsides (El-Beltagi et al. 2018). *Hyphaene thebaica* can reach up to 17 m tall with a trunk diameter of 90 cm. Although the palm is known for the products made from its fibre and leaves, wood is also widely used for building (POWO 2019f).

3.9.1.12 Ziziphus mauritiana

Ziziphus mauritiana (jujube) is indigenous to southern Asia, particularly India, although it has been introduced to dry tropical regions, such as east and northeast Africa. The tree tolerates extremely dry environments and grows fast in arid regions, reaching 12 m in height (Capretti et al. 2010: 5). The wood of the jujube is strong, durable and smooth, and had a variety of uses, including shipbuilding (Outlaw et al. 2002: 199).

3.9.1.13 Terminalia sp.

The genus *Terminalia* comprises 287 accepted species, distributed in tropical and subtropical regions from south and central America to Africa, India and Southeast Asia (POWO 2019i). Various species of *Terminalia* occur in Arabia, and east and northeast Africa, and were used in boatbuilding (Semaan 2018: 508). *Terminalia catappa* (Indian almond) has a strong, durable wood, which is widely used in ship construction (Vosmer 2019). *Terminalia dhofarica* (also known as *Anogeissus dhofarica*) could also be the species of one of the al-Balid timbers. Endemic to Dhofar, southern Oman, it produces a wood resistant to insect attacks, and was used as a building material (Miller et al. 1988: 102, 309). *Terminalia brownii* is native to central and northeast Africa, and is the most common of the *Terminalia* species in Ethiopia, where it grows in a semi-arid environment. Its wood is medium hard, light and termite resistant, and commonly used in house construction (Bekele-Tesemma 2007: 492). Lastly, *Terminalia pruinoides* is a tall tree found in both coastal and inland environments in East Africa. The wood is hard and very durable, and was used to build boats in Tanzania because of its resistance to Teredo worms (*Teredo navalis*) (Weiss 1973: 185).

3.9.2 Bitumen

Traces of a dark substance are visible on thirteen planks (36%). Chemical analysis carried out by Dr Jacques Connan at the Laboratoire de Géochimie Bioorganique of the University Louis Pasteur-Strasbourg on samples extracted from the timbers identified the substance as bitumen (Table 3.4). Along with that extracted from the timbers, a specimen from a lump of bitumen (X-35) discovered in the citadel of al-Balid was also submitted for analysis. This small sample, measuring 60x100 mm, provided no hints that could help in revealing its purpose, such as impressions of wood or cordage (Figure 3.54). Perhaps the people of al-Balid stripped it from boats and stored it at the site where it could be reused.

Figure 3.54: Bitumen lump X-35 from al-Balid. (Photo: Author)

ID	Substance	Location	Origin	Comments
BA1104065.450	Bitumen amalgam	Outer surface between holes and edge	Iran	Connan, pers. comm. 3/01/2017
BA1104065.454	Bitumen amalgam	Edge and inner surface between holes and edge	Iraq?	Connan, pers. comm. 3/01/2017
BA0604128.74	Bitumen amalgam	Under the wadding	Luristan, southern Iran	Belfioretti and Vosmer 2010: 113
BA0604159.263 & BA0604172.69	Bitumen amalgam	Inner surface	Fars, Iran	Vosmer 2019: 311
Wo37	Bitumen amalgam	Outer surface, around sewing holes	Ain Gir, Dehluran, Iran	Connan, pers. comm. 2/04/2019
BA0604145.175	Bitumen amalgam	Inner surface between holes and edge	Ain Gir, Dehluran, Iran	Connan, pers. comm. 2/04/2019
BA0301-106	Bitumen amalgam	Outer surface, around sewing holes	Probably Iran	Connan, pers. comm. 7/03/2020
Wo73	Bitumen amalgam	Inner surface between holes and edge	Probably Iran	Connan, pers. comm. 7/03/2020
Wo98B	Bitumen amalgam	Edge and inner surface between holes and edge	Probably Iran	Connan, pers. comm. 7/03/2020
Wo98A	Bitumen amalgam	Inner surface between holes and edge	Probably Iran	Connan, pers. comm. 7/03/2020
Wo98D	Bitumen amalgam	Inner surface between holes and edge	Probably Iran	Connan, pers. comm. 7/03/2020
Wo52	Bitumen amalgam	Inside a broken dowel	Probably Iran	Connan, pers. comm. 7/03/2020
BA.01.11.01	Bitumen amalgam	Outer surface?	Probably Iran	Connan, pers. comm. 7/03/2020
X-35	Bitumen amalgam	Lump of bitumen	Probably Iran	Connan, pers. comm. 7/03/2020

Table 3.4: Al-Balid timbers with bitumen traces.

In eight timbers the bitumen layer is located on the former inner surface of the plank between the stitching holes and the edge. The best examples are BA1104065.454 and BA0604145.175, on which a large amount of the substance is preserved, ranging in thickness between 2 mm and 5 mm (Figure 3.55).

A thin, dark coat of the material is visible under the wadding in BA0604128.73 and BA0604128.74, which indicates that bitumen was used as a luting agent to seal the hull seams prior to sewing the planks. In one case, BA0604159.263 and

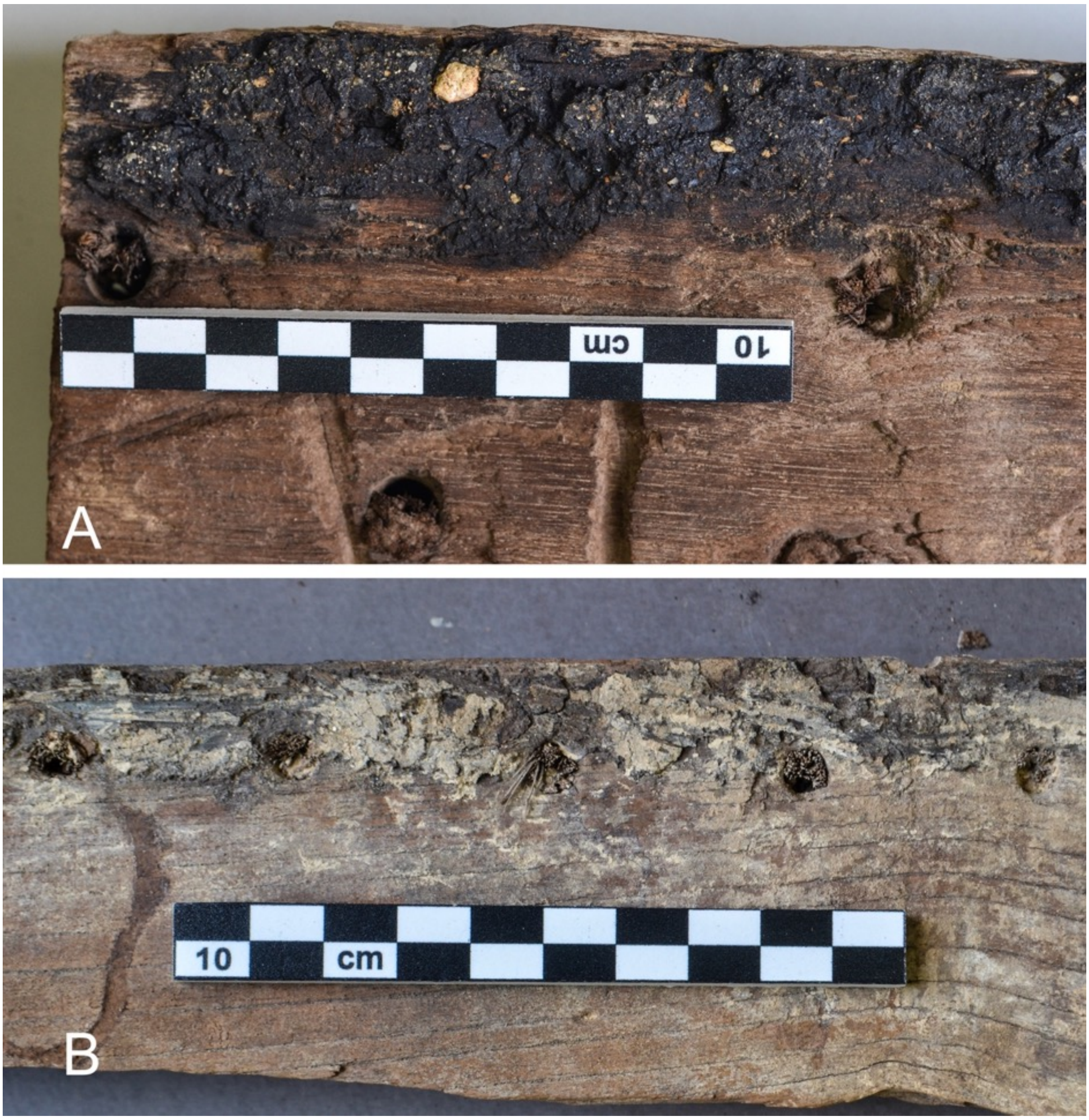


Figure 3.55: A thick layer of bitumen visible between the sewing holes and the edge of planks BA0604145.175 (A), and BA1104065.454 (B). (Photos: Author)

BA0604172.69, fragments of the same plank, a thick layer of this substance covers most of the former inner surface (Figure 3.56).

Four planks display traces of bitumen between the edges of the plank and the stitching holes, but on their outer surface. All but one (Wo37) have a flat surface with no rebates, and the presence of a sealing material, generally under the wadding, indicates that it was on the outside of the hull, reinforcing the hypothesis of a double-

Figure 3.56: Bitumen on the inner surface of timber BA0604172.69. (Photo: Author)

wadding sewn pattern for these planks. In the case of Wo37, traces of bitumen are located around the stitching holes and extend towards the centre of the plank. Evidence of the same material is also found on the faying edges of three planks.

Three samples from BA0604128.74 (Belfioretti and Vosmer 2010: 113), BA0604172.69 and BA1104065.450 (Jacques Connan and Tom Vosmer, personal communication, January 2016) display a chemical signature typical of Iranian bitumen sources. BA0604128.74 was likely to have originated from natural seeps in Luristan, in the south of the region, while BA0604172.69 appears to be from Fars (Vosmer 2019). The chemical composition of BA1104065.454 and Wo98C differs from the above-mentioned three samples, but it is necessary to refine the data to determine whether or not they are from Iranian sources. Overall, the chemical signature of the bitumen appears to indicate that it was supplied from Iranian seeps, but analyses are still in the preliminary stage and the data need to be refined.

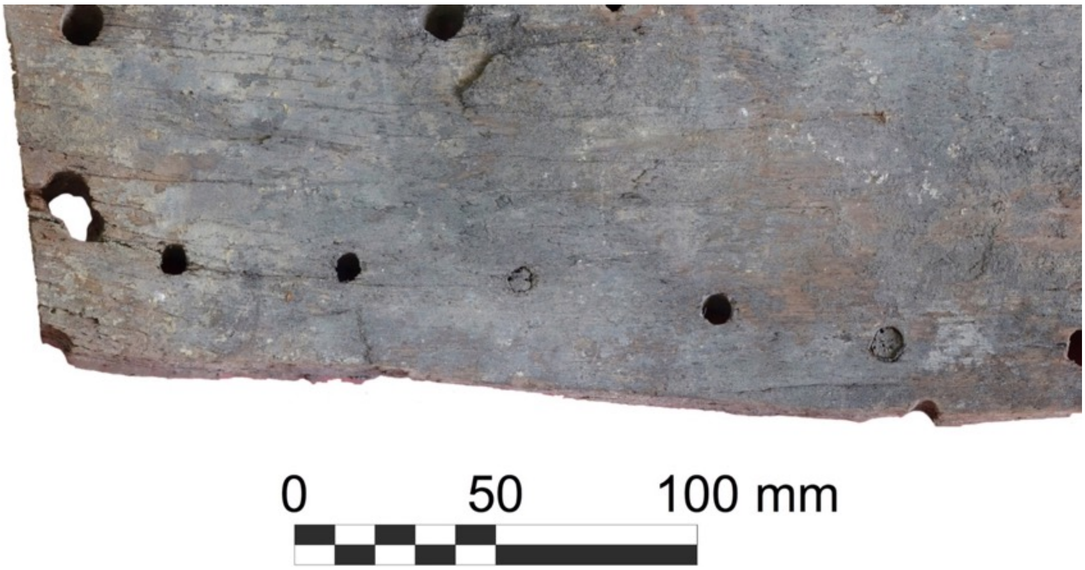


Figure 3.57: A thin coat of a light grey substance on the inner surface of timber Wo68. (Photo: Author)

The dark substance on BA0604145.175 contains various inclusions, such as sand grains, fragments of crushed stones and, perhaps, barnacles, shell or coral. Chemical and mineralogical analyses also showed that all the bitumen used to lute the planks of the vessels in al-Balid was impure and mixed with other constituents (Jacques Connan, personal communication, email 6/03/19).

While the dark substance is bitumen on thirteen timbers, that exhibited on Wo68 differs in colour and texture. The inner surface of the plank appears to be covered with a thin coating of a light grey colour (Figure 3.57). The substance is slightly lumpy but seems to be less thick and viscous than that displayed on the other timbers, bearing similarities to fish oil.

Timber Wo37 has preserved traces of a white material around the holes on its outer surface (Figure 3.58). This white coating has a sandy (limey) texture displaying cracks and has a thickness of 1–2 mm. The substance covers a thin layer of bitumen and resembles traditional lime-based antifouling (*shaham* in Arabic; *chunam* in Tamil) used for centuries to protect the hull of Indian Ocean watercraft against marine wood borers (Al-Masʿūdī 1861: 365; Hornell 1942: 12; Agius 2002: 173-174).

Figure 3.58: Timber Wo37 bearing traces of a white substance around the sewing holes on its outer surface. (Photo: Author)

3.9.3 Sewing Cordage

Cordage from five timbers has been visually identified as coir, which is the fibre from the outer husk of the coconut (*Cocos nucifera*) (Belfioretti and Vosmer 2010: 111). One sample of cordage extracted from plank Wo86 was sent for species identification and the result confirmed it was made of *Hyphaene thebaica*, commonly known as *doum* palm (Figure 3.59) (Cartwright 2019).

Figure 3.59: A doum palm from Khotib in the Farasan Islands, Saudi Arabia. (Photo courtesy of Chiara Zazzaro)

The ropes preserved on the other planks of the collection are made of a fibrous material, ranging in colour between light and dark brown, which could be either *doum* palm, coir or the fibre surrounding the stem of the date palm (*Phoenix dactylifera*). The texture of the latter two is practically identical, which makes it impossible to distinguish them by eye.

3.9.4 Wadding

As we have previously seen, the wadding preserved on planks BA0604128.73 and BA0604128.74 consisted of ropes running longitudinally along their seams (Figure 3.25). Apart from their size, these are almost identical to the stitching cords in terms of colour and texture, suggesting that they are likely made of coir or date-palm fibre.

One interesting aspect emerging from the timbers displaying a thick coating of bitumen is that it often bears impressions of vegetal materials (Figure 3.60). Four planks (BA0604145.175, BA0604159.263, BA0604172.69 and BA1104065.454) provide evidence of fibres, stripped leaves, straw or perhaps reeds and, in one case (BA0604159.263), rope imprinted in the bitumen. The evidence is a clear indication of

Figure 3.60: Bitumen coating on timber BA06004159.263 bearing impressions of grass/leaves, fibres and ropes. (Photo: Author)

the presence of a wadding roll between the stitching holes and the edge of the plank, providing information about the caulking material and the sewing patterns of the al-Balid ship remains.

3.10 Dating the Timbers

Samples from sixteen timbers have been radiocarbon dated with the aim of providing a context for the study of the remains from al-Balid. Ten samples were sent to the Beta Analytic Radiocarbon Dating Laboratory, Miami, Florida, during the preliminary study carried out on some of the timbers by Luca Belfioretti and Tom Vosmer. These comprised two timbers without rebates (BA1104065.449 and BA1104065.450), four with rebates (BA1104065.454, BA0604148.70, BA0604145.175 and BA0604172.69), two with preserved stitching (BA0704128.73 and BA0604128.74), one with decoration (BA0704156.1477) and one displaying triangular notches (Wo98C). The results showed an overall period ranging between the beginning of the 10th and the end of the 15th century (Table 3.5) (Belfioretti and Vosmer 2010; Vosmer 2017, 2019).

Five additional samples were sent to the same laboratory by the author, three in June 2017 and two in March 2019. These timbers were selected according to their significance and particular features displayed on their surfaces:

- Planks BA01.11.01 and 823.B3.98-1235, without rebates;
- Plank Wo54, exhibiting one edge with rebates and one without;
- Plank Wo98A, showing both nailed and sewn construction techniques;
- Plank Wo98B, part of four timbers used in the locking system of the southern gate of the citadel.

One of the aims of the date analyses was to verify a possible trend observed by Vosmer that the planks without rebates were the oldest of the dataset. The radiocarbon dating on the two timbers with a flat surface indicate a period ranging from the 11th to the early 13th centuries, confirming the date range of the previous results (Table 3.5).

The author has slightly revised a chart produced by Vosmer illustrating the date of ten timbers from al-Balid and the two sewn shipwrecks of Belitung and Phanom-Surin (2017: 199) in the light of new data emerging from both the additional radiocarbon analyses on five timbers and the study of the additional al-Balid timbers (Figure 3.61). Plank BA0604128.70, one of the oldest of the collection, was erroneously interpreted as being without rebates. Although very worn and rounded due to a bad state of conservation, grooves are, in fact, visible on one of the surfaces, between the holes and the plank's edge.

The revised chart reveals that nine planks (64%) show a date of between the early 10th and late 13th centuries (1010–1280) while the remaining seven show a period between the late 13th and late 15th centuries. Among the earliest planks of the collection discovered, those without rebates dated between 900 and 1220. Planks with channelled grooves are found throughout the period, ranging from the early 11th to the late 15th centuries (1030–1480). The radiocarbon dating on the timber associated with V-shaped notches and exhibiting evidence of nail fastenings (Wo98C) indicates a calibrated date of Cal AD 1320 to 1350 (Cal BP 630 to 600) and Cal AD 1390 to 1430 (Cal BP 560 to 520).

Beta Analytic No.	Sample ID	Service	Conventional Age (BP)	Calendar Calibration: 2 Sigma	Calendar Calibration: 1 Sigma	IRMS d13C
469879	**Wo54**	AMS	880 +/- 30 BP	Cal AD 1117 - 1222 (Cal BP 833 - 728) (68.4%) Cal AD 1042 - 1104 (Cal BP 908 - 846) (27%)	Cal AD 1154 - 1212 (53.8%) Cal AD 1055 - 1076 (14.4%)	-24.7
46878	**BA.01.11.01**	AMS	920 +/- 30 BP	Cal AD 1028 - 1184 (Cal BP 922 - 766) (95.4%)	Cal AD 1044 - 1098 (41.9%) Cal AD 1120 - 1157 (26.3%)	-25.9
469877	**823.B3.98-1235**	AMS	880 +/- 30 BP	Cal AD 1117 - 1222 (Cal BP 833 - 728) (68.4%) Cal AD 1042 - 1104 (Cal BP 908 - 846) (27%)	Cal AD 1154 - 1212 (53.8%) Cal AD 1055 - 1076 (14.4%)	-25.7
519639	**Wo98B**	AMS	580 +/- 30 BP	Cal AD 1300 - 1369 (Cal BP 650 - 581) (63.3%) Cal AD 1380 - 1418 (Cal BP 570 - 532) (31.8%)	Cal AD 1316 - 1354 (46.2%) Cal AD 1389 - 1408 (22%)	-26.7
519640	**Wo98A**	AMS	570 +/- 30 BP	Cal AD 1304 - 1364 (Cal BP 646 - 586) (57.7%) Cal AD 1384 - 1422 (Cal BP 566 - 528) (37.7%)	Cal AD 1320 - 1350 (40.9%) Cal AD 1391 - 1411 (27.3%)	-26.2
325166	**Wo98C** (Former BA120621)	AMS	540 +/- 30 BP	Cal AD 1320 - 1350 (Cal BP 630 - 600) Cal AD 1390 - 1430 (Cal BP 560 - 520)	Cal AD 1400 - 1420 (68%)	-25.2
325165	**BA1104065.454**	AMS	950 +/- 30 BP	Cal AD 1020 - 1160 (Cal BP 930 - 790)		-25.1
325164	**BA1104065.453**	AMS	950 +/- 30 BP	Cal AD 1020 - 1160 (Cal BP 930 - 790)		-26.5
325163	**BA1104065.450**	AMS	930 +/- 30 BP	Cal AD 1020 - 1170 (Cal BP 930 - 780)		-25.1
325162	**BA1104065.449**	AMS	990 +/- 30 BP	Cal AD 990 - 1050 (Cal BP 960 - 900) Cal AD 1090 - 1120 (Cal BP 860 - 830) Cal AD 1140 - 1150 (Cal BP 810 - 800)		-25
325161	**BA0704156.1477**	AMS	620 +/- 30 BP	Cal AD 1280 - 1400 (Cal BP 660 - 550)		-24.6
358506	**BA0604128.73**	AMS	600 +/- 30 BP	Cal AD 1290 - 1410 (Cal BP 660 - 540)		-24.4
218106	**BA0604128.74**	AMS	490 +/- 40 BP	Cal AD 1400 - 1460 Cal AD 1420 - 1440	Cal AD 1420 - 1440	-24.1
358507	**BA0604145.175**	AMS	850 +/- 30 BP	Cal AD 1160 - 1260 (Cal BP 790 - 690)		-26.2
218108	**BA0604172.69**	Radiometric	690 +/- 50 BP	Cal AD 1210 - 1310	Cal AD 1280 - 1440	-23.8
218107	**BA0604148.70**	Radiometric	950 +/- 50 BP	Cal AD 1010 - 1220;	Cal AD 1030 - 1180	-26.2

Table 3.5: Radiocarbon dating of the al-Balid timbers. The five additional timbers sent for radiocarbon dating by the author are highlighted in blue.

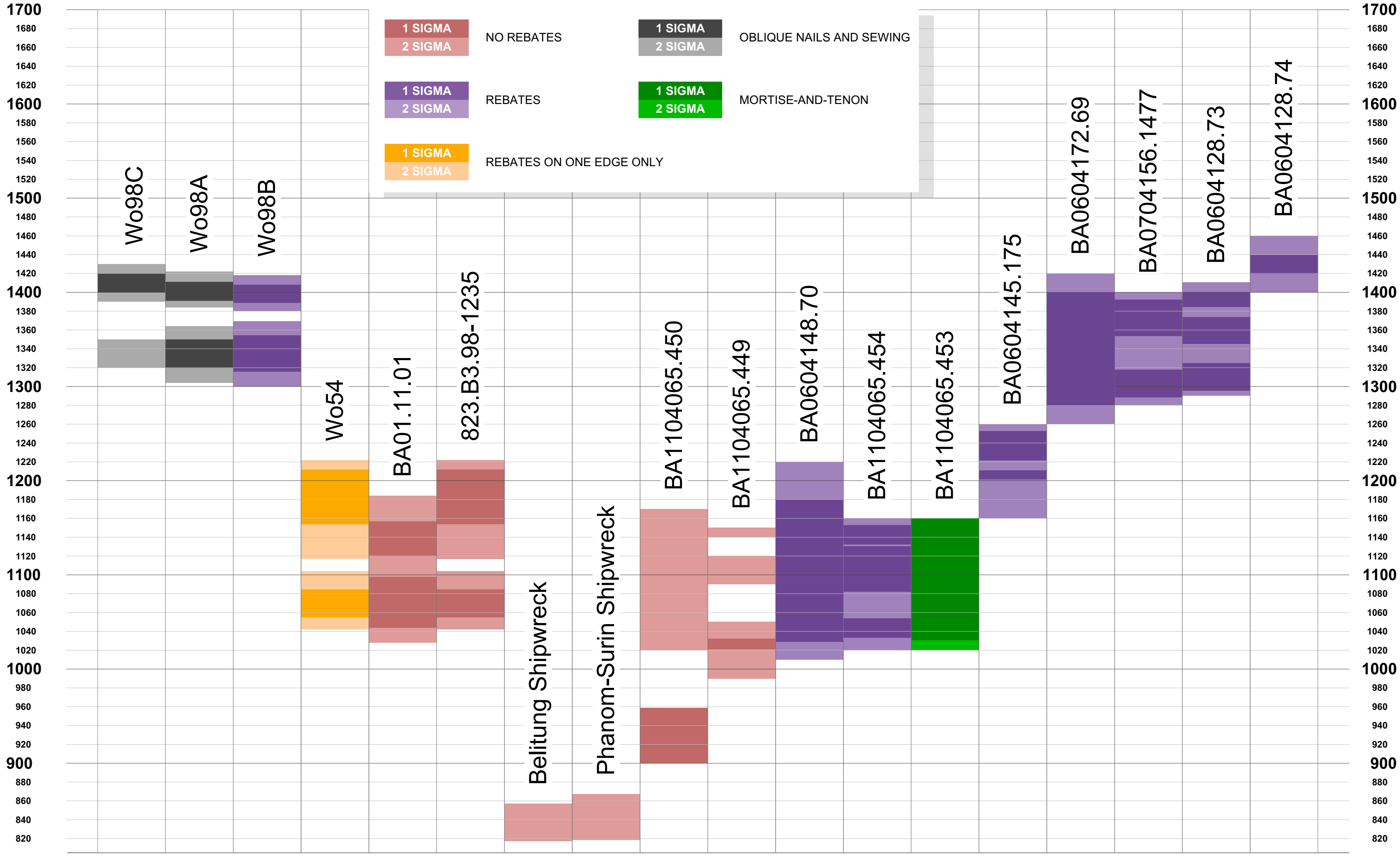


Figure 3.61: Chronological distribution of fastening features of the al-Balid timbers, and the Belitung and Phanom-Surin shipwrecks according to their radiocarbon dates. The chart is based on those published by Vosmer (2017: 199; 2019: 308).

3.11 Conclusion

The study of the al-Balid timbers provides a picture of the various forms of medieval sewn vessels found at the site. Figures presented in this chapter represent the core of my research and the basis on which I formulate answers to my research questions. Technical analysis of the features on the timbers, such as the arrangement of the holes, indicates differences in sewn-construction practices and alludes to two main sewing patterns and two different fastening methods (sewn and nailed). Other features, such as dowels, rebates and frame lashings, could provide information about how these boats were built while highlighting the similarities and differences with modern sewn boats in the region. Plank thickness and beam size, meanwhile, enable speculation about the size, shape and function of the ships. Wood species identification and date analyses are useful tools when discussing the origin of vessels, material trade and possible development of sewing practices.

Overall, the technical study of the timbers provides elements to be used in a comparative context with other relevant archaeological, ethnographic, historical and iconographic sources, which will be examined in Chapter 5 and aims to expand knowledge of the maritime world of the Indian Ocean during the Premodern Islamic period.

4 The Qalhat Timbers

4.1 Archaeological context

The builders of the city of Qalhat (Figure 4.1) reused wooden parts of Indian Ocean vessels as architectonic elements in the construction of buildings, in a similar way to that observed in al-Balid. The few timbers unearthed at the Islamic port of Qalhat display similar features to those from al-Balid, such as series of holes regularly spaced near edges, or grouped in pairs in the centre of planks. These ships' remains were discovered in Room F of building B12, identified as the Friday Mosque of the city. The mosque, also mentioned in the historical sources (Albuquerque 1875, i: 64-66, 221; Ibn Baṭṭūṭa 1962, ii: 396), is a large building measuring 20x30 m built near the sea in what appears to be the main quarter of the city. Founded on a rocky terrace, it overlooks a long, sandy beach, which was the only landing spot in Qalhat (Rougeulle 2010: 308-310), as evidenced by the discovery of several large stone anchors (Vosmer 2004: 399-401; Vosmer 1999a: 250-252).

The building of the mosque occurred sometime between the end of the 13th century and the beginning of the 14th century, while archaeological evidence indicates several periods of renovation in the 14th and 15th centuries (Rougeulle et al*.* 2012: 353). It is not clear when the mosque was abandoned; archaeological data do not corroborate its destruction by the Portuguese in 1508 as claimed in textual sources, and it could have easily survived since the occupation of the city of Qalhat extended until the mid-16th century (2012: 353).

Figure 4.1: Map of the medieval city of Qalhat, showing the location of the Friday Mosque (Grande mosquée). (Image redrawn by the author from Rougeulle et al. 2012: 343, Fig. 1, ©Qalhāt Project).

4.2 The Timbers

The Qalhat timbers comprise only a small number of fragments in various states of preservation. Most are heavily degraded making their interpretation impossible; only three timbers were chosen because they retained some of the distinctive sewn-plank construction features such as sewing holes and, in one case only, dowels.

4.2.1 Timber 3210

Overall Measurements

The original length of timber 3210 is not entirely preserved, and the remnant measures 938 mm (Figure 4.2). Similarly, it has not retained an original edge; its width ranges between 96 mm and 146 mm. Its maximum thickness is 59 mm but its surface is degraded, meaning that the original was likely to have exceeded 60 mm. The edge associated with the holes has a bevel of 44–66˚, and the presence of a large knot protruding from the centre of the edge of the plank suggests that this bevel was cut at a later stage, perhaps when the timber was reused. More specifically, in the context of its nautical use, the bump created by the knot on the edge would have made for a difficult fit between this plank and the adjacent one, exposing the hull to the risk of leakage.

Characteristics

Overall, the timber is relatively well preserved, despite having both its moulded surfaces degraded. It is not flat and smooth but has exposed wood grain, which is fine and straight, except for the presence of two knots on each edge. The regular grain

Figure 4.2: Timber 3210 from Qalhat. (Photo: Author)

and the colour of the timber (still bright yellowish/reddish) reflect the result of the species identification as teak (*Tectona grandis*) (Axelle Rougeulle, personal communication, 26 March 2018). Marks on the surface, such as those left by carpentry tools, occur only on one end of the plank and they consist of several saw marks made from different directions, pointing to an intervention carried out by an unskilled person, perhaps in a hurry, or someone using an inappropriate tool. Evidence suggests that the sawing of the timber occurred at a later stage, when the plank was recycled, to reduce the length for its new purpose. Indeed, the saw marks are very clear and more recent than the surface of the planks, strengthening the hypothesis that they were produced during the construction of the mosque.

Holes

There are six holes of similar diameter in a line near one edge of the plank, and since the edge has a bevel, the holes are located right on the edge of the slope. Their width is relatively regular, with an average diameter of 14 mm. Their spacing also appears quite consistent, averaging 85 mm. However, there is some variation in the spacing of the holes, ranging from 80–97mm. The sewing holes appear to be arranged in pairs from one side of the plank, and one of these was not drilled perpendicularly to the plank, instead having a 39˚ angle with its length. There is no evidence of rebates between the sewing holes and the edge of the plank. Even though the surface of the plank is degraded, traces of channels or grooves should nevertheless be visible unless the thickness of the timber had been removed entirely to the level of the rebates but there are no tool marks, such as from the use of saw, chisel or adze, indicating such a reduction.

There are other holes located, seemingly randomly, in the centre of the plank. Their diameter is larger than that of the six holes along the edge and one in particular, which is near the edge very close to the last series of six holes, was drilled at an angle of 45˚ relative to the plank’s surface and measures 18 mm in diameter. Another large hole, with a squarish shape, perhaps caused by the degradation of the wood, is in the centre of the plank near one of its edges and has the largest diameter, measuring 20 mm.

There is no trace of loose fibre or fastening cordage in the holes, which also have no preserved plugs. There are no dowels or channels to indicate their former presence on either edge of the plank. Similarly, there is no substance on the surface of the plank or near the holes that might suggest the presence of luting and caulking (wadding).

Dating

The archaeological context of the discovery of timber 3210 points to a period between the 13th and 14th centuries (Axelle Rougeulle, personal communication, 26 March

2018). The author sent a sample from the timber to Beta Analytic for radiocarbon dating (AMS) to confirm this hypothesis. The specimen was extracted from a section of timber with outer growing rings, and the result showed a much later date, between 1430 and 1620 cal AD, with an 82.6% possibility of a 1430–1522 cal AD range (Table 4.1).

Beta Analytic No.	Sample ID	Conventional Age (BP)	Calendar Calibration: 2 Sigma (95.4%)	Calendar Calibration: 1 Sigma (68.2 %)	IRMS d13C
519641	**3210**	410 +/- 30 BP	Cal AD 1430 - 1522 (Cal BP 520 - 428) (82.6%) Cal AD 1590 - 1620 (Cal BP 360 - 330) (12.2%) Cal AD 1577 - 1583 (Cal BP 373 - 367) (0.6%)	Cal AD 1441 - 1486 (Cal BP 509 – 464)	-24.7

Table 4.1: Radiocarbon dating of timber 3210 from Qalhat.

4.2.2 Timber Qalhat-1

Overall Measurements

The author determined the overall measurements of the timber from two photographs taken of each side provided by the director of the archaeological mission in Qalhat. Therefore, the figures here may not be precise. The timber, which has not retained its original length, is 414 mm long and 175 mm wide (Figure 4.3). The author could not determine the thickness of Qalhat-1 from the photographs.

Timber Characteristics

Most of the timber’s original surface has disappeared, exposing the wood grain, which is straight, regular and fine. One end is broken, while the opposite, showing a clean, straight edge appears to have been cut, most probably with a saw. The plank does not bear any other mark left by carpentry tools. At the same end, there is a small step or rebate, perhaps resulting from the recycling of the plank to its secondary, terrestrial,

Figure 4.3: Timber Qalhat-1. (Photo courtesy Auxelle Rougeulle).

context. As in the case of timber 3210, the characteristics of the wood grain corroborate the result of the species identification as teak (*Tectona grandis*) (Axelle Rougeulle, personal communication, 26 March 2018). One of the edges of the plank is straight, suggesting that this is the original edge. The opposite edge has a large knot exposed, which caused the plank to crack. Cracks also occur longitudinally along the wood grain, often along the lines of holes.

Holes

The plank displays a series of six holes along one of its edges, located at an average distance of 32 mm apart. Their diameter is very regular in four cases, measuring 11 mm, while two are much larger and range between 13–15 mm. It is probable that these two larger holes initially had the same diameter as the others but were enlarged at a later stage because of a large crack formed between them along the wood grain. The holes are spaced 47–69 mm apart, with an average of 59 mm, and no grooves connect them to the edge of the plank.

On the opposite longitudinal edge of the timber, there are four holes arranged in a line that is not parallel to the edge but is instead slightly angled. Their distance from the edge is considerable, measuring 50 mm at its maximum. They have the same diameter (11 mm) as those on the opposite edge of the plank but are more widely spaced, ranging between 79–85 mm with an average of 83 mm. As in the other set of holes, there is no evidence of rebates associated with them.

Six further holes are arranged in transverse pairs along the centre of the timber. These, most probably part of the frame-lashing system, are slightly larger than those near the edges, measuring an average of 13 mm in diameter. Their vertical spacing is similar, measuring 35 mm, while the horizontal distance between the pairs ranges between 71 mm, in the closest pairs, and 136 mm. Similarly to those located near the edges of the plank, there is no evidence of rebates associated with them. None of the holes has any trace of sewing cordage, such as remains of fibre ropes or loose fibres. Likewise, there is no evidence of wooden or fibre plugs inside the holes. Moreover, the plank does not bear any trace of luting or caulking, or any sealant material near its edges or around the sewing holes.

Dowels

Two channels on the edge of Qalhat-1, associated with the six sewing holes, reveal the presence of two obliquely driven dowels. The diameters of the channels indicate dowels of different size: 12 mm and 16 mm. They are located very close to the edge of the plank, at an average distance of 15 mm, and are spaced 242 mm apart.

Dating

No radiocarbon dating has been carried out for the timber. The archaeological context of the discovery suggests a potential date ranging from the 13^{th}–16^{th} centuries.

4.2.3 Timber Qalhat-2

Overall Measurements

This timber is 345 mm long and only 26 mm thick. It is difficult to determine whether the edge associated with the sewing holes is the original (Figure 4.4) as most of the plank's width has disappeared, making it very narrow, with a maximum measurement of just 54 mm.

Timber Characteristics

The timber consists of a small fragment bearing holes near one edge, a small section of which appears to be the original edge of the plank. While one surface is in relatively good condition, the opposite side is degraded, exposing the wood grain, which is fine

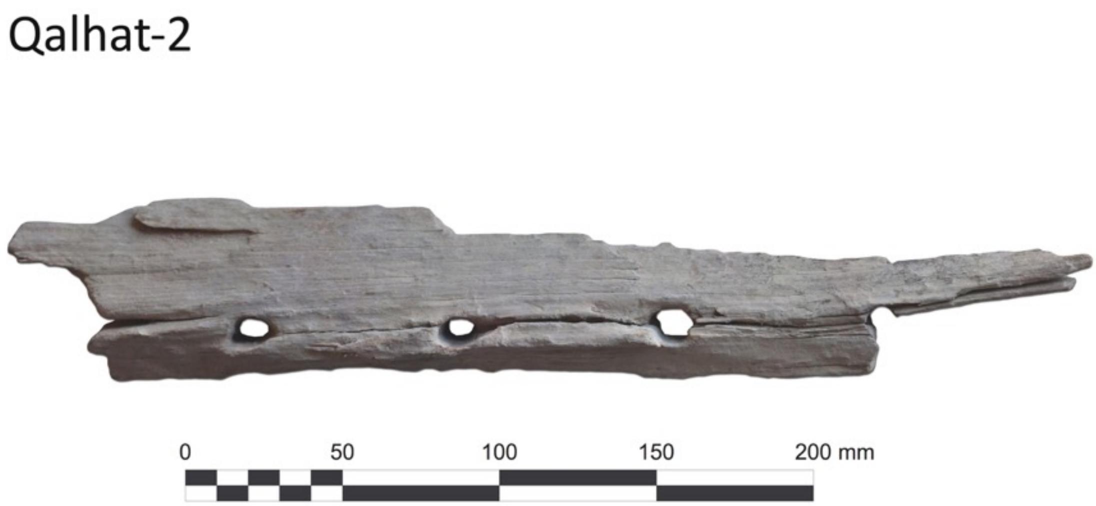


Figure 4.4: Timber Qalhat-2. (Photo: Author)

and regular, while the wood is light and pale in colour. Although not identified scientifically, it resembles teak.

Holes

The timber has only four holes, set in a line close to the edge of the plank. These all have the same diameter, 8 mm, and are spaced 64 mm apart. The holes were drilled at a 127˚ angle to what the author believes to be the actual surface of the plank. No rebates connect the holes to the edge of the plank. Because the width of the timber is very narrow, there is no evidence of other holes in the centre of the plank indicating frame lashings, or channels pointing to the presence of dowels. As seen in the other timbers from Qalhat, plank Qalhat-2 has retained no cordage, fibres or plugs, and bears no trace of luting material.

Dating

Similarly to timber Qalhat-1, the archaeological context of the discovery suggests a potential date ranging from the 13th–16th centuries.

4.3 Conclusion

The timbers discovered in Qalhat are few compared to those from al-Balid. They are also more fragmented and degraded, with no example that has its original width preserved. Overall, they display fewer features than those from al-Balid, for example showing no traces of cordage, fibres, plugs, luting material or decoration. This appears to suggest that the builders of Qalhat heavily modified these ships' remains for their new purpose, removing most of the elements revealing their previous use, including tool marks. These marks are also absent due to the poor state of preservation of the surface of the timbers, which has exposed the wood grain.

Nevertheless, the Qalhat timbers provide an excellent opportunity for a comparative study with those discovered in al-Balid, providing a brief, and still preliminary, picture of sewn-plank technology in the Indian Ocean of the 15th–16th centuries. This is particularly important because that period is immediately subsequent to the date range of the remains from al-Balid, offering information about Indian Ocean watercraft throughout a broad period ranging from the 10th–16th centuries. The dataset from Qalhat, despite consisting of only three samples, complements that of al-Balid, and provides an opportunity to establish whether archaeological evidence of sewn vessels in different places and from different times reflects differences in materials and construction techniques.

The evidence from Qalhat also confirms that the practice of recycling ship timbers for structural and architectural purposes in a terrestrial context was well established in the Indian Ocean throughout the medieval period, particularly on its western shores. This practice also alludes to various maritime activities at the port city, such as the building, repairing and maintenance of sewn vessels, which will be discussed in the next chapter.

However, the study of the Qalhat timbers also highlights two main differences from those of al-Balid. One is the lack of rebates between the holes and edges of the planks, whereas these are present in the majority of the al-Balid dataset. The other is the scarcity of dowels, found only on one of three timbers. While this might be due to the small size of the remains on timber Qalhat-2, the absence of dowels is certainly surprising on timber 3210, which is the largest of the Qalhat dataset.

These differences raise questions:

- Are they indicative of a different boatbuilding tradition? Does this evidence tell us that at least some of the vessels sailing to Qalhat in the medieval period came from different regions than those visiting al-Balid?
- Do these differences, particularly on timber 3210, which is from a later time than the period range of the planks from al-Balid, allude to a chronological change in construction technique that relied less on dowels?
- Is the interpretation of timber 3210 as a hull plank correct? Or could it be a different structural element of a ship, such as a frame or a stringer?

The next chapter will try to address these questions within a comparative analysis with other relevant evidence of sewn boats in the Indian Ocean, aiming to provide interpretations for the various features of the timbers from both Qalhat and al-Balid.

This comparison, involving data from archaeology and experimental archaeology projects, textual and iconographic sources, and ethnographic records will deepen our knowledge about Indian Ocean watercraft, and contextualise these timbers within the broader material networks in the Indian Ocean during the early Premodern Islamic period.

5 Structure and Forms of Medieval Indian Ocean Sewn Vessels in the Light of the al-Balid Timbers

5.1 Introduction

As we have seen in the previous chapter, the surfaces of the al-Balid timbers exhibit a variety of features: from their size, position and material of various elements, such as sewing and lashing holes, rebates and dowels, to marks left by tools used for shaping and the substances smeared on the timbers.

This chapter analyses these features with the aim of providing an interpretation of their function and location in boats. In turn, these hull components tell us about the methods and technology used by medieval shipwrights to build their vessels. Finally, some features on the timbers enable us to speculate about the size and shape of Indian Ocean vessels.

To achieve this goal, the timbers will be compared to archaeological, experimental archaeological, textual, iconographic and ethnographic evidence of sewn-plank vessels in the Indian Ocean.

5.2 Planking

Planks are the most represented element in the al-Balid dataset and provide information about a variety of boatbuilding processes and their sequence, and of the sewn vessels from where the timbers originated. As seen in Chapter 3, several timbers retain tool marks on their surfaces, generally the outer ones, indicating that they were shaped with a saw as opposed to having been split or carved from a log. The same method was employed to fashion the planks of the Belitung wreck, as indicated by the parallel lines on their surfaces as a result of the use of a saw (Flecker 2000: 206). The location and arrangement of holes not associated with plank sewing and frame lashing provide insights into the devices and techniques used to fit planks together during the building of the hulls of vessels.

5.2.1 From Log to Plank

The wood grain visible on the al-Balid timbers gives an insight into the techniques and tools used by medieval boatbuilders for shaping planks. The patterns of annual growth rings displayed on the transverse sections at the ends of each timber show angles of between 20˚ and 45˚ (Figure 5.1), indicating that the timbers were plain sawn (or flat sawn) from a log (Greenhill 1976: 241). The plain-sawn method consists of making planks by sawing a log with parallel cuts along its length; it is the simplest, cheapest and most practical way to convert a log into planks and was widely used in the western Indian Ocean until recently.

There are number of ways and variety of tools to fashion planks, and splitting and carving were probably the earliest methods used in boatbuilding. Evidence from ancient Egyptian watercraft indicates that vessels were built with planks obtained by either sawing, splitting or carving logs to the desired shape (Ward 2000: 10, 27). These different techniques probably depended on various factors, ranging from the technological level of a society/community to the availability of materials. They could also reveal the individual needs and requirements of people who commissioned the vessels. Overall, splitting and carving have the advantage of producing strong, durable planks but they are more difficult to produce and require particular skills and experience by the woodworker. Carving also requires a considerably longer time than

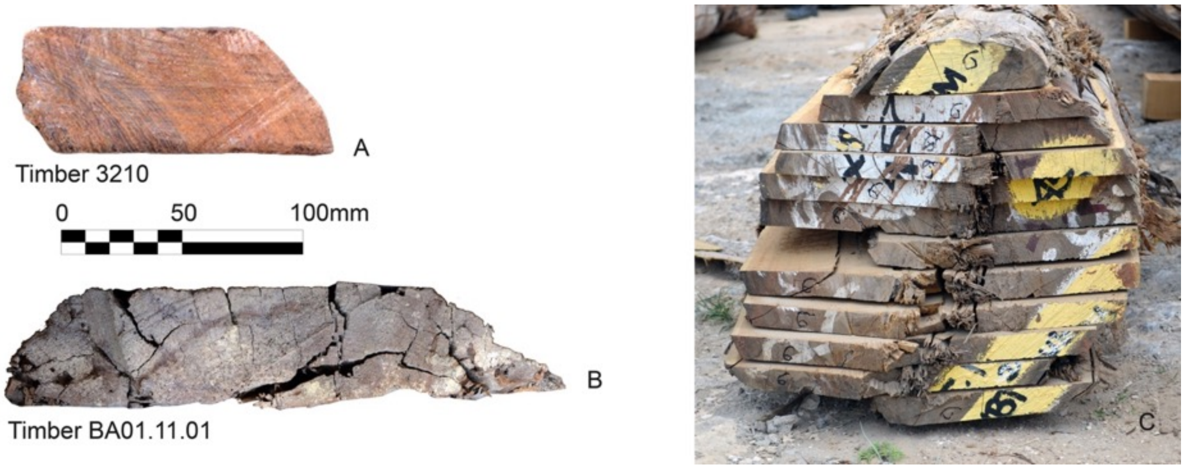


Figure 5.1: Wood grain visible on the timbers' sections (A & B) indicates a plain-sewn technique (C). (Photos: Author)

sawing. Lastly, and most importantly, these two techniques produce a lot of waste, particularly in the case of carving.

The flat-sawn technique enables the carpenter to use as much of the wood as possible from a log, thus limiting waste. Material economy would have been particularly crucial in dry environments, such as Arabian Peninsula, the Gulf and the Red Sea, where timber for planking is scarce and often imported from India, Africa and Southeast Asia (Casson 1989: 18, 73; Hourani 1963: 70, 89-90; Lewis 1973: 257; Mookerji 1912: 202; Pâris 1843: 10; Villiers 1948). Boatbuilders working in these regions would have probably chosen a method that allowed them to use most of the timber when shaping each part of the boat. The plain-sawn technique would have been the best option compared to splitting or carving, which produces considerably more waste.

One disadvantage of a flat-sawn log is that the planks are structurally unstable. When the wood dries and ages, the tension between the tangential grain, visible on the surface of plain-sawn lumber as loops and growths, can cause the plank to cup, twist and bow, and over time these movements can result in splitting and cracking (Greenhill 1976: 242). Nevertheless, this milling technique was predominant in Indian Ocean

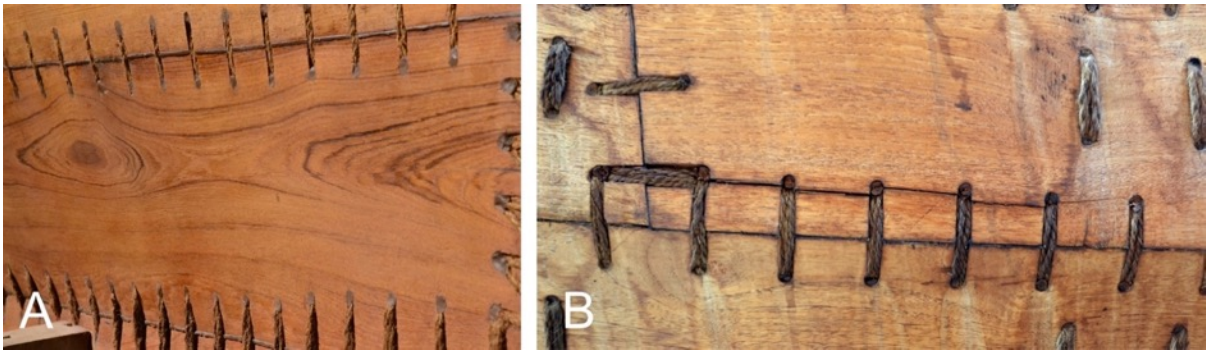


Figure 5.2: Wavy grain pattern produced by the plain-sewn technique (A). Crack formed along the holes in a plank with a finer straight grain (B). (Photos: Author)

boatbuilding, and is still used today in Oman and India (Author, personal observation, Sur and Alleppey, 2018).

There might be a further explanation for the use of the plain-sawn method and its persistence in the region, apart from it being the fastest and most cost effective. It could produce a wavy grain pattern that might be better suited to the sewn-plank technique (Figure 5.2(A)). Sewing holes arranged on the same line along a plank create a potential splitting line following the linear, straight grain of planks obtained with other methods, such as a radial split[1] (Figure 5.2(B)). The winding pattern of plain-sawn timber would probably be less likely to experience this problem. Moreover, sewing and wadding on the planks would act as a clamp around their edges, preventing deformation caused by the plain-sawn method.

Medieval boatbuilders probably used a pit saw to produce the al-Balid planks from logs, while a small hand saw would have likely been employed to work them into their final shape, as indicated by saw marks displayed on the edges of some timbers, which they would have used to reduce the width and length of the planks as well as to make the scarf joints or hood ends. Other tools, such as adzes and chisels, would have also

[1] The technique, primarily used in northern Europe during the medieval period, consisted of cleaving planks parallel to a log's rays across its growth rings (Goodburn 2002: 193; McGrail and Denford 1982: 33, 67).

been suitable for trimming planks, and reconstruction projects such as *Sohar* and *Jewel of Muscat* show that traditional carpenters from southern India mainly relied on broad chisels to shave the edges of boards (Severin 1985: 283; Author, personal observation, 2009-2016).

Plank Width

The variety of widths of the al-Balid timbers, ranging from 90–300 mm, provides the opportunity to speculate about where these planks were formerly located on a vessel. Since thickness is generally the same for planking across an entire vessel, width and length are key factors in determining the function and position of planks in a hull assemblage. The geometry and shape of a hull, rather than its size, affects the pattern and width of plank strakes, and because the cross section of a double-ended vessel's hull is curved amidships and gradually turns to straight and vertical at the bow and stern, its girth is larger at the middle of the ship than at the ends (Figure 5.3). This difference in hull sections influences the planking pattern, which means that strakes need to widen amidships and gradually taper towards the stem and sternposts. The widest planks from al-Balid might have been garboards or strakes located in the middle of the hull or at the sheer line. Wide, long planks are generally preferred for the lower part of the hull below the waterline and because this part is particularly critical in terms of structural integrity, and is more subject to the risk of leakage, boatbuilders prefer to limit the use of joints. Other timber characteristics, such as the presence of cracks, sapwood or knots, would also determine the function and location of each plank, and planks displaying these features are usually avoided below the waterline.

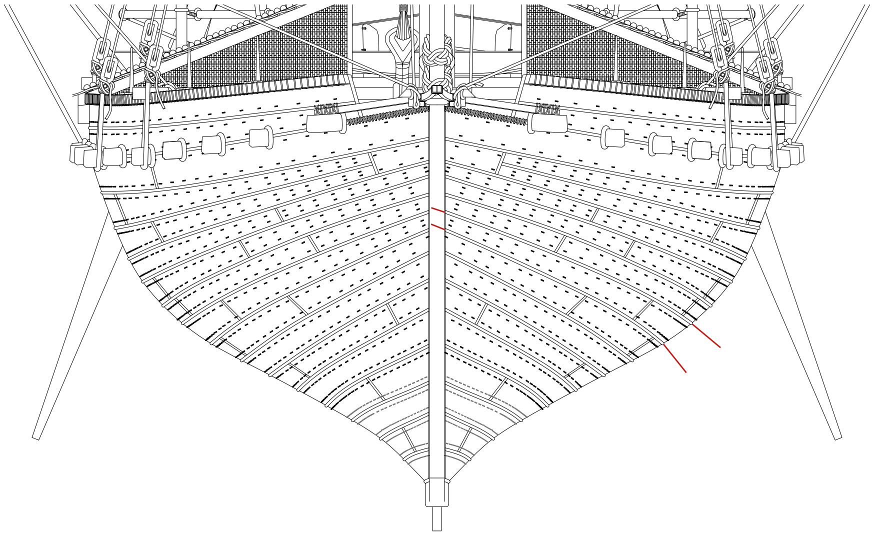


Figure 5.3: Bow view of *Jewel of Muscat* showing plank reduction from midship to stem post, highlighted in red. (Drawing courtesy of Nick Burningham and Lilli Haar)

Plank Bending and Twisting

The al-Balid planks are generally straight and show no evidence of twisting and bending before their fitting. In a shell-first construction method associated with sewn boats, the lack of an internal structure provided by frames during assembly and fastening of the hull planking means that planks cannot be force-bent around *a* vessel's frames to obtain the desired bend and twist.[23] Hence, carpenters have to bend and twist them before fitting and fastening them.

One traditional and effective way to achieve this is through the use of controlled fire to heat planks while gradually forcing them into shape (Figure 5.4). The timbers from al-Balid bear no evidence of fire heating, such as blackened areas on their surfaces, which could suggest the practice of pre-bending them before fitting. Traces of burning on one side of some of the sewn planks discovered in Quseir al-Qadim appear to point to this practice there (Blue et al. 2011: 182). Ethnographic maritime records from the

[23] This is especially true in the case of the garboards, which, depending on the shape of the hull, can sometimes display a twist close to 90˚, from being almost horizontal at the centre of the keel to vertical where they meet the stem and sternposts.

Figure 5.4: Boatbuilders in Zanzibar use controlled fire to bend and twist planks. (Photo: Author)

Indian Ocean, and boat reconstruction projects provide information about this process. Shaikh et al. described this method when recording the construction of sewn boats in Goa, stating that boatbuilders locked the planks into frames and gently bent them while pouring oil onto them to avoid burning their surfaces (2012: 152). Fire bending is also the preferred method used in the building of vernacular vessels in Zanzibar[24] (Author, personal observation, July 2018). Experimental reconstruction projects, such as the al-Hariri boat and the *beden seyad*, relied on fire bending, showing the advantages and effectiveness of this method (Ghidoni 2019; Staples 2019).

These projects also highlighted the issues and difficulties of this method and the skill required to achieve a perfect job. The person in charge of the process should keep

[24] Observation carried out as part of the British Academy-funded The Boat Builders of Zanzibar: Nautical Technology and Maritime Identity in a Changing World project (Project SL-08385; 2018–19; P.I. John P. Cooper; Co.I Lucy Blue; participant researcher Alessandro Ghidoni).

the fire going constantly, while being careful not to burn the plank. At the same time, he should be as cautious as possible when forcing the plank into the required shape and twist to avoid any cracking or splitting. For this reason, the construction team of *Jewel of Muscat* experimented with this technique only occasionally, since the boatbuilders were not experienced with this method and were afraid of damaging the timbers. The planks of the vessel were steam bent instead, using a wooden steam box built in situ by the carpenters (Vosmer et al. 2011: 417).

One further implication of having planks with no twist or curvature in the al-Balid dataset is that it makes it difficult to identify their definitive location within the hull of the vessel they came from, thus providing no information about its shape. It is probable that the builders of al-Balid's citadel intentionally used short, straight sections of planks that would have been more suitable for their new purpose as ceiling timbers, shelves and lintels.

5.2.2 Plank Shaping and Fitting

Tool marks on the surface of the al-Balid timbers offer insights into the shaping and fitting of hull planking. For example, parallel lines on the edges of connected timbers Wo71 and Wo72 point to the use of a hand saw to trim them. However, this evidence could also imply the practice of sawing the seam between two adjacent planks to obtain a perfect fit between them during the assembly of the hull. One implication of sewn-plank construction is that the hull of a vessel cannot be caulked like that of nailed boats (Vosmer 2007: 232). In the latter, this process involves the driving of cotton with a caulking iron[4] into planking seams to make the hull watertight (Agius 2002: 171; Al-

[4] The tool is similar to a chisel with a blunt edge.

Hijji 2001: 73). The extant stitches across the seams outside the hull would make the process of caulking impossible in a sewn vessel and would probably damage the sewing cordage. For this reason, sealing a sewn hull is primarily achieved through a perfect fit between the planks (Vosmer 2007: 328). Severin provides a sense of the importance of this process when describing the shaping and fitting of the planks in the building of *Sohar*:

> *The edges of the planks were prepared flat and perfectly flush to one another. This required the minutest care, shaving the edges with broad bladed soft iron chisels. Fitting one plank's edge to the next called for as many as five trials applications, putting the new plank in place, checking the surface contact (even using a simple form of engineer's blue, ordinary blue clothes dye), removing the plank, checking again, and so on (Severin 1985: 283).*

A perfect fit between planks was also the main priority during the construction of *Jewel of Muscat* (Vosmer 2010: 127) and was achieved by sawing the seams between the planks during the shaping of the hull, which was done in conjunction with a traditional spilling gauge called *qalam*[25] (Al-Hijji 2001: 31; Vosmer 2010: 127) (Figure 5.5).

[25] The device consists of a piece of wood, often from date-palm branches, split in half to form a V-shape. The boatbuilder dips the two ends of the tool in red pigment and marks a line on the fitting plank parallel to the edge of the plank below. The edge is then chiselled and the seam between the planks sawn several times until the fit between the two planks is perfect.

Figure 5.5: Shaping *Jewel of Muscat* garboards: a shipwright marks the plank with the *qalam* (A) then chisels out the portion indicated by the line (B) before making a perfect fit between the planks by sawing its seam (C). (Photos: Author)

5.2.3 Temporary Lashings, Battens and Clamps

The hole patterns of some of the al-Balid timbers indicate the devices that were used in the shaping and fitting processes of medieval sewn vessels. Seven planks have significant differences in hole spacing and diameter along the same edge, and individual holes are located between the main series of evenly spaced sewing holes. Moreover, they are closer to the edge than the sewing holes. Other planks have random holes, some of them plugged with wooden pegs, located in their centre that

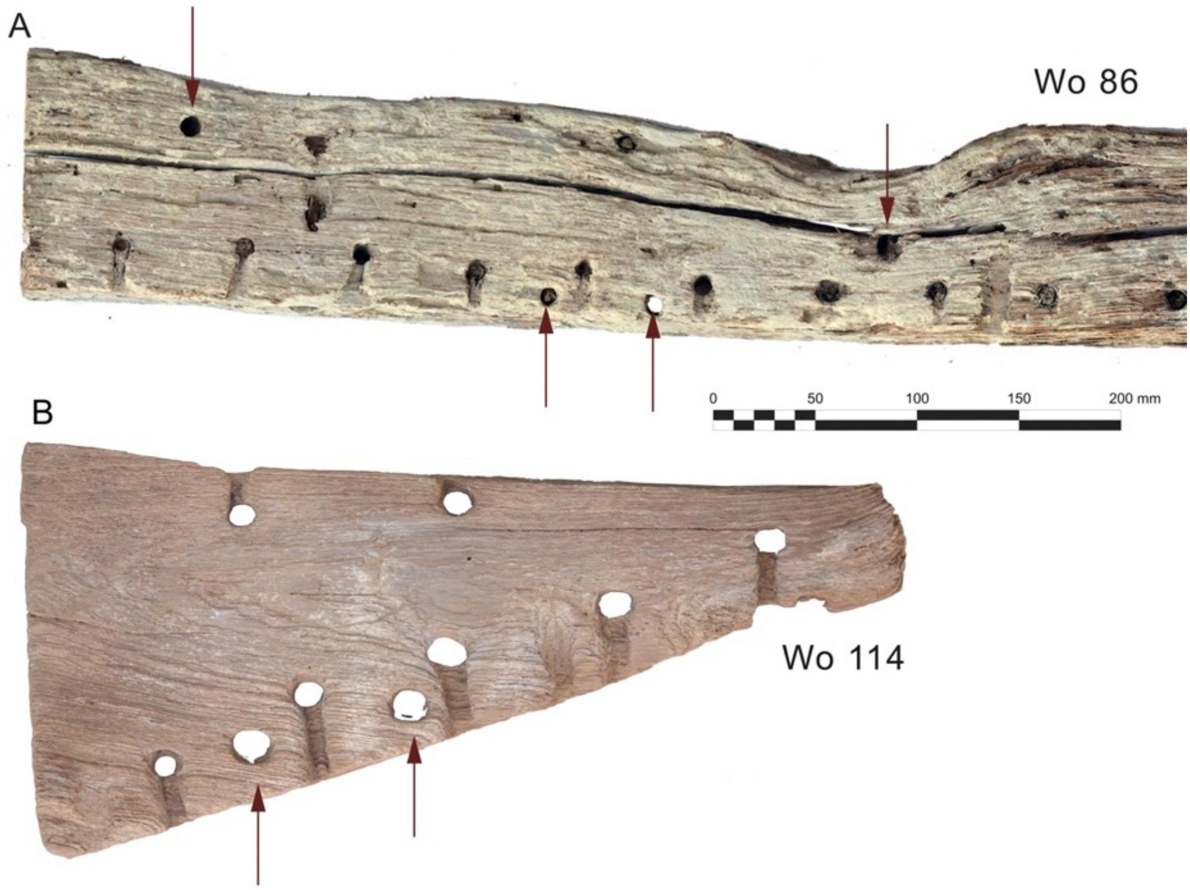


Figure 5.6: Holes without rebates located near the sewing holes and close to the edge of timbers Wo86 (A) and Wo114 (B). (Photos: Author)

do not appear to be related to frame lashings and are not associated with rebates. While at first glance, this evidence shows what looks like a confusing hole arrangement, perhaps pointing to an inadequate fastening technique, in fact, it might instead suggest the use of temporary lashings to hold the planks together prior to sewing. It could also point to the use of some sort of clamping devices or battens that were pegged onto the planks for the same purpose.

Timber Wo86 exhibits four of these “random” holes; two along the centre of the plank and two near the edge (Figure 5.6(A)). Those located in the centre, one at the very end and one near the middle, are single holes and are, thus, not part of a frame lashing. Both are plugged with wooden pegs and their diameters are larger than the other sewing holes, suggesting that they had different functions and were probably drilled at different times. The two holes along the plank's edge are located between the plank-to-plank sewing holes. They are not associated with rebates and are closer to the edge than the other sewing holes. The evidence from timber Wo86 suggests that the holes in the centre of the plank could have been used to temporarily fasten the plank, either with ropes or treenails, to a removable batten during the shaping of the hull. Those located along the edge could have been employed to provisionally secure the plank to the one below with lashings. Timber Wo114 shows a similar feature, with two large holes located near the edge between the sewing holes (Figure 5.6(B)).

As previously mentioned, shell-first construction consists of fitting and fastening the planks before the insertion of frames. However, ethnographic records of sewn and nailed vessels in the Indian Ocean (Agius 2002: 152), and experimental sewn-boat reconstruction projects, show that it is practically impossible to assemble the hull of a vessel without using some sort of alignment devices. In order to be shaped, planks have to be held in position above adjacent ones with clamps, temporary battens, and sometimes even templates (*furma*) (Agius 2002: 154; Al-Hijji 2001: 46-54; Johnstone and Muir 1964: 316) (Figure 5.7). Many of these temporary battens and clamps (*tawārī* in Arabic) are external on both sewn and nailed boats (Agius 2002: 220; Al-Salimi and Staples 2019: 177). The construction teams of *Jewel of Muscat* and the al-Hariri boat relied on various devices, including temporary templates, to keep the planks in position before sewing the hull, and these proved to be essential even for the building of a frameless vessel such as the 19th-century Omani sewn *beden seyad* (Ghidoni 2019: 367). While on nailed ships the planks are generally nailed or screwed to these temporary battens, in sewn boats they would have probably been secured with ropes.

Figure 5.7: Temporary templates used in boatbuilding in Oman: internal frames (*furma*) (A); internal battens (B); external frames (C-D). (Photos: Author)

The location of some of the holes on the surface of the al-Balid timbers suggests the practice of using discrete lashings to draw and hold the planks together to facilitate their shaping and fitting during the assembly of the hull. The *vadhera* technique, which is used on the Indian *pattamar*, described in the 19th century by Admiral Pâris and observed in Gujarati vessels in the following century by Hornell, relied on this particular method (Hornell 1920: 145; Pâris 1843: 17-18, Pl. 10). In both these cases, the vessels were nailed. However, lashings made through sets of holes, tightened by wooden wedges, served to draw the adjoining planks together on Indian vessels before nailing them (Green 2001: 66, fig. 1) (Figure 5.8). Vosmer noted this practice in the construction of the Omani *battīl* and *kambārī*, where planks were temporarily fastened to each other, or to frames, with ropes run through sets of temporary holes drilled in their surfaces. Once the planks were sewn, the boatbuilder sliced off the temporary lashings and plugged the holes (Vosmer 1997: 233; 2005: 292). During the construction of *Sohar,* Indian boatbuilders used temporarily lashings to allow unseasoned timber to dry out until reaching its dimensional stability (Vosmer 2007: 372).

Figure 5.8: A temporary lashing tightened with a wedge to hold two planks together during the assemblage of a sewn boat in Kerala, India. (Photo courtesy of Colin Palmer)

5.2.4 Plank Joinery

One of the al-Balid timbers that has retained one of its ends offers information regarding the end-joinery system between planks of the same strake. The composite plank BA0604128.73 shows two planks of the same strake joined with a scarf with a blunt shoulder (nib) at one of its ends (Figure 5.9). The joint is sewn and reinforced with dowels but still remains relatively tight. The joinery of this plank bears some resemblance to that used in early 2nd-millennium BCE Egyptian boats, as evidenced in the Lisht timbers (Ward 2000: 110).

Evidence of scarf joinery is visible in both sewn and nailed boats in the western Indian Ocean. This system is commonly employed in southern Arabian and East African vessels, such as the Omani *kambārī* (Weismann et al. 2019: 351), Somali *beden* (Chittick 1980: 301, fig. 4) and Yemeni sewn *sanbūq*.[26] The use of scarfs is also attested in planks used in the ceiling of the guardroom in Fort Jesus, Mombasa, which are believed to come from the hull of a *mtepe* (Prins 1982: 97), and in various scaled models of the *mtepe* and *dau la mtepe* (Prins 1986: 77, 79, figs. 46b-47b).

Since only two of the al-Balid timbers have preserved ends, information about how planks were joined is still extremely limited, and a scarf joint may be only one of the methods used to connect planks during the medieval period. Archaeological and ethnographic data highlights a variety of techniques used by Indian Ocean boatbuilders to join two planks on the same strake. Earlier archaeological evidence, such as those of the Belitung and Phanom-Surin wrecks, shows a different method: planks are butted and sewn in the same way that was used for the plank seams (Flecker 2000: 206). Although no technical studies have yet been published on the hull structure of the Phanom-Surin wreck, two photographs included in Guy's paper on the ship's cargo clearly show butted planks (2017: 179, 181; figs. 1, 2). Unfortunately, the planks from Quseir al-Qadim had all been cut to be used as the ceiling of a grave and so did not provide any information about their ends, and hence how they were end-joined.

In more recent times, butted planks have been observed in Indian and Sri Lankan sewn vessels, such as the *masula* (Kentley 2003: 138) and *madel paruwa* (Kentley

[26] A photograph by Thesiger taken in Shihr, Yemen, shows two men standing in front of a beached sewn *sanbūq* with scarfed planks. Source: Pitt Rivers Museum, University of Oxford: http://photographs.prm.ox.ac.uk/pages/2004_130_3325_1.html

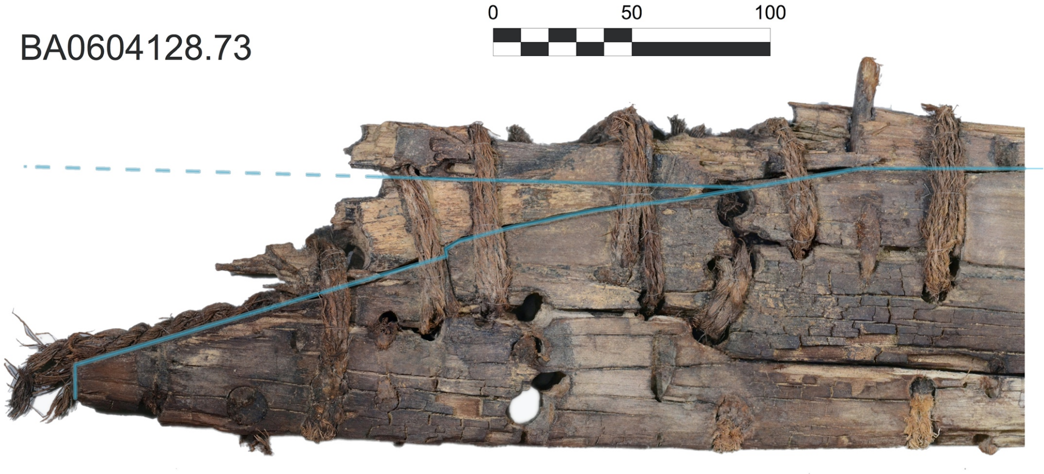


Figure 5.9: The scarf joint, highlighted in blue, on timber BA0604128.73. (Photo: Author)

2003b: 172), and in the watercraft of the Lakshadweep (Varadarajan 1998: 58, fig. 54-57). One cannot exclude that different joinery methods could have been used within the same vessel. Butt and scarf joints alternate in some of the riverine sewn vessels of Goa, but the scarf angle is less pronounced, making the planks almost butted (Sheikh et al. 2012: 151, 153, fig. 12).

Collectively, all this evidence indicates different methods of joining the ends of planks of sewn boats in the Indian Ocean, and data from the al-Balid timbers cannot offer any definitive suggestion about the reasons for using one method instead of another. The Belitung and the Phanom-Surin wrecks, which date to an earlier period, seem to suggest that butt joints were preferred in sewn-plank construction at least until the 9th century. However, since both wrecks were discovered in Southeast Asia and the identification of the Belitung shipwreck as a western Indian Ocean vessel has recently been disputed (Haw 2019), their plank-joinery methods could also be a feature associated with a specific regional boatbuilding tradition. *Ngwanda*s from Zanzibar have different plank joints according to their location in the hull, pointing instead to a structural reason for this difference. Its garboards, which are structurally crucial in boatbuilding, are usually scarfed, while the planks above are often butted (Author, personal observation, July 2018).[27] A butt joint is the simplest way to connect two pieces of timber by simply placing their ends together. However, the connecting edge between the timbers is relatively short, resulting in a weak bond. Scarf joints require more carpentry skill and time but result in a broader point of contact between timbers, thus providing greater strength. Coates' structural study on sewn boats indicates that butted planked vessels are more likely to be subject of hogging (Coates 1985: 11-12, fig. 2.3). This behaviour of hull planking was observed at the sheer strake of *Jewel of Muscat* at the end of its voyage. The planks of the vessel were butted, based on those from the Belitung wreck and, after the strain of the five-month voyage from Oman to Singapore, the top edges of the joints between the planks on the sheer strake had a gap of a few millimetres.

The use of different joinery methods in boatbuilding might also be related to the availability of material. For example, scarf joints are also used when the planks being joined are not available in the length required, allowing the boatbuilder to maximise the use of timber. Therefore, their presence could also be an indicator that perhaps the boat was built in regions with a scarce wood supply. Butt joints instead might point to places with plenty of timber resources. Indeed, the geographical distribution of different joinery methods of sewn-vessel planking show that butt joints are predominant in India and Sri Lanka, where boatbuilding timber is abundant, while planks are scarfed in the hulls of the watercraft of the Gulf and southern Arabia.

[27] Observation carried out as part of the British Academy-funded *The Boat Builders of Zanzibar: Nautical Technology and Maritime Identity in a Changing World* project (Project SL-08385; 2018–19; P.I. John P. Cooper; Co.I Lucy Blue; participant researcher Alessandro Ghidoni).

5.3 Ship Beams

Ship beams are the second most represented boat structural element in the al-Balid dataset. Three timbers from the site's citadel and mosque had previously been used as ship beams (Figure 3.38, Figure 3.39 and Figure 3.40). Small grooves displayed on opposite faces of each timber reveal the most obvious feature for their identification as ship through-beams (Belfioretti and Vosmer 2010: 115) because they share similarities with those from the Belitung wreck (Flecker 2000: 207-208, figs. 17-18) and other traditional boats of the western Indian Ocean (Hornell 1941: 60; Lydekker 1919: 88; Prins 1982: 90; Vosmer 1996: 230). These grooves, located transversely to the length of the timbers near their ends, reveal particular joinery between the beams and the hull planking (Figure 5.10). They indicate that the beam's upper and lower sided faces were notched into the edges of planks from adjacent strakes, in a halving joint (Vosmer 1996: 242, fig. 16). Clamped between the planking, the beams were firmly locked in place with their ends extending outside the hull.

5.3.1 Through-beams in Sewn Boats

Evidence from al-Balid corroborates the limited data from iconography and archaeology suggesting that through-beams were one characteristic of sewn-plank craft of the Indian Ocean during the medieval period (Vosmer 2007: 64-65). A few preserved beams from the Belitung wreck penetrated the hull planking and extended outboard (Flecker 2000: 207-208), and a number of ship depictions from various regions of the Indian Ocean illustrate this feature during the Premodern Islamic period and even earlier. A seagoing vessel painted in cave no. 2 from Ajanta, India (Deloche 2010: 203, fig. 3d; Mookerji 1912: facing p. 40), and dated to the 6th century appears

Figure 5.10: Fitting the plank above the through-beams on *Jewel of Muscat*. The top and bottom strakes, and the beams are notched to accommodate each other. (Photo: Author)

to show a series of through-beams right below its sheer line. Similar evidence is found in a 10th–11th century stone relief from Orissa (Deloche 2010: 224, fig. Xb) and the 16th-century painting of Babur crossing the river Son (Gorakshkar and Desai 1989: facing p. 29) (Figure 5.11). The small rectangular device near the steering oar at the stern of the ship in the *Maqāmāt* of al-Ḥarīrī, illustrated by Yaḥyā bin Maḥmūd al-Wāsiṭī in 1237, might also be a through-beam used to tie and secure the oar.

Because of the relatively limited role of frames in the shell-first construction technique, builders of sewn boats relied on through-beams to provide lateral strength and rigidity to the hull (Vosmer 2007: 65). By penetrating the hull, and being firmly locked into the planking, they hold the side of the vessels together, helping to reduce hogging and sagging, and preventing hull distortion. The ends extending outboard could also provide supports for the quarter rudders or belaying the rigging on each side of the stern.

Figure 5.11: Through-beams visible on vessels depicted in the 16th-century illustration of Babur crossing the river Son, from the *Baburnama* (*Memoirs of Babur*). (Source: https://commons.wikimedia.org/wiki/File:Babur_crossing_the_river_Son.jpg)

5.3.2 Shaping and Fitting of Through-beams

Tool marks visible on the surfaces of some of the beams from al-Balid indicate that boatbuilders shaped them from medium-sized logs using an adze or a chisel. The carpenters also used chisels to carve the rebates on through-beams, such as those on their upper and lower surfaces. Boatbuilders then shaped the beams and put them in place when the hull planking was nearly assembled and framed, and before it was sewn. Since one of their functions is to support the deck, the al-Balid through-beams were most probably fitted either through the sheer strake or immediately below it, as indicated by the Belitung shipwreck as well as by recent Indian Ocean watercraft (Cooper et al. 2020: 16; Flecker 2000: 208; Hornell 1941: 60; Vosmer 1997: 224 Vosmer 2007: 179; Weismann et al. 2014: 429).

5.3.3 Carlings and Stretchers

Beams BA1104065.447 and Wo105 from al-Balid also have a number of rebates on their surfaces, in addition to notching for the planking at their ends. While some of these could have been made when the timbers were recycled, others suggest the accommodation of structural elements such as carlings. For example, rebates displayed in the centre of beam Wo105 resemble those found on the forward beams of traditional Arabian boats, which were used to fit the ends of removable carlings (Figure 5.12(A)) (Weismann et al. 2014: 431). These fore-and-aft timbers, which act as stretchers for rowing, are placed between the beams to provide additional longitudinal strength to the hull, support the deck (*nashshāb*) or as hatch frames (*mashshāy*) (Agius 2002: 213; Al-Hijji 2001: 152-153; Johnstone and Muir 1964: 320-321). Carlings are inserted between beams and notched into their top side, which

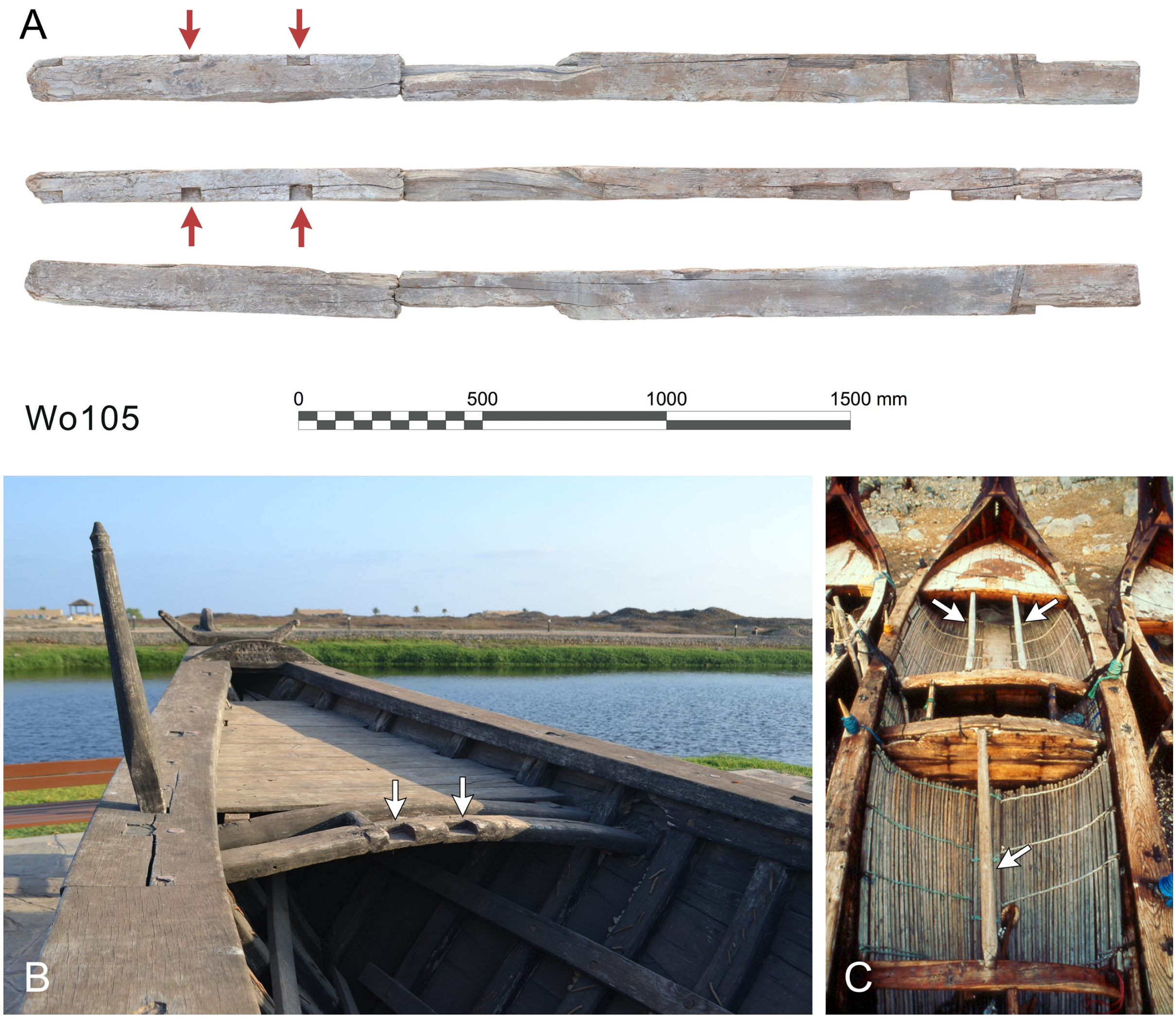


Figure 5.12: Beam Wo105 showing recesses (A) similar to those carved on a beam of a *battīl* on display at the Museum of Frankincense Land, Salalah, Oman (B) (Photos: Author). These rebates serve to accommodate the stretchers placed between the beams on a *battīl* from Musandam, northern Oman (A) (Photo: Tom Vosmer).

means that the position of the notches in Wo105 indicates the upper face of the beam. There seems to be no evidence of holes, dowels or treenails, or any fastening system associated with the notches, suggesting that the carlings were probably removable and simply laid against the beam, similar to those on Omani *battīl*s (Figure 5.12(B)).

Evidence of longitudinal structural elements implied by the beams from al-Balid might also reveal the presence of a deck, or a partial deck. According to textual sources, most of the sewn boats of the Indian Ocean did not have a deck. Marco Polo remarks that, after loading their ships, the merchants of Hormuz “cover the goods with boiled hides of animals, and above the goods, when they have a covering, on the hides they put the horses which they carry into Indie to sell" (Moule and Pelliot 1938: 124). European travellers also noted undecked ships in Malabar, southern India, in the 14th century (Jordanus 1863: 54) and East Africa in the early 16th century (Dames 1918,I: 27; Stanley 1869: 240). However, there are also historical sources indicating the presence of decks in Indian Ocean sewn vessels, such as the boat illustrations from the *Maqāmāt*, and Vasco Da Gama's observations of Mozambique watercraft (Ravenstein 1898: 26). In his account of the ships at the port of Cananor, southwest India, the Portuguese historian Gaspar Correa describes the use of "cane mats" over date-palm leaves covering the cargo and allowing the crew to walk on them without damaging the merchandise (Stanley 1869: 241). These are likely to be removable mats made of bamboo or palm fronds, similar to those covering the 19th-century *beden seyad* (Pâris 1843: 15-16, pl. 8), and still used in modern fibreglass boats in Oman (Figure 5.13).

Figure 5.13: Removable deck made of palm ribs on the replica of Pâris' *beden seyad*, Oman. (Photo: Author)

The beams of al-Balid provide no information regarding whether the deck was made of planks or mats. A wooden peg associated with a wide rebate near the end of beam Wo105 points to the use of a treenail to fasten a timber across the beam. This longitudinal element could, perhaps, have been the plank of a deck running along the sides of the ship, where it would have been particularly useful. The lack of other means of fastening associated with other notches on the beams might instead suggest the presence of a deck made of bamboo mats, such as that previously described by Correa. Placed between the beams and supported by a few carlings, a deck made of mats could be rolled and removed to facilitate the loading of the cargo while providing a structure for the crew and passengers.

Conclusion

Despite the limited number of beams, the evidence from al-Balid provides valuable information about this structural element and, more generally, the construction technology of sewn-planked vessels. The importance of these timbers is further underlined by a scarcity of evidence in the archaeological record. Data from al-Balid suggest the significance of through-beams in sewn-plank construction for providing structural strength to the hull, scarcely supported by frames. At the same time, they also tell us about other elements not occurring in the dataset, such as carlings and deck, as well as giving clues to the size and shape of vessels. However, the most exciting aspect of the through-beams discovered in al-Balid is their similarity to those from Modern-era sewn boats of the Indian Ocean, reflecting their persistence in the Indian Ocean until the end of the 20^{th} century.

5.4 Frames

Although no frames were found at al-Balid, twenty-three timbers of the dataset, displaying series of holes drilled in the centre of the plank, provide evidence of their

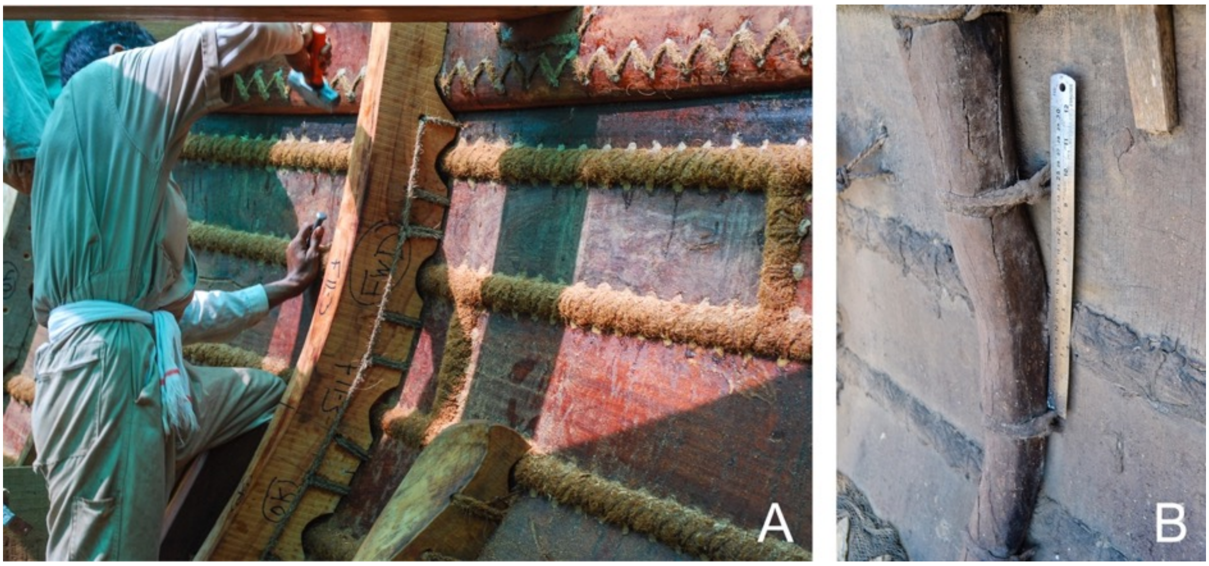


Figure 5.14: Different techniques used to fasten frames in sewn boats: *Jewel of Muscat* with cordage through holes on its moulded surface based on evidence from the Belitung wreck (A) or simple lashings around the frames, as in the Omani *kambārī* (B). (Photo: Author)

fastening, offering some insight into their size and spacing. This evidence matches that from archaeological and ethnographic examples from Indian Ocean sewn vessels where sets of holes in the centre of the planks indicate frame lashings (Bowen 1952: 203, 212; Flecker 2000: 207; Prados 1996: 103, 106; Shaikh et al. 2012: 154, fig. 13; Weismann et al. 2019: 352, fig. 12 First Regional Office 2016: 105, fig. 116). Frames are secured against the hull by turns of rope running through these holes on the outside of the plank and around the frame on the inside of the hull (Figure 5.14(B)) or through holes drilled through the moulded face of the frame, as observed in the Belitung shipwreck (Flecker 2000: 207) and recent sewn boats from southwest India (Figure 5.14(A)) (Cooper et al. 2020: 29-30; Author, personal observation Alleppey, India 2014).

5.4.1 Frame dimensions

By observing the pattern of the frame holes in the planks from al-Balid, it is obvious that their horizontal spacing can vary considerably. Close pairs of holes indicate the sided dimension of the frame, which is the surface lying against the inside of the hull, while the distance between one pair and the next corresponds to the frame spacing. The frame-lashing holes of the al-Balid timbers show a considerable variation in frame sided dimensions, ranging between 36 mm and 215 mm, with the majority being between 80 mm and 100 mm.

Overall, the al-Balid frame sidings are much larger than those from the Belitung wreck, or the ship timbers from Quseir al-Qadim, which measures 40–50 mm and 65 mm respectively (Blue et al. 2011: 183; Flecker 2000: 207). This difference does not necessarily mean that the al-Balid vessels were larger. Plank thickness, rather than frame dimension, is a better indicator of the size of a ship in the Indian Ocean, particularly with sewn-plank construction. Generally, the former increases with the dimension of the vessel (Belfioretti and Vosmer 2010: 116). In contrast, a comparison between the plank thickness and the frame size across all the al-Balid timbers shows that relatively thin planks can display frames of significant siding.

The significant variety of frame sidings implied by the frame-lashing holes on the al-Balid timbers could be due to a number of factors. Some of the planks with more than one frame fastening indicate the presence of frames of different sizes within the same vessel. This variety might reveal a distinction between different types of frames, such as floor timbers, half-frames and futtocks (Figure 5.15). For example, floor timbers sit across the keel with their two arms lying against both sides of the hull. They are generally larger in section than half-frames, which sit on one side of the hull, because they need to provide strength to the lower part of the hull.

Figure 5.15: Framing arrangement of a QM Iranian sewn *baggāra*, where floor timbers alternate with half frames. (Photo courtesy of John Cooper)

Frame joinery could also be one of the reasons for having lashings of different sizes, especially if ends are joined side-to-side instead of being butted. Repairs, replacements or the addition of new frames, or parts of them, might also have resulted in longer lashings on the outer face of the timbers.

Lastly, the difference in the size of the frames in the al-Balid timbers also points to the use of naturally grown timbers. In Indian Ocean boatbuilding, floors and frames are often natural crooks of local trees selected for their shape to fit specific locations in the hull (Chittick 1980: 300; Prados 1996: 94; Vosmer 1997: 229) because their naturally curved shape makes them stronger than straight timbers cut into the same profile. Medieval carpenters would have only roughly worked these crooks into frames to take advantage of their curvature, hence the presence of frames with dramatic twists and bends with a variety of sided dimensions. Flecker remarked (2000: 206) that the siding of the frames on the Belitung wreck, also showing a wide range, was dependent on the way they had been shaped, some showing a regular rectangular section, while others were just a quarter section of a log.

5.4.2 Frame Spacing

The distance between sets of frame-lashing holes in the al-Balid timbers is also irregular and indicate the spaces between frames, which range between 55 mm and 373 mm. It is likely that the same reasons for the variety of frame sidings also explains the variety of their spacing. However, this can also be the result of the particular construction method of a sewn vessel. Since frames are inserted after the hull is assembled and fastened, their position is not generally planned (or marked) in advance but it often depends to a degree on the shape of available timber and on the location of the joints between plank ends on the same strake. Indian Ocean boatbuilders were likely to have shifted the frames fore and aft of scarfs or butt joints to avoid their bulky wadding.

Evidence from the al-Balid timbers also offers an opportunity to compare the spacing and size of the frames of Indian Ocean sewn boats with those of Mediterranean and North Sea watercraft of similar size and period. The 12th-century Serçe Limani wreck, discovered in Turkey and with an estimated length of 15–16 m, shows similar figures, with frames sided 9–12 cm and spaced 32 cm apart (Bass and Van Doorninck 1978: 122). Even seaworthy Viking ships had frames spaced considerably more widely apart. For example, the frames of the Gokstad ship (9th century) measuring 23 m in length, show spacing of roughly 1 m. Similarly, the deep-sea cargo ship Skuldelev-1 had frames with a sided surface of 10-15 cm spaced 93 cm apart (Steffy 1994: 111-

112). These figures show that, structurally, medieval Indian Ocean vessels did not differ much from those of the Mediterranean or North Sea from the same period.

5.4.3 A Frame from Qalhat?

While the vast majority of the al-Balid timbers are either planks or beams, and provide no direct evidence for frames, some features on Qalhat timber 3210 (Figure 4.2) might point to its interpretation as a frame (Figure 5.16). The presence of holes of similar diameter along one of its edges resembles the typical pattern of the Indian Ocean plank-sewn technique. The lack of rebates, in contrast, seems to suggest that the plank might have belonged to the hull of a vessel sewn with a double-wadding method. However, a few characteristics displayed on the timber and the fact that it has not retained any original edge makes it difficult to determine for certain to which part of the vessel it belonged.

Figure 5.16: Timber 3120n from Qalhat (above) and a close-up of a *Jewel of Muscat* half-frame showing holes seemingly grouped in pairs. (Photos: Author)

The fact that some of the holes near the edge of Qalhat timber 3210 are drilled at an oblique angle is somewhat puzzling: there does not appear to be a particular reason. While, generally, sewing holes are drilled not perfectly perpendicular to the plank on sewn boats, the noticeable angles of two holes on plank 3210 are such as to make the sewing less effective. The lack of dowels, luting material and traces of fibre, cordage and plugs, which are typically associated with sewn-plank remains, is also anomalous. Timber 3210 shows no evidence of holes in the centre of the plank indicating frame lashings. Moreover, despite the series of holes at a distance from the edge matching the range observed on other sewn planks from al-Balid, the presence of one large knot protruding from that edge would have resulted in a very bad fit between the planks, increasing leakage.

This evidence seems to suggest an interpretation other than a sewn plank for timber 3210. One particular feature points to it being a frame rather than a plank: the holes along the length of the timber appear to be grouped in pairs. One frame from the Belitung wreck reveals a similar hole arrangement, along with the presence of recesses on the side facing the hull to accommodate the stitching (Flecker 2000: 207, fig. 15). This evidence could indicate that the holes on timber 3210 were for fastening it as a frame against the hull planking. The timber from Qalhat bears no evidence of recesses for sewing that were observed in the Belitung wreck. However, the knot and the partial bevel on one of the edges tells us that this part of the timber was almost certainly cut, perhaps causing the removal of notches, when it was reused. One last aspect pointing to the identification of timber 3210 as a ship's frame is its thickness. While 60 mm is an unusually thick plank for a boat, it is not uncommon for the siding of a frame, as indicated by the evidence from the Belitung wreck (Flecker 2000: 206).

Discussion

Data from the al-Balid timbers regarding the framing arrangement of medieval sewn boats deepen our understanding of the construction method of the ships that sailed there. The importance of this evidence is underlined by the scarcity of information about the framing of Indian Ocean sewn boats in the medieval period. Archaeological evidence, almost exclusively from the Belitung wreck, is also limited due to the salvage nature of its excavation. Historical references to the frames of Indian Ocean vessels are essentially non-existent, with the only exception being the Portuguese historian Gaspar Correa. In his description of Indian ships, he informs us that they had just a "few ribs" sewn to the planking (Stanley 1869: 239). This paucity of evidence for frames, along with frequent references in textual sources to the flexibility of sewn boats, even led early 20th-century scholars to the assumption that Indian Ocean medieval sewn vessels were frameless (Moreland 1939: 66). While there are more recent examples of Indian Ocean sewn craft without frames, such as the southeast Indian *masula* (Kentley 1985; 2003b) and the 19th-century Omani *beden seyad* (Ghidoni 2019; Pâris 1843: 15, pl. 8), they are both small coastal boats. However, larger seagoing vessels involved in long-distance sailing, such as the Belitung and the Phanom-Surin ships, show that frames were necessary to strengthen the hull and make it seaworthy. The evidence from al-Balid not only corroborates the data from these two wrecks but also points to the use of frames in smaller vessels, evidenced by their lashings being displayed in both thick and thin planks.

The frame size and spacing of the al-Balid timbers also points to the ingenuity of Indian Ocean boatbuilders in using available resources, such as the natural curvature of crooked branches of trees for specific functions. Some of the best examples of these trees, such as *Ziziphus spina-christi* and *Acacia* sp., grow in arid environments such

Figure 5.17: A *sidr* tree (*Ziziphus spina-christi*) in a wadi, Oman (left) and its crooked branches, which are well suited for framing. (Photo: Author)

as the wadis of the Arabian Peninsula, Egypt and Iran (Agius 2002: 103-104, 139, 149; Vosmer 1997: 218) (Figure 5.17). The implication is that the boatbuilding communities of these regions would not have had to import timber from distant countries such as India or East Africa to frame their vessels, but could use local wood. As we have previously seen, the practice of shaping frames out of naturally curved timbers persisted on the western shores of the Indian Ocean until recently, highlighting the similarities between medieval and 19th–20th century sewn boats.

This same evidence might also hint at the lack of standardisation in medieval Indian Ocean boatbuilding while reflecting the nature of a shell-first construction technique. Frames were probably not planned meticulously in advance and regularly placed along the keel. Instead, their size and position might have been dependent on a number of factors relating to the shape of the hull and the pattern of the planking. Lastly, roughly shaped frames and floor timbers also meant that less work was required by the carpenters to shape them, decreasing the overall construction time of the vessel.

To conclude, data on the frames of the al-Balid timbers is particularly useful for an evaluation of sewn-plank construction technology, supporting the idea that Indian Ocean ships were lightly framed (Flecker 2000: 201, 203, 206, 209; Vosmer 2007: 62, 182). However, as we have previously seen, their framing appears not excessively light and spaced apart when compared to that of watercraft of similar period from other regions, such as the Mediterranean and the North Sea. While it is true that plank sewing provides most of the hull strength in a sewn boat, evidence from al-Balid suggests that frames still played an important role within the structural integrity of a vessel.

5.5 Keel

The only contribution that the al-Balid timbers make to our understanding of the keel of medieval sewn watercraft is the presence of a bevel on a single timber (Figure 5.18). Plank Wo54 has one edge cut square to the plank's surface and one bevelled at a 139˚ angle measuring 50 mm in width. The bevelled edge appears to have been present on the plank before its reuse, as indicated by traces of bitumen luting on its edge. Moreover, the holes along the bevelled edge are not perpendicular to the plank's surface but at an angle matching that of the edge, indicating that they were drilled after the edge was cut. Since the edges of the other timbers from al-Balid are generally square to a plank's surface, evidence from Wo54 suggests the interpretation of the plank as a garboard, the first strake of the hull of a ship that is connected to the keel. While one edge of Wo54 is square and was butted to the adjacent plank, the bevelled

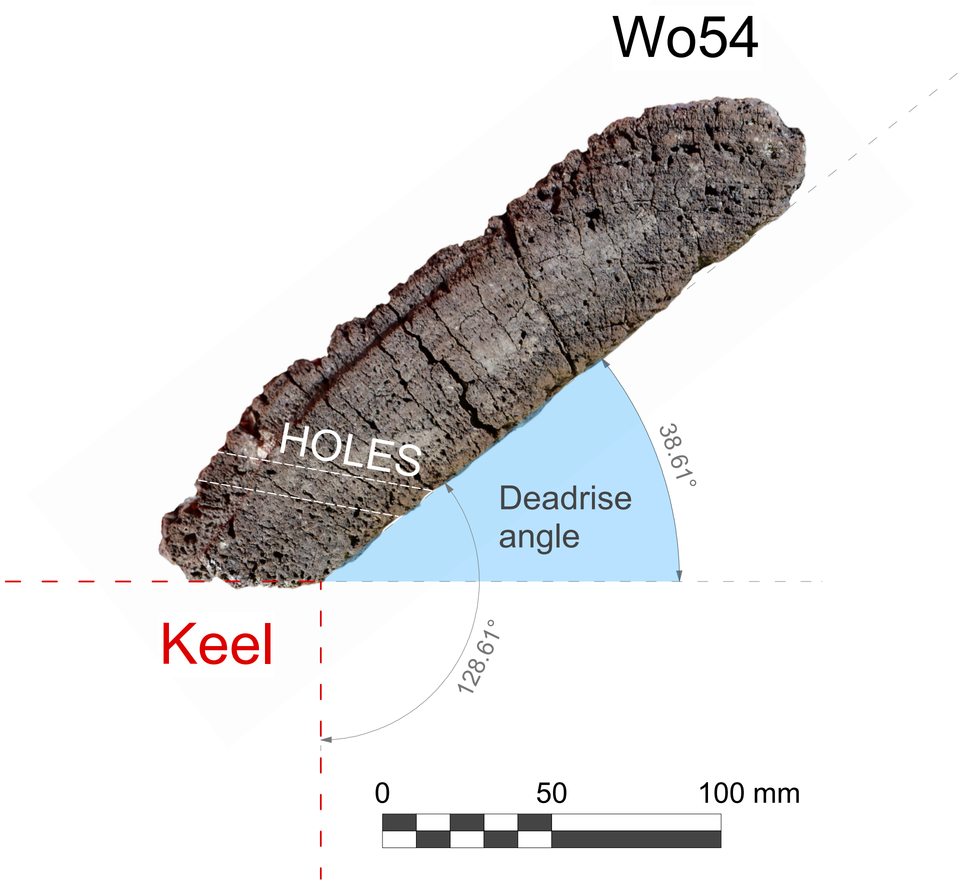


Figure 5.18: Hypothetical reconstruction of Wo54's position on the keel. (Photo: Author)

edge would have had to sit on the keel because garboards are usually angled and not perpendicular to the top surface of the keel, particularly amidships.

Generally, in sewn-plank construction, the lower edge of a garboard is fitted into rabbets that are carved onto the top of the keel (Prados 1996: 100; Vosmer 1997: 231) (Figure 5.19). These provide a tight joint between the keel and the garboards and prevent lateral movement of the strakes. Although, timber Wo54 does not provide definitive information as to whether the garboard strake was fitted inside rabbets or simply laid on the keel's top surface, there is a small amount of evidence pointing to the latter. The edge of the garboard inset into the rebate is usually slightly tapered to facilitate the fitting, rather than bevelled as in the case of Wo54. Also, the presence of two dowels on the bevelled edge of timber Wo54 indicates that sewing was not the only fastening system between the garboard and the keel, but that their fixing also relied on the use of dowels. This evidence might indeed point to the absence of rabbets, whose function of preventing lateral movements of the planks would be achieved by a series of evenly spaced dowels. The keel of the 9th-century Belitung wreck was not rabbeted to accommodate the garboards; rather the planks were laid directly on its surface (Flecker 2000: 202). One of its noticeable features was the presence of square lugs spaced along the centre line of its top surface. Although there is no definitive explanation for their function, the lugs are likely to have had a similar purpose as rabbets in preventing slippage of the garboard strakes by providing lateral support (2000: 202). The construction team of *Jewel of Muscat*, the design of which was primarily based on the Belitung wreck, experimented with this feature by carving lugs along the keel (Vosmer 2010: 123) (Figure 5.20). These proved a valid method of avoiding the shift of planks towards the centre of the keel, even without the use of dowels. There are also more recent ethnographic examples such as the two *kambārīs* on display in Sur, and the Museum of Frankincense Land in al-Balid, Oman, showing that rabbets are not always employed in the keel–garboard assemblage of sewn boats (Weismann 2019: 350).

Figure 5.19: Rabbets on the keel of a *kambārī*, southern Oman. (Photo courtesy of Tom Vosmer)

Timber Wo54 also offers a rough idea of the sided dimension of the keel. The surface of the bevelled edge of the plank measures 50 mm, meaning that with two garboards, one on each side, the keel had at least a sided dimension of 100 mm. These figures are similar to those of the Belitung shipwreck where, according to Flecker's drawings (2000: 201), the edge of the garboards laying on the keel was approximately 45 mm. The lugs carved on the keel of the Belitung wreck, and supposedly used in place of rabbets, measured 40 mm in width. If the keel that timber Wo54 was fitted into had similar devices, its sided dimension would be around 140 mm, which is the same size of that of the Belitung wreck (Flecker 2000: 201).

Figure 5.20: Lugs carved on the keel of *Jewel of Muscat* based on the evidence from the Belitung shipwreck. (Photo: Author)

The implication of evidence from Wo54 is that the timber almost certainly belonged to a seagoing vessel. Different environments and variations in coastal topography were the main factors in determining the difference in a hull's bottom and, generally, ships with a keel are better suited for sailing in open seas than plank-bottomed vessels, which are suited to coastal and tidal waters, and riverine navigation. By placing the bevelled edge of timber Wo54 on a hypothetical keel, the angle formed by the plank with the vertical plane (the moulded face of the keel) is 128˚. The angle formed by the plank with the horizontal plane, called a "deadrise" in nautical terminology, measures 38˚ (Figure 5.18). The deadrise on Wo54 is significant and, if the plank was on the keel at amidships, it might indicate a vessel with a sharp V-shaped hull section and a deep draft, meaning it sits deeper in the water and can handle rough sea conditions. The thickness of plank Wo54, measuring almost 60 mm, suggests that the ship was of considerable size. A keeled ship with significant deadrise and size could have easily been a vessel engaged in long-distance trade in the Indian Ocean, of which al-Balid was one of the main centres.

Along with keeled seagoing cargo ships, flat-bottomed boats could have also been used in al-Balid, and some of the sewn planks discovered on the site could have been part of the latter. The shallow lagoon surrounding al-Balid, as well as others scattered along the coast of southern Oman, would have offered an ideal environment for their use.

The timbers of al-Balid provide no other information about the keel of Indian Ocean watercraft in the medieval period. Beyond the limited evidence from plank Wo54, other sources, such as archaeological, iconographic and experimental data, must be consulted in order to gain a glimpse of the size and shape of the keel of sewn vessels in the region. The only documented evidence of a keel of an Indian Ocean sewn vessel comes from the Belitung shipwreck.[28] Only partially excavated, it had a U-section, 15 cm moulded and 14 cm sided, with an estimated length of 15.3 m (2000: 200-201). One interesting aspect emerging from this keel is that it appears weak and lightly built in relation to the size of the vessel (2000: 202). Vosmer states that light construction is a common feature of Indian Ocean sewn boats (2005: 182), especially if compared with Mediterranean boatbuilding standards in similar periods (Steffy 1994: 80). Vosmer also remarks that one of the reasons for this could be the scarce availability of materials, which forced boatbuilders to economise on wood as far as possible

[28] The Phanom-Surin shipwreck has a keel (Vosmer and Komoot, personal communication, October 2018), but no information has been provided regarding its size as the wreck has not yet been excavated.

(2007: 178). This would certainly be true in the case of recent sewn boats built in Arabia, such as *kambārī*s, which appear lightly built with a narrow keel and very basic construction elements, reflecting a short supply of timber in the region. However, in the Belitung wreck, the weakness of the keel was counterbalanced by a massive keelson placed on and locked to the frames, increasing the rigidity and structural strength of the hull (Flecker 2000: 203). The presence of a keelson, which is much larger than the keel, seems to exclude the fact that the boatbuilders of the Belitung ship lacked materials. Rather, a keel with small sided and moulded dimensions appears to be a distinctive feature of sewn-plank construction. Although being the backbone of the ship, the keel plays a limited role in the structural integrity of sewn-built vessels, which rely mainly on the sewing between the planks. The closely spaced stitches of a sewn boat distribute the fastening forces and create a strong monocoque hull in which the planking represents the primary structure, making a large and heavy keel unnecessary (Vosmer 2007: 158). This aspect was evident in *Jewel of Muscat* at the end of its passage. The keel of the ship was a replica of that of the Belitung wreck, and looked weak compared to the size of the hull. However, when the boat was lifted for cleaning before being installed in the Maritime Experiential Museum on Sentosa Island in Singapore, the keel showed no distortion and remained perfectly straight (Burningham 2019: 339). Burningham remarked that that was unusual because some distortion always occurs when a wooden ship is lifted with slings because of the considerable forces in limited areas of the keel. The coir cordage that held the planks together was the main element of the hull's structural strength conferring rigidity to the keel, which did not bend under load.

Evidence from timber Wo54 tells us nothing about the shape of the keel either and, once again, we need to turn to the Belitung wreck for information. Despite being the

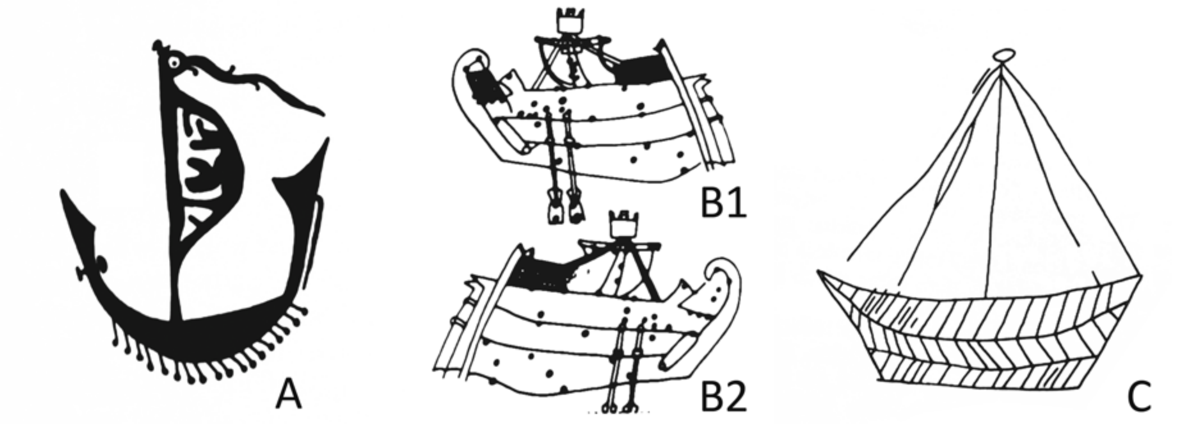


Figure 5.21: A variety of keel profiles from iconographic sources: (A) curved keel vessel on a 9th-century ceramic vessel from Nishapur, Iran (from Nicolle 1989: 170, fig. 5). (B1-2) illustrations of *Argo* from the *Ṣuwar al-kawākib* (from Nicolle 1989: 173-175, figs. 14a-b. (C) a boat with a straight keel from Husuni Kubwa, Kilwa, Tanzania (from Nicolle 1989: 183-184, fig. 48).

only archaeological evidence for a keel of an Indian Ocean sewn vessel, data evidenced by the keel of the shipwreck are nevertheless limited. The part of the keel exposed was straight, with the fore tip curving upwards to accommodate the stem post, the foot of which was fitted into a mortise cut on the fore tip surface (2000: 201). According to Burningham, who designed *Jewel of Muscat* on evidence from the Belitung wreck (2019: 339), the keel of the wreck probably curved upward towards the stern[29] (Nick Burningham, personal communication, 17 September 2019).

Iconography can be called upon to provide further information regarding the shape of the keel of Indian Ocean medieval watercraft. Illustrated sources of Islamic vessels, such as those collected by Nicolle (1989), suggest that keels of these watercraft could be either straight, rockered or curved. For example, an illustration of a 9th-century

[29] The distribution and volume of the cargo, as well as the keelson widening at the stern, suggest a "water drop" shape with the aft part of the boat being more rounded and capacious than the bow. Such a hull shape would have been difficult to achieve with a straight keel without excessively twisting and bending the first two or three strakes but this would have put considerable strain on the sewing. Traditional Omani *battīl* has similar hull lines, with the stern fuller than the bow, and a keel gently curving upwards towards the stern (Vosmer 2010: 122). Therefore, a rockered keel was a structural solution to the problem of a very full lower stern shape and also based on ethnographic evidence.

ceramic plate from Nishapur, Iran (Nicolle 1989: 170, fig. 5) (Figure 5.21(A)), and graffito discovered during the excavation of the port of Siraf, Iran, and dated to the 11th century, clearly show a crescent-shaped vessel, perhaps suggesting that the keel was slightly curved (Nicolle 1989: 172-173, fig. 10). The *Kitāb ṣuwar al-kawākib al-thābita* (*The Book of the Constellations of Fixed Stars*) by al-Ṣūfī provides illustrations of the *Argo* (Figure 5.21(B1-2))*,* believed by Nicolle to be a representation of a ship from either the Gulf or the Indian Ocean, showing two vessels whose keel is slightly curved upwards at the stern (1989: 173-175, fig. 14a-b), with a profile similar to that of a *battīl*. Along with curved keels, drawings of watercraft with straight keels are featured on a graffito discovered in a house at Husuni Kubwa, Kilwa, Tanzania, and dated to the 15th–16th centuries.

5.6 Stem and Stern Posts

As with the keel, there is no direct evidence for stem or sternposts in the al-Balid dataset. Timber 823.B3.98.1235, that features holes near its edge without rebates, might be interpreted as part of a stem or sternpost but the evidence is too fragmentary to be considered definitive (Figure 5.22(A)). This plank is among the thickest of the dataset, exceeding 40 mm, and has relatively large holes with an average diameter of 12 mm and evenly spaced apart (72 mm average). The thickness of the timber might appear small for stem or sternposts but ethnographic data from recent sewn, or partially sewn, vessels shows that these construction elements are, indeed, often narrow. The stem of the *battīl*, for example, can be as thin as a plank (Weismann et al. 2014: 427) (Figure 5.22(B)). Meanwhile the stem and stern of the *kambārī* have sided dimensions that are often just twice the thickness of the hull planks, measuring 40–50 mm and hence very similar to the al-Balid timber (Vosmer 1997: 229, fig. 16;

Figure 5.22: Timber 823 B-3/98-1235 (A) and the thin stem post of a *kambārī*, Museum of the Frankincense Land, Salalah, Oman (B). (Photos: Author)

Weismann et al. 2019: 353, Table 2, fig. 13). The stem and sternposts of these watercraft are particularly narrow because they were generally sewn to the hood ends of the planks after the hull planking, or part of it, was already assembled and fastened. Light scantlings were also characteristics of the 9th-century Belitung shipwreck, where the stem post was 140 mm sided and 230 mm moulded (Flecker 2000: 201, fig. 4). All the above examples further indicate that sewn vessels were built lightly due to the particular nature of sewn-plank construction. As previously seen in the case of the keel, weak stem or sternposts do not compromise the overall strength of a sewn vessel, which rely mainly on the sewing.

Timber 823.B3.98.1235 shows no evidence of rabbets on its preserved edge. Rabbets are used to fit and lock the hood ends of hull planks but archaeological and ethnographic data have shown that these were not always used (Figure 5.23). Planks can be simply butted against stem or sternposts, as seen in the Belitung wreck (Flecker 2000: 202) and Yemeni sewn *sanbūq* (Prados 1996: 103), or fitted into a

Figure 5.23: Hood ends of *Jewel of Muscat*'s second strake butted against the stem post (A). Detail of the inner face of the stempost without rabbets (B). (Photos: Author)

single shallow groove carved into the inner face of the stem post, as in the case of the *kambārī* (Weismann et al. 2019: 350).

The al-Balid timbers might offer further insights into the stem or sternposts of Indian Ocean sewn boats. Plank Wo86 has a diagonal edge at one end that might indicate a hood end, which is the part of the plank that is attached to the stem or sternpost (Figure 5.24). The angle of Wo86 matches that of the stem post of the *kambārī* (28˚ from horizontal) on display at the Museum of Frankincense Land at al-Balid, Oman (Author personal observation, May 2017). This similarity might reinforce interpretation of the plank as a hood end of a small fishing vessel, probably the size of the Omani sewn vessel. However, the end of timber Wo86 could also be a scarf, employed to join two planks on the same strake, in a similar way observed on timber BA0604128.73.

No other information about the stem or sternposts is provided by the al-Balid timbers, and to gain an idea of what the bow of a medieval sewn vessel would have looked like

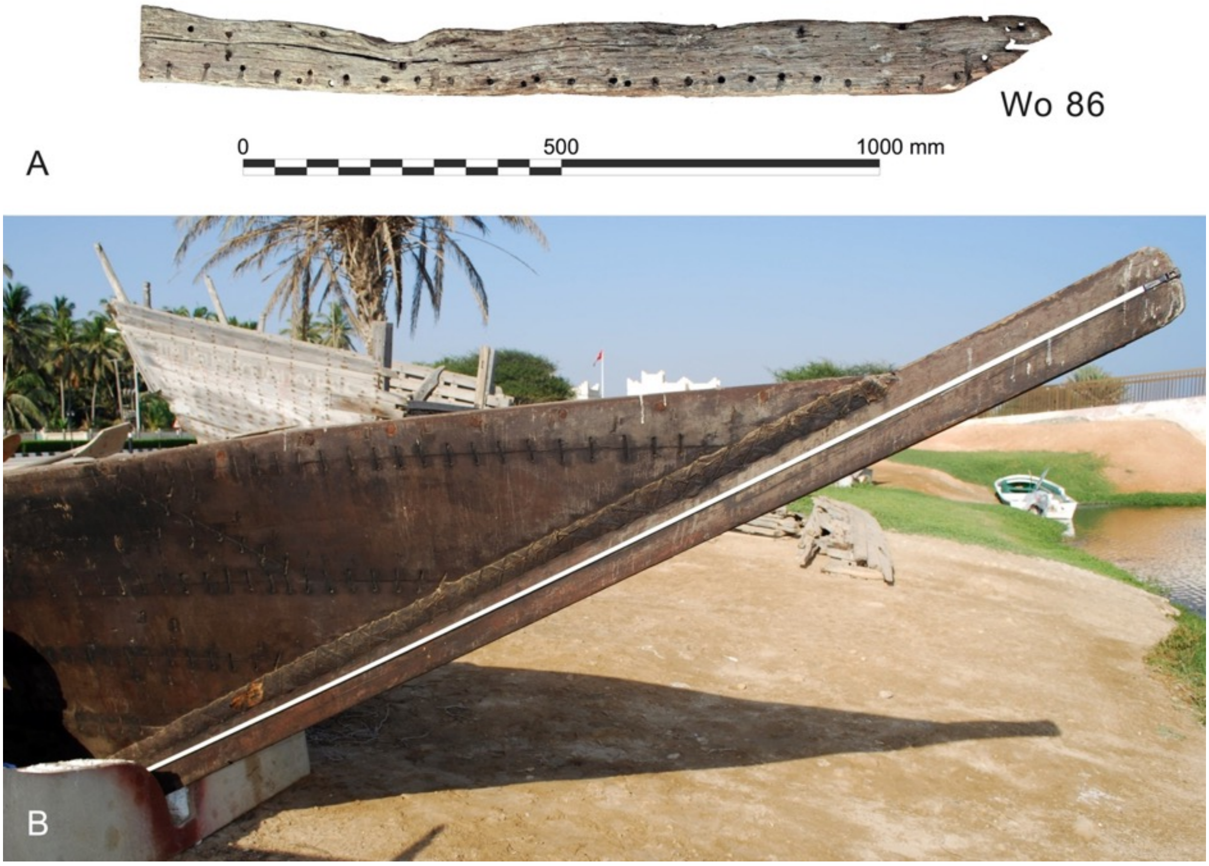


Figure 5.24: Timber Wo86 with a diagonal end (A) at a similar angle to the hood ends on the bow of a *kambārī*, Oman (B). (Photos: Author)

evidence from the Belitung shipwreck needs to be examined. According to a technical drawing provided by Flecker (2000: 201, fig. 4) the stem post was shaped from a single log and fitted onto the forefoot of the keel with a mortise-and-tenon joint, onto which it was sewn with ropes.

Meanwhile, little information about the stem and stern is available from the 8^{th}-century Phanom-Surin shipwreck. This large sewn vessel lies in the mud and only exploratory excavation has been carried out to date. There is very little published evidence about the wreck, and only a few photographs that show only one end of the ship (Jumprom 2014: 1-2, fig. 1). An image, kindly provided by Abhirada Komoot, illustrates this end of the shipwreck emerging from the mud, which is thought to be the bow (Tom Vosmer personal communication, 2018) (Figure 2.7). Only the top half is visible but the similarities between the post of the Phanom-Surin and the stem post of the Belitung wreck are noticeable.

To conclude, the timbers of al-Balid provide clues about stem or sternpost arrangements but these remain mostly speculative. Only a few pieces of archaeological evidence, such as the Belitung and Phanom-Surin wrecks, yield information regarding these structural elements, which indicate double-ended hull shapes, as discussed below. Finally, studies of more recent sewn watercraft of the Indian Ocean reveal strong similarities between these and medieval vessels, confirming the practice of light construction and highlighting the flexibility of sewn hulls.

5.7 Other Maritime Remains

Excavations at al-Balid brought to light evidence of other possible ship construction elements and maritime tools apart from easily recognisable planks and beams. These artefacts suggest a function probably associated with either boatbuilding or seafaring. This section provides an interpretation of these elements, and contextualises them within data from archaeological, historical and ethnographic evidence from the Indian Ocean.

5.7.1 Cleats (zand)

As noted in Chapter 3 (Section 3.5.3), there are a series of wooden handles or cleats of different sizes and shapes. These resemble boat elements that are generally located inside the hull and above the deck of recent sewn and nailed boats of the Arabian coast and the Gulf.

Figure 5.25: Wooden brace locking a bollard in a *battīl*, Oman (A)(Photo: Author) and the oar thole pin of the QM *baggāras* (B) (Photo courtesy of Chiara Zazzaro); similar devices are also nailed to the inside of a small dugout canoe (*hūrī*) on display at the Museum of Frankincense Land, Salalah, Oman (C). (Photos: Author)

The closest match to the smallest of these objects (Wo1, Figure 3.41) is a device used to brace and lock the lower end of thole pins in traditional boats of the region. These are wooden pins that are set vertically to the sheer (gunwale) of a rowing boat and serve as a fulcrum for the oars. Similar evidence has been observed in small watercraft, ranging in length from 4–9 m, from Oman and the Gulf (Figure 5.25(B-C)). These devices also act as sockets to accommodate and lock the heel of the upright bollard near the stern of Omani *battīl*s (Figure 5.25(A)). Wo1 might, therefore, hint at a small-sized craft propelled by oars, most probably a fishing boat that would have been rowed along the coast of al-Balid.

Ethnographic examples of boats in the region provide analogies for the interpretation of the two largest examples of these artefacts. These look almost identical to a

Figure 5.26: A *zand* on the last Omani *sanbūq* in Sadah (A) and on a *shūʿī*, Muscat, Oman (B). (Photos: Author)

crescent-shaped boatbuilding element from Arabia and the Gulf called *zand*, which are attached to each side of the foredeck of a vessel and used to tie the anchor cable (Agius 2005: 165; Johnstone and Muir 1964: 311, fig. 15) (Figure 5.26(B)). Alternatively, as indicated by a *sanbūq* in Mirbat, southern Oman, they also served as cleats to tie rigging cables, such as braces and sheets[30] (Figure 5.26(A)). The rounded handles of Wo40 and Wo122, and their lack of sharp edges, make them ideal for lashing ropes around them, reinforcing the interpretation towards *zand*. Their dimensions suggest that they could belong to a medium-sized fishing or coastal trading vessel.

While these cleats could have also been part of a door lock mechanism, housing the crossbar that slid into them across the door, their discovery context, with other ship

[30] Braces and sheets are cables used to control the yard and sail of a boat. In traditional Indian Ocean sailing vessels, braces are tied to either end of the yard, while sheets are lashed to both lower corners of the sail (Al-Salimi and Staples 2019: 269, 286; Johnstone and Muir 1964: 308, 310).

remains such as planks and beams, and similarities to recent ethnographic evidence, points instead to a previous use in boats.

The cleats have not been radiocarbon dated, but the archaeological context indicates a period ranging from the 14^{th}–17^{th} centuries (Alexia Pavan, personal communication). The fact that two of these devices bear evidence of nail fastening might suggest either that they came from nailed boats or that Indian Ocean boatbuilders may have employed two different fastening methods within the same boat: sewing for the hull and nailing for other elements above deck. A similar practice was observed in the QM sewn *baggāra*s where boatbuilders lashed the lower aft cheekpieces, but preferred nails to attach the upper — forward and aft —cheek pieces, which are above the waterline (Cooper et al. 2020: 20). Perhaps, the evidence from al-Balid might also point to the builders' distrust of iron fastenings for boat parts that were extensively immersed.

5.7.2 Rigging Block Sheave

The discovery of a sheave in al-Balid's citadel provides information about the rigging of medieval Indian Ocean vessels. Its size suggests that it belonged to a very large block, and offers insights into its use and function.

Blocks are used to raise heavy items, and in combination with others in tackles, used to gain mechanical advantage. The evidence from al-Balid may not necessarily indicate a maritime context. Blocks could have been used to lift weights during the construction of buildings on the site. Nevertheless, the fact that sheave Wo48 was discovered in the same context as other ship remains makes it more likely to have come from a boat. Blocks are a necessary piece of ship equipment, where they are

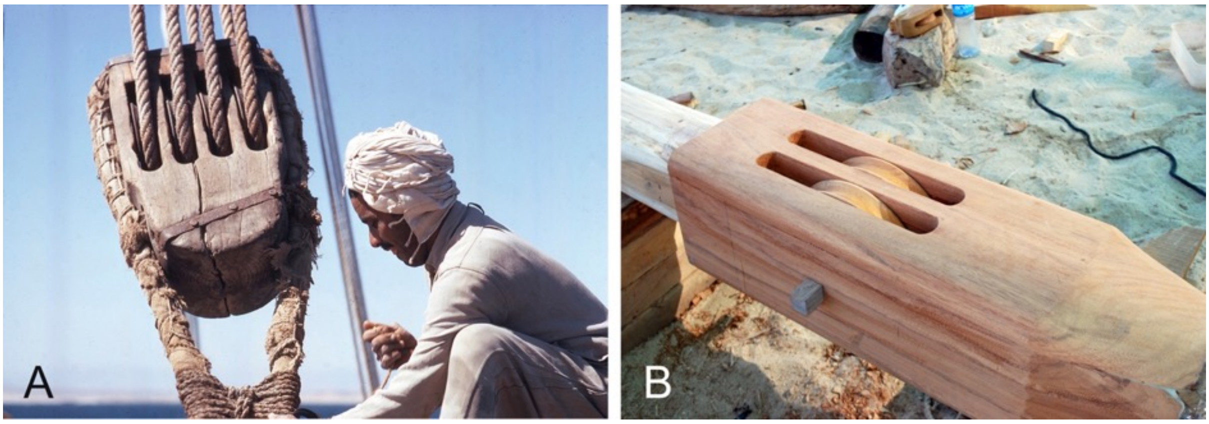


Figure 5.27: Large halyard block of a Kuwaiti *būm* (A) (Photo courtesy of Marion Kaplan). Sheaves in *Jewel of Muscat*'s main masthead (B) (Photo: Author)

employed in the rigging to hoist and lower the yard to which the sail is attached. They also help to apply purchase to cables, as in the case of the stays and shrouds that support the mast, or the sheets and tacks that control the sail.

The diameter of the al-Balid sheave suggests a large block measuring at least 320 mm in thickness. Due to its massive size, it is unlikely to be from a stay or shroud, which generally have smaller blocks. The timber may, instead, be one of the sheaves of the lower or upper blocks of the halyard tackle (*ʿubaydār* and *jāmaʿa* in Arabic), which was used to raise and lower the sail on a large vessel (Figure 5.27(A)) (Johnstone and Muir 1964: 315). It could also be one of the sheaves housed in the head of the mast through which the halyard cable is reeved in wooden watercraft of the region (Johnstone and Muir 1964: 327) (Figure 5.27(B)). Similarly, a sheave was also located at the fore end of the bowsprit, a long wooden timber projecting beyond the bow of a ship used to extend the forward lower tip of the sail (tack) (Al-Salimi and Staples 2019: 272; Villiers 2006: 97). The thickness of the sheave also provides information about the size of the rope, which can be estimated at between 35 mm and 40 mm in diameter.

	Size	Wo48	*Jewel of Muscat*[1]	*Sohar*[1]	*Baggala* from Pâris[2]	*Ghanja Fatah al-Khair*[3]
Main Halyard Block Sheave	Diameter (mm)	**320**	200	320	320	c. 340
	Thickness (mm)	**45**	30	45	N.A.	c. 50
Masthead Sheave	Diameter (mm)	**320**	310	c. 340	280	c. 330
	Thickness (mm)	**45**	35	70	N.A.	N.A.
Vessel Length			18 m	23 m	27 m	34.2 m
[1] Author personal observation, Oman 2009–10. [2] Pâris 1886: Plate 125. [3] Dziamski and Weismann 2010: 30, 131, fig. 17.5.						

Table 5.1: Dimensions of the al-Balid sheave in comparison to the sheaves from the halyard block and mast head on other watercraft of the Indian Ocean.

Interestingly, the diameter of the al-Balid sheave matches that of the halyard blocks of *Sohar*, the *ghanja Fatah Al Khair* on display in Sur and the Arab *baggala* documented by Admiral Pâris (1886: Pl. 125). The masthead sheaves of these vessels, as well as those of *Jewel of Muscat*, also have dimensions similar to timber Wo48, suggesting that it may have belonged to a relatively large vessel ranging from 18–34 m in length (Table 5.1).

Timber Wo48 looks almost identical to a wooden disk (WO 321) found at Quseir al-Qadim, also interpreted as a sheave and dated to the 2nd century (Blue et al. 2011: 189). The archaeological context of Wo48 probably makes it more recent than the artefact from Quseir al-Qadim but no date analyses have yet been carried out. Both the evidence from al-Balid and Quseir al-Qadim have no grooved edge, showing a bevelled side instead. This bevelled edge is unlikely to have been initially present on the sheave; it would have caused the rope threaded through the block to become jammed, making it useless. We may assume that this feature is the result of a later intervention, most probably carried out by the builders of al-Balid when they recycled timber in the citadel. It is, however, interesting that both the sheaves from al-Balid and Quseir al-Qadim share this same feature, perhaps indicating that both were reused in a terrestrial context with a similar function. While it is not possible to determine the purpose of these bevelled edges, it is nevertheless curious that they occurred on both Roman and Islamic artefacts, perhaps suggesting a similar practice carried out in two different geographical areas and periods.

To conclude, evidence from the al-Balid sheave is significant because archaeological records of rigging in the Indian Ocean during the medieval period are practically non-existent, apart from a possible fragment of a running stay from Quseir al-Qadim (Blue et al. 2011: 197-198). Our knowledge of the rigging is predominantly based on iconographic sources such as those from the *Maqāmāt* of al-Hariri, East Africa and India (Deloche 2009: 556-557; 2010: 220-222; Garlake and Garlake 1964: 198-201; Nicolle 1989), while textual documents are vague about this aspect. However, these illustrations provide stylised versions of the rigging, while blocks and tackles are never depicted.

Nevertheless, the evidence from al-Balid is useful because it hints at the possible function of the block and offers insights into the size of the vessel. Moreover, it shows similarities with archaeological evidence from a similar period, such as that from Quseir al-Qadim, as well as with ethnographic records from the region.

5.7.3 Sounding Device (buld)?

The round stone object Wo81 (Figure 3.42) discovered in the al-Balid citadel also points to a device used in a maritime context, either as a weight or sounding device. The shape and material of the tool resemble the diving weights used by pearl divers

Figure 5.28: Stone objects (weights?) on display at the NMoQ. The one of the left is almost identical to that discovered in al-Balid. (Photo: Author)

(*hajar lasif*) in order to reach the seabed (Agius 2005: 147; Shamlan 2000: 106-107). However, the size and light weight of the al-Balid object makes it unlikely to be a diver's weight, which generally ranged between 4.5 and 6.4 kg (Carter 2012: 220; Lorimer 1915: 2230). There is an almost identical object on display in the newly built National Museum of Qatar (NMoQ) (Figure 5.28).

The curator of NMoQ, Alexandrine Guerin, describes it as a net sinker or pearling weight (Personal communication, June 2020). The object (INV. Arc.2010.8.217, NMoQ - Gallery 3 - 0306-9) was discovered on the Islamic site of al-Rubaiqa (also al-Rubayaqa) during the 2010 excavation. Its size is very similar to Wo81 from al-Balid, and both have the same shape, although the al-Balid one is more pot-bellied. The main difference is the weight, measuring 265 gm in that from NMoQ and 640 gm in the al-Balid object. The archaeological context of the discovery of the Qatar object is dated to the 18th–19th century, while that of al-Balid is most probably from the 17th century according to the archaeological context of its discovery.

Figure 5.29: Reconstruction of a traditional Indian Ocean sounding lead (*buld* or *bild*). (Photo: Author)

While its weight might point to a net sinker, its material, hematite, raises a few doubts about this interpretation. Evidence would imply that the net was most probably used by fishermen operating along the coast around al-Balid but hematite is only found in northern Oman, near the al-Batinah region, and sources are not very close to the coast (Hudson Institute of Mineralogy 2020). It is, therefore, quite unlikely that Dhofari fishermen would have used imported — and most probably valuable and precious — stone for a function that could have been achieved with a variety of materials available locally. Coastal fishing communities could have used any small rock, pebble or even ceramic sherd as net sinkers. The evidence suggests instead a different purpose for the al-Balid object in order to justify the use of such a particular mineral.

Because of its size and shape, the object can perhaps be interpreted as a depth sounding stone, called *buld* or *bild* in Arabic (Figure 5.29) (Johnstone and Muir 1964: 302; Tibbetts 1981: 278). Ships' captains used this by dropping it over the side of a vessel to measure the depth of the sea bottom, a practice that was crucial to avoid running the ship aground, especially in particularly difficult bodies of water, such as the Red Sea with its shallow reef. Ibn Mājid, translated by Tibbetts (1981: 238, 271), states that the sounding line (*al-buld*) was one of the essential instruments used by mariners in the Indian Ocean, and that the sea floor bathymetry was often determinant in finding a vessel's position and course. The tool also served to determine when to drop the anchor. The *buld* was generally made of lead, but stone could be used if the former was not available[31]. Shihāb, quite generically, remarks that the lack of metal in the Indian Ocean forced people from that region to use stone for their sounding tools (1987: 220).

One additional function of the *buld* was to collect samples of sediments from the sea floor, which stuck either in a recess carved on its lower end or to a lump of tallow applied to its bottom (Agius 2005: 178). As for its depth, the composition of the seabed provided essential clues, to the eyes of an experienced captain, about the nature of the holding ground (sand, mud, rock) and position of the vessel. For example, the two shores of the Red Sea, Sudanese and Arabian, could be easily recognised because the sea bottom was sandy in the former while rocks and sand were characteristics of the latter (Tibbetts 1981: 278).

The object from al-Balid might also have been associated with the pearl-diving activities. The practice of measuring the sea's depth and collecting specimens from its bed was also used within a pearling context, where the quality of pearl banks often depends on the sea bed. A muddy bottom is a poor habitat for oysters, and a hazardous working environment for divers (Carter 2012: 213), therefore the captain of a pearling vessel would test the sea floor in order to choose the best spot for diving (Shamlan 2000: 135). The Persian scholar and polymath al-Bīrūni describes the same

[31] The density of hematite is 5.3 gm/cubic centimetre, more than double that of limestone (average 2.16gm/cm^3), and nearly double the density of basalt (2.9gm/cm^3) (Barhelmy 1997-2014).

method in the 11th century (in Carter 2012: 42). While the best and most famous pearling spots were those along both coasts of the Gulf, 10th–11th century historical sources report that pearls were also found in a number of areas in the Indian Ocean including the Dahlak Islands, Qulzum in the Red Sea, areas off the coast of Aden and Shihr in Yemen, Muscat and Masirah in Oman, Socotra, Lujjah Barbar off the northern coast of Somalia, and south of Sofalah in Mozambique, East Africa (Carter 2012: 38-41). Therefore, is not unlikely that the al-Balid object Wo81 could have also been a sounding device used for pearling due to the presence of pearling beds relatively close to the port, such as the Dahlak Islands, Aden, Shihr and Socotra.

The al-Balid artefact could also be a plumb bob (also called *buld*), a tool widely used in general building to determine the vertical reference line, or plumb (Johnstone and Muir 1964: 302). The device consists of a weight with a pointed end, generally on the bottom, suspended from a string tied to its top. The presence of a plumb bob would allude to both terrestrial and maritime construction at al-Balid. However, this tool is particularly useful in boatbuilding when aligning various construction elements, particularly during the fitting of the stem and sternposts with the keel. The *buld* was often associated with a wooden or brass quadrant called *hindāsa* (*hindāza, handāza*), which was lashed to its corner with a string (Figure 5.30). Lines called *akhnān* (sing. *khann*), which were carved on the quadrant, divided its surface into fifteen segments measuring 6˚ each and served to measure the angle of specific elements, such as the rake of the stem and sternposts (Agius 2002: 148; Al-Hijji 2001: 69; Johnstone and Muir 1964: 322).

Lastly, object Wo81 could also be a scale or loom weight. The physical characteristics of hematite, such as density and hardness, make it ideal for this purpose, as indicated

Figure 5.30: A Zanzibari shipwright uses a wooden quadrant (*hindāsa*) to determine the angle of the stem post of a vessel. (Photo: Author)

by archaeological evidence discovered throughout the Near East from the late 3rd millennium BCE (Hafford 2005; Moorey 1994: 84).

5.8 Forms of Medieval Indian Ocean Sewn Vessels

5.8.1 Hull Shape

Bow and Stern

The al-Balid timbers might offer further insights into the shape of hulls of medieval Indian Ocean sewn boats, particularly their bows and sterns. Assuming that the end of timber Wo86 is a hood end, its angle would match that of the bow or the stern of the vessel, providing clues about its profile. The angle, measuring 28˚ from the horizontal, indicates a considerable rake that is more likely to represent the bow of a boat than the stern. The rake of the stem measured on recent Indian Ocean sewn vessels of similar size and shape ranges from 28˚ on a *kambārī* on display at the Museum of Frankincense Land at al-Balid, Salalah (Author, personal observation, May 2017) and 43˚ on a Yemeni sewn *sanbūq* (Prados 1996: 191).

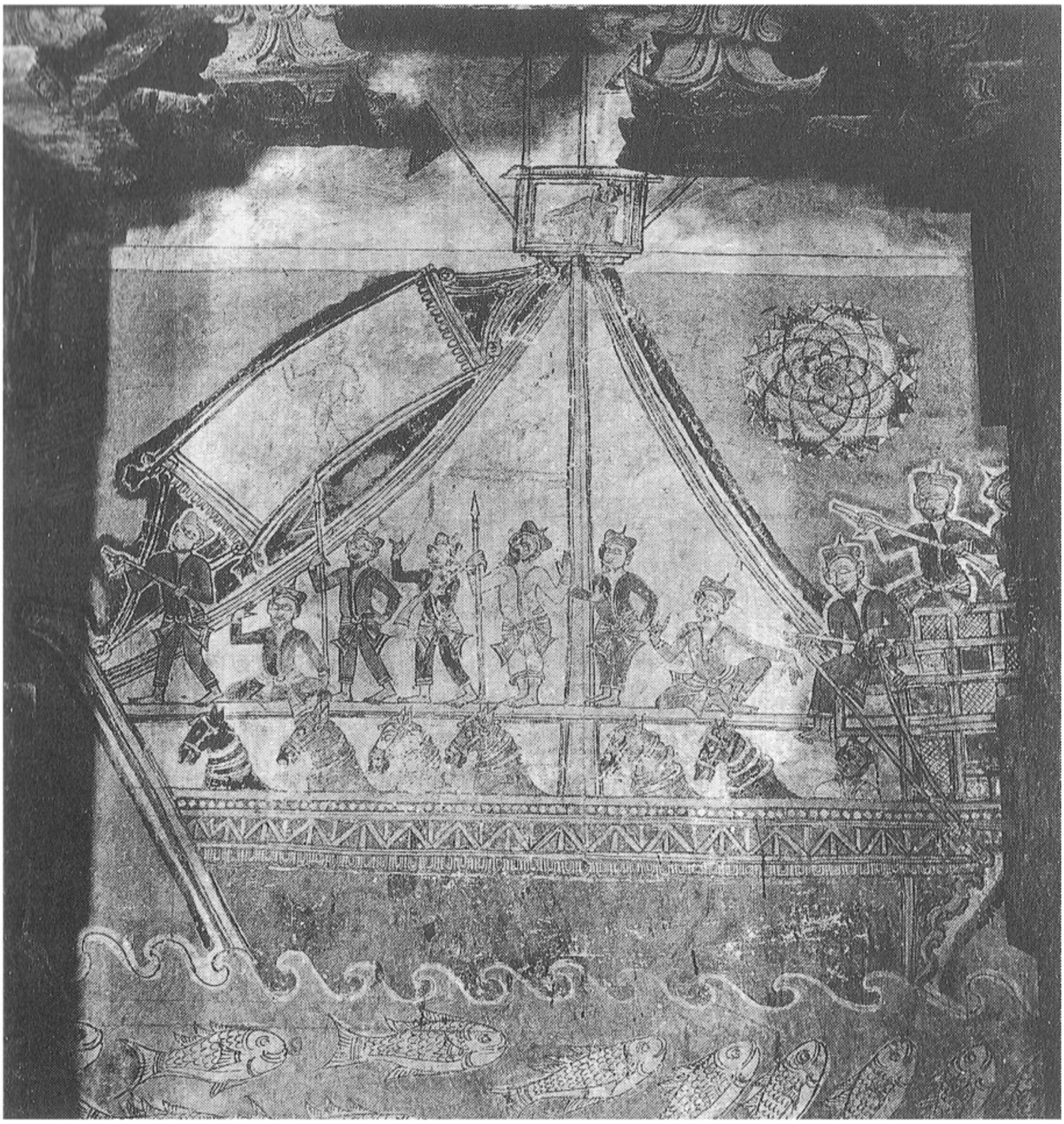


Figure 5.31: A painted panel at the Narumpunatasāmi temple, Tiruppudaimarudur, southern India, depicting a vessel transporting horses (16th century) (Photo: Guy 2004: 54)

The boat where timber Wo86 came from was almost certainly double-ended with both stem and stern raked. This particular hull profile persisted for millennia in the Indian

Ocean and suggests a strong link between the fastening method and hull design.[32] Vosmer (2007: 224) points out that the double-ended profile is tightly bound to sewn-plank construction because it is easier to stitch a vessel whose planking converges to a stem or sternpost rather than to the sharp edge of a transom.[33]

A double-ended shape with raking stem and sternposts remained a distinctive feature of western Indian Ocean vessels until the arrival of the Portuguese in the 16th century (Deloche 2010: 209; Hornell 1942: 22; Johnstone and Muir 1962: 62). Iconographic evidence, such as the 13th-century *Maqāmāt* (Hourani 1963: 98-99, fig.7; Nicolle 1989: 178-179, fig. 24a) and the painted panel in the Narumpunatasāmi temple of Tiruppudaimarudur (Deloche 2009: 556, fig. 6), in southern India, approximately dated to the mid-16th century, show vessels with similar features (Figure 5.31). An angle of approximately 60˚ appears to be the preferred bow rake in some representations of medieval vessels from the Indian Ocean, such as those from the *Maqāmāt* in St. Petersburg (1225-1235 CE) (Nicolle 1989: 176-177, fig. 23) and the Tiruppudaimarudur fresco (Deloche 2009: 556, fig. 6). Interestingly, this evidence is very similar with that observed in the Belitung wreck, where the stem post had a 61˚ rake (Flecker 2000: 201; Vosmer 2007: 180). Two sewn ships depicted in another

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[32] Stamps and cylinder seals discovered at Failaka, Kuwait, and dated to the early 2nd millennium BCE illustrate that a hull shape with a straight overhanging bow and stern was characteristic of Bronze Age watercraft involved in the exchange network between Mesopotamia and the Indus Valley in the late 3rd and early 2nd millennium BCE (Johnstone 1980: 173; Potts 1995: 566). These were most probably wooden vessels fastened with ropes, perhaps using a technique observed in archaeological evidence from the 3rd millennium site of RJ-2 on the eastern coast of Oman comprising bitumen coating from a Bronze Age vessel bearing impressions of wooden planks lashed with ropes (Vosmer 1996: 231; Cleuziou and Tosi 1994: 745; Cleuziou and Tosi 2000: 64).

[33] Sewn boats with a transom stern have been observed during the last twenty years in Yemen (Prados 1996: 105), Socotra (van Rensburg 2013: 272-273, fig. 57), India (Fenwick 2015: 407, fig. 22) and Oman (Vosmer 2007: 317). However, they were all originally double-ended but converted into transom-stern craft in order to fit outboard motors.

manuscript of the *Maqāmāt* illustrated by al-Wāsiṭi (123) (Nicolle 1989: 177-178, fig. 24a, c) show a less-pronounced overhang with a bow angle measuring 67˚–68˚.

The sharp angle of plank Wo86 points to a vessel with a much longer overhang than that displayed in the iconographic sources discussed above, with the bow extending far beyond the keel and the waterline. According to Deloche (1996: 209), iconographic evidence for Indian boats from the 3rd century BCE to the 15th century CE suggests that the rake of the stem post increases after the 11th century, when Indian artists started depicting watercraft with long projecting bows. In the 20th century, the rake of the stem appears significant in sewn vessels from the south Arabian coast, such as the *kambārī* (Vosmer 1997) and the Yemeni *sanbūq* (Prados 1996: 109), and from East Africa, such as the *mtepe* (Gilbert 1998: 44, fig. 1) (Figure 5.32) and the Somali *beden* (Chittick 1980: 303, fig. 8). According to Vosmer (2007: 304) the overhang of the bow could be related to the sail arrangement, "making a bowsprit not needed to balance the sail plan with the hull profile." Also, a forward-raked bow helps to cut

Figure 5.32: Model of a *mtepe* on display at the Institute of Arab and Islamic Studies, University of Exeter, UK (Photo: Author)

through water, keeping the foredeck dry in rough seas, and extends the deck area of the vessel, providing more space for the crew and passengers. Length being equal, a vessel with a long overhang requires less material in its construction than one with less rake or a near-vertical stem, which saves on timber required for the keel and planking. Friedrichsen's description of a *mtepe* in Zanzibar notes the significant rake of the vessel's bow and states that it was capable of sailing at great speed (Prins 1982: 90-91). The angle of the bow, as that of plank Wo86, could also have depended on the environment where the vessel was used and its function, and it would have suited the condition of southern Oman, the coast of which is characterised by heavy surf.

Iconographic sources offer insights into bow and stern profiles of medieval vessels of the Indian Ocean, revealing a variety of forms and perhaps alluding to different regional traditions. Curved and long stem and sternposts are depicted on a 9th-century ceramic plate from Nishapur (Nicolle 1989: 169-171, fig. 5), which although very stylised, provides information not only regarding the curvature of the posts but also about their forward tips (heads), which seem to be decorated with a particular shape. A similar profile is shown in a boat illustrated in a copy of the *Kitāb Ṣuwar al-Kawākib al-Thābita* by al-Sufi (*The Book of Fixed Stars*) dated to 1465 (Agius 2007a: 158, fig. 42), but in an earlier copy of the *Ṣuwar* (1009-10), an assumed Indian Ocean vessel has a curved stem post with a scimitar-shaped head and a straight vertical stern (Nicolle 1989: 171-172, fig. 9a). Other medieval sources, such as another copy of the *Ṣuwar* from the 12th century, provide information about the top section of the stem, depicting two almost identical vessels with the tip of the stem post curled inwards (Nicolle 1989: 173-175, fig. 14).

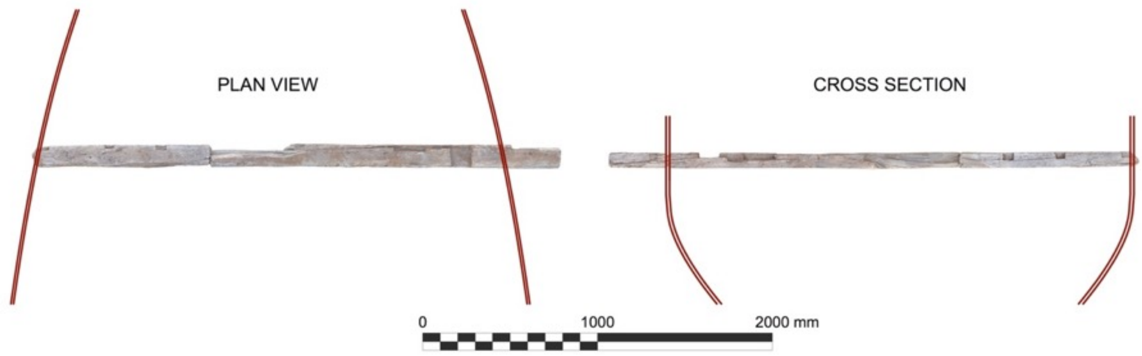


Figure 5.33: Hypothetical reconstruction of the vessel's top view and cross section at the position of beam Wo105, based on the horizontal and vertical angles of the rebates. (Image: Author)

Hull Width and Profile

Notching on the ends of the beams reflects the thickness of the planking to which they are notched and offers clues as to the size and shape of vessels. The distance between the notching on beam Wo105, the only specimen retaining both rebates at its ends, corresponds to the width of the hull at the location of the beam measuring 2.6 m.

The angle formed by the notching with the length of the beam provides clues to the possible position of the beam in the boat. On beam Wo105 this angle indicates that at the point where the beam was located, the hull profile tapered slightly towards the ends, either forward or aft from amidships. This evidence also shows that the boat was beamier than 2.6 m (Figure 5.33(A)).

Lastly, the vertical angle of the rabbet (the angle formed by the plank and the moulded surface of the beam) also provides information about the shape of the boat. In both beams this is close to 90˚, indicating that the hull was vertical at that point (Figure 5.33(B)).

5.8.2 The Size of the Vessels

Evidence from the al-Balid timbers yields insight into the size of the vessels that visited — or operated out of — the port in the medieval period. The thickness of the planks, rather than the width, is particularly useful for estimating a vessel's length. Data from the Qalhat timbers are, meanwhile, limited because the thickness could only be measured on two of the three. Of these, only one appears to be a hull plank, while the other, as discussed previously, could be the fragment of a frame. Archaeological and ethnographic evidence from the Mediterranean and the Indian Ocean indicates that plank thickness is directly related to the overall size of a vessel (McGrail 2001: 156; Belfioretti and Vosmer 2010: 116; Vosmer 2017: 200), with thicker planks corresponding to larger and more seaworthy ships. A comparison between the thicknesses of the al-Balid timbers and those provided by the archaeological and ethnographic examples of sewn vessels of the Indian Ocean offers an opportunity to speculate on the size of ships from which the planks were removed.

As we have seen in Chapter 3 (Figure 3.6), timber thickness is regularly distributed within a 22 mm and 58 mm range. Almost a third of the planks have a thickness between 22 mm and 30mm, pointing to relatively small vessels. This range appears to be the "standard" thickness of many sewn boats recorded in the Indian Ocean in the 20th century[34] (Table 5.2). One thing these sea craft have in common is their relatively small size, ranging between 6 m and 11 m in length. The only examples of relatively small sewn vessels with thick planks are from southern India, where wood is

[34] These were used on both sides of the Indian Ocean, and include the Omani *kambārī* (Vosmer 1997: 231; Vosmer 2007: 330, 333; Belfioretti and Vosmer 2010: 116), the *beden* of the northeast coast of Somalia (Chittick 1980: 299-300), the southwest Indian *masula* (Kentley 1985: 311), the Iranian sewn *baggarā*s held by QM (Cooper et al. 2020) and some vessels from Goa (Shaikh et al. 2012: 152, figs. 8-9).

VESSEL	LENGTH (m)	PLANK THICKNESS (mm)	REFERENCE
Belitung wreck	18–22*	40	(Flecker 2000: 205, 209; Flecker 2010: 106)
Phanom-Surin wreck	25–30*	70	(First Regional Office of Fine Arts 2016: 55)
Iranian *baggarā*	8-9	25	(Cooper *et al.* 2020: 9-14)
Omani *beden seyad*	11.26	45	(Ghidoni 2019: 347; Pâris 1843: plate 5)
Omani *kambārī*	9–11.7	15–25	(Vosmer 1997: 231; 2005: 330, 333; Weismann et al. 2019: 350-351)
Yemeni *sanbūq*	7–11	n/a	(Bowen 1952: 210; Prados 1996: 101-102)
Somali *beden*	10	20	(Chittick 1980: 299-300)
East African *mtepe*	15.2-20.4	n/a	(Hornell 1941: 55; Lydekker 1919: 91; Prins 1982: 89)
Indian *revenchem vodem*	12	25	(Shaikh et al. 2012: 150)
Indian *kettuvallam*	10.5	40–45	(Cooper et al. 2020: 9, 27)
Indian *masula*	4.5–10.5	22	(Kentley 1985: 303, 311)
Sri Lankan *madel paruwa*	10	29	(Kentley and Gunaratne 1987: 35; Kentley 2003: 174)
Sri Lankan *yathra dhoni*	15.2–20.4	50	(Hornell 1943: 43)
***Estimated length**			

Table 5.2: Length and plank thickness of published sewn watercraft of the western Indian Ocean.

abundant.[35] For example, a *kettuvallam* from Kerala, recently acquired by Qatar Museums has a plank thickness of 40–45 mm. The evidence provided by ethnographic research suggests that at least some of the 22–30mm-thick planks discovered in al-Balid might have previously belonged to boats not exceeding 12 m in length.

The width and distance of the notching on both ends of beam Wo105 from al-Balid points to a medium-sized vessel with 20-mm planking with a beam measuring up to 3

[35] Small boats are generally sailed near the coast and do not undertake long journeys or cross large bodies of water such as the Indian Ocean or Arabian Sea. This also means that they are usually built not too far from where they are used. At the same time, it is unlikely that maritime communities living near al-Balid would have used thick timbers to plank small boats, thus wasting precious material. Therefore, it is more probable that the thin planks in the dataset came from small vessels used along the coast of Arabia, where wood economy would have been a priority in boatbuilding.

m. Assuming a maximum length of 12 m suggested by the plank's thickness, this would indicate a beam-to-hull ratio of approximately 1:4, resulting in a relatively beamy boat. Alternatively, evidence from Wo105 might instead suggest that thin planks could have been used in larger ships.

Planks measuring 31–40 mm thick, and representing 26% of the dataset, point to medium-sized vessels. By comparison, the Belitung wreck planks measured 40 mm thick, and the overall length of the hull has been estimated between 18 m and 22 m (Flecker 2000: 205, 209; Flecker 2010: 106). The thickness of the shipwreck's planking is also the most frequent in the al-Balid timbers (five planks, 15% of the dataset), pointing to boats of a similar size to the Belitung wreck. The construction team of *Jewel of Muscat,* which measured 18 m in length, also used planks 40 mm thick. The moulded and sided dimensions of the al-Balid beams are smaller than the largest beam discovered on the Belitung wreck, which measured 250x220 mm (Flecker 2000: 207). While this might suggest that they belonged to ships smaller than that of the shipwreck, one should remember that the overall size of the beams can change according to their location in the hull. Two beams near the stern of the Belitung wreck had sided dimensions of 150 and 180 mm respectively, which is similar to that of the al-Balid beams.

The last medium-sized sewn vessels of the East African coast, the *mtepe* and *dau la mtepe*, were between 50 ft and 67 ft (approximately 15–21 m) long (Hornell 1941: 55; Lydekker 1919: 91; Prins 1965: 120; 1982: 89, 91); they could have provided additional evidence to verify whether 30–40 mm is the ideal thickness for sewn vessels with such length range.

The remaining timbers of al-Balid have a considerable thickness, ranging from 40 mm to almost 60 mm, and point to large vessels. The notching's width on beam

BA1104065.447 indicates a plank thickness of 55 mm, indicating a ship of considerable size. Phanom-Surin planks measure 70 mm thick and an approximate length of 25 m (First Regional Office of Fine Arts 2016: 55). According to Vosmer, who had access to the shipwreck during the ASEAN workshop in Thailand in 2015, the vessel could be up to 30 m long and "the planking thickness of Phanom-Surin is proportionally larger than the Belitung" (Vosmer 2017: 198). Hence, a significant number of the al-Balid timbers could have come from the hulls of significantly large ships ranging in length from 20–30 m. There are only two recent sewn vessels of the Indian Ocean within this plank-thickness range: the Indian *kettuvallam* previously mentioned and the *yathra doni* from Sri Lanka. The latter had 50-mm-thick planks and could reach up to 100 ft in length (approximately 30 m) (Vosmer 1993: 38), although it was generally 50–60 ft long (approximately 15–18 m) with a cargo capacity of 50 tons (Hornell 1941: 43).

The large sheave Wo48 (Figure 3.40) included in the al-Balid dataset was probably part of a massive pulley block, strengthening the hypothesis that some of the ships sailing to and from the port were of considerable size.

5.8.3 The Function of the Vessels

The variety of sizes of sea craft implied by the timbers from al-Balid probably reflects a diversity of functions. It is likely that some of the smaller vessels sailing around the port would have looked like the *kambārī* from Dhofar, and have had a similar use. The coastal people of southern Oman would have rowed or sailed them along the coast for fishing, as was done in the region with sewn craft until the 1980s (Vosmer 1997; Weismann et al. 2019: 347-348). Indeed, al-Balid was renowned for exporting sardines, which, along with frankincense and indigo, constituted the most commonly

Figure 5.34: A *kambārī* being used to unload cargo from a ship anchored off Salalah, Oman. (Photo courtesy of Marion Kaplan)

traded group of commodities produced locally (Zarins and Newton 2017: 73). Ibn Baṭṭūṭa (Ibn Baṭṭūṭa 1929: 113) and Ibn al-Mujāwir (Smith 1985: 85) inform us that Omanis dried sardines and used them as fodder for the horses that were exported to India, or as fertilizer.

These small sea craft would have also been used for lightering. This was also one of the main functions of *kambārī*s in Dhofar (Vosmer 1997: 231; Alian 2006: 10; Kaplan 2015: 46-47; Weismann et al. 2019: 344, fig. 3) (Figure 5.34). Due to a lack of proper harbour facilities in southern Oman until the 1970s (Alian 2006: 10; Allen 2017: 170), these sewn boats used to ferry goods and people back and forth from large cargo and transport ships anchored offshore. Ibn Baṭṭūṭa witnessed similar watercraft when he visited Zafar (al-Balid in medieval sources) in the 14th century, stating that it was customary in the city to send small vessels called "*sumbuq"* to ships arriving at the

Figure 5.35: *Jewel of Muscat* sailing off Muscat, Oman. (Photo: Author)

port (Ibn Baṭṭūṭa 1962: 383). Since the absence of harbour structures, the people of al-Balid would have probably used small-sized sewn craft to transport Arabian horses from the site to ships bound for India.

Medium-sized ships could have been used for fishing, and to transport goods and people. They could have also been used for coastal sailing, connecting maritime centres along the Arabian coast within a medium range. However, as indicated by the *mtepe*, 15–20-m vessels could also travel long distances (Hornell 1941: 62). Sea craft of similar length, such as *badan*s, *sanbūq*s and *baggarā*s/*gharookuh*s, used to sail from the Gulf to East Africa (Facey 2005: 137; Hornell 1942: 18; Jewell 1969: 59-60; Wilson 1909: 52) and even cross the Indian Ocean to reach southern India (Pâris 1843: 13-14). *Jewel of Muscat* (Figure 5.35), successfully sailed from Oman to Singapore, crossing the western Indian Ocean and the Bay of Bengal during the southwest monsoon and even skirting a cyclone (Staples 2013; Vosmer 2010; Vosmer et al. 2011).

Another maritime activity associated with medium-sized vessels could have been the transportation of pilgrims on the last stretch of their voyage through the Red Sea for the *Hajj* (the Islamic pilgrimage to Mecca). Sailing in the Red Sea was particularly challenging due to its numerous shallow reefs and unpredictable weather conditions, and large ships would generally avoid it (Ibn Baṭṭūṭa 1962: 364). Pilgrims undertaking the *Hajj* across the Indian Ocean were often transferred onto smaller boats more suitable for sailing into the Red Sea (Agius 2007a: 219), and this was also the case for cargo. Transhipment usually occurred at Aden (Agius 2013a: 86). Moreover, al-Balid was a regional pilgrim centre, and it is likely that it attracted Muslims on their journey to other holy places in Arabia (Zarins and Newton 2017: 66). According to historical sources, smaller sea craft called *jalba* carried the pilgrims on the last leg of their journey to Jeddah, the port of Mecca (Ibn Baṭṭūṭa 1962: 361). These were sewn and operated along the coasts of Yemen, Oman and the Dahlak Islands, Eritrea (Agius 2007a: 316).

Lastly, medium-sized boats could have also been used for pearling. Although this activity was carried out predominantly in the Gulf, al-Bīrūni, reported by Carter (2012: 41), informs us about the presence of pearl banks near Shihr, Yemen, not too far from al-Balid.

The thickest of al-Balid's planks point to large ocean-going cargo vessels. References to the size of Indian Ocean ships occur mostly after the medieval period, and were reported by Europeans. They are usually generic, and boat dimensions are generally expressed in estimated cargo capacity instead of length. Portuguese accounts comment on large trading ships in East Africa, such as those observed in 1569 by

Father Monclaro in Lamu that were lying on the beach in Mombasa (Prins 1986: 67) and Mozambique (Ravenstein 1898: 26), and there are similar remarks about large Indian vessels, such as those reported by Correa in Kannur (Stanley 1869: 240-242). Vasco Da Gama informs us of the arrival of "1500 Moorish vessels" at Calicut, the largest of which did not exceed 800 tons (Ravenstein 1898: 128). Of all the ships sailing in the Indian Ocean during this period, Gujarati ships are often described as being of considerable size (Cortesão 1944: 45). Ubiquitous in the Indian Ocean (Lewis 1973: 243), they generally carried 300–600 tons but could reach up to 800 tons and have a crew of a thousand men (Manguin 2012: 605-606).

The presence of large watercraft at al-Balid and Qalhat is also indicated by the discovery of several large stone anchors offshore of the two port cities (Newton and Zarins 2010: 259-260; Vosmer 2004: 400) (Figure 2.4). The largest were probably mooring anchors (Käpitan 1994) and could weigh as much as 1734 kg, like those discovered in Qalhat (Vosmer 1999a: 259, fig. 12). Using the weight of thirty stone anchors mostly from Qalhat Vosmer to estimate that ships exceeding 100 metric tonnes were in common use (1999: 259, fig. 12).

Massive ships, such as those indicated by the timbers from al-Balid, would have also been suitable for transporting horses that were traded in the Indian Ocean. Al-Balid and Qalhat were the main centres involved, exporting Arab horses to India, as stated by Ibn Baṭṭūṭa and Marco Polo (Ibn Baṭṭūṭa 1929: 113; Yule 1871: 381). Very little is known about the modalities of this exchange. The 200-ton merchantman from Aden loading horses in Qalhat described by Albuquerque (1875: 66) suggests the use of large ships for this enterprise. Chinese sources in the 13th–14th centuries commented on "horse boats" sewn with coir fibre and of a greater capacity than a typical trading vessel (Li 1989: 283). A painted panel in the Narumpunatasāmi temple of

Tiruppudaimarudur, southern India, provides pictorial evidence of one of these vessels in the 16th century (Deloche 2009: 553, 556, figs. 2,6). Unfortunately, due to its sketchy and stylised nature, it is not possible to determine its size with accuracy, however, the presence of six horses in the hold hints towards a large ship.

To conclude, evidence from the al-Balid timbers suggests a variety of sizes and functions of ships, which is crucial for the study of Indian Ocean boatbuilding in the Middle Islamic period. On one hand, it corroborates the few textual accounts mentioning vessels of various sizes, while on the other it provides further insights into a particular aspect that has scant detail in historical accounts. This outcome of the study on the timbers is also particularly relevant because of their dates, which range between the 10th and 15th centuries, while most of the references as to the dimensions of ships of the Indian Ocean occur only after the beginning of the 16th century. Overall, data from al-Balid also yields, by speculating on ships' size and function, a glimpse of the various maritime activities carried out at this port and, more generally, in the broader Indian Ocean during the medieval period.

5.9 Decoration

Thirteen timbers from al-Balid have decorations either painted or carved on their surfaces and edges. Because these ship remains had more than one use and context, examining and interpreting these ornaments raises one major question: are they the original ones used to embellish vessels, or did the builders of the citadel of al-Balid make them for their new purpose? In the case of planks, a good way to distinguish between the primary (maritime) and secondary (terrestrial) contexts is to determine on which side of the plank decorations are located. Generally, boatbuilders paint or carve motifs in the planking outboard, well above the waterline (Agius 2007b; Bowen 1955; Prins 1970) where people can see them and where they are far from potential water damage and sea borers, rather than on the inside where they would usually be covered with cargo and gear. Luckily, as previously detailed, the features displayed on the al-Balid timbers provide clues as to which surface was on the outside of the hull: the presence of rebates associated with plank-to-plank sewing and frame lashing indicates the vessel's outboard surface.

On this basis, only two planks from al-Balid, BA0704156.1477 and BA1104065.450, exhibit decoration on their outer surfaces, indicated by the presence of rebates in the former case and recessed frame lashings on both (Figure 3.43 and Figure 3.44). This the first direct evidence that maritime communities of the western Indian Ocean decorated their boats.

Hornell (1970: 237-238) speculates that the carved and painted decorations on Arab and Persian boats were influenced by European watercraft, and particularly by the English ships of Tudor times. According to Hornell, similarities between the designs and colour of the ornaments on Elizabethan galleons and Arab *sanbūq*s, and between the beautifully carved transoms of Arab and Indian ships with those of European vessels were enough to confirm this hypothesis, although it is evident that this statement was based on assumption rather than substantial evidence. Iconography from periods before European expansion in the Indian Ocean, such as the illustrations from the *Maqāmāt*, show that the hulls of 13th-century vessels were decorated with floral and geometrical motifs (Agius 2007b: 106). Moreover, woodcarving was one of the most distinctive artistic features of the Islamic/Arab world in the medieval period (Mayer 1958). Therefore, evidence from al-Balid refutes the idea that western Indian

Figure 5.36: Triangular motifs carved on the stern fin (A) and stem post (B) of a *battīl*, and on the foredeck beam of a *zārūqa* (C) from Musandam, Oman. (Photos: Author)

Ocean boatbuilders would have had to wait for European ships to borrow their decorative motifs.

The geometrical designs displayed on the two timbers reflect the precepts of Islamic religion and culture. Because of aniconism[36] on some forms of Islamic art, Muslim artists and craftsmen favoured abstract and geometrical motifs (Burckhardt 2009: 29). Similar design patterns persisted on the hulls of vessels along the coast of Arabia and East Africa until the 19th–20th centuries (Agius 2007b: 105-107; Bowen 1955: 11; Prins 1982: 87, pl. 2; Villiers 2006: 55, 75) (Figure 5.36). Series of triangles or zigzag incisions, frequently observed on traditional crafts from Yemen, Oman and East Africa, resemble those on the border of Persian carpets (Agius 2007b: 106), and triangular pennants, also alternating in colour, flutter from the masts of Muslim ships depicted in the 1519 Lopo Homen Atlas (Vosmer 2019; Weismann 2002). It is noteworthy that triangles and zigzags are also distinctive decorative features of Early Tana Tradition ceramics, which developed in East Africa from the 7th century (Chami et al. 2002: 30; Fleisher and Wynne-Jones 2011: 246, 253-257). Similarly, the same decorative motifs

[36] Avoidance of icons or visual images to depict living creatures or religious figures.

Figure 5.37: Decorative motifs similar to those on timber BA1104065.450 on the stem and stern of the *mtepe* model at the Institute of Arab and Islamic Studies, University of Exeter. (Photos: Author)

are found on various models of the East African *mtepe*, carved and painted on their bows and sterns (Prins 1970: 126-127, diagrs. XV-XVI).

The carved motifs on BA1104065.450 are arranged diagonally across the plank and extend beyond its edge to adjacent planks. Traces of bitumen and fibres on the motifs, consistent with the luting and wadding of seams, indicate that part of the decoration was concealed by sewing, meaning that it was carved before the hull was stitched (Vosmer 2019: 311). Boatbuilders could have decorated the hull before commencing stitching, holding the planks in place with dowels and temporary lashings, as the evidence on some of the al-Balid timbers appears to suggest and as detailed earlier in this chapter.

Vosmer has also argued that the incisions on timber BA0704156.1477 might suggest multiple recycling of the plank. The fact that the carved motifs are arranged at an angle across the plank, continuing on the adjacent one, might reveal that the timber belonged to a terrestrial decorated structure before being employed in a vessel (Vosmer 2019: 311). This is certainly a valid point, especially considering the common practice of recycling timber in the region through time. This hypothesis can also apply to timber BA1104065.450 since its decoration is similarly arranged obliquely across its length. Nevertheless, these planks could originally have belonged to other seacraft instead of coming from a terrestrial context. Similar decorative motifs to those displayed on BA1104065.450 occur on several 19–20th-century models of the East African *mtepe* (Prins 1986: 77, 80, 85, figs. 46c, 48a, 51) (Figure 5.37). In all these models, a series of triangles are carved and painted obliquely on their stem and sternposts and are concealed by stitching where the posts meet the planking. Perhaps timber BA1104065.450 was the stem or sternpost of a vessel decorated in a similar way as the *mtepe*, before being recycled as a plank in another vessel. Moreover, there are various recent examples of boat decorations that are arranged at an angle in southern Arabia, such as those on the bow and stern of the *zārūq* and the *zaʿīma* from Yemen (Agius et al. 2014: 149-151, figs. 5-6; Bowen 1955: 8). Evidence from the two decorated al-Balid timbers might, therefore, reveal a similar practice.

5.9.1.1 Boat Symbolism

The decoration on the timbers from al-Balid also alludes to various aspects associated with boatbuilding, and more generally with maritime communities of the Indian Ocean. The practice of embellishing watercraft is common in this part of the world (Agius 2007b: 101) and reflects a particular symbolism encompassing the maritime world. The various design patterns can be expressions of superstition, protection and power (Vosmer 2007: 356), which are particularly significant among sailors and fishermen. Decorative motifs can also allude to ancient rituals that surround boatbuilding activities, such as laying the keel at the beginning of construction, the launch and the departure and arrival of a long journey (Vosmer 2017: 183).

Various forms of maritime art could also reveal cultural differences within coastal communities of the Indian Ocean, providing an insight into the origin of vessels. As remarked by Agius (2007: 109), “artistic motifs on objects that are traded produce ideas that are borrowed and became part of the maritime art repertoire.” With this statement in mind, the temptation to make a connection between the triangles typical of Early Tana Tradition ceramics from East Africa and those displayed on al-Balid plank BA1104065.450 is strong; particularly considering that the same decorative design is distinctive of *mtepe* from the same region. One might speculate as to whether this artistic motif could have developed from the East African ceramic context, perhaps suggesting that the vessel, to which timber BA1104065.450 once belonged, might also have been linked to that region.

5.10 Carpentry Tools

Evidence from some of the al-Balid timbers reveals information regarding the tools and technology of Indian Ocean boatbuilding. The presence of woodworking tools is indicated by marks left on the surface of timbers, providing information about their type and size. At least five carpentry tools are evident from these marks: bow drill, adze, saw, chisel and file.

5.10.1 Bow Drill

Shipwrights most likely used a bow drill to bore the holes used for sewing the planks, lashing the frames and for dowels. The drill features a metal bit connected to a spindle, a handle and a stick (bow) with a rope lashed to both ends. To use the drill, the rope

Figure 5.38: Indian Head Shipwright Babu Sankaran using a traditional bow drill in the Oman Maritime Boatyard, Oman. (Photo: Author)

of the bow is coiled around the spindle and the bow is moved back and forth to rotate the spindle while holding and pressing the handle at the top (Figure 5.38). The difference in hole sizes recorded on the al-Balid planks indicates the use of drill bits ranging from 7–20 mm. Bow drills are typical carpentry tools of Indian Ocean boatbuilding, and are employed in the construction of both sewn and nailed-plank vessels. They are still in use in the traditional boatyards of Zanzibar (Author, personal observation, July 2018).[37] Experimentation with a bow drill during the building of *Jewel of Muscat* has shown that an experienced carpenter would take between six and seven seconds to drill one sewing hole, approximately ten times slower than a power drill (Vosmer et al. 2011: 422). No bow drill has ever been discovered in the Indian Ocean

[37] As part of the British Academy-funded *The Boat Builders of Zanzibar: Nautical Technology and Maritime Identity in a Changing World* project (Project SL-08385; 2018–19; P.I. John P. Cooper; Co.I Lucy Blue; participant researcher Alessandro Ghidoni).

dating to the medieval period; the only examples in a maritime context come from the Mediterranean, the oldest having been found on the Uluburun shipwreck discovered in Turkey, which dated to the 14th century BCE (Pulak 1998: 208; 2005: 43). An illustration from the *Eskandarnama*, c.1475–1535, at the Golestan Palace Library No. 2237 (de Ruyter 2018), Iran, is the only iconographic source for the use of this tool in the Indian Ocean region during the medieval period. The image shows the building of the Ark with a carpenter using a bow drill that looks remarkably similar to those in use in the Indian Ocean until today, suggesting that it has changed little in the past five hundred years.

5.10.2 Adze

The adze is a traditional boatbuilding tool consisting of a metal blade with a sharp end that is fitted at right angles to a wooden handle (Figure 5.39). It is particularly suitable for shaping large timbers but can also be used for trimming the edges of planks or fairing their surfaces. The size of the marks on the al-Balid timbers suggests the use of different adzes, ranging from 62–73 mm. Interestingly, plank Wo54 and beam BA1104065.447 both show impressions 62 mm wide, perhaps indicating that this was a standard size for adzes.

The earliest iconographic evidence of the use of the adze in the region dates back to the end of the 4th millennium BCE (Odler 2015). The painted relief of the Mastaba of Ti from the Fifth Dynasty in Saqqara, Egypt, illustrates shipwrights using various boatbuilding tools, including adzes (Steffy 1994: 30-31, figs. 3-7, 3-8). Meanwhile, the image of a deity trimming a tree branch with an adze, which is carved on an Akkadian


Figure 5.39: Shipwright using an adze to shape a dugout canoe in Zanzibar. (Photo: Author)

cylinder seal, indicates that this tool was known in Mesopotamia from the second half of the 3rd millennium BCE (Moorey 1994: 354, fig. 24).

5.10.3 Chisel

The chisel is probably the most versatile tool in boat construction, being used for multiple purposes. It is composed of a metal blade ending in a sharp edge, usually connected to a wooden handle (Figure 5.40). It is usually associated with a hammer or mallet, with which it is struck to shape any part of a vessel, either large or small, including keels, stems and sternposts, frames and planks. The decorative motifs carved in some of the planks point to the use of chisels with a variety of blade shapes and sizes. Similarly, the V-shaped notches on planks Wo98A and Wo98C could indicate the use of chisel with a triangular cross section. Similarly to the adze, the

Figure 5.40: Chisels of various size from Kerala, southern India (A). An Omani boatbuilder using a chisel in Sur, Oman (B). (Photos: Author)

chisel is also an ancient tool used in ancient Egyptian boatbuilding from the 3rd millennium BCE (Steffy 1994: 30-31; Ward 2000: 28).

Incisions visible on the al-Balid timbers suggest different blade sizes, measuring between 22 mm and 50 mm across. This reflects ethnographic records from traditional boatyards of the Indian Ocean, where shipwrights used chisels of various sizes to shape different elements of vessels from rough timbers (Shaikh 2019: 380, fig. 4; Staples 2011: 92) (Figure 5.40(A)). Salimi and Staples (2019: 128) remarked that chisels were preferred by most Indian boatbuilders, while Arab builders generally used adzes. Adzes are generally more difficult and dangerous to use, requiring long experience and particular skills. The chisel was also the primary tool employed by south Indian boatbuilders to shape most of the wooden parts of *Jewel of Muscat* (Vosmer et al. 2011: 422).

5.10.4 Saw

The al-Balid timbers provide no direct information about the type of saw used to shape planks with the only tool mark providing clues about the size being from timber Wo54

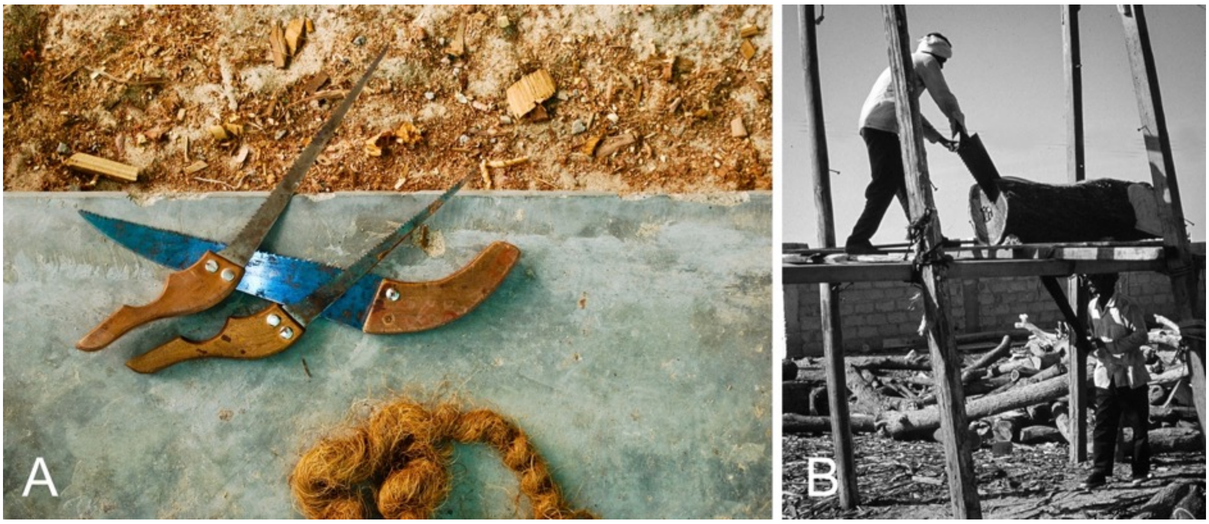


Figure 5.41: A set of traditional handsaws used for boatbuilding in Oman (A) (Photo: Author). Two carpenters using a pit saw in Sur's traditional boatyards (B) (Photo courtesy of Tom Vosmer)

where a cut through its edge suggests a blade thickness of 2–3 mm. This was probably done with a small saw when the plank was recycled in the building of the site.

Two types of saw are usually associated with traditional boatbuilding in the Indian Ocean: the hand and the pit saw. Both consist of a metal blade with triangular teeth on one edge. The former is smaller with a wooden handle at one end and is used by one person (Figure 5.41(A)), while the pit saw is a long two-handled saw positioned vertically and used by two men (Figure 5.41(B)). One may assume that the marks on the surface of some of the al-Balid planks were left by a pit saw, which is generally the preferred tool to cut a large timber into planks. The use of the pit saw has a long tradition in the region, dating to pharaonic Egypt, and persisting in Oman until the 1990s (Vosmer 2007: 360).

5.10.5 File or Rasp

Evidence from the exposed section of a frame lashing on timber BA0604172.69 points to the use of a tool to smooth the sharp edges of the holes. Boatbuilders could have used a file or a rasp, or even a chisel with a narrow blade for this purpose. Vosmer (2007: 190) remarked that rope workers from Agatti, Lakshadweep, asked for stingray tails to file the edges of the sewing holes of *Sohar*. This would not have been necessary in the case of a double-wadding sewing method because the wadding on both sides of the hull would ease the sharp edge of the holes.

5.10.6 Measuring Tools

Other features of the al-Balid timbers point to measuring devices and suggest the practice of using body parts as measuring units. For example, the spacing between sewing holes ranging between 70–80mm in most of the timbers appears to match with the width of three to four fingers. Shipwrights might have also used one or two fingers to determine holes' distance from the edge of the plank, which is 20–30 mm in the majority of the timbers. Similarly, fingers could have served to calculate the thickness of planking and the sided size of frames.

Evidence from al-Balid appears to reveal a further inheritance of boatbuilding practice between the medieval period to the Modern era in the Indian Ocean. The custom of using parts of the body to measure boat components was observed in the region until recent times. For example, Omani shipwrights have used fingers, palm width, hand span, forearm length, the foot and the distance between the ends of outstretched arms during the building of traditional watercraft (Agius 2002: 143; Vosmer 2007: 190). The finger (*iṣbaʿ* in Arabic) was a critical measurement unit and particularly crucial in celestial navigation. Medieval navigators relied on the width of fingers to measure the altitude of a star in order to calculate latitude before the development of the sextant (Agius 2007a: 198-201; Al-Salimi and Staples 2019: 370; Tibbetts 1981: 76, 314-315).

Fingers were also the primary measuring unit in the building of the southeast Indian *masula*, the sewing-hole spacing and location of which resembled that of the majority of the al-Balid timbers (Kentley 2003b: 142).

Discussion

Overall, data from the al-Balid timbers provide insights into the boatbuilding technology of the medieval period while showing similarities with that of recent times. The evidence of boatbuilding tools is significant, given their absence in the archaeological record and the scarcity of their mention in the historical sources. This is particularly true in the case of sewing and measuring tools with the former usually being made from perishable materials such as wood, which disintegrates quickly. Measuring using parts of the body, while having a significant advantage because the "tools" were always at hand, unfortunately, means that they do not occur in the archaeological context.

Tool marks retained on the surfaces of timbers not only hint at the diversity of devices employed by Indian Ocean shipwrights but also allude to various activities revolving around the construction of sewn watercraft, such as the making or purchasing of tools and their maintenance. These activities would have had a considerable impact on building schedules, since adzes, chisels and saws require regular sharpening, a process can take up to a third of the time in the case of woodcarving tools (Pye 1994: 120).

This information cannot be found in the archaeological record but ethnographic studies, such as those carried out by Jesse Ransley in the boatbuilding communities of Kerala, India, have underlined their importance as part of the routine and working pattern of the people behind the boats (Ransley 2009: 89, 101, 116-117). Boat reconstruction projects in the Indian Ocean have experimented with traditional tools but have failed to document their use and performance in detail or their marks on timber. Moreover, they have not focused on the maintenance of the tools in relation to building time. It would be interesting to address this aspect in future boat reconstructions in order to provide a view of all these understated activities involved in the building of a sewn vessel.

5.11 Conclusion

The al-Balid dataset offers interesting information about how medieval shipwrights shaped and assembled various structural components of Indian Ocean vessels, such as planks and beams. The timbers tell us about boat elements that are not physically present in the dataset, such as frames, keels and posts, which are essential for assessing a structural analysis of vessels. These boat parts, in turn, yield insights into various aspects of the building of sewn watercraft, including their construction stages, sequence and tools, information that is particularly important in light of extremely limited archaeological evidence and absence of references in historical sources.

Various devices, such as temporary frames and lashings, used in the alignment and fitting of hull planking, indicate that medieval boatbuilders were well aware of the main characteristics of sewn-plank technology. It also reveals their ingenuity in finding technical solutions to deal with a shell-first construction technique.

Moreover, the construction methodology of medieval sewn vessels revealed by the al-Balid timbers shares similarities with recent 19th–20th-century sewn boats of the western Indian Ocean, pointing to the success of sewn-plank construction as the main reason for its survival and indicating the longevity of boatbuilding practices in the region.

Lastly, despite the fragmentary nature of the timbers, the al-Balid dataset provides hints about the shape and size of medieval watercraft, in turn revealing clues about their use and function. The diversity of vessels alludes to various maritime activities carried out around the area of the port and deepens our understanding of the role of al-Balid during the medieval period.

Now that the forms and structure of medieval Indian Ocean vessels have been assessed, the next chapter will explore the clues the timbers offer regarding the techniques used by medieval boatbuilders to fasten their boats.

6 Fastening Methods of Medieval Indian Ocean Watercraft in the Light of the al-Balid Timbers

6.1 Introduction

Because some of the al-Balid timbers have preserved portions of sewing and other fastening elements, such as dowels and nails, they represent a valuable source of information about the technique/s used to hold various structural parts of medieval sewn vessels together. Historical sources provide no technical detail regarding how the boats were sewn nor specify whether different techniques were used, so scholars have often seen this lack of data as indicative of a general lack of development in sewn construction since the medieval period, or even earlier, which has further promoted the idea of Indian Ocean vessels as being timeless and incapable of changing (Hourani 1963: 88; Johnstone and Muir 1962: 59; Moreland 1939: 182). Archaeological evidence indicates instead that since the 8^{th}–9th centuries, Indian Ocean boatbuilders developed various sewing techniques with different characteristics.

This chapter analyses evidence of fastenings of the al-Balid timbers with the aim of defining fastening techniques of Indian Ocean vessels in the 10^{th}–15^{th} centuries, and looks for differences and similarities to other archaeological and ethnographic evidence of watercraft. Covering a period of five hundred years, the al-Balid timbers offer a valuable opportunity to look for possible hints of development in sewing methods.

6.2 Sewing Techniques

6.2.1 Continuous Sewing

One obvious outcome from the stitching preserved on two of the timbers from the al-Balid dataset is that they were fastened with continuous sewing, as opposed to individual lashings. The main distinction between these two methods is that in the former the cordage is threaded continuously through sewing holes, resulting in connected stitches, while the latter relies on discrete lashing (Figure 6.1). Although the stitches have disintegrated in the rest of the planks, the hole size, spacing and pattern, as well as the diameter of the cordage still inset in the holes, points indubitably to a continuous-sewing technique. This evidence is important because it shows that vessels sailing to and from al-Balid were fastened in a fashion that is still distinctive in recent western Indian Ocean sewn-plank technology (Belfioretti and Vosmer 2010: 116; Bowen 1952: 204; Prins 1986: 100; Vosmer 1997: 232).

Figure 6.1: Discrete lashings associated with nails on a vernacular *ngalawa* from Zanzibar. (Photo: Author)

Vosmer (2007: 157–158) states that individual lashings were probably the earliest form of hull fastenings of Indian Ocean watercraft, and had developed into continuous sewing in Pre-Islamic times. Discrete ligatures, which focused fastening forces on specific points of the hull, gradually evolved into a method that spread these more uniformly throughout a vessel's planking. Stitching holes probably reduced in size as a result and became more closely spaced, while lashing cordage became smaller in diameter and increased in number, strengthening the bond between planks and increasing the strength of the hull.

Bowen (1952: 208), examining the representation of stitches of sewn vessels illustrated in the 13th-century *Maqāmāt*, remarked that these are grouped in pairs, and interpreted this as revealing individual lashings. According to him, this evidence indicated that continuous sewing had not yet developed in the Indian Ocean by the 13th century. Recent data from the Belitung and the Phanom-Surin wrecks made it clear that boats were, in fact, already sewn in a continuous pattern in the 8th–9th centuries. More recently, Burningham (2019b: 147-150) has agreed with Bowen's interpretation of the stitching arrangement of the *Maqāmāt* vessels, suggesting that both continuous sewing and individual lashing could have been used in the same period. According to Burningham, this evidence might tell us that discrete stitches became spaced further apart because structurally it was less critical, perhaps because it was combined with other forms of fastening, such as nails. He also remarks that this development, from a technique relying mainly on continuous sewing towards the use of individual lashings, may have been dependent on the type and size of the ships (2019b: 150). He reasons (2019b: 147-150) that large Gujarati vessels described by Portuguese sources (Manguin 2012: 605-608; Moreland 1939: 176) would have probably required a more effective and stronger construction method than that used

Figure 6.2: *Jewel of Muscat* rope workers sewing in short sections so that several teams can work simultaneously on the same plank. (Photos: Author)

for more “modest-sized” sewn vessels. Although this hypothesis cannot be excluded, Portuguese sources (Greenlee 1938: 65) report that ships from Gujarat were sewn, making this argument less convincing. Finally, iconographic sources can often be deceiving. Their sketchy and stylised nature calls for caution when interpreting the features of watercraft depicted, which are often illustrated by authors not familiar with the maritime world (Nicolle 1989: 168).

Sections of sewing found on two planks from al-Balid also reveal striking similarities with recent sewn boats of the Indian Ocean. Timber BA0604128.73 suggests that medieval boatbuilders carried out the sewing process in small sections rather than fastening a plank from end to end in one go. Experimental archaeological projects and ethnographic records have shown that this practice has survived in recent sewn watercraft (Figure 6.2(A)). Rope workers from Kerala who fastened the hull of *Jewel of Muscat* were familiar with this approach. Meanwhile, Hornell reported that the average length of stitching in East African *mtepe*s was 6 ft (approximately 1.8 m) (Hornell 1941: 61). The reason for this is not clear, but it might be related to the length of ropes used for the cordage. Also, as noted during reconstruction processes, such as those of *Jewel of Muscat*, the al-Hariri boat and the *beden seyad*, short sewing

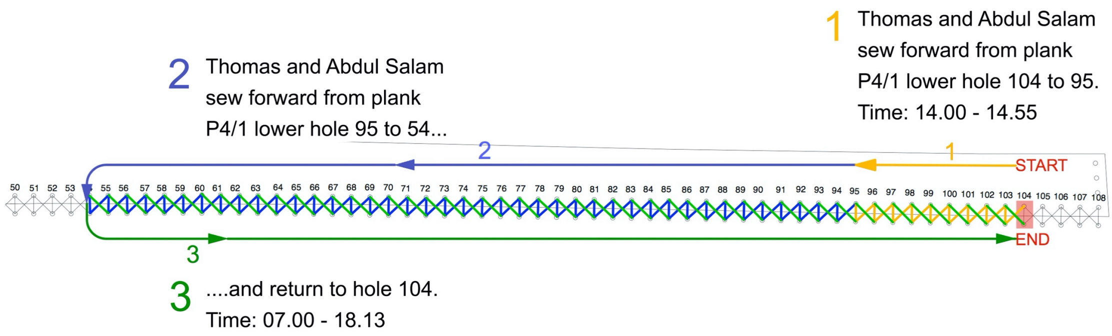


Figure 6.3: The stitching history form used during the *Jewel of Muscat* project to record the sewing team, sewing pattern and time required to fasten a plank. (Image: Author)

sections allow more people to work simultaneously on the same plank, thus increasing the speed of construction (Figure 6.2(B)).

Moreover, evidence from timber BA0604128.73 shows that the sewing did not follow a linear direction, starting from one end of the section and ending at the opposite extremity. The fastening was, instead, done in a circular pattern with one going initially in one direction and then reversing over the same section to the starting point (Figure 6.3). Once again, this process is identical to that used in recent sewn vessels of the Indian Ocean (Hornell 1941: 61; Kentley 1985: 310-311, fig. 19.7; Prados 1996: 102, fig. 60; Vosmer et al. 2011: 418, fig. 6).

Some of the timbers from al-Balid also indicate that medieval boatbuilders used a continuous-sewing method to fasten other parts of the hull. For example, the scarf joint on timber BA0604128.73 and the probable hood end of Wo86 were sewn with the same pattern used for the planks' edge fastenings. Large longitudinal cracks, representing weak areas and potential water leakage points in the hull, were also continuously sewn, as revealed by the plank comprising connecting fragments Wo56, Wo60 and Wo73.

6.2.2 Sewing patterns

6.2.2.1 Single Wadding Sewing Pattern

As we have seen, the planks from al-Balid can be divided according to the presence or absence of rebates between stitching holes and a plank's edge on one of their surfaces. Planks exhibiting rebates, which are the vast majority, along with evidence of wadding on the opposite side, clearly point to a single-wadding or single-web sewing technique (Belfioretti and Vosmer 2010: 113; Kentley 2003: 107; Vosmer 2017: 200), a distinctive trait of sewn watercraft of the western Indian Ocean that has been documented in various regions stretching from East Africa to southern India (Figure 2.8(A)). Evidence of the single-wadding method has been observed in sewn vessels along the coasts of southern Arabia, such as the *beden seyad* described by Pâris when he visited Muscat (1843: 15-16, pl. 8-9), the *kambārī* of Dhofar (Vosmer 1997: 231-234; Weismann et al*.* 2019: 355-356), southern Oman, and the Yemeni sewn *sanbūq* (Bowen 1952: 205; Prados 1996: 98-110). In the Horn of Africa, Chittick recorded the single-wadding method in Somali *beden*s, which were still used at least until the 1980s (1980: 301-303). This was also the pattern of the last two sewn seagoing cargo vessels, the *mtepe* and *dau la mtepe,* built in the Lamu archipelago, Kenya (Lydekker 1919: 89; Prins 1982: 94-99). On the opposite side of the western Indian Ocean, the single-wadding method was used to join the planking of boats of the Lakshadweep Islands (Varadarajan 1998: 58-79), and riverine vessels used in the backwaters of Kerala (Author, personal observation, Alleppey 2014) and Goa (Shaikh et al*.* 2012: 152-154) in southwestern India.

There is also further archaeological evidence for this technique, such as the sewn timbers discovered in Quseir al-Qadim. Similarly to the al-Balid timbers, the ship remains from Quseir were also found in a secondary context, recycled to seal one of the tombs of the Islamic necropolis (Blue 2002: 149; 2006; Blue et al. 2011: 181-185). Their estimated date (late 12th–early 15th centuries) occurs within the period range of the al-Balid timbers, suggesting that the single-wadding method was predominant during the 12th–15th centuries, and vessels fastened in this fashion circulated broadly in the western Indian Ocean.

Rebates in the timbers from al-Balid can also help distinguish between the outer and inner surfaces of planks. Generally, single-wadding sewn vessels of the western Indian Ocean have rebates on the outside of the hull, with the wadding placed above the seams on the inside. Cut between two corresponding sewing holes, these recesses served to protect the stitching ropes against chafing and abrasion (Severin 1985: 283), so it made sense to have them outboard. The surface displaying rebates on the planks of Quseir al-Qadim was also assumed to be the former outer side of the hull because of similarities with more recent watercraft and the presence of substances, such as bitumen, coating the surface (Blue et al. 2011: 182). Other elements, such as frame lashings, further provide hints to determine which side of the al-Balid planks was the outer one. In sewn vessels, frames are lashed to the inside of the hull through holes drilled in the planking on either side of the intended timber position. Outboard, the lashing pattern appears as pairs vertical stitches, often recessed, on the outside of the hull. Several of the al-Balid timbers have preserved frame lashings and rebates with the ropes still in situ. Frame lashings recessed on the same side of the timbers displaying rebates indicate that this particular side had originally been the outer surface. Lastly, the presence of holes made by marine organisms such as barnacles and shipworms (*Teredo navalis*) associated with the surface of the plank displaying rebates (Figure 3.18) further confirm that cordage was recessed on the outside of the hull.

6.2.2.2 Planks without Rebates: Double-Wadding Sewing Pattern?

Four planks from al-Balid with no rebates between the holes and the edge of the plank perhaps suggest a different method from the single-wadding technique described above. Unfortunately, none of these planks has preserved portions of the stitching, which would allow a definitive interpretation of their sewing pattern.

The absence of rebates points to various sewing patterns. One could indicate a single-web technique with the stitches exposed, rather than recessed in grooves. Ethnographic evidence of sewn watercraft from the Indian Ocean suggests that the absence of rebates does not necessarily exclude a single-wadding method (Figure 6.4). For example, a type of *masula* built in Tamil Nadu is sewn in a single-wadding method with the cordage not recessed in rebates (Kentley 1985: 313; 2003: 156). The *madel paruwa,* flat-bottomed watercraft employed on the southwest coast of Sri Lanka, also display no rebates, with the wadding covering the seams inboard in the planked-bottom and outboard on the hull planking (Kentley and Gunaratne 1987: 42). Lastly, a few models of the East African *mtepe* documented by Prins indicate a flat surface on the outside of the hull (Prins 1982: 94) with stitches cut away so that they are flush with the hull planking. The District Commissioner of Lamu informed Hornell, in the first half of the 20th century, about the practice of cutting the cordage on the outside of the hull of the *mtepe* after the sewing was completed and the holes pegged (Hornell 1941: 62).

Further evidence that might help identify the sewing pattern of the few planks from al-Balid that are without rebates comes from the fastening method of the Belitung and Phanom-Surin shipwrecks (Flecker 2000: 206; 2010: 103; Vosmer 2017: 200). Generally called either double wadding, double-sided wadding or double web (Vosmer 2017: 199-200; Kentley 2003: 163), the technique consists of sewing over wadding

Figure 6.4: Model of a *mtepe* at the Institute of Arab and Islamic Studies, University of Exeter, with the stitches sliced off the outside of the hull showing no rebates (A) (Photo: Author). A *masula* in Orissa, India, sewn with a single-wadding technique without rebates (B). (Photo courtesy of Colin Palmer)

placed on the plank seams on both sides of the hull in a pattern that alternates vertical and cross stitches (IXIXIXI) (Figure 2.8(B)). This method has persisted in the Indian Ocean only in one type of the *masula* that is used on a stretch of Andhra Pradesh's coast, from Puri to Dainaipeta, on the southeastern coast of India (Kentley 1985: 311; Kentley 2003: 137).

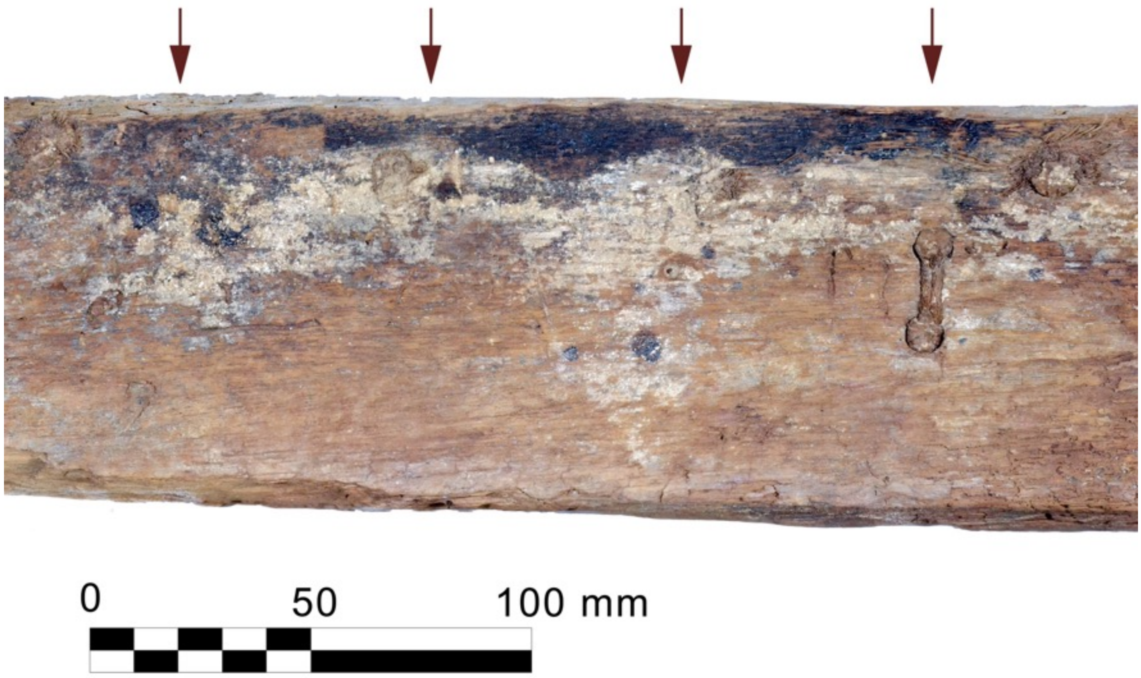


Figure 6.5: Timber BA1104065.450 bearing traces of bitumen and fibre between the holes and its edge, indicating the presence wadding on its outer surface. (Photo: Author)

Historical sources, whether textual or iconographic, provide no clue to the sewing pattern of the al-Balid planks without rebates, and all the above ethnographic and archaeological examples could provide the basis for equally valid interpretations. However, I am inclined to agree with Vosmer's interpretation (2017: 200) that the closest match is the double-wadding technique of the Belitung and Phanom-Surin wrecks. Their date indicates that a double-wadding sewing method was already known in the Indian Ocean during the 8th–9th centuries, an earlier period than that of even the oldest timbers from al-Balid. Moreover, the presence of substances on the surface of one of the timbers might give an insight into the interpretation of the sewing pattern. Plank BA1104065.450 has traces of bitumen between the holes and the edge of the plank on the former outer face, as indicated by a preserved frame lashing recessed in a rebate, as well as the presence of decorative motifs. Fibre impressed in the bitumen on BA1104065.450 reveals the presence of wadding on the outside of the hull, perhaps suggesting a double-wadding sewing method (Figure 6.5).

6.2.2.3 "Hybrid" Sewing Method

A few timbers from al-Balid show evidence of both single- and double-wadding techniques on different portions of their surfaces, pointing to the use of different stitching patterns to fasten specific elements. For example, plank Wo54, identified as a garboard, has rebates only on the top edge while the bottom is flat (Figure 6.6(A)). The absence of rebates on the edge sitting on the keel suggests that, while the hull above was sewn with a single-wadding method, the assembly of the garboards and keel was achieved using a different technique, with wadding on both the outside and inside. Cooper et al. have observed similar evidence on the three Iranian sewn *baggarā*s held by Qatar Museums (2020: 16-18) (Figure 6.6(B)). Boatbuilders in Goa have used this sewing arrangement to fasten additional strakes to their dugouts (Chittick 1980: 306, fig. 10; Fenwick 2015: 392, 396, fig. 5b), while Kentley and Guanaratne described a similar practice in the *madel paruwa* of Sri Lanka[38] (Kentley and Gunaratne 1987: 41).

In other timbers from al-Balid, not all the sewing holes in a sequence are associated with rebates. For example, those along one edge of plank Wo98B all have rebates except the last five that are located at one of its ends (Figure 6.7(A)). This evidence suggests that the boatbuilders started to sew a plank with a single-wadding method and then switched to a double-wadding technique towards its end. Ethnographic studies revealed that a similar practice occurs in many sewn boats of the Indian Ocean fastened in a single-wadding technique and is characterised by the presence of short sewing sections with wadding outboard along the keel/garboard seams near the bow

[38] The above examples are all vessels expanded from logs: either one log acting as a keel in the former, or two logs forming chine strakes in the *madel paruwa*. These are generally small- to medium-sized watercraft that are often used in combination with an outrigger.

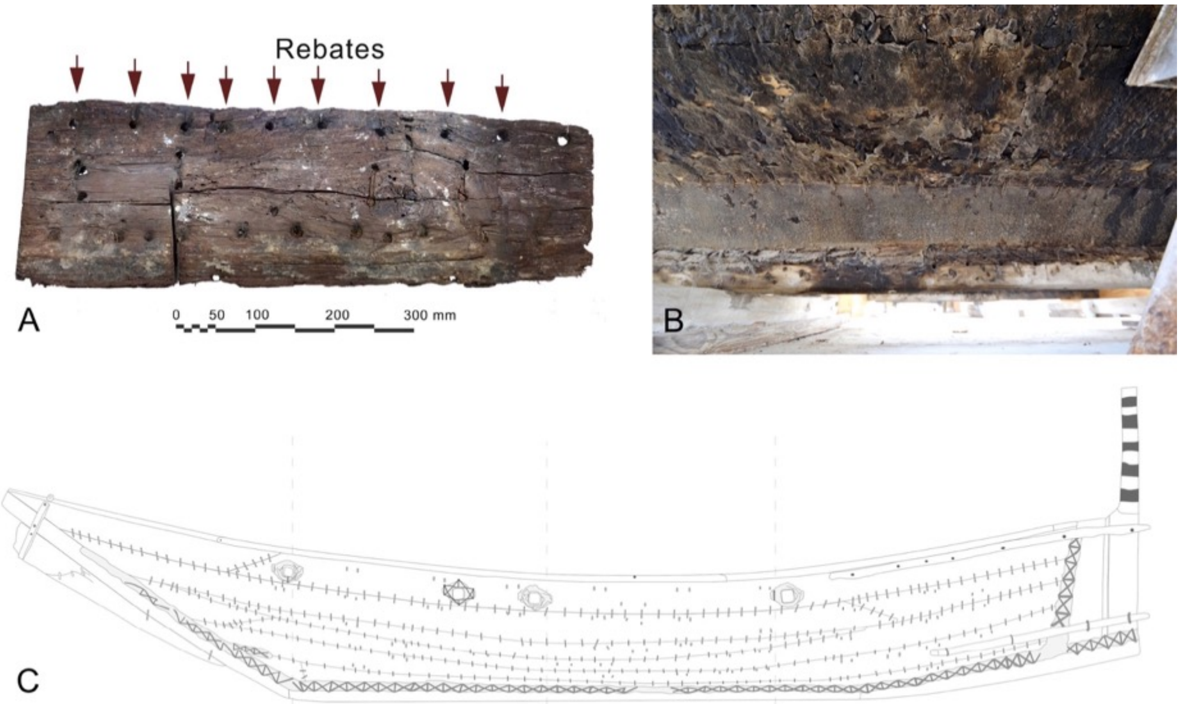


Figure 6.6: Timber Wo54 with only one edge without rebates (A). Wadding on the outside of the garboard–keel assemblage of an Iranian *baggāra* by Qatar Museums (QM) (B and C). (Photos and drawing: Author)

and stern (Figure 6.7(B-C-D)). Similar evidence was found in boats from Yemen (Bowen 1952: 204; Prados 1996: 104), Oman (Weismann et al*.* 2019: 356; Author, personal observation, Salalah 2017), Somalia (Chittick 1980: 302, 303, fig. 8) and East Africa (Hornell 1941: 61; Prins 1965: 125; Vosmer 2007: 181). Scholars have provided different explanations for this practice. According to Hornell, it served to strengthen the assembly of keel, garboards and posts, where the seams are subjected to considerable strain (1941: 61) but Bowen, instead, remarked that placing the wadding outside was necessary because the inside of these areas was too narrow to access during sewing (1952: 204). Finally, Chittick believed that this practice had more to do with the necessity of increasing the watertightness of the hull at the bow and stern (1980: 304, note 8). While it is true that the garboards of double-ended vessels are often very close together at the two ends, leaving little working space, this aspect was

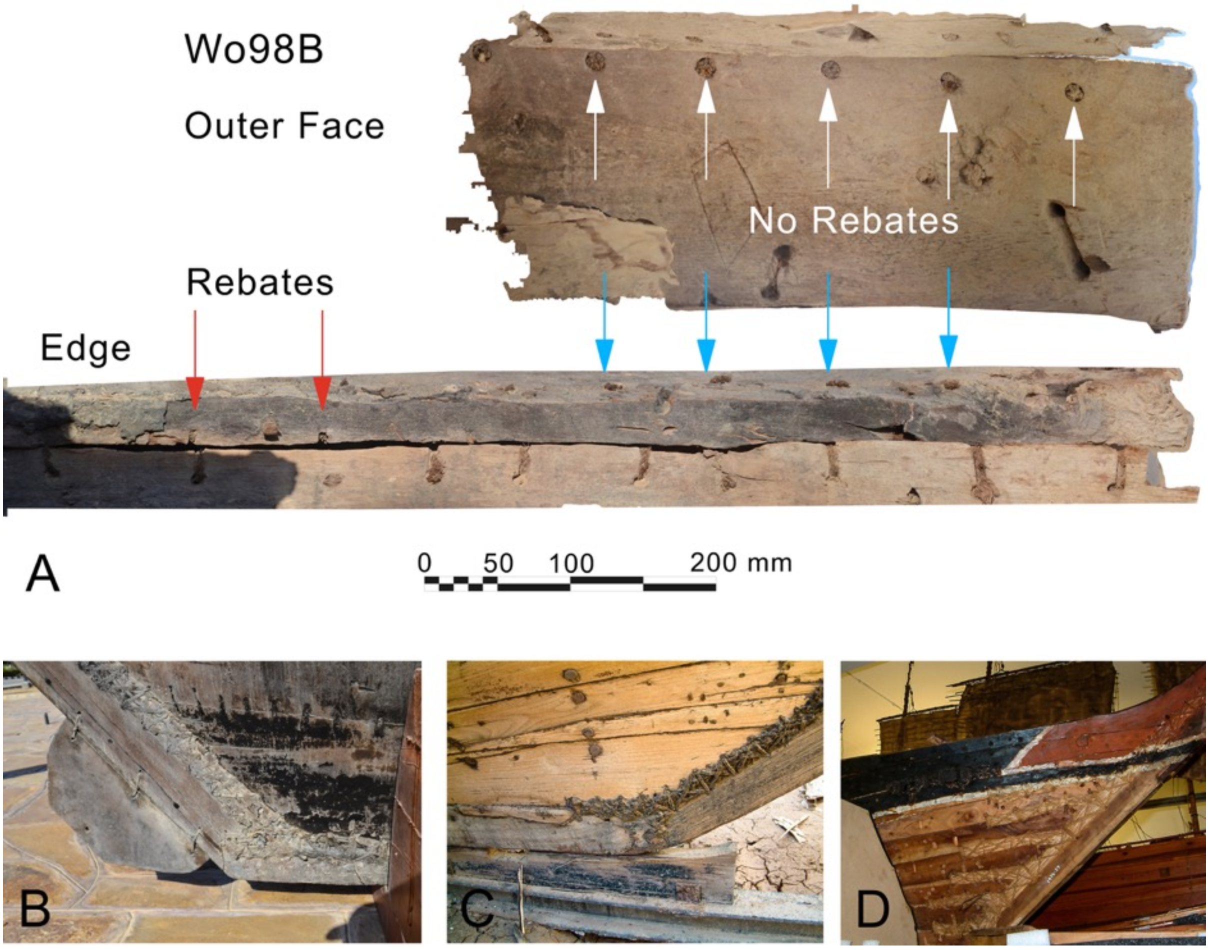


Figure 6.7: Timber Wo98B with a series of holes without rebates (A) suggesting the presence of sections of wadding outside the hull as observed in an Omani *kambārī* (B) and *battīl* (C) (Photos: Author). The *mtepe* model at the Science Museum, London (D). (Photo courtesy of Norbert Weismann)

never a problem in sewn craft from southwest India, where boatbuilders used single wadding in the same place.

However, the hull of a vessel is generally subject to particular stress at the joint between the keel, garboards and posts, which can result in water leakage. Hence, sections of outboard wadding might have had the double function of strengthening and waterproofing these parts of the vessel. Whatever the reason, this method must have been particularly crucial since it even survived in Omani *battīl*s, which retain sewing at the stem and sternposts, while the rest of its hull is nailed (Vosmer 1997: 224: Vosmer 2007: 181) (Figure 6.7(C)).

Collectively, these examples offer analogies into the interpretation of, and explanation for, evidence for using different sewing methods on the same structural element indicated on the al-Balid timbers, and suggest that this practice was well established during the medieval period. These ethnographic records also show that, in recent times, this procedure was documented mainly on the western shores of the Indian Ocean, from East Africa to southern Arabia.

Figure 6.8: Holes without rebates at the corners of hood ends (A) and scarf joints (B) of the QM *kettuvallam*. (Photo: Author).

Lastly, there are timbers, such as Wo64 and Wo68, where rebates are associated with all but one of the sewing holes, generally located at the end of the plank. Again, the arrangement of the stitches in more recent sewn boats provides some insight into the interpretation of this evidence. A south Indian *kettuvallam*, owned by Qatar Museums (Cooper et al. 2020), appears to suggest that the boatbuilders avoided making rebates for holes in particularly weak parts of the planks, such as the corners, especially when associated with the stem and sternposts or scarf joints (Figure 6.8). Carving a groove in a hole too close to the edge of a plank would undoubtedly increase the risk of weakening the plank and causing it to break or split.

6.2.2.4 Single Wadding vs. Double Wadding

Assuming that the lack of rebates indicates a double-wadding method, the main question arising is: What are the fundamental differences between the two sewing patterns? Apart from the apparent difference concerning the quantity and location of the wadding, a comparison between the two sewing methods highlights a distinction in techniques, and the quality and amount of material used. As we have seen in the previous chapter, the diameter of stitching holes in the al-Balid timbers, despite showing significant size variation, is around 11 mm in the majority of the planks. One interesting difference emerges between the average hole diameter of the two sewing methods, indicating that those on planks displaying a single-wadding technique are slightly smaller (10 mm) than those identified as double wadding (12 mm). Experimentation on *Jewel of Muscat,* which replicated the sewing pattern of the Belitung wreck, indicates that this method employed four turns of rope for each hole, compared to three turns in the single-wadding technique (Figure 6.9) (Vosmer et al. 2011: 418). An extra turn of rope could certainly be a valid reason for having larger holes on planks with wadding inboard and outboard. However, technical and statistical analyses of the al-Balid timbers also show that other factors, such as the width of a plank and the hole spacing, may also play an essential role in determining the diameter of the sewing holes.

6.2.2.5 Advantages of Double Wadding

One of the most obvious benefits of a double-wadding pattern is the presence of wadding on both sides of the hull. Having a thick caulking roll over the seams outboard and inboard may help increase the watertightness of the hull compared to a single-

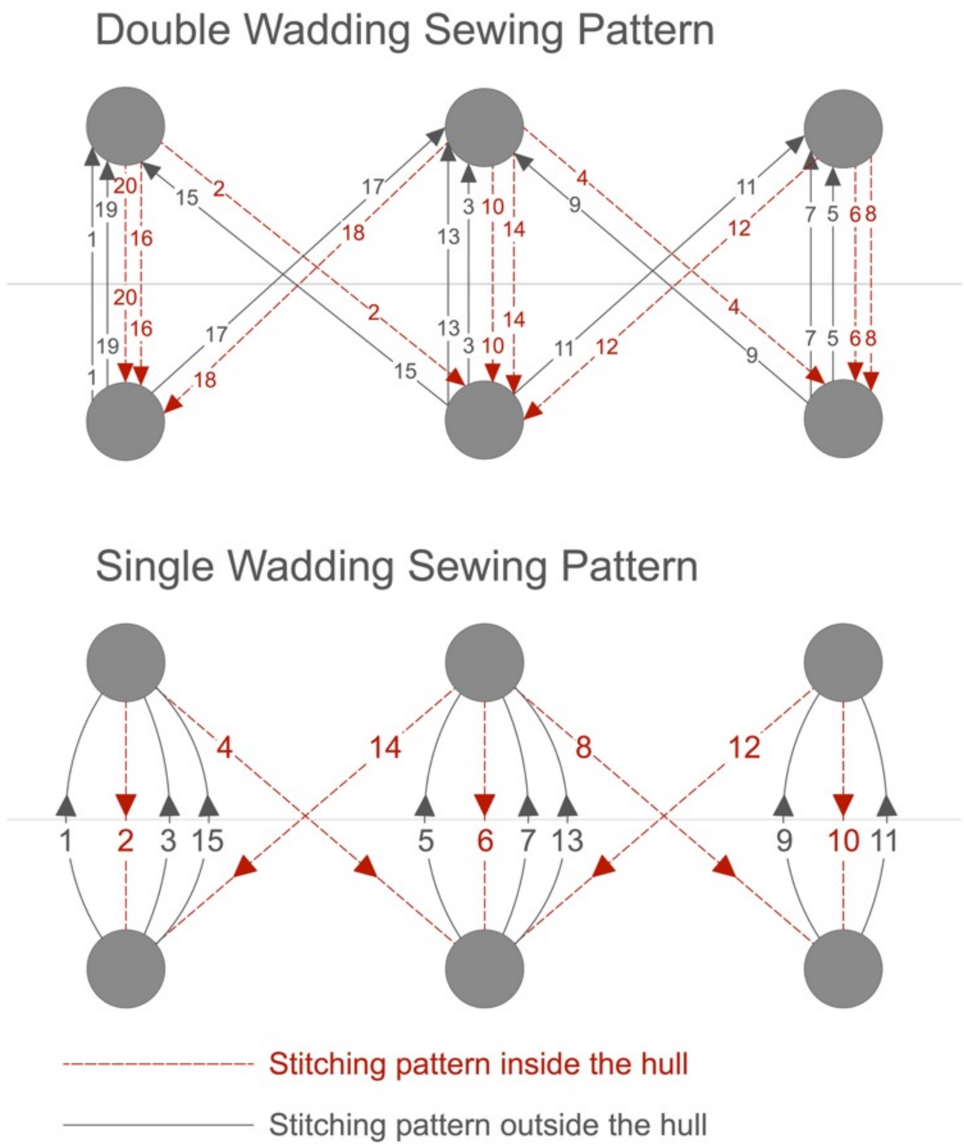


Figure 6.9: Sewing pattern and sequence of double-wadding (top) and single-wadding (below) techniques. (Image: Author)

wadding method. Planks of vessels, such as the Belitung wreck, which have no dowels connecting planks, are more susceptible to longitudinal movement along their seams, which in turn results in a higher risk of leakage. Perhaps, therefore, double wadding was a particular requirement to reduce water intake caused by plank movement. However, the timbers from al-Balid suggesting this specific sewing pattern display regularly spaced dowels along their seams, perhaps indicating other reasons for having the wadding on both sides of the vessels. Moreover, a single-wadding method appears to create no issues in a type of *masula*, the planks of which are not dowelled (Kentley 1985: 313). Kentley speculates a development from double to single wadding, stating that one of the reasons may be the material used (2003: 165). He observed that, generally, coir is preferred in for single-wadding, while the *masula* boatbuilders would instead use grass in for double-wadding. Coir fibre is the most effective because it is particularly resistant to rot and salt water, but its higher price might have limited its use for wadding to just one side. Grass, on the other hand, is widely available but, because of its poorer quality, would be required on both sides of the hull (Kentley 2003: 165). The use of paperbark (*Melaleuca*) instead of coir in the wadding of the Belitung wreck (Flecker 2010: 117) might have also been a factor influencing a double-wadding technique. The team of *Jewel of Muscat* carried out several tests to determine the best wadding material before commencing the fastening of the hull, and chose coir because of its superior quality (Vosmer et al. 2011: 414) (Figure 6.10).

As remarked by Vosmer (2007: 175), wadding achieves two other primary purposes, apart from acting as a form of caulking. The first is to soften the angle of the cordage emerging from the holes, which would reduce the risk of cutting the rope on a sharp edge between the hole and the surface of the plank. The second is that wadding acts as a shock absorber, helping to ease the forces applied on the stitching by the movement of hull planking when sailing in rough sea conditions or in case of collision, for example against reefs or sandbanks. The reason for double wadding could, perhaps, also be the need for a more flexible hull than that of the vessels stitched with single wadding. The pliable nature of sewn watercraft has been mentioned in a number of historical sources. Ibn Baṭṭūṭa wrote in the 14th century that vessels fastened with ropes benefited from a certain flexibility (Agius 2007a: 164). Two centuries later (16th

Figure 6.10: The wadding of *Jewel of Muscat* consisting of loose coir fibre under coir ropes. (Photo: Author)

century), Jesuit Father Monclaro (Prins 1986: 67), who sailed on a sewn boat in East Africa, remarked that these vessels were most suitable for sailing in shallow water, because they can endure hitting sandbanks without damage. The *masula* of the northern and central sectors of Andhra Pradesh, is the only sewn vessel of the Indian Ocean fastened with a double-wadding technique, and is used on a stretch of coast characterised by particularly heavy surf[39] (Kentley 2003: 132). However, Burningham has recently questioned the assumption of the flexibility of sewn-planked vessels, showing that this fastening method, although providing some resilience, "is not intrinsically more flexible in the sense of bending more easily than other traditional modes of construction" (Burningham 2019a: 341).

[39] The Venetian merchant Gasparo Balbi, in his account of his travels to India and the East at the end of the 16th century, provides one of the most vivid descriptions of the strain involved in the beach landing of a *masula* in the city of San Thomè. He states that these boats would not break even if they hit the shore (Balbi 1590: 89).

Another advantage of having wadding placed on either side of adjacent planks is that it may also act as a clamp. Sewing cordage tightened over a caulking roll would press it against each side of the planks, keeping their edges flush and reducing their transversal movement, further decreasing the chance of leakage. One last reason for having a double-wadding pattern is that, when immersed in water, it might help increase the bond between planks. By absorbing water, the fibrous and vegetal material of the wadding expands, resulting in tightened stitching cords.

6.2.2.6 Advantages of Single Wadding

One distinct function and strength of a single-wadding method associated with rebates is that the sewing cords are recessed in grooves connecting the matching holes of two adjacent planks. Hence, the vertical stitches are not exposed but flush with the hull and protected against chafing. The *Jewel of Muscat* voyage showed that the wadding outboard is prone to abrasion damage, and resulted in the breakage of sewing rope on several occasions. Even a small boat rubbing against the hull would be sufficient to cut the stitches.

A single-wadding technique would certainly create a more hydrodynamic hull; recessed stitches would create a smoother surface, reducing the drag and increasing the speed of the vessel. At the same time, the thick caulking rolls of the double-wadding method exposed outboard would have an impact on frictional resistance, and subsequent performances, of the hull. Bitumen sealing some of the rebates on the al-Balid timbers, as well as the cracks and imperfections of the wood, may also have had the function of filling recesses to create smoother planking and a faster boat.

One of the main differences between the two sewing systems is that a single-wadding method requires less material. Having the wadding on just one side instead of two obviously means halving the vegetal matter used for this purpose. Similarly, because there are no diagonal cross stitches on the outside, the amount of rope needed is less. The two sewing techniques can be compared by calculating the length of cordage required by each to sew two sets of holes spaced 70 mm apart and located 50 mm from the edge on a plank with a thickness of 30 mm. A rope worker would use 590 mm of cordage to sew the section with a single-wadding method, compared to 910 mm with wadding on both sides, meaning that the single-wadding uses 35% less material. This significant reduction also reflects a decrease in sewing time. Staples compared the sewing patterns of *Jewel of Muscat* (double wadding) and the al-Hariri boat (single wadding) by calculating the time required by the same teams of “stitchers” to sew two planks sharing similar positions in the hull of the vessels (2019: 330-331). Analysis showed that single wadding was faster than double wadding, taking 59% of the time required by the double-wadding to sew a plank in the middle of the hull[40] (Staples 2019: 330). However, part of, if not all the time saved using this technique would have had to be employed in carving the rebates between the sewing holes, reducing the advantage of the method.

Evidence from al-Balid might reveal a further advantage associated with the use of rebates. These are generally quite deep and narrow, always narrower than the diameter of the holes, meaning that recessed stitching cords would be bundled deep inside them. Experience with sewn-plank technology shows that these stitches can be as hard and strong as wood, and extremely tight bundles of ropes inside rebates

[40] This figure increased to 78% when sewing planks near challenging sections of the hull, such as particularly narrow ones near the bow or the stern (Staples 2019: 330).

literally act as dowels, further locking adjacent planks together and preventing them from sliding along their seams.

6.2.2.7 Development in Sewing Technique?

Vosmer has suggested that there may have been a chronological development from a double- to single-wadding technique because the double-wadding occurs in the oldest timbers of al-Balid (Vosmer 2017: 200). The fact that these planks appear to share the same method used in the early shipwrecks of Belitung and Phanom-Surin further hints at the double-wadding technique as an early stage of the evolutionary pattern of sewn-plank construction (Vosmer 2017: 200).

In the al-Balid collection, additional radiocarbon dating analysis carried out on two timbers without rebates appears to strengthen this hypothesis, showing that planks without rebates are not found after the 13th century. At the same time, those sewn with a single-wadding technique are found throughout the date range of the timbers, between the 10th and 15th centuries.

However, evidence from one of the Qalhat timbers seems to undermine the hypothesis of a development implied by the al-Balid dataset. Timber 3210 has no rebates and the radiocarbon dating analysis suggests that boatbuilders continued to use the double-wadding method in the 15th and 16th centuries. However, as we will see in the next sections, particular features displayed on the timber point to its being a different construction element instead of a plank.

As discussed earlier, the main differences between the two methods concern the quantity of the material used and the execution time required. Economics could have influenced medieval boatbuilders to abandon the practice of laying the wadding on both sides in favour of a technique where the wadding is only inboard. Saving rope and caulking materials would have been particularly critical in regions where suitable sewing fibres, such as coir and grass are scarce. Abū Zayd, quoted in translation by Agius (2007b: 149-150), highlights the importance of purchasing the right materials for boatbuilding by mentioning that, in the 10th century, Omani shipwrights sailed as far as the Lakshadweep islands for their coconut products, including coir for cordage.

The need to protect stitches against abrasion might also have led boatbuilders to opt for a technique where the sewing cords were recessed in rebates. In the Indian Ocean, small coastal boats were traditionally hauled out and dragged onto the beach at the end of each day (Bowen 1952: 201; Vosmer 1997: 233), or seasonally in the case of large cargo ships, for either repairing or resewing the hull, or while waiting for the shift of the monsoon winds (Agius 2007a: 142). A frequent haul-out would produce a significant chafe on exposed stitches, causing them to break. Hence, protecting the sewing outboard would have been a crucial requirement to prevent leakage and prevent the hull from breaking apart.

Apart from a chronological distinction between the two sewing techniques, some of the timbers from al-Balid might offer additional clues towards development from single to double wadding. As we have seen, there are planks that show a hybrid fastening system, combining both stitching patterns. In the case of timber Wo54, only the lower edge was fastened with wadding on both sides, while other planks reveal the presence of small sections of wadding outboard (Figure 6.7), as in the case of the sewing preserved at the bow and stern of the *battīl* and *badan*, indicating that these vessels were once sewn and the sections of wadding outboard might represent the remainder of a double-wadding method. Rebates could have gradually replaced wadding outboard in most hull planking except for specific areas, such as those near the bow and stern.

Although the single-wadding method appears as the predominant technique in the Indian Ocean, the double-wadding technique did not disappear entirely but persisted until the modern era in sea craft of southeast India (Kentley 1985: 2003). Iconographic sources also point to the use of this fastening system in the western Indian Ocean at the end of the 16th century (Figure 6.11): an illustration by Johannes Baptista van Doetechum (c.1554–1606) shows two small vessels sailing off Goa with a thick caulking roll on each side of the hull (Van Linschoten 1605).

Figure 6.11: Illustration by Johannes Baptista van Doetechum (c.1554–1606) depicting sewn boats of Goa and Cochin, India, with wadding inside and outside the hull. (Photo: Van Linschoten 1605)

Differences in planks with and without rebates in the al-Balid dataset appear not to be related to the material used. Wood species of the planks without rebates are various and include *Tamarix*, *Ziziphus spina-christi*, *Celtis africana* and teak (*Tectona grandis)*. They all have different characteristics ranging from high-quality timber with regular grain, such as teak, to a poor-quality wood for planking, such as *Ziziphus*.

Perhaps this variety in sewing patterns reflects different regional boatbuilding traditions. Other factors, such as available technology or evidence of repairs, can equally provide a reason, including the "force of tradition" expressed by Hourani as one of the causes of the persistence of sewn boats in the Indian Ocean (1963: 97).

To conclude, despite suggesting a possible chronological development in sewn-plank technology, evidence from the al-Balid timbers is far from being conclusive. The data should be handled with caution due to the limited number of planks without rebates, consisting of only four examples that represent merely 14% of the dataset. Moreover, identification of their sewing arrangement as double wadding is still debatable until more definitive data is provided, such as the further discovery of planks retaining sections of stitching.

6.3 Dowels

Dowels are, after the sewing, the most distinctive feature of the al-Balid timbers, being located along their seams in the vast majority of the dataset. They appear to have a common diameter, and their relatively regular use and spacing suggests that they represent a crucial element in sewn-plank construction in the Indian Ocean. As observed in the previous chapter, only one of the timbers from Qalhat bears evidence of dowels, and these are similar in diameter and spacing to those from al-Balid.

6.3.1 Edge Joining

The dowels on the al-Balid timbers and those from one specimen from Qalhat are all oblique and are an integral part of the fastening system, where they worked in conjunction with the sewing (Figure 6.12(A-B)). Fitted along the edge of planks, they hold them together and lock them in place.

6.3.2 Scarf Joints

Evidence from timber BA0604128.73 indicates that medieval shipwrights of the Indian Ocean also relied on dowels to strengthen scarf joints (Figure 6.12(D)), which are weak points in the hulls of sewn boats, and because they are generally not supported by frames, dowels are particularly useful in locking the ends of planks and keep their edges flush. Frames are rarely placed on scarf joints so there are no frame lashings, for example, on timber BA0604128.73. This might be due to the presence of wadding along the seams of the scarf and planks, covering most of that area. In this case, the surface of contact between the planks and the frames would be extremely limited because the frame would have to be notched to accommodate not only the wadding on both edges of the plank but that of the scarf as well.

6.3.3 Hood Ends

If the interpretation of one of the extremities of plank Wo87 as a hood end is valid, then the presence of channels on its edge points to the use of dowels to connect the ends of the planking to the stem or sternposts in order to reinforce the assemblage (Figure 6.12(B)).

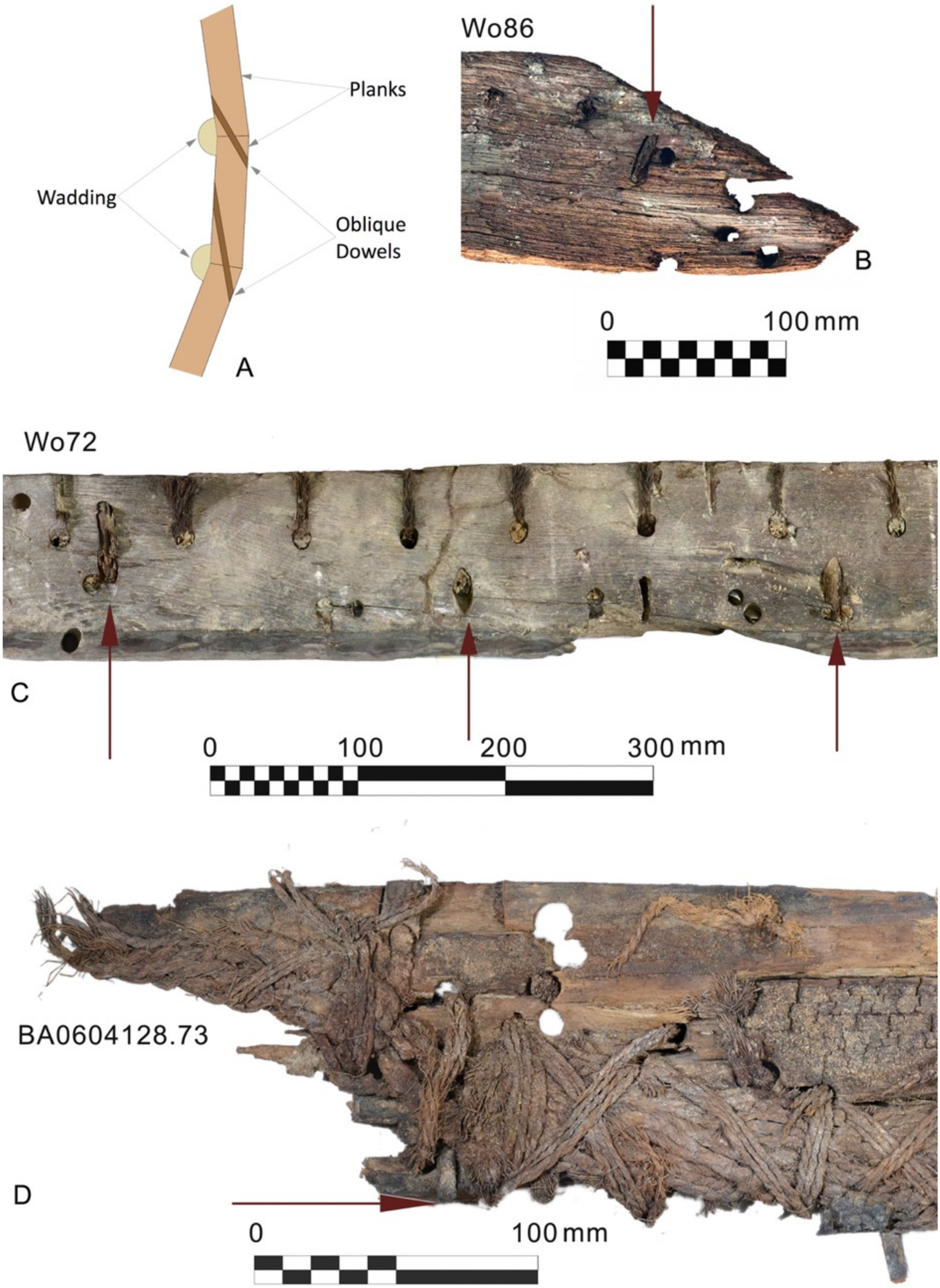


Figure 6.12: Sketch showing the dowelling technique of the al-Balid timbers (A). Boatbuilders used dowels to secure planks' hood ends to posts (B), to fasten planks together (C) and to reinforce scarf joints (D). (Photos and drawing: Author)

The timbers from al-Balid and Qalhat provide no definitive clue about how and when in construction the dowels were driven. They are likely to have been drilled from the outside of the hull because the curvature of the planking makes this process easier from outboard, but it is difficult to determine whether this activity was carried out from the plank above or below from the evidence on the timbers. Studies on recent sewn watercraft, such as the East African *mtepe* and the Omani *kambārī* indicate that boatbuilders fitted the dowels upwards from the lower plank, and outside the hull (Prins 1982: 95, Fig. 1b; Vosmer 1997: 219-220, fig. 3). Taylor has argued against this interpretation, stating that hammering a dowel from the bottom up could easily cause the strakes to separate rather than draw them together (Taylor 2007: 114). There is probably no general rule on how Indian Ocean shipwrights fitted dowels, and the direction would have depended on a number of factors, and might have changed according to the strake and curvature of the hull. For example, they were likely to have been driven downwards to fasten the garboard fragment from al-Balid Wo54 to the keel, since that would have been easier.

One of the functions of the dowels in the al-Balid timbers is intrinsically related to sewn boats and their structural integrity, and that is in preventing hogging. A vessel afloat is subjected to forces along its length caused by either sailing in rough seas, where the two ends are frequently exposed and thus not adequately supported, or by an incorrect distribution of cargo (Figure 6.13(A)). These forces push the middle of the hull upwards and the ends downwards, particularly on a boat with overhanging bow and stern, causing a bend in the structure of the vessel called hogging. In a sewn vessel where frames widely spaced and provide very little longitudinal strength to the hull, this stress is even more evident and can cause the planks to slide along their edges (Figure 6.13(B)). Regularly spaced dowels help maintain the structural integrity of the hull by

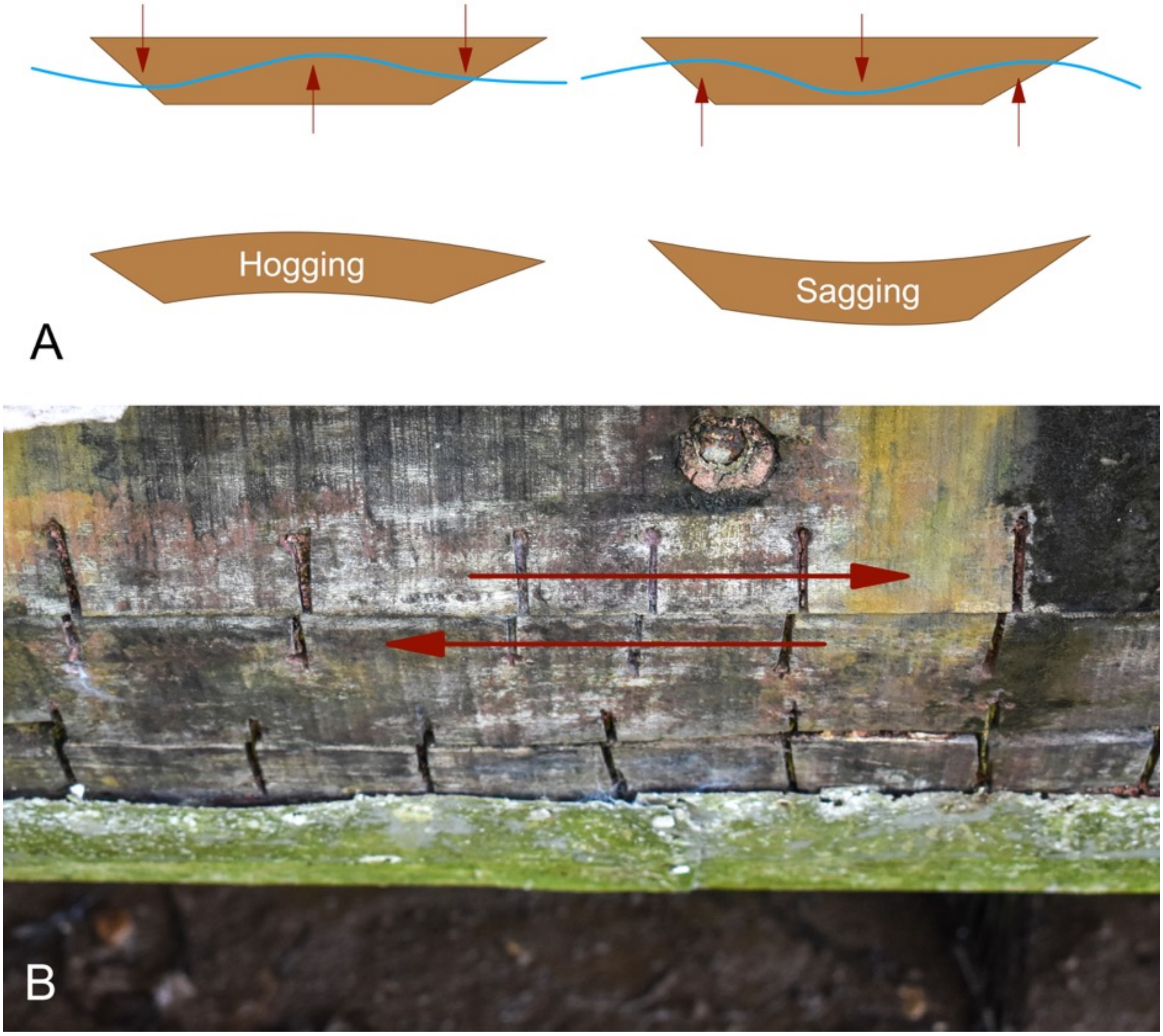


Figure 6.13: The effects of hogging and sagging on the hull of a vessel (A) (Image: Author). Rebates staggered showing planks sliding along their seam on an Indian sewn vessel from Kannur, Kerala. (Photo courtesy of Sajid Madhatile Valappil)

preventing longitudinal movement of the planking, caused by the hogging of the hull (Coates 1985: 17-18).

Green states that oblique dowels were likely to have been inserted only after sewing was completed (2001: 64-65), an assumption that is based on the difference between boatbuilding traditions of Southeast Asia and those of the western Indian Ocean. In the former, planks are held together by vertical pegs, which are not visible from the exterior (blind dowels) driven perpendicularly through the edges of adjacent planks. In this method, also employed in the sewn *odam*s of the Lakshadweep (Varadarajan

1998: 71-73) and Maldives (Manguin 1985: 12), dowels are inserted before the planks are fitted and fastened. According to Green, to drive oblique dowels typical of Arab and East African boats, boatbuilders would have had to assemble and attach (either by sewing or nailing) the planks beforehand (Green 2001: 65).

While Green's assumption is partially correct – the planks have to be fitted and held together to insert the oblique dowels – it is not correct to assume that they would have to be sewn, in the case of a sewn boat, or fastened to the frames, in the case of a nailed boat, before driving a dowel. Ethnographic studies on south Arabian and East African sewn craft have shown that dowels served the purpose of aligning and securing planks in place for sewing the hull, and scholars have described this function for the Omani *kambārī*, Yemeni *sanbūq* and East African *mtepe* where the boatbuilders inserted the dowels before fastening the planks (Prados 1996: 101; Prins 1982: 94-95; Vosmer 1997: 233; 2005: 176). The hole patterns in some of the timbers of al-Balid suggest the use of temporary lashings to draw the planks together. These may have looked like those illustrated in Green (2001: 65, fig. 1) showing the hull of a vessel under construction in Bombay, the planking of which is held together by individual stitches tightened with wooden wedges. Similar lashings, as previously seen, were common in Arab boatbuilding and would have been sufficient to draw planks together to create a perfect fit between them, allowing dowels to be driven in before the final sewing of the hull.

The dowels of the al-Balid timbers might have also been essential during renewal of the stitching. Historical sources, as well as ethnographic records, indicate that boats were resewn on a regular basis (Chittick 1980: 301; Lydekker 1919: 91; Yule 1914: 66). During this process the old stitching, as well as the frames, had to be removed, and dowels could have served to hold the hull planking together.

Dowel Diameter

More than half the planks from al-Balid with dowels have either a smaller or larger diameter than that of the sewing holes. This difference is significant and tells us that boatbuilders often used different drill bits during the construction. If we assume that the bow drill has not changed much in the last 5–10 centuries, then their bits were not interchangeable as in modern power tools: each drill came with a specific bit. This means that shipwrights of vessels that visited al-Balid used more than one version (or size) of the same tool during construction.

The variety of dowel diameters in the al-Balid timbers reflects their importance as fastening devices and also points to the ingenuity of the shipbuilders in preserving the strength of the hull. As seen in Chapter 3, the diameter of a dowel is not proportional to the thickness of a plank, meaning that thinner planks can have thick dowels, and vice versa. They appear instead to have a larger diameter on planks with sewing holes that are spaced further apart. Since the tensile force exerted by sewing also depends on the distance between stitches (Coates 1985: 13), widely spaced sewing holes means weaker fastening, which can cause planks to slide along their edges. Perhaps the use of thick dowels suggests an attempt by boatbuilders to counteract weak joinery between planks caused by widely spaced holes. These devices also allowed them to save on material for the sewing cordage and reduce construction time.

The difference in diameter between dowels and sewing holes on the al-Balid timbers could also suggest that the drilling of dowel channels and sewing holes were two separate activities carried out by different construction teams. This seems to be supported by ethnographic data from Modern-era sewn boats, where carpentry and sewing are often two different processes performed by different groups of people

(Ransley 2009: 95-96; Severin 1985: 281; Vosmer 2010: 130; Vosmer et al. 2011: 422). Although the skills and activities of each group can often overlap, and a rope worker can sometimes help with woodworking and vice versa, it is probable that these processes were separate. One possible reason would be that with two teams, different activities could be done simultaneously, decreasing the boatbuilding time. Experimental archaeological projects have shown that sewn-plank construction requires a considerably longer time, and more people, than nailed-fastening techniques (Staples 2019: 327-331). Specialised "stitchers" (Severin 1985: 281) or rope workers carrying out sewing would free up woodworkers and carpenters, allowing them to continue shaping planks during the fastening of the hull. While there is no evidence for this separation of activities and tasks in the medieval period, this aspect was common in boatyards of the western Indian Ocean, which relied on the shared work of carpenters, carvers, caulkers, riggers and sailmakers.

6.3.4 Repair and Recycling

There are also planks from al-Balid showing a wide variety of dowel diameters within the same timber, which points to dowel channels being drilled at different times and indicating a probable repair with planking being refastened or reinforced with new dowels. Additional dowels could also suggest that the plank was recycled in another vessel, or in architecture.

6.3.5 Dowels in Medieval Boatbuilding

The presence of dowels in the al-Balid timbers also represents a feature that distinguishes them from the other maritime archaeological evidence in the Indian

Ocean. According to Flecker, the Belitung wreck showed no evidence of dowels; its planks were simply fastened together by ropes (Flecker 2008: 200). The preliminary survey of the Phanom-Surin wreck also indicates a lack of dowels (Abhirada Komoot, personal communication, 16 March 2020). The reason for the lack of what looks like such a vital element in sewn construction is somewhat surprising. The Belitung wreck was excavated in a very short time, and some evidence such as the presence of dowels might have been missed. The Phanom-Surin, however, has only undergone a preliminary survey and only a small section of the hull has been observed. Alternatively, the builders of these shipwrecks could also have occasionally used blind dowels, like those employed in Lakshadweep (Varadarajan 1998: 71-73) and Maldives (Manguin 1985: 12) watercraft, and in *Sohar*, by Keralite boatbuilders (Severin 1985: 283). This method, relying on dowels set perpendicularly through the edge of the plank, hence not visible on the outside, was predominant in Southeast Asian boatbuilding (Manguin 1985: 16) (Figure 6.14).

Perhaps the sewing method of the Belitung and Phanom-Surin shipwrecks, consisting of wadding on both sides, was sufficiently strong to hold the planks in place without

Figure 6.14: Blind dowels used during the construction of *Jewel of Muscat*. (Photo: Author)

the use of dowels. However, the timbers from al-Balid show that dowels were indeed used on both timbers with rebates, indicating single wadding, and those without, interpreted as double wadding. Similarly, the only timber from Qalhat with dowels has no rebates. The lack of dowels appears even more surprising in the ship timbers from Quseir al-Qadim, which are very similar in terms of size, date and sewing technique to those from al-Balid, indicating different boatbuilding practices and perhaps pointing to ships built in different regions.

Hole Plugs

Evidence from al-Balid shows that wooden plugs[41] closed both sewing and frame holes of the hull planking of the sewn vessels in connection with the site. The vast number of planks that retained plugs in some sewing holes indicates the importance of this practice and reveals that it was a distinctive feature of sewn boats in the medieval Indian Ocean, persisting until the 20th century (Chittick 1980: 302, fig. 7; Hornell 1941: 60; Kentley 2003: 142, 150; Kentley and Gunaratne 1987: 40; Lydekker 1919: 88-89; Prados 1996: 102; Prins 1982: 91; Severin 1985: 285; Varadarajan 1998: 70; Vosmer 2007: 238, 327). Indeed, an impression on a bitumen fragment discovered on the 3rd millennium BCE RJ-2 site at Ra’s al-Jinz, eastern Oman, appears to suggest that this practice was already in use during the Bronze Age (Figure 2.3). The bitumen fragment is likely to be from the coating of a wooden vessel that was fastened with ropes through rectangular slots filled with wooden plugs (Vosmer 1996: 227). Pedersen (2004: 234) has remarked that the passage of the flood in the eleventh tablet of the epic of Gilgamesh describes the construction of a sewn vessel in the 3rd

[41] Hereafter also referred to as pins or pegs.

millennium BCE. The cuneiform text mentions “water-plugs” hammered into the hull of the ship, indicating the plugging of sewing holes and providing the earliest reference to this practice.

The wooden plugs in the al-Balid timbers would have served two main purposes in a sewn vessel. Their primary function would have been to close the sewing holes, as is clearly suggested by recent sewn watercraft of the Indian Ocean, such as the southeast Indian *masula*, where, generally, only the holes below the waterline are plugged (Kentley 2003: 142). Filling the sewing holes is a crucial requirement in a sewn boat due to the considerable number of holes in its the hull used to secure various structural elements. Experimental reconstruction projects, such as *Jewel of Muscat*, have shown that a sewn vessel measuring 18 m in length required nearly 38,000 holes to fasten its planks, frames and beams (Staples 2019: 324; Vosmer et al*.* 2011: 417). These holes, despite being partially filled with stitching cordage, represent potential water intake points, thus the importance of plugging them properly.

Another function of plugs is to lock the sewing cordage. This is also an essential aspect of sewn-plank construction, particularly when the stitching is continuous. Without a plug holding it firmly in place, even a single broken stitch could result in the loosening of large sections of sewing in a plank’s seam, thus causing leaking. When driven into the holes, these wooden pegs act as stoppers, preventing the stitching from becoming loose in case of damage to the cordage. Moreover, by locking small sections of stitches, wooden pegs also prevent stretching of the cordage.

The timbers of al-Balid also indicate that medieval boatbuilders used wooden pegs to close and plug the holes of temporary lashings used to hold the planks in place during assemblage of the hull, as well as old or damaged holes replaced with new ones during repair. Some of the pegged holes of the al-Balid timbers could be the result of reuse of the timbers in their new terrestrial context.

6.4 Hole Plugs

6.4.1 Plugging Process

It is not possible to determine whether holes were plugged during the sewing process or after from evidence on the al-Balid timbers. Ethnographic evidence appears to indicate the latter, further indicating that their primary function was to plug the holes rather than locking the sewing cordage (Shaikh et al*.* 2012: 152; Staples 2019: 322; Vosmer 1997: 233) (Figure 6.15).

Another aspect that is difficult to determine from the al-Balid timbers is whether the plugging was done from inboard or outboard. The plugs of some timbers indicate that the boatbuilders had tapered them in order to drive them into the holes easily. For example, timbers BA0604145.175 and BA0604159.263 appear to suggest that the plugging process took place from outside because the end of the pegs is larger than on the inner side. Evidence from other timbers, such as Wo56-Wo63-Wo70, points instead to an inboard activity. Again, examples from recent sewn vessels show that it is generally done from the inside (Kentley 2003: 156; Varadarajan 1998: 70); perhaps this is another hint that their primary function was to make the hull watertight.

Figure 6.15: The plugging process of *Jewel of Muscat* and the al-Hariri boat. In the former, rope workers made plugs with loose coir fibre (A) and inserted them into the sewing holes with a metal punch (B). In the al-Hariri boat, the team used wooden plugs (C) and then chiselled out the protruding part (D). (Photos: Author)

6.4.2 Material

An interesting aspect revealed by the timbers of al-Balid is the material used for the plugs: the people who built these vessels closed the holes exclusively with wood. The ship timbers from Quseir al-Qadim also show the use of wooden pegs for the same purpose (Blue et al. 2011: 182) but ethnographic records indicate that Indian Ocean boatbuilders plugged the holes of sewn vessels either using wooden pins or loose fibre (Chittick 1980: 302, fig. 7; Hornell 1941: 60; Kentley 2003: 142, 150; Kentley and Gunaratne 1987: 40; Lydekker 1919: 88-89; Prados 1996: 102; Prins 1982: 91; Severin 1985: 285; Varadarajan 1998: 70; Vosmer 2007: 238; 1997: 233). The fact that the planks from Quseir al-Qadim are of a similar period to those from al-Balid perhaps tells us that wood was preferred to fibre as a plugging material during the medieval period. Could this evidence point to a development from the use of wood to fibre in Indian Ocean sewn-plank construction? Data from the 9th-century Belitung wreck, where unidentified fibre filled the sewing holes (Michael Flecker, personal communication, 27 January 2020), appears to refute this hypothesis. This diversity might instead allude to boatbuilding traditions from different geographical areas, and that the al-Balid ship remains belonged to vessels built or repaired in the same region. The temptation to associate the use of fibre, generally coir, to places where this material was mostly available, such as the tropical regions of the Indian Ocean, is strong. This fibrous material is generally used in sewn boats from the Lakshadweep, southern India, and Sri Lanka (Kentley 2003142, 150; Kentley and Gunaratne 1987: 40; Varadarajan 1998: 70; Vosmer 2007: 239; 295; 326, 334), where coconut palm trees flourish.[42] *Sohar* and *Jewel of Muscat* had their sewing holes plugged with coir by traditional rope workers respectively from the Agatti island, in Lakshadweep, and Kerala, southern India (Severin 1985: 285; Vosmer 2010: 130).

Boatbuilders of sewn vessels of the western shores of the Indian Ocean, such as in southern Arabia, the Gulf and East Africa, seemed to prefer wooden plugs to fill the holes on the hull instead of fibre[43] (Chittick 1980: 302; Hornell 1941: 60; Lydekker

[42] Although there are exceptions, such as some sewn boats from Goa (Shaikh et al. 2012: 152).

[43] Lydekker (1919: 88-89, fig. 2) mentions the use of wooden pegs, called locally *nguruthi*, to “firmly wedge” the sewing cordage of *dau la mtepe.* The same practice was confirmed for the *mtepe* by Hornell (1941: 60) and Friedrichsen (reported in Prins 1982: 91). Chittick states that the sewing holes of the Somali *beden* are plugged after sewing, but does not specify the material (1980: 302). A close-up photograph of the hull of one of these vessels seems to suggest the use of wooden pins or pegs, although the image is not very clear (1980: 302, fig. 7). Prados assumed that the boatbuilders of the southwestern Arabian coast would have used plugs, again not stating the material, to secure the ends of the sewing cord (Prados 1996: 102). It is not clear whether he refers to the practice of locking the cordage during the sewing to allow the release of the tension of the rope before passing it through the next hole, or the actual pegs inserted in each hole. Various photographs of the remains of a sewn vessel at a boatyard in Dakkat Al-Ghaz, Yemen, show wooden pegs inside the sewing holes, as

1919: 88-89, fig. 2; Prados 1996: 102; Prins 1982: 91). *The kambārī* of southern Oman appear to be one exception in this trend because, according to Vosmer (1997: 233) it could have its sewing holes plugged with coir, wooden pins or cloth. The presence of coconut plantations thriving in the region where these boats were used, particularly around Salalah and Taqa, might explain why southern Omani boatbuilders also used fibre to make their *kambārī*s watertight. However, wooden plugs are visible inside the sewing holes of the *kambārī* on display at the Museum of the Frankincense Land, in Salalah, Oman.

The ethnographic records mentioned above appear to point to variety in plugging materials based on geographical factors, at least in more recent times. Could this trend be valid in the case of the al-Balid timbers as well? Unfortunately, the archaeological data on medieval vessels of the Indian Ocean is still too sparse to determine whether this regional distinction occurred in earlier periods. The Belitung shipwreck, identified as a vessel from Oman, Yemen or Iran (Flecker 2010: 118), had holes plugged with an unidentified fibre instead of a wooden peg, evidence that seems to dismiss our initial hypothesis that timber was predominantly used on the western shores of the Indian Ocean. However, the assumed Arab/Persian origin of the Belitung wreck is still far from certain. Moreover, according to Flecker (2010: 117-118) the boat was probably resewn in Southeast Asia and the plugging fibre, along with the use of locally available material for sewing, such as hibiscus and paperbark (*Melaleuca*), could be the result of this activity in that region.

previously remarked by Bowen (1952: 203). Wooden pegs are also displayed inside the holes of Iranian *baggarā*s in the collection of Qatar Museums (Cooper et al. 2020: 17).

6.5 Luting

Bitumen on the al-Balid timbers points to the practice of luting, the use of a malleable material to seal the seam between two adjoining elements (Steffy 1994: 275). This substance covers both the edge and portions of the side of some of the planks of the dataset, where it is found between the plank edge and the sewing holes on the inside of the hull, evidence that indicates bitumen was used to seal adjacent planks before the sewing of the hull (Vosmer 2010: 127). The particular construction method of sewn hulls makes it impossible to waterproof them by driving caulking into their seams, in the way practiced in nailed ships. Hence, after achieving the desired fit between adjacent planks, boatbuilders luted their edges and seams before sewing them together.

The location of bitumen on the al-Balid timbers points to two luting methods carried out at different stages of the construction of vessels. Planks with bitumen on their edge indicate that the boatbuilders smeared it on the seams of each plank just before drawing them together for their final fitting (Figure 6.16). The bitumen was heated with fire, perhaps in cauldrons like those used in southern Iraq (Ochsenschlager 2004: 180-181), to make it plastic and liquid, and easy to apply. This process was probably done near the ship because the material tends to harden quickly after being removed from the heat. Once the bitumen was soft enough, the boatbuilders would then spread it on the edge of the plank being fitted and that of the one below, perhaps using brushes. The final fitting of the planks, consisting in drawing them together with the help of clamps or lashings, squeezed the bitumen, forcing it to fill every fissure and irregularity in the seam, thus increasing the hull's waterproof viability.

Correa reported this practice in the 16th century when describing southern Indian sewn vessels, stating that Indian boatbuilders "do not pitch the ships as we do, they only put

Figure 6.16: Shipwrights apply molten resin on a plank's edges before the fitting. (Photo: Author).

bitumen of *quil*[44] in to the seams" (Stanley 1869: 241). Recent records of sewn boats from the Lakshadweep and Goa show that, along with luting material consisting of a resinous mixture, a cotton strip is often added between the planks (Shaikh et al. 2012: 152; Varadarajan 1993: 64, 67, Fig. 76). The boatbuilders of Kerala and the Lakshadweep Islands involved in the construction of *Sohar* and *Jewel of Muscat* used the same method (Severin 1985: 283; Vosmer et al. 2011: 417), indicating that this was common practice in this part of the Indian Ocean.

Smearing bitumen or other substances on the edges of the al-Balid planks would also have served a second function. The luting could have increased the friction between

[44] The term '*quil*' is a rendition of the Malayalam or Tamil word *kil*, meaning pitch or bitumen (Yule and Burnell 1886: 368).

the planking, further preventing longitudinal sliding often associated with sewn-plank construction (Coates 1985: 11; Vosmer 2007: 176).

Other timbers from the al-Balid collection have bitumen between their stitching holes and the edges of planks, generally on the side without rebates. This evidence indicates that the seams were sealed inboard, a process that took place after the planks were set in place and locked together, and associated with the sewing activity (Figure 6.17). Indeed, bitumen was smeared between the lines of holes of each plank just before laying the wadding onto the seams and commencing the fastening of the planking. Impressions of vegetal material, such as loose fibres, leaves, straw and ropes, on the surface of the bitumen show that this was firmly compressed by the wadding and sewing cordage, providing further watertightness.

Bitumen on the al-Balid timbers highlights the importance of luting in sewn boats. The large number of planks bearing this substance, almost half the dataset, clearly indicates that sealing the seams of the hull was a crucial stage of construction. This practice occurs throughout the timber assemblage, which tells us that the sealing materials and process remained unchanged in vessels visiting al-Balid between the 10th and 15th centuries.

Luting appears to have been a requirement regardless of the sewing pattern of the vessels, being recorded on planks both with and without rebates. This evidence seems to exclude that one sewing method was better than another in making the hull watertight. The Belitung wreck, which was sewn with a double-wadding technique, also had luting along its seams (Flecker 2000: 207).

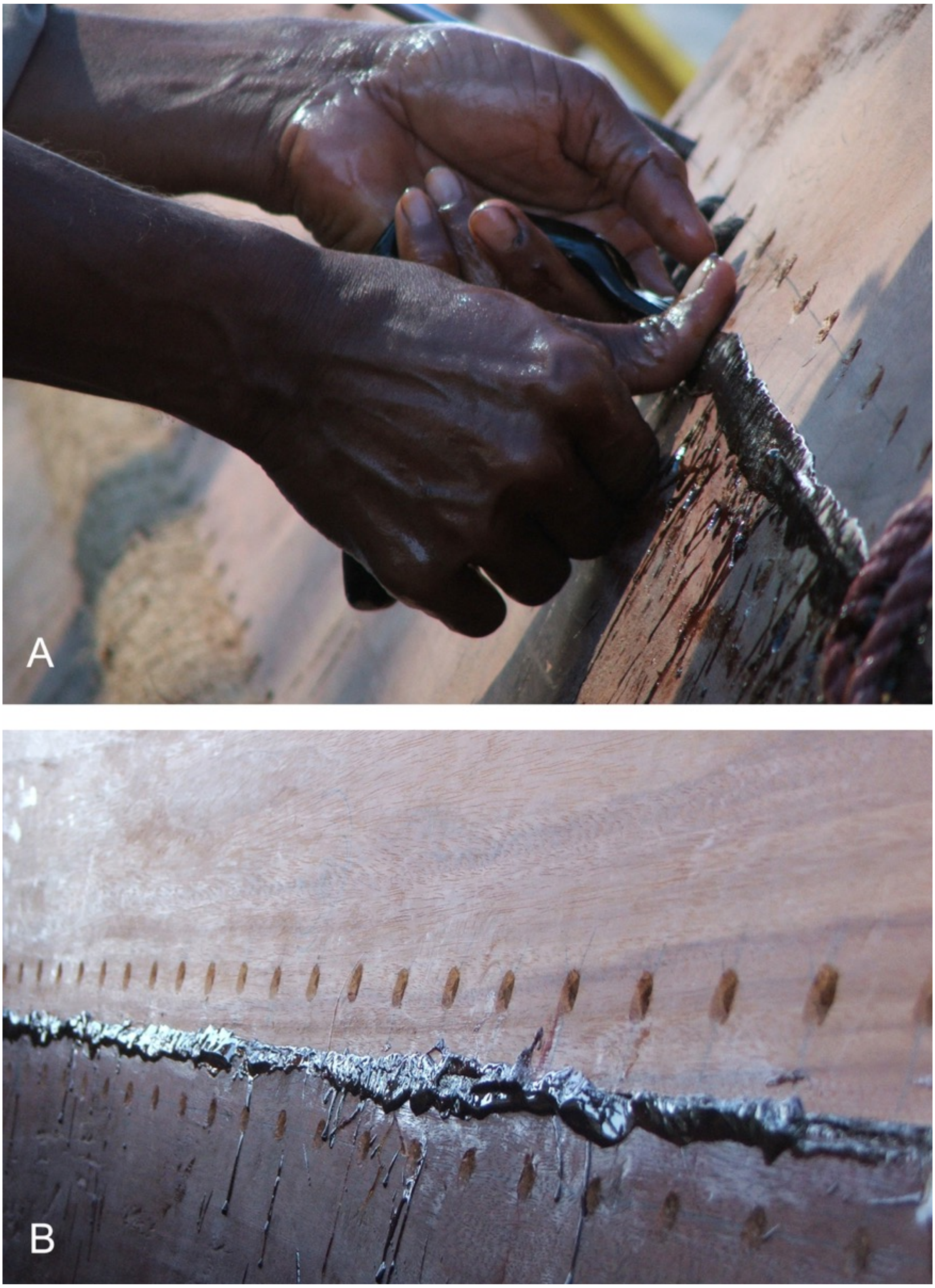


Figure 6.17: Rope workers apply resin between matching holes before commencing sewing the planks. (Photos: Author)

Why do some planks from al-Balid show no evidence of luting if this is such a crucial requirement in sewn boats? The lack of luting on some timbers is, perhaps, due to the reuse of planks in their new terrestrial contexts, and the bitumen could have been removed to make the planks smoother or more suitable for their new purpose. As previously seen in some cases the surfaces of planks were removed and their thickness reduced, perhaps causing the bitumen to be removed or scraped away. Builders of the citadel of al-Balid also reduced the width of most of the planks, which means that their original edges were removed along with any bitumen that was on them.

Overall, the study of the luting material of the artefacts from al-Balid yields interesting insights into various aspects of sewn vessels of the Indian Ocean. It indicates that this was a standard practice at the time and was, perhaps, used in this region for more than a thousand years.[45] Moreover, the diversity of substances used for luting, as indicated by textual, archaeological and ethnographic evidence, also alludes to material availability and different boatbuilding traditions, offering clues about where these ships were built or repaired. I will discuss this aspect in more depth in the next chapter.

6.6 Frame Lashing

The frame-lashing pattern appears as pairs of transverse stitches in nearly all the timbers from al-Balid. Timber BA1105065.454 is the only specimen in the dataset to show a single frame lashing recessed in a rebate arranged obliquely to the length of

[45] If we take into consideration, instead, the use of bitumen in boatbuilding, that period extends to seven millennia (Carter 2002), pointing to the great importance that this material had in the context of Indian Ocean watercraft.

the plank (Figure 6.18(A)). Fragments of ropes and fibres show that a lashing cordage of similar diameter, with what appears to be the same material as that used in the hull sewing, served to fasten the frames to the hull through holes. The lashing cordage is recessed into rebates outboard, similarly to the plank-to-plank stitches in most of the timbers from al-Balid, to protect it against chafing.

Rebates in frame lashings are useful in the al-Balid timbers for two main reasons: firstly they indicate which side of the plank was outboard and, secondly, the alignment of the rebate indicates the pattern of frame lashings on the outside of the hull even without having the actual cordage, which is rarely preserved. What is interesting is that frame lashings are recessed outboard even on planks that are without rebates. In the case of plank sewing, the presence and absence of rebates usually distinguishes different techniques and patterns. However, frame lashings from the al-Balid timbers indicate that one method would not necessarily exclude the other, and that medieval boatbuilders combined them within the same vessel.

Frame lashings recessed into rebates on the al-Balid planks, assumed to be sewn with a double-wadding technique, might hint at the process of development in the sewing method. The Belitung and Phanom-Surin shipwrecks, both with wadding on both surfaces of the hull, have no recessed frame lashings. Assuming that the sewing technique in the Indian Ocean developed from double to single wadding (Vosmer 2017: 200; 2019: 307-308), then the evidence from al-Balid might suggest that this development might have first occurred in frame lashings.

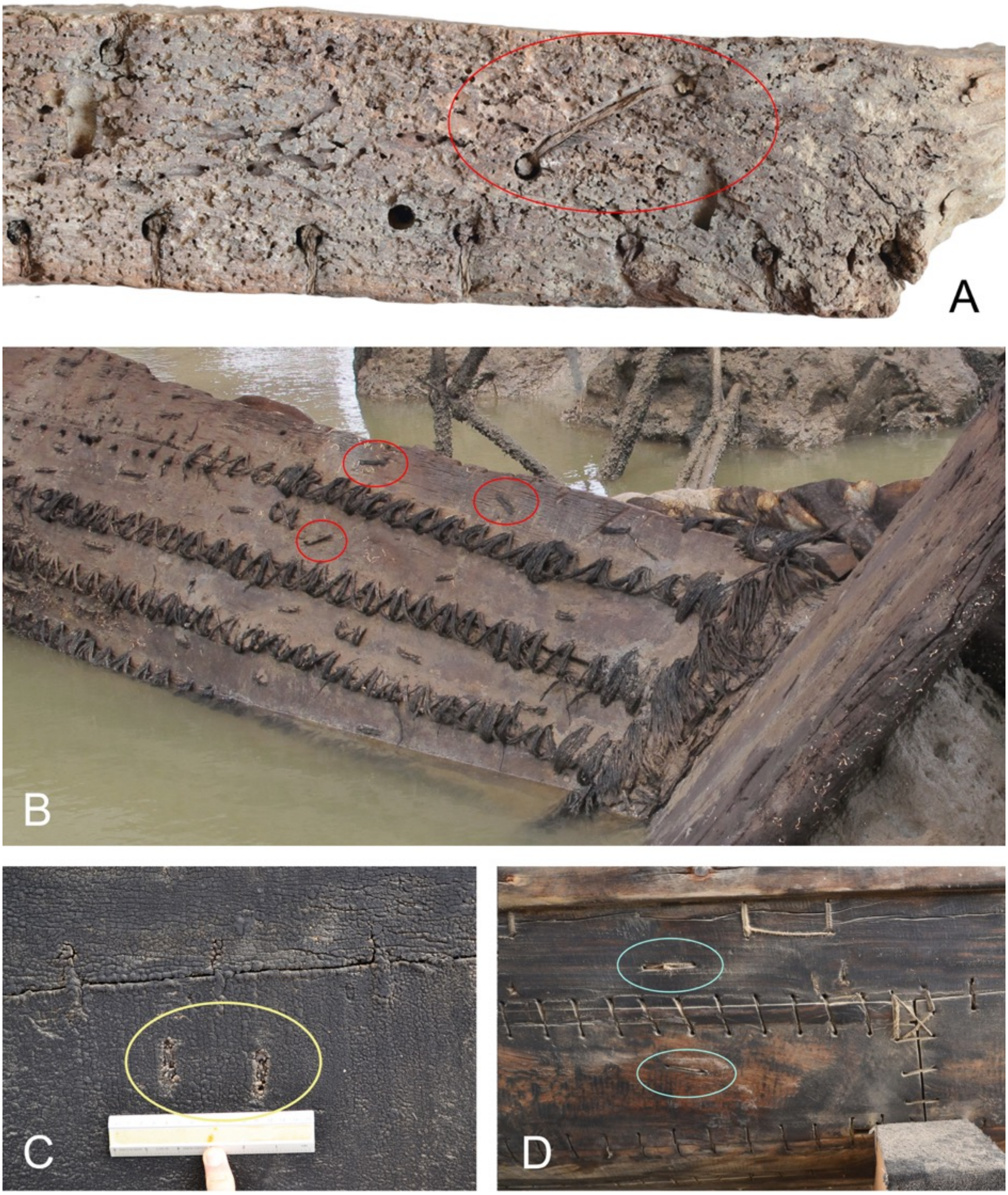


Figure 6.18: Oblique frame lashing on timber BA1105065.454 (A), similar to that on the Phanom-Surin shipwreck (B)(Photo courtesy of Abhirada Komoot). The frame-lashing pattern on the outside of the hull consists of pairs of vertical stitches on the QM Iranian *baggāra*s (C), while it is a single horizontal stitch on the QM Indian *kettuvallam* (Photos: Author).

As seen in the case of plank-to-plank sewing, the holes used in frame lashings share similarities with those from archaeological evidence, such as the Belitung wreck. Although using different lashing techniques, the diameter of the holes is similar (10–12 mm) between the majority of the timbers on the Belitung shipwreck (Flecker 2000: 207), perhaps indicating a “standard” figure.

The frame-lashing pattern on the al-Balid timbers indicates uniformity in the dataset and underlines a further difference with other archaeological evidence of sewn boats in the Indian Ocean. For example, frame lashings on the outside of the hull of the Belitung shipwreck consisted of two pairs aligned horizontally (Michael Flecker, personal communication, 27 January 2020). A similar pattern was also noted in some of the timbers from Quseir al-Qadim (Blue et al. 2011: 182-183, fig. 15.5). Two photographs of the planking of the 8^{th}-century Phanom-Surin wreck reveal the same arrangement, showing one to two horizontal lashings per frame on each strake (Guy 2017: 181, fig. 2; Jumprom 2014: 2, fig. 5) (Figure 6.18(B)). Interestingly, some of the frame lashings near the exposed end of the shipwreck are oblique, resembling those on timber BA1105065.454 of the al-Balid dataset.

The difference in frame-lashing patterns in the archaeological record might point to different boatbuilding traditions, perhaps indicating that al-Balid ships were from the same geographical area. Ethnographic data from 19^{th}–20^{th}-century sewn boats of the Indian Ocean appear to support this hypothesis. Generally, sets of two pairs of vertical lashings were commonly used on sewn craft from southern Arabia, such as the *kambārī* of Dhofar (Weismann et al. 2019: 354, fig. 15) and the sewn *sanbūq* from Yemen (Prados 1996: 103) (Figure 6.18(C)). However, in recent sewn boats from Goa and Kerala, frame lashings often consist of one or two stitches arranged horizontally

(Cooper et al*.* 2020: 29-30; Shaikh et al*.* 2012: 154, fig. 13; Author, personal observation, November 2013) (Figure 6.18(D)).

Single horizontal frame lashings, such as those observed on the Phanom-Surin shipwreck and in India, usually appear to be associated with narrower planks where the width is not enough to have two rows of holes without the risk of weakening the structure of the timber. Wood grain can also be a factor influencing different frame lashing arrangements. Transverse lashings would probably work better in the case of straight-grained timbers such as teak, because vertical rebates would go across the grain, preventing the risk of splitting occurring along it. Planks made from timber species with interlocking grain, such as the *Afzelia africana* or *Artocarpus hirsutus* (*anjili*), for example (Vosmer 2019), could instead be lashed to frames with cordage recessed into horizontal rebates.

Information provided by the al-Balid timbers pertain only to the part of the frame lashings outboard, but tell us nothing about how the frames were secured to the hull inboard. The assumed frame from Qalhat timber 3210 suggests that it was lashed to the planking through a series of holes drilled on its moulded surfaces, in a method observed in the Belitung shipwreck and some southwest Indian sewn boats, such as the *kettuvallam* of the Qatar Museums (Cooper et al*.* 2020: 29–30). Moreover, the presence of holes drilled diagonally on the timber from Qalhat might, perhaps, point to oblique frame lashing, such as those seen on the Phanom-Surin wreck and timber BA1105065.454 from al-Balid, strengthening the hypothesis of its identification as a frame.

6.7 Through-beam Fastening

The presence of two holes with traces of rope on each side of the rebates on timber BA1104065.447 might reveal how the through-beam was fastened to the hull. Along with the halving joint, medieval boatbuilders could have also secured beams to the planking by lashing or sewing with cordage threaded through these two holes. The beams of the Belitung wreck were sewn into the hull in an elaborate pattern through four diagonal holes, one on each corner of its ends (Flecker 2000: 207; Vosmer 2010: 131) (Figure 6.19(A)). Instead, the method suggested by the evidence from timber BA1104065.447 resembles that of the traditional Omani *battīl* (Vosmer 1997; Weismann et al. 2014: 429) and the sewn *baggarā*s of Qatar Museums (Cooper et al. 2020: 20), the through-beams of which are sewn to the hull through one vertical hole in the protruding end of the beam and six holes drilled in the planking (Figure 6.19(B)). This fastening technique looks like a simplified version of that observed in the Belitung wreck and appears to produce a weak bond between the beam and the hull of the vessel.

Beam Wo105 shows no evidence of sewing or lashing, indicating that it was simply notched to, and clamped by, planking. Nineteenth–twentieth-century sewn boats from the Indian Ocean show a variety of ways in which boatbuilders secured beams to planking. Sewing is mentioned, but not described in detail, as the method used in the *masula* (Kentley 1985: 307) and *mtepe* (Hornell 1941: 60; Lydekker 1919: 88; Prins 1982: 90). Pâris documented the use of wooden pins driven vertically through the beam on each side of the hull in the mid-19th-century *beden seyad* (1843: 15-16, pl. 8) and *masula* (1843: 36-37, pl. 27) (Figure 6.19(C)). In other examples, beams are simply slotted into the planking without cordage, as in the Omani *badan* (Author, personal observation, Oman 2012). All these fastening methods do not appear

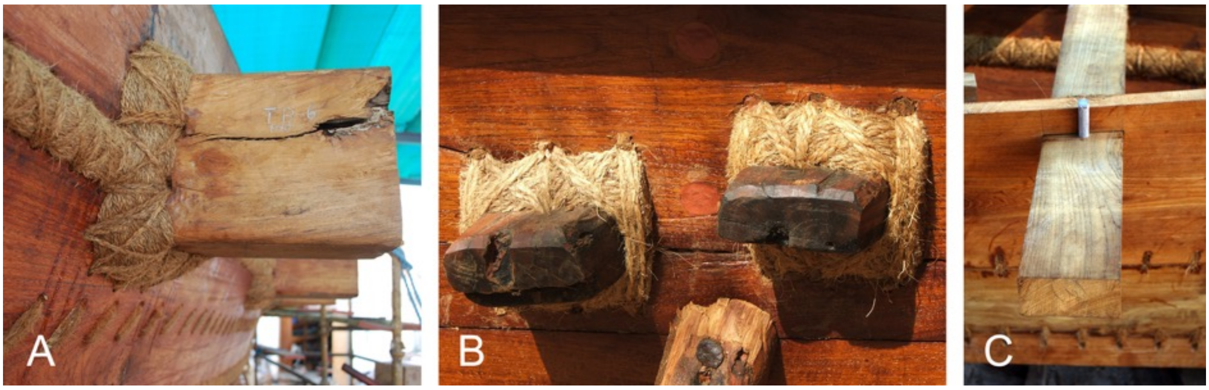


Figure 6.19: The fastening technique of the through-beams of *Jewel of Muscat* (A), *battīl* (B) and the *beden seyad* (C). (Photos: Author)

particularly strong, suggesting that the assemblage between through-beams and the hull relied more on the halving joints. Relatively small vessels, such as most of those mentioned above, would not have required strong, complicated fastening, however, two of the beams from al-Balid could have belonged to a large vessel the size of the Belitung wreck because they share similar beam dimensions, perhaps strengthening the hypothesis that notching them to the hull provided most of the strength in the assemblage.

6.8 Sewing Tools

While marks on the surface of the al-Balid timbers indicate the tools that the shipwrights used, their fastening methods imply the use of sewing tools. However, there is no evidence for these in the archaeological record or historical sources. They would likely have not differed much from those used to fasten and resew sewn boats that survived in the Indian Ocean in the 20th century. Ethnographic studies reveal that maritime communities used the same tools to fasten sewn boats on both shores of the western Indian Ocean. From East Africa to southern India (Hornell 1941: 61; Kentley 1985: 311; Kentley and Gunaratne 1987: 40; Severin 1985: 285; Shaikh et al. 2012:

Figure 6.20: Selection of tools used in the sewing of the *Jewel of Muscat* hull. (Photo: Author)

152; Staples 2019: 321, fig. 5; Vosmer 2010: 127; Vosmer et al. 2011: 417), a typical rope worker's tool kit consisted of:

- a wooden bar used as a lever to apply tension to the sewing cordage;
- a mallet to pound the ropes while under tension;
- a series of wooden tapered dowels to insert into the holes to lock the stitching (Figure 6.20).

Projects such as *Sohar* (Severin 1982; 1985; Severin and Awad 1985), *Jewel of Muscat* (Vosmer 2010; Vosmer et al. 2011), the al-Hariri boat (Staples 2019) and the *beden seyad* (Ghidoni 2019) replica relied on these sets of tools, showing their function and effectiveness within an experimental approach.

The uniformity of sewing tools from different regions of the Indian Ocean, as revealed by ethnographic records, is a further element highlighting the homogeneity of sewn-plank construction technology in this vast geographical area. These ethnographic studies also showed how simple and easy it was to make these tools. The widespread use of similar tools for the same purpose in such a vast geographical area points to their efficiency and utility, despite their apparent simplicity, and evidence suggests that medieval boatbuilders would have probably used similar, if not identical, tools to sew Indian Ocean watercraft.

6.9 Coating and Antifouling

6.9.1 Bitumen

Traces of bitumen on the surface of one plank from al-Balid points towards the practice of coating the outside of the hull. On timber Wo37, a thin layer of bitumen covers the area around the stitching holes on the surface with rebates (Figure 3.58). Since rebates generally indicate the outer surface of a plank, the evidence suggests that the outboard of the vessel was covered with this material.

This coating applied outboard certainly would have provided a waterproof skin around the hull, further reducing water leakage. Applied when still warm and plastic, bitumen would have filled the seams, sewing holes and any planking imperfections, such as cracks or bad carpentry, completely sealing the hull of a vessel.

It could also have served as a protective layer for the planking and stitching against the sun or marine organisms. Shipworms (*Teredo navalis*) and barnacles proliferate in the tropical waters of the Indian Ocean, causing severe damage to the hull of wooden sea craft (Figure 6.21). Sun exposure could make the stitching dry and brittle,

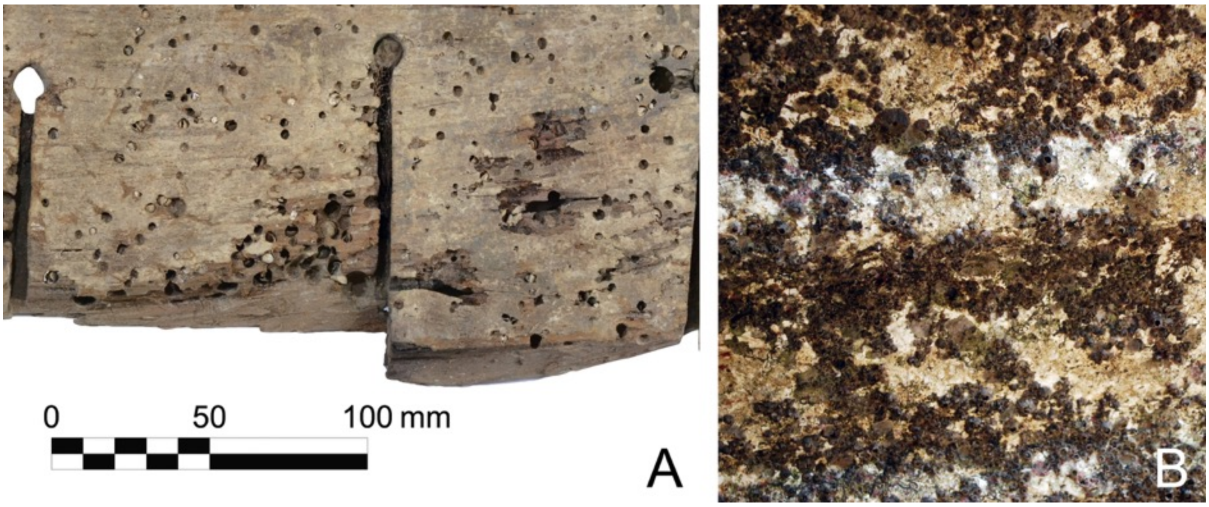


Figure 6.21: Channels bored by ship worms (*Teredo navalis*) into timber Wo82's surface (A). The hull of *Jewel of Muscat* infested by barnacles on its arrival in Cochin, India, after just two months in sea water. (Photos: Author)

while a long immersion in salt water could result in rapid disintegration of the fibres. Chafing, during haul-out or as a result of a collision with another vessel when moored, could also have been an issue for sewing cordage. All these scenarios could have caused serious problems to a boat, ranging from significant leakage to the weakening of the hull structure. A bitumen coating would have been an optimal solution to these problems.

Evidence of bitumen coating from these few al-Balid planks echoes that of the ship remains from Quseir al-Qadim. A black substance tentatively identified as bitumen (Blue et al. 2011: 181) occurred on all the planks, mainly on the side with rebates, indicating the outside of the hull (2011: 182). The similarities between the two collections of timbers point to the practice of using bitumen, or other similar compounds, to protect the planking of Indian Ocean vessels during the 10th–15th centuries.

Timbers BA0604159.263 and BA0604172.69 from al-Balid, meanwhile, indicate that bitumen was also applied to planking inside the hull (Figure 6.22). Similarly to the layer outboard, a thick coating inboard would have protected the stitching against abrasion

Figure 6.22: The thick layer of bitumen coating the inside of one of the QM *baggāra*s. (Photo courtesy of Chiara Zazzaro).

and sun exposure, discouraging the breakage of sewing cordage. It would undoubtedly have helped to avoid any damage to the stitching and wadding caused by the cargo, thus extending the life of the cordage (Cooper et al*.* 2020: 21-23).

6.9.2 Wood Preservative: Fish Oil?

One thin layer of a light-grey substance covering the former inner surface of timber Wo68 from al-Balid suggests a different material from bitumen. Although chemical analysis has not been carried out for identification, the texture and colour of the substance resemble oil, which might point to the practice of applying fish oil to preserve the wooden planking outside and inside the hulls of vessels. Traces of oil in the bitumen mixture on a few timbers from al-Balid (Jacques Connan, personal communication, 13 March 2020) appear to reinforce this hypothesis.

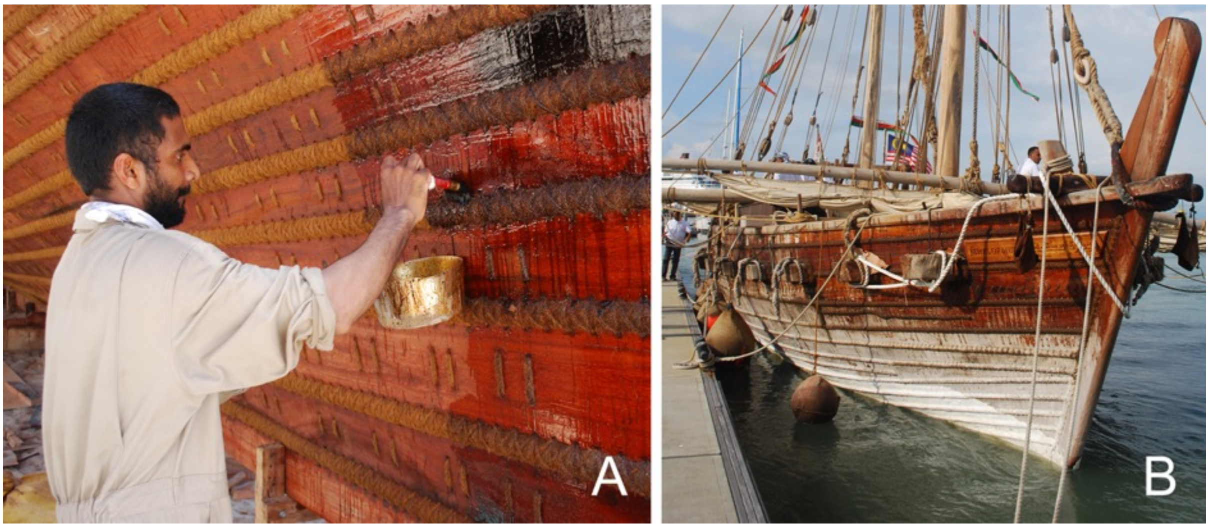


Figure 6.23: Applying fish oil on the hull of *Jewel of Muscat* before the launch (A). *Jewel of Muscat* 's arrival in Georgetown, Malaysia. The rough conditions of the passage through the Bay of Bengal during the southwest monsoon washed away the fish-oil coating, leaving the hull planking exposed below the beams. (Photos: Author)

Fish oil is a crucial boatbuilding product in the Indian Ocean and was used to preserve and maintain both sewn and nailed wooden vessels in the region until recently (Agius 2002: 175; Al-Hijji 2001: 73; Bowen 1952: 199; Donaldson 1979: 234; Hornell 1942: 12; 1970: 197; Johnstone and Muir 1962: 234; Lorimer 1915: 2319; Miles 1919: 404-405; Vosmer 1997: 233). With its unmistakable stench, shark-liver oil was regularly applied to the hulls of Arab, Persian, African and Indian boats in order to protect the timber against the sun exposure and heat of these latitudes, which could cause untreated wood to crack and split (Figure 6.23(A)). Fish oil could also have protected stitching by keeping it moist. On one hand, an oil coating could make the ropes more hydrophobic, thus more resistant to salt water, while on the other, it could prevent them from becoming too dry and susceptible to breakage due to sun exposure. According to boatbuilders from the Lakshadweep, who built and stitched *Sohar*, oiling the stitching cords every 4–6 months — in this case, they used coconut oil — would extend the life of the ship for as long as a hundred years (Severin 1982: 68).

In contrast to a coating made of viscose, thick materials such as bitumen or resin, a layer of fish oil would not have provided watertightness to the hull or served as antifouling. Experiments conducted on samples of timbers smeared with fish oil during the *Jewel of Muscat* project indicated that this substance is not effective against shipworms and barnacles, which are capable of attacking wood to which it has been applied in a matter of days. For this reason, boatbuilders usually applied fish oil only on the upper strakes of the hull, while preferring lime-based antifouling for the part of the vessel below the water (Lorimer 1915: 2319). Lorimer remarks that Arab wooden ships required a new coat of oil twice a year (1915: 2319). However, the *Jewel of Muscat* voyage has shown that the hull of a vessel sailing required several coats of fish oil at least once a month during a long journey. After its crossing of the Bay of Bengal, which was characterised by rough weather conditions, the hull of *Jewel of Muscat* appeared extremely dry on its arrival in Malaysia, indicating that constant waves can easily remove the oil coating in approximately two weeks (Figure 6.23(B)).

A small quantity of fish oil was also mixed with resin (*dammar*) and burnt lime to make the putty used to seal the plank seams and stitching holes of *Jewel of Muscat* (Vosmer et al. 2011: 418). The "recipe" was provided by the rope workers from southern India who stitched the vessel. Finally, fish oil was occasionally added to the compound consisting of lime powder and rendered animal fat, which was used as traditional antifouling (*chunam*).

6.9.3 Antifouling

Evidence of a white substance on the outer surface of timber Wo37 from al-Balid (Figure 3.58) alludes to the presence of lime-based antifouling. This is a thin white coat of a few millimetres located on the outer surface of the timber around the stitching holes over a thin layer of bitumen. The white substance on timber Wo37 could have been used like putty to seal stitching holes, rebates and seams, however, the fact that it is found around the holes and mostly on the surface of the timber extending from the holes and the centre of the plank, suggests that it was applied on the entire hull planking.

The amount of substance on timber Wo37 was too little to allow scientific analyses to determine its chemical composition and the identification of the material (Jacques Connan, personal communication, 18 December 2018). However, its colour and texture point to the use of a traditional Indian Ocean antifouling called, among other things, *shūna* in Arabic (Agius 2002: 175), derived from the Malayalam/Tamil term *chunam* (Yule and Burnell 1886: 168) (Figure 6.24).

Chunam served to protect the planking against barnacles and shipworm by creating a thick layer to which these marine pests would stick and could be easily removed. Boatbuilders and crew members applied it to the hulls of vessels, most probably by hand, creating a thick layer. During careening a ship, most probably carried out between the shift of monsoonal winds[46], this coating was removed along with the fouling sticking to it. *Chunam* also served to protect the cordage of sewn watercraft from sea water and chafing, and provided additional watertightness to the hull.

[46] The sailors at Sur, Oman, often applied a new coat of chunam at spring tides (Author, personal observation, April 2005).

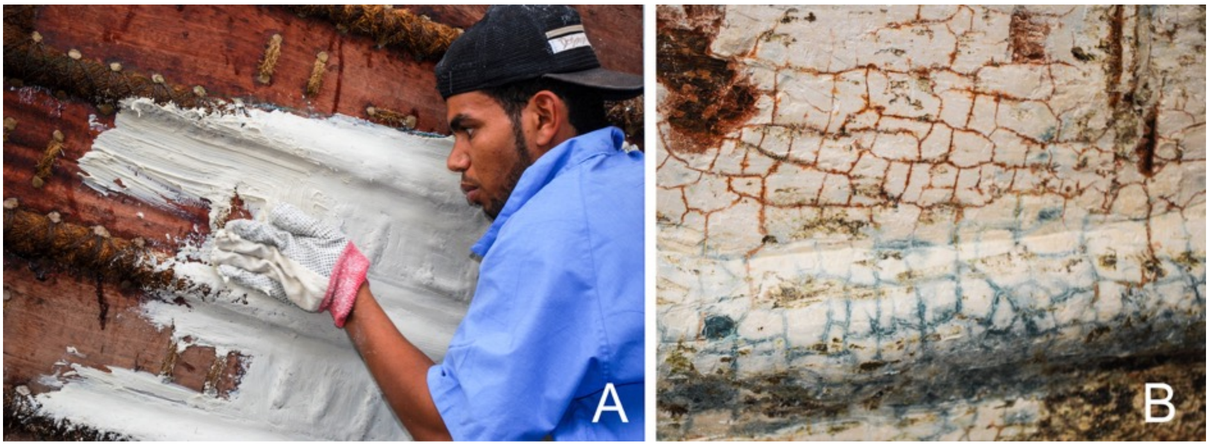


Figure 6.24: Omani shipwright and sailor trainee Fahad al-Sha'aibi applying *chunam* to the hull of *Jewel of Muscat* (A). The antifouling showed cracks when the vessel was hauled out in Cochin to renew the *chunam* (B). (Photos: Author)

The presence of cracks on the white substance on timber Wo37 appears to reinforce its identification as *chunam*. Indeed, this traditional antifouling usually cracks and flakes off a few months after its application, as indicated by experimentation on *Sohar* (Severin and Awad 1985: 202) and *Jewel of Muscat* (Author, personal observation, Oman 2010).

Evidence from al-Balid timber Wo37 could also provide an insight into the size of the vessel. The white substance on its surface might point to a cargo ship or a medium-to-large fishing boat, rather than a small vessel. Because they are regularly hauled out onto the beach, small vessels are less affected by sea growth and marine parasites and usually do not require antifouling. It is, however, necessary on medium-sized sea-going ships since their dimensions would make them too heavy to be beached on a regular basis.

6.10 Repairs

The sewing pattern of the al-Balid and Qalhat timbers is not always easy to identify. As seen in previous chapters, unusual hole arrangements and inconsistencies in their diameter and spacing occur on several planks and, in most cases, indicate repairs. This would have certainly been a crucial requirement for the crews of Indian Ocean ships in order to keep the vessels sound and capable of undertaking long voyages in safety. The following examples are the most common repairs displayed on the timbers. Data from ethnographic research on sewn boats, as well as the archaeological record and experimental archaeology projects, once again provide valuable analogies for interpreting boatbuilders' interventions on the timbers. Overall, evidence from al-Balid shows the ingenuity of the people who built these boats in solving everyday problems, while highlighting the most significant issues of sewn-plank construction.

6.10.1 Cracks on the Surface of a Plank

The single plank formed by timbers Wo56, Wo60 and Wo73 shows a series of regularly spaced transverse stitches recessed in rebates in the centre of the outer face of the plank (Figure 3.24). Although it could also resemble a frame-lashing pattern, the presence of a large longitudinal crack between the stitching holes suggests that this was an attempt to avoid the plank splitting along it. It is noteworthy that the boatbuilders appear to have repaired the damage by using the same sewing technique employed to edge-join the plank. The stitching cordage is made of fibre and very similar in colour and size to that used for plank fastening, and is recessed in rebates on the outside of the hull. It is unknown how the sewing looked on the inside: builders of the citadel of al-Balid probably removed it when they decorated the plank with Arabic

Figure 6.25: A large crack repaired by sewing on QM *kettuvallam* B (A); and on *Jewel of Muscat* (B). (Photos: Author)

text. However, given the similarities between its outboard pattern and that of other timbers from al-Balid, it likely had a wadding and a criss-cross pattern inboard.

This particular method of dealing with imperfections and damage on hull planking, indicated by the al-Balid timbers, is evidenced in ethnographic records. The illustration of the Indian *masula* from Pâris' original manuscript, *Essai sur la Construction Navale des Peuples Extra-Européens,* shows similar repairs (Musée National de la Marine/P.Dantec. Inv.: 3 EX 8). Several stitched cracks occur in a number of its hull planks, even below the waterline. Boatbuilders of the *kettuvallam*, another south Indian sewn vessel, used the same technique to prevent the splitting of a plank along a fracture (Cooper et al. 2020) (Figure 6.25(A)). This method also allowed the construction crew of *Jewel of Muscat* to use planks with imperfections, damage and cracks in its hull, thus avoiding wasting precious material (Figure 6.25(B)).

6.10.2 Sewing Repair and Reinforcement

Other planks, such as Wo68 and Wo85, show significant differences in hole spacing along the same edge. While the pattern looks very regular in some sections of the sewing, some holes are more closely spaced in others, and their diameters often differ,

Figure 6.26: Additional holes added to replace or reinforce the sewing on a *masula* from Orissa, India (A) (Photo courtesy of Colin Palmer). A plank recycled on the deck of a sewn vessel in Alleppey, India, shows similar evidence (B) (Photo: Author). New sewing holes drilled between the old ones and sewn with synthetic rope on the hull of a boat in Kerala. (Photo courtesy of Colin Power)

suggesting that they were drilled at different times. They are also commonly found aligned in rows located at a different distance from the edge than other sewing holes. For example, in the case of timber Wo68, two additional holes appear to be drilled halfway between the other stitching holes and the edge of the plank. They have different sizes, with those that are closer to the edge being the smallest. This is likely to indicate that boatbuilders drilled additional holes at a later stage to replace the old sewing or to reinforce the fastening of the planks in critical areas of the hull (Figure 6.26).

Planks showing a discrepancy in the distance of holes from the edge of the plank also indicate recycling; boatbuilders might have reduced their width by cutting away a damaged portion of its edge before using it on another vessel. This reduction is reflected by the fact that the original holes are now closer to the edge, between it and the additional ones (Figure 6.27). A dowel that appears to be too close to the edge of timber Qalhat-1 might suggest that the plank was repaired in this way. Because it is driven in obliquely, a dowel so close to the edge would go through the side of the adjacent plank, rather than through its thickness and could, therefore, damage the

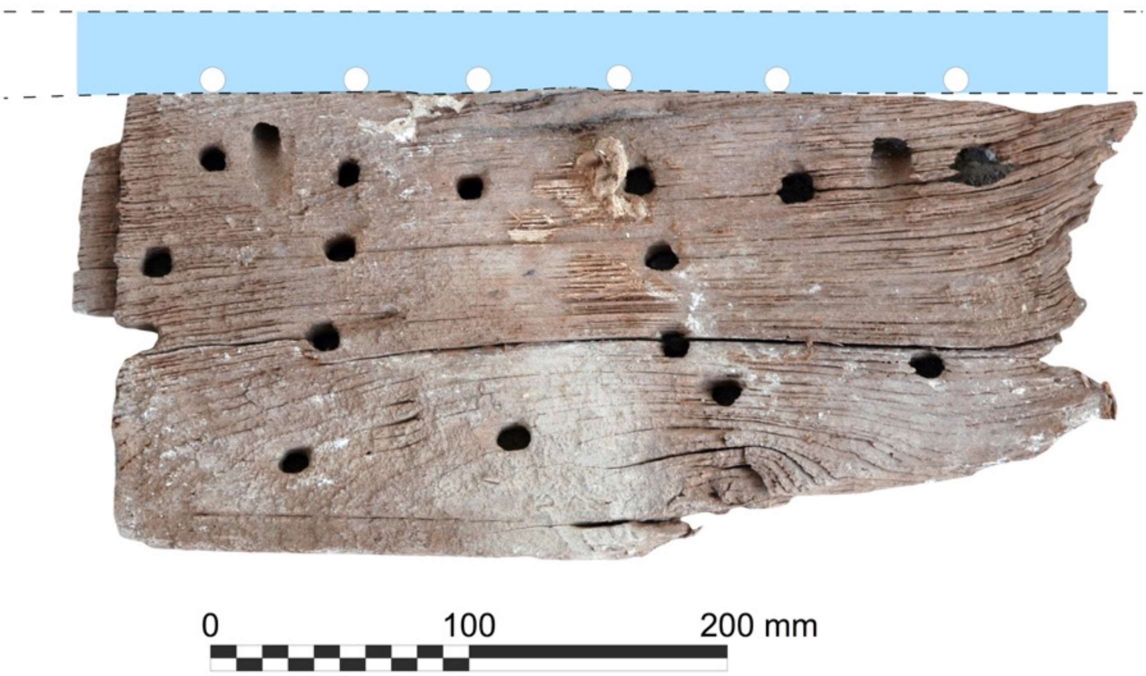


Figure 6.27: Hypothetical reconstruction of the former edge of timber Qalhat-2. (Photo: Author)

plank's edge rather than creating a strong joint. This suggests that the boatbuilders cut off a portion of the edge of the plank, along with the original sewing holes, and drilled a new set of holes 35 mm from the new edge.

The drilling of a row of additional holes at a new distance from the edge of the plank is apparent in the case of timber BA0604128.73. Here boatbuilders were probably concerned about a long crack that formed along the line of the sewing holes and, therefore, decided to add a series of holes above the original ones, instead of cutting the damaged part of the edge away (Figure 6.28). They then stitched the plank with the same single-wadding technique above the previous sewing.

6.10.3 Cordage

Thickness variations in sewing cordage within the same plank might also provide hints about repair or maintenance. For example, the pieces of rope associated with the additional row of holes displayed on al-Balid plank BA0604128.73 are thinner than

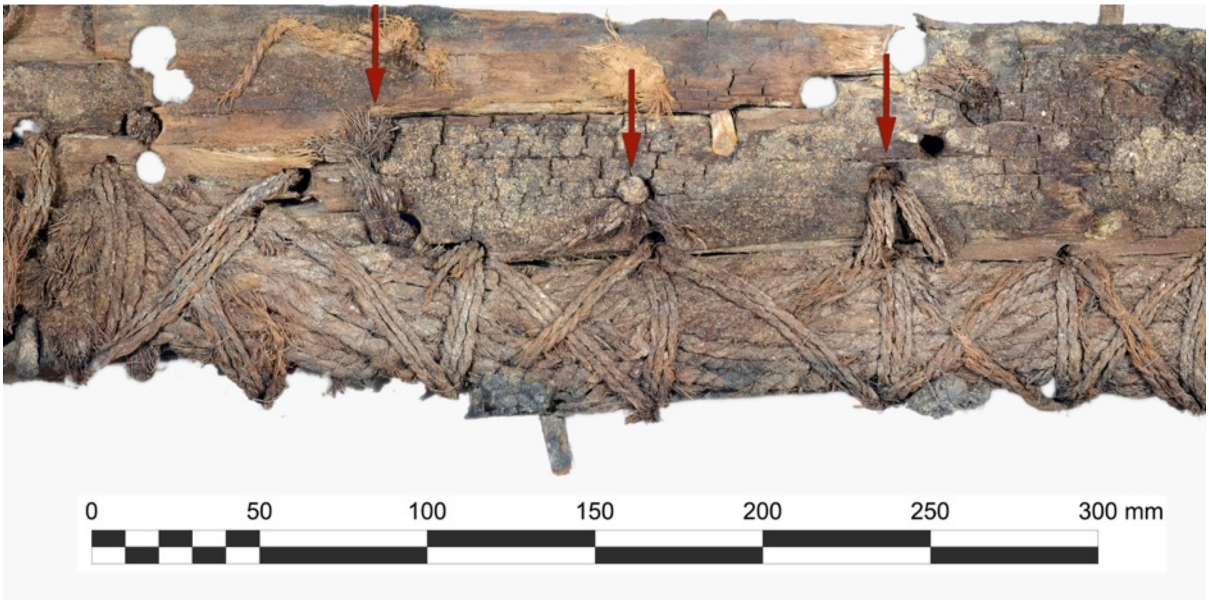


Figure 6.28: Series of holes added to timber BA0604128.73 to reinforce the sewing. (Photo: Author)

those used in the original sewing (Figure 6.28), indicating that the boatbuilders repaired or reinforced the plank joint at a later stage with different cordage. Evidence from timber BA0604128.73 mirrors that from recent sewn vessels of the region, where repair activities are often associated with the use of new material. New fibre, and in many cases synthetic, ropes replace the old sewing cordage as observed, for example, in the case of the Iranian *baggarā*s of Qatar Museums (Cooper et al. 2020).

Historical sources and ethnographic records (Hornell 1941: 62; Yule 1914: 66) indicate that sewn boats required constant maintenance and stitching had to be replaced regularly. Stitches can break easily for several reasons, and damaged ropes could have been replaced with others of different thicknesses. The practice of hauling out sewn vessels by dragging them onto a beach could undoubtedly be one of the causes of damage to ropes due to abrasion and chafing. Sailing in particularly rough seas could also cause stress to stitching, resulting in breakage. Lastly, and probably the most crucially, sun exposure can affect stitching above the water by making it dry and frayed, and easy to break. It should also be noted that fibre ropes, such as those made of coir or date palm, sometimes display variations in thickness.

Overall, the timbers from al-Balid and Qalhat provide valuable insights into some activities related to the use of a boat. Maintenance and repairs are generally understated in historical sources and ethnographic records, but features displayed on the planks of the dataset point to the importance of these activities. Experimental archaeology and boat reconstruction projects, such as *Jewel of Muscat* and *Sohar*, revealed the amount of work needed to keep the vessels in good condition during their voyages. Crew members were kept busy, constantly checking the hull for potential damage and other issues either at sea or in port. Sections of the stitching were replaced with new cordage, as well as plugs and putty that sealed holes. For instance, during the voyage from Oman to Singapore, severe squalls damaged the main mast and the main lower yard of *Jewel of Muscat*, forcing the crew to carry out temporary repairs while sailing (Staples 2013: 49). These projects also highlight the necessity of having crew members with carpentry skills on board, who are capable of carrying out ship maintenance.

Evidence of repairs from the al-Balid and Qalhat timbers reflects the desire of boatbuilders and ship owners to extend the life of vessels. It also points to the recycling of wood and, more generally, to material economy. It is plausible to think that some ships undertook repair and maintenance in coastal areas where wood was scarce, and where the only available timber would have been that from wrecks around the harbours. Therefore, some of the al-Balid and Qalhat planks could have been previously reused and recycled within the same maritime context, which would explain the reason for additional holes of different diameters that were probably drilled to fasten these planks to the hull of new vessels or to repair older ones. Moreover, ship crews would have often been forced to carry out urgent repairs at sea using what was available onboard.

Recycling and reusing planks could also point to the boat owner's desire to minimise expenses related to running a boat. Medieval boatbuilders, like modern ones, were undoubtedly aware of the durability of timber and avoided replacing a plank just because of a crack or minor damage. It is easier and cheaper to repair an old plank rather than shape a new one, with the latter involving the use of multiple tools and tasks, ranging from the felling of a tree to shaping the log into planks, which takes time and costs more than using old, but perfectly solid, timber. Ethnographic records show that the requirement of using a boat for as long as possible did not change in more modern times. Indian Ocean sewn boats generally bore signs of multiple repairs, which indicated that these occurred even in regions with an abundant supply of timber, as exemplified by the *kettuvallam* of southern India held by Qatar Museums (Cooper et al. 2020).

At the same time, evidence of repairs in the timbers from al-Balid and Qalhat is also useful in determining common issues associated with sewn-plank construction. As previously mentioned, splitting along a line of sewing holes is one of the leading causes of damage to a sewn boat. A straight wood grain facilitates this issue, as observed in various timbers of the dataset (Vosmer et al. 2011: 416). Indian Ocean boatbuilders must have found themselves dealing with this problem as soon as they started drilling holes in a plank, but they found ingenious solutions, using whatever was available.

To conclude, the maintenance and repairs indicated by medieval ship timbers from Oman also allude to the versatility of sewn-plank construction. Sewn vessels are relatively easy and cheap to repair, especially when compared to nailed boats. The process of making rope is more affordable and less labour-intensive than producing metal fastenings as it does not require a specific setting or equipment and can be done in every situation, including on board a sailing ship. The Indian Ocean littoral offers plenty of different materials for making sewing cordage. Some, such as *doum* and date palms, are widely available even in places with arid environmental conditions, such as southern Arabia. Inexpensive and easily accessible materials for construction and repair represented apparent advantages for sewn boats of the Indian Ocean, and were, perhaps, the main reason for their persistence in the maritime communities of the region for such a long time.

6.11 Nailed-plank Construction

Planks Wo89A and Wo98C from the southern gate of al-Balid's citadel exhibit a unique fastening technique within the timbers' dataset. One side of the planks displays a single-wadding sewing pattern, while the opposite shows evidence of oblique nails, the heads of which are recessed in triangular-shaped rebates. Wooden dowels also occur near the edges, driven in obliquely and regularly spaced.

The presence of three distinctive fastening techniques (sewing, nailing and dowelling), which are displayed together on the two planks, raises some questions about their interpretation.

- Should we consider them as examples of a hybrid system, combining nail and stitching?
- Do they illustrate a stage in the development from a sewn- to nailed-construction technique?

- Or do they simply represent further evidence of recycling within a shipbuilding context? In other words, were they taken from one vessel fastened by one method to another that employed a different technique?

6.11.1 Plank Recycling

Belfioretti and Vosmer (2010: 115) previously interpreted the triangular recesses displayed on the planks from al-Balid as typical of the Mediterranean maritime context. However, the use of obliquely driven iron nails (technically called spikes) to edge-join hull planks was a distinctive feature of 13th–15th-century Chinese vessels (Flecker 2007: 82; Green 1983: 258; Green and Burningham 1998: 258; McGrail 2001: 375) (Figure 6.29). This fastening method was associated with dowels on one of these vessels (McGrail 2001: 372). These were driven in perpendicular to the edge of adjoining planks (also called blind dowels) and were not visible from the outside, such as oblique dowels of the al-Balid timbers. Moreover, Chinese boatbuilding never combined iron nails with continuous sewing.

The presence of three different fastening techniques on the same vessel at the same time appears unnecessary and provides an argument against the hypothesis of a hybrid construction. Sewing, combined with regularly spaced diagonal dowels, would be sufficient to provide strong joinery between hull planking without the need of oblique nails. While the 14th-century Chinese shipwreck Penglai featured both dowels and iron nails to secure its planks (McGrail 2001: 372), the former were not as closely spaced as those in the al-Balid timbers Wo98A and Wo98C.

Chinese boatbuilders generally drove oblique nails in from outboard, meaning that triangular recesses occur on the outside of the vessel, which was waterproofed with a

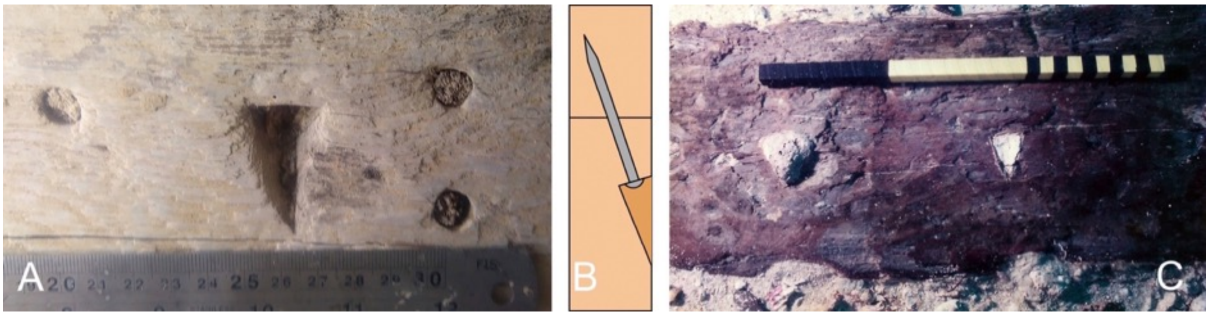


Figure 6.29: A close up of the triangular rebate on timber Wo98C (A) and a sketch showing its fastening technique (B) (Photos: Author). Similar evidence from the 15th-century Bakau wreck discovered in Indonesia (Photo courtesy of Michael Flecker)

lime-based compound (Green 1983: 258; Green and Burningham 1998: 286; McGrail 2001: 375). On al-Balid timbers Wo98A and Wo98C these triangular recesses are found on the side opposite that with sewing rebates, which, in sewn boats, indicates the inside of the hull. The two fastening devices, generally found outboard on opposite sides of the timbers, appear to exclude their use at the same time.

Lastly, different conservation states of the fastenings on the al-Balid timbers might also provide a further hint against a hybrid interpretation. The sewing is almost entirely preserved on the outer face of the planks, recessed in the rebates, and dowels are still visible inside their holes. Nails, instead, have entirely disappeared except for a small trace of metal in one hole (Figure 3.35). This evidence suggests that the two fastening methods were done at different times, and that sewing is likely to be the most recent.

The different state of preservation of the fastening devices on Wo98A and Wo98C also appear to exclude nails serving to secure planks of the gate-locking system together. Besides, if the builders of the citadel had used nails, they would have driven them from the outside of the wooden box formed by the planks instead of inside, which is too narrow to access. Moreover, there are no holes on the edges of timber Wo98B,

Figure 6.30: The edges of timbers Wo98C (left plank) and Wo98A (right plank) lined with bitumen. (Photo: Author)

located above Wo98A and Wo98C, that match the triangular rebates on the two planks below and suggest nail fastenings.

Evidence of the gate timbers points to recycling from a maritime context, and that the plank would initially have belonged to the hull of a nailed boat. Apart from being suggested by the better conservation state of the stitches, traces of bitumen used as luting material that still coat the edges of Wo98A and Wo98C also strengthen this hypothesis (Figure 6.30). The bitumen, along with the sewing, would likely have been removed from the planks if these had been taken from a sewn boat to build or repair a nailed vessel. The sewing holes also appear to be arranged in a pattern according to the position of the triangular rebates, and their spacing appears quite regular, except in the case of the holes on either side of the rebates, suggesting that these were already in place when the boatbuilders drilled the sewing holes.

6.11.2 The Origin of al-Balid's Nailed Planks

The diverse fastening techniques on the al-Balid gate timbers provide information regarding the practice and dynamics of multiple recycling of ship remains, in both maritime and terrestrial contexts. Similarities between planks Wo98A and Wo98C, such as their date (early 14^{th}-15^{th} centuries), overall dimensions and spacing of the triangular rebates, suggest that they came from the same nailed vessel. However, determining the origin of the ship to which they originally belonged is complicated and involves a great deal of speculation. A Chinese origin can be ruled out on the basis of some of the evidence. Firstly, ships built in that region had thicker planks, ranging between 80 mm and 165 mm and reaching up to 280 mm (Flecker 2001: 224; Green 1983: 225; Green and Burningham 1998: 285; McGrail 2001: 365, 368-369, 372-373) compared to the two al-Balid timbers that measure 30 mm. The angles of nail holes on Wo98A and Wo98C make them fit with the planks' thickness, excluding the possibility that this was reduced when they were recycled in a sewn boat.

Secondly, is the location of the triangular recesses. On two shipwrecks, Bakau (Flecker 2001: 224, Fig. 3) and Quanzhou (Green and Burningham 1998: 286) these are carved in the middle of the plank at roughly 90–100 mm from the edge (Figure 6.29(C)). Although their spacing, between 170–200 mm, matches the evidence from al-Balid, their distance from the edge is considerably larger than those on the gate planks of the citadel, where these rebates are found at 35–40 mm from the edge.

Finally, wooden species identification analysis provides additional evidence against a Chinese origin. The planking of Chinese vessels was primarily made of pine, fir or cedar (Flecker 2001: 224; Green 1983: 255; Green and Burningham 1998: 284; Li 1989: 277; McGrail 2001: 365, 369, 372), while Wo98A and Wo98C are both made of teak (Table 3.3).

6.11.3 If Not Chinese, Where From?

The identification of the place where the boat was built belongs to the field of hypothesis. Although references to the use of nails in western Indian Ocean boatbuilding occur in the early years of the 16th century (Castanheda 1833 III: 30; Greenlee 1938: 105; Stanley 1869: 240; De Varthema et al. 1863: 152), the earliest mention of this particular technique in the region is found only in the 19th century. The *pattamar*s documented by Admiral Pâris along the coast of Malabar, India, in the mid-19th century share strong similarities with the gate planks of al-Balid (1843: 17-19, pl. 10, figs. 4-6) (Figure 6.31). The method illustrated by Pâris consists of edge-joined planks, the seams of which are rabbeted, with curved diagonal nails and individual lashings tightened by wedges (McGrail 2001: 271). The nails are spaced 200 mm apart and driven through the plank seams from the outer side of the hull. Pâris remarks that their fastening technique is very old and typical of India, though occasionally used by Arabs as well (1843: 18). This method, called *vadhera*, was recorded in Gujarat,

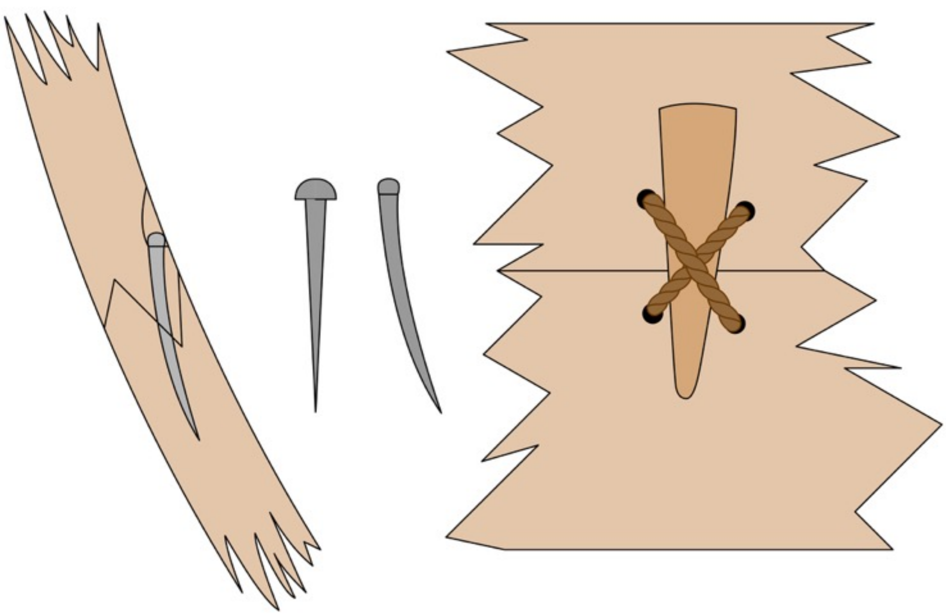


Figure 6.31: The *vadhera*-fastening method of the Indian *pattamar* illustrated by Pâris (1843: pl. 10) and redrawn by the Author.

northwest India, in the first half of the 20th century (Hornell 1930: 311; Manguin 1985: 9; Varadarajan 1993: 554; 2011: 155-178). According to Manguin, Portuguese accounts of nailed ships in India in the early 16th century indicate that this particular technique developed in this region (1985b: 11).

The use of diagonal nails illustrated by the *vadhera* technique appears to be the closest match to the fastening system of the gate planks of al-Balid. Both have similar nail spacing, and the plank thickness is closer to that of the two timbers, perhaps suggesting a previous use in a nailed watercraft from India before being recycled in a sewn boat. The earliest accounts of the use of nails in the region all refer to Indian ships (Stanley 1869: 240; De Varthema:152; Greenlee 1938: 105; Castanheda III: 30). The fact that the wood species identified in both Wo98A and Wo98C is teak seems to reinforce the hypothesis of an Indian origin for the nailed vessel from where the planks came. However, the only archaeological evidence for a medieval nailed boat from India shows a different technique. The Thaikkal-Kadakkarappally wreck, discovered in Kerala and dated to the 13th–15th centuries, was fastened with nails riveted inboard and iron spikes perpendicular to the hull, instead of driven diagonally through the planking (Tomalin et al. 2004: 258-259, figs. 8-9).

Moreover, the practice of fastening the edges of two planks together by oblique nails was ubiquitous in the Indian Ocean in the 20th century and is still used today (Figure 6.32). Bowen and Hornell remarked that this method was typical of Sudanese watercraft (Bowen 1952: 207, 209; Hornell 1970: 193). In Oman, shipwrights used it in combination with other fastening techniques in *battīl*s from Musandam (Vosmer 1997: 224) and cargo *badan*s (Weismann 1998: 244, 250, 254, fig. 8). A *kettuvallam* from Kerala, recently acquired by the Qatar Museums, has its planks edge-joined with continuous sewing and diagonal nails driven in from the outside (Cooper et al. 2020:

Figure 6.32: Oblique nails recessed in triangular rebates on the hull of QM *kettuvallam* (A). Zanzibari boatbuilders have combined this fastening technique with discrete lashings on a vernacular *ngalawa* (B). (Photos: Author).

29). This technique is still widely used in Zanzibar in the building of a variety of traditional vessels (Author, personal observation, 2018).[47]

6.11.4 Nail Fastening in the Indian Ocean before the Portuguese

Evidence from timbers Wo98A and Wo98C, which display both sewing and oblique nails, is of considerable significance within the context of western Indian Ocean shipbuilding during the medieval Islamic period. Until recently, sewn-plank construction was presumed to be the only method employed in watercraft in the region before European expansion in the late 15th century (Hourani 1963: 88; Moreland 1939: 179). Portuguese historical sources that mention nailed vessels in the early years of the 16th century led scholars to the general assumption that Europeans introduced this fastening technique in western Indian Ocean boatbuilding (Johnstone and Muir 1962: 59). Radiocarbon dating analysis on timbers Wo98A and Wo98C indicates a period range between the early-14th and early-15th century (Table 3.5). The date of the

[47] Observation carried out as part of the British Academy-funded The Boat Builders of Zanzibar: Nautical Technology and Maritime Identity in a Changing World project (Project SL-08385; 2018–19; P.I. John P. Cooper; Co. Lucy Blue; participant researcher Alessandro Ghidoni).

planks, therefore, refers to a period prior to Portuguese expansion in the Indian Ocean, showing that nailed construction was known and practised to some extent in the region a long time before their arrival. Archaeological discoveries such as the nailed planks of Quseir al-Qadim (12^{th}–15^{th} centuries) on the Red Sea coast of Egypt (Blue 2006: 607; Blue et al*.* 2011: 182, 184), and the southwest Indian Thaikkal-Kadakkarappally shipwreck (Tomalin et al*.* 2004), already provided evidence that challenged the assumption that all western Indian Ocean vessels were sewn before the 16^{th} century. New data from al-Balid corroborates that and provides the first evidence of a nailed-construction technique in Arabia.

The similarity between the iron-fastening method of the al-Balid timbers and that used on medieval Chinese ships offer further insights into the debate about an external influence in the use of nails in the western Indian Ocean. Scholars such as Manguin (1985: 11) and Vosmer (2017: 196-198) have remarked that nail construction would more likely have been the result of contacts with the Chinese rather than through the Portuguese. Arab and Indian boatbuilders would most probably have seen Chinese ships, which sailed in the western Indian Ocean between the 9^{th} and the 15^{th} centuries (Agius 2007a: 77), and evidence from al-Balid appears to strengthen this hypothesis, limiting the extent of the European influence on Indian Ocean boatbuilding technology.

The metal fastening on the al-Balid timbers also reveals a different technique from those seen in other archaeological evidence from the western Indian Ocean. The planks from Quseir al-Qadim indicate nails driven from outboard and perpendicularly to the planking; their heads were recessed in square rebates and flush to the plank's surface (Blue et al. 2011: 196). The boatbuilders of the Thaikkal-Kadakkarappally wreck used a similar technique as well as nails rivetted on a rove inside the hull. In both these cases, the method indicates that the nails served to fasten the planking to the frames. In the al-Balid timbers, the diagonal nails edge-joined the planks. Collectively, this evidence indicates that not only was nailed construction known in the western Indian Ocean before the arrival of the Portuguese, but that it was practised with at least three different techniques.

To conclude, the al-Balid timbers provide pieces of valuable but still limited information. Only one small section of timbers Wo98A and Wo98C is exposed, while the remainder is still inside the wall of the citadel's southern gate. The planks are the longest of the dataset, with an estimated length of over 3 m, and could potentially offer further and more definitive insights into their interpretation. Having access to the entire length of the planks could also help to answer other questions and allay doubts regarding their possible previous use. For example, if they originally belonged to a nailed boat, how were the frames fastened? The planks only show typical frame lashings but no other technique such as nail or pegs, which one would expect to find in a nailed boat. Does this suggest that shipwrights used nails to secure the planking and cordage to attach the frames, perhaps pointing to a hybrid construction? The last question concerns the location of the nails on gate planks, found only near one of their edges.

Once, and if, the archaeologists working at al-Balid remove the planks from the masonry of the citadel, there will be a better opportunity to answer these questions. Therefore, caution is advisable in the interpretation and origin of timbers Wo98A and Wo98C until then, or until further data are provided by either archaeology, iconography or new archival sources.

6.12 Conclusion

Indian Ocean boatbuilders employed a variety of fastening techniques and materials to assemble the hull of the vessels sailing during the medieval period. These assembly methods, including both sewing and nailing, are identical to those used in 19th–20th century sewn craft revealing, once again, a continuity in boatbuilding practices from the medieval period to the Modern era.

The evidence from al-Balid indicates the presence of at least two distinct sewing systems, which appears to match earlier archaeological evidence in the region, as well as with Modern era sewn boats from India. This diversity alludes to a dynamic boatbuilding scene, in contrast to a fixed and rigid context assumed by early scholars. It also appears to suggest a possible development from one method to another, as indicated by the disappearance of the double-sewing method in the al-Balid archaeological context, after the 13th century.

Analysis of the sewing techniques of the al-Balid timbers once again indicated the ingenuity of medieval boatbuilders in solving the technical issues of sewn-plank construction, such as the application of bitumen to increase the watertightness of the hull. The extensive use of dowels is, however, the most remarkable and distinctive feature of these timbers, and their frequency clearly indicates their importance.

The presence of nailed planks is the other significant evidence from the al-Balid dataset, and sheds some light on the complexity and diversity of Indian Ocean boatbuilding before European expansion. The complexity and diversity of these vessels is further accentuated by the information provided by the timbers regarding the materials used for construction, which will be addressed in the next chapter.

7 The Use and Trade of Materials in the Indian Ocean in Light of the al-Balid Timbers

7.1 Introduction

Evidence on shipbuilding materials from the al-Balid timbers is significant, especially in light of the dearth of information in historical sources and the archaeological record. References to materials, particularly wood, used for vessel components are minimal and often vague. As previously seen in the case of bitumen, tar and pitch, historians, geographers and travellers could often not distinguish between different materials that looked similar, sometimes making their accounts misleading. Scholarly discourse on the materials used in medieval ships of the Indian Ocean has often relied on assumptions that are based on limited information provided by textual sources, as well as on the data from ethnographic studies on more recent watercraft and maritime communities of the region.

Historical sources, as well as scholars, focused more on exotic and luxury commodities, such as silk, ivory, horses, etc. but timber and other boatbuilding materials would have played a vital role in commercial networks, connecting different and distant regions of this vast geographical area while, at the same time, allowing maritime communities to build the vessels involved in these networks (Figure 7.1). Collections of timbers such as those from the site of al-Balid and, partially, Qalhat, that belonged to different boats spanning over a considerable period, offer valuable insights into the use and trade of boatbuilding materials in the Indian Ocean during the Middle Islamic period.

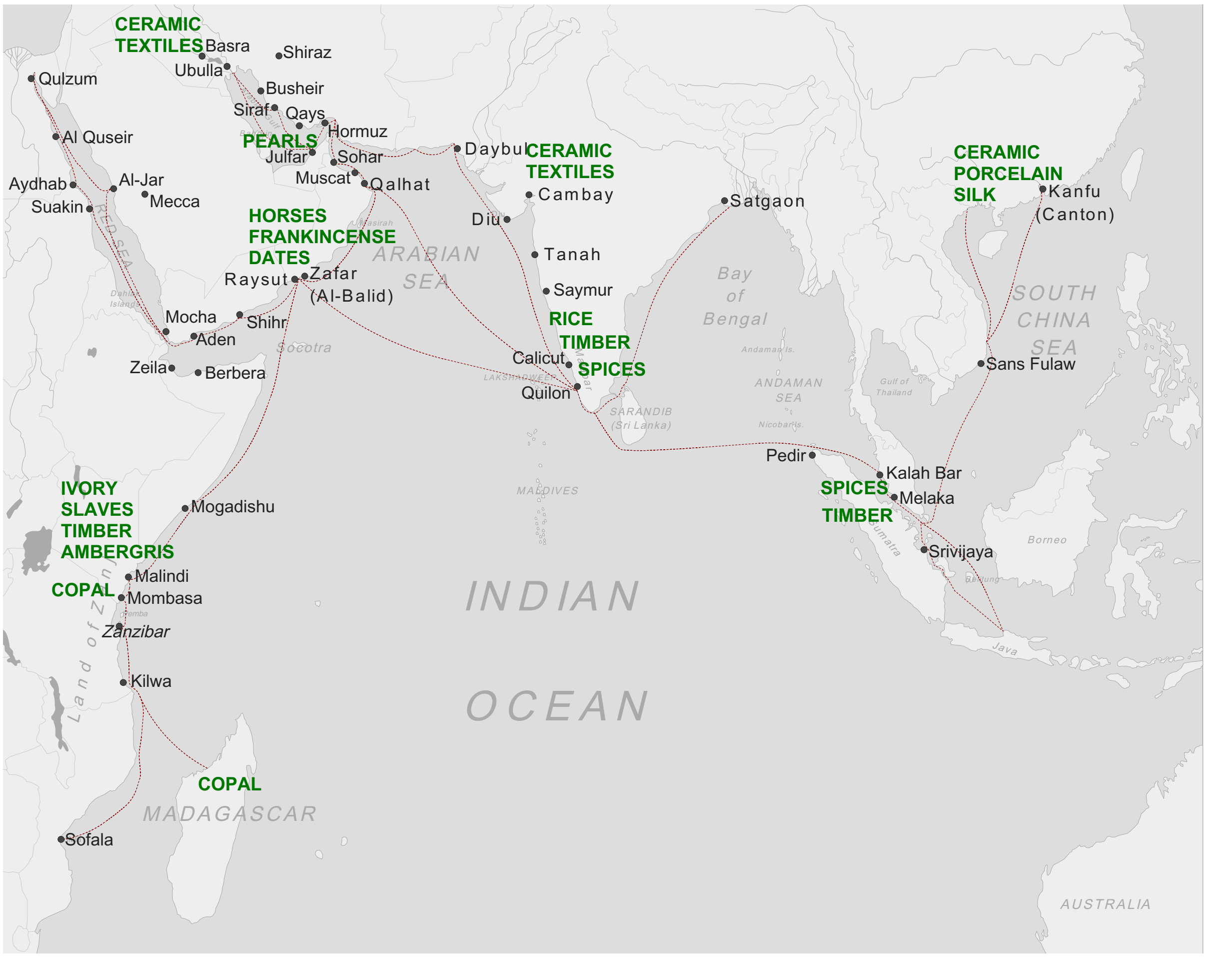


Figure 7.1: Map of the Indian Ocean showing main centres, maritime routes and material sources in the 10-15th centuries.

7.2 Timber

Botanical analyses of the al-Balid timbers identified six species, four genera and two families. These data are particularly significant considering wood is by far the least mentioned material in medieval and later Portuguese sources; detailed references to specific types of wood used in a boatbuilding context in the region are rare (Semaan 2015: 44; 2018: 507).

The most remarkable aspect of the results is the variety of wood species in the al-Balid dataset. These are native to various regions of the western Indian Ocean and their distribution stretches from India to Arabia and East Africa, including both coasts of the Red Sea and the Gulf. Some of these trees, such as *Acacia* sp., *Ficus* sp. and white mangrove (*Avicennia marina*) are widely found along the western Indian Ocean littoral.

7.2.1 Teak

Teak (*Tectona grandis*) is the most predominant of the al-Balid timbers occurring in one-third of those sampled, as well as all those discovered in Qalhat (Figure 7.2). The presence of teak is not surprising since it is one of the two timber types mentioned in textual sources for the construction of western Indian Ocean sewn vessels (Hourani 1963: 90; Lewis 1973: 250; Moreland 1939b: 145). In his bizarre account of the discovery of Indian Ocean sewn planks in the Mediterranean, al-Masʿūdī (d. 345AH/896CE) (Al-Masʿūdī 1861: I, 365) states, in the 10th century, that they were made of teak. During the same period, Ibn Durayd (d. 321AH/933CE) and Ibn Sīda (d. 458AH/1066CE) inform us that teak provided the planking material of a type of watercraft called *qurqūr* (Agius 2007a: 332; Staples 2018: 206). It was also identified

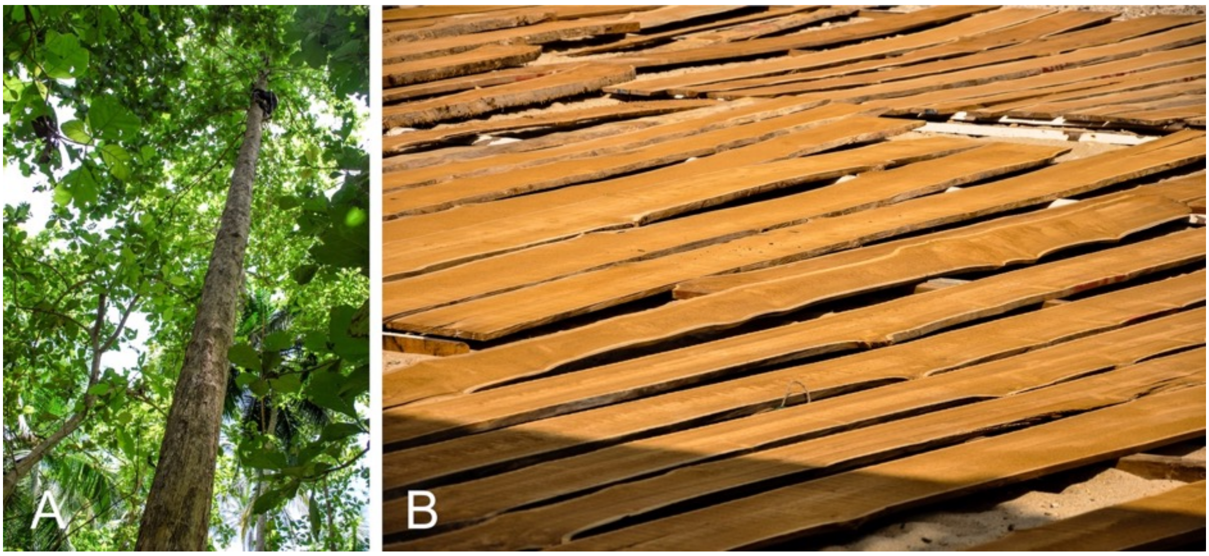


Figure 7.2: A tall, straight teak tree (*Tectona grandis*) in Sri Lanka (A). Teak plank seasoning in Oman, before the construction of the al-Hariri boat (B). (Photos: Author)

as the timber of the Belitung shipwreck through-beams (Flecker 2000: 215; 2008: 385, table 1). The colour and regular grain of teak is aesthetically pleasing and was considered an exotic/luxury commodity in the Arab world. Al-Muqaddasī, translated by Agius (2007a: 75-76, 86), mentions the use of teak in the buildings of Sohar and Siraf to highlight the economic wealth of those cities.

The Malabar coast, southern India, was the main supplier of teak from early times. The *Periplus* in the 1st century provides perhaps the earliest reference to the Indian Ocean teak trade (Casson 1989: 73), saying it was exported from the city of Barygaza, north-western India. Claims of teak traded in the 3rd millennium BCE from India to Mesopotamia, based on mid-19th century identification of Indian teak in Ur (Mookerji 1912: 85, 87), have been challenged since its identification was not carried out by modern scientific standard procedures (Moorey 1994: 352, 360).

7.2.2 Mangrove

Mangrove (*Avicennia marina*) grows in a broad range of climatic conditions, particularly in lagoons along the Arabian and East African coasts (Figure 7.3(A)). It thrives in the brackish waters of the Rufiji River delta, Tanzania, and Lamu archipelago, Kenya, and provided the poles (*boriti*) used in the roofs of Arabian and Iranian buildings (Chittick 1977: 184; Edwards 1940: 380; Villiers 1962: 112). Mangrove poles would have probably been a vital export during the medieval period. In the 10th century, al-Iṣṭakhrī (fl. c. 340 AH/951 CE) and Ibn Ḥawqal (d. after 367 AH/978 CE) (Chittick 1977: 192) mention that Siraf imported a particular type of wood from Zanj (the Swahili coast) for the building of its houses. According to Chittick (1977:

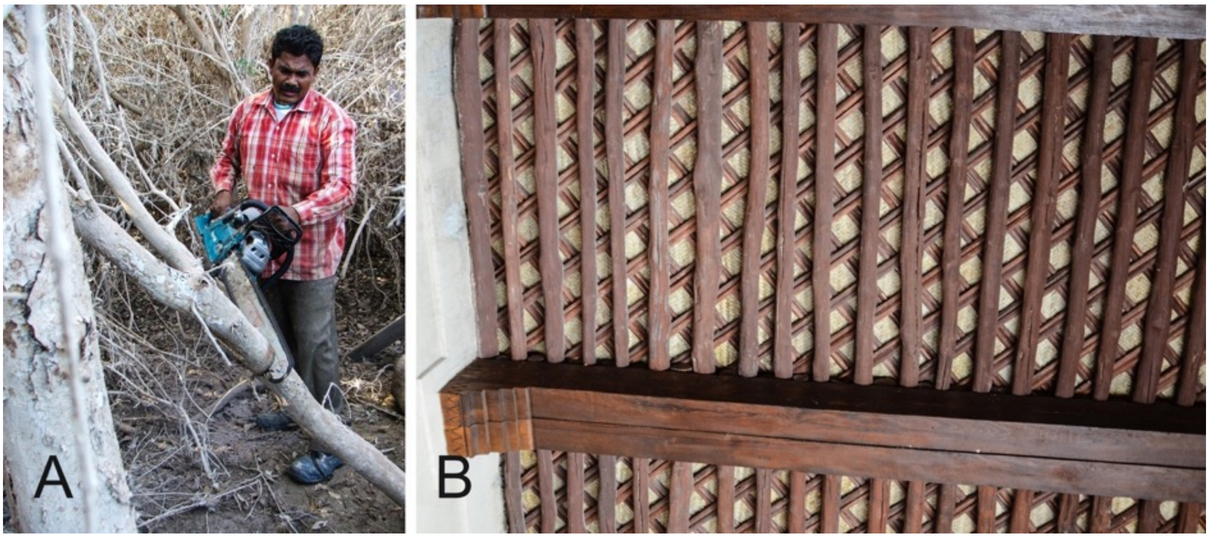


Figure 7.3: Shipwright Babu Sankaran cutting mangroves in Qurum, Oman (A). Mangrove poles as roof beams in Nizwa Fort (17th century), Oman (B). (Photos: Author)

192), al-Iṣṭakhrī and Ibn Ḥawqal are most probably referring to mangrove poles (*boriti*) (Figure 7.3(B)).

7.2.3 Acacia

Acacia can be found in arid places such as Arabia, particularly in Oman (Al-Hijji 2001: 41) and the African coast of the Red Sea. Although not an ideal boatbuilding timber, one species, *Acacia nilotica*, was an important wood source for southern Egyptian and Sudanese watercraft for millennia. It was the material used for the planking of ancient Egyptian freight vessels, such as those that carried granite blocks along the Nile (Ward 2000: 16, 107). Acacia was the primary timber for the construction of the frameless Sudanese river vessels (Hornell 1939: 418) and is still in use in the region today (Zazzaro 2017: 182) (Figure 7.4). Hornell (1939: 418) states that this wood is hard and cracks easily, and the tree only provides short planks. Acacia was also suitable for making keels, stem and sternposts (Agius 2005: 33) as well as beams, as in the case of al-Balid timber BA1104065.447.

Figure 7.4: Thick planks made of *Acacia nilotica* in a boat under construction in Omdurman, Sudan. (Photo courtesy of Dionisius Agius)

7.2.4 Other Timbers

While some of the species identified in the al-Balid timbers occur widely in the western Indian Ocean, others are specific to other limited regions. Teak and *Albizia lebbeck*, for example, are found only on the eastern side of the western Indian Ocean: the former flourishes in the mountain range of the Western Ghats of southern India while *A. lebbeck* occurs east of Pakistan. Other species, such as *Celtis africana* and

Ziziphus spina-christi are, instead, typical of the western shores of the Indian Ocean, stretching from East Africa to Yemen and Pakistan.

Species identification analysis of the al-Balid timbers also indicates wood with different characteristics ranging from high-to-low quality boatbuilding timbers; timbers such as teak, *Celtis africana* and *Albizia lebbeck*, belong to the former. *Albizia*, for example, is relatively durable and its interlocking grain makes it a particularly suitable wood for planking sewn boats.

The presence of *Ziziphus spina-christi*, in species identified in the al-Balid timbers, is perhaps the most surprising of the identification analysis. This tree grows in an extremely arid environment, such as in the wadis of the Arabian Peninsula, making it one of the very few locally available timbers in the region. The wood is extremely strong and durable but because of its tendency to split and crack easily, it is a particularly poor choice for planking. Similar to acacia, the tree is generally short with crooked, twisted branches, making it ideal for shaping curved boat elements such as framing, cheek pieces and knees (Agius 2005: 33–35; 2007: 148-149; Al-Hijji 2001: 6; Al-Salimi and Staples 2019: 163; Vosmer 1997: 218-219). Timber BA1104065.454 from al-Balid is the first and only evidence of the use of *Ziziphus spina-christi* for planking.

Two samples, plank BA0604129.176 and one hole plug from timber BA0704156.1477, were identified as palm wood but the species was not determined. Identification of BA0604129.176 is debatable since the timber connects with BA0604159.69 and BA0604159.263, which returned results of *Terminalia* sp. and *Leguminosae Caesalpiniaceae* respectively. Although the species of palm wood from the hole plug sample was not determined, historical sources suggest that coconut palm (*Cocos nucifera*) was used in this context. Apart from the frequently cited account of Abū Zayd of Omanis sailing to the Lakshadweep Islands for coconut palm products, including its wood (Al-Sīrafī and Ibn Faḍlān 2014: 119-121), other references to the use of this timber for boatbuilding are from Portuguese sources. Correa and Barbosa both remark that boatbuilders of the Maldives sew coconut tree trunks together to build their ships because that was the only timber available (Dames 1918: 107-108; Manguin 2012: 615). It is worth mentioning that, although indigenous to south Asia, coconut was already cultivated around al-Balid in the 11th century (Ibn Baṭṭūṭa 1962: 387; Hourani 1963: 89-91).

7.2.5 Timber Selection

As previously noted, wood species have a wide variety of physical characteristics, such as strength, durability, flexibility, dimensional stability and hardness. Some, such as teak and *Albizia*, are excellent for planking, while others are instead suitable for making other boat elements. The evidence from al-Balid provides interesting insights into the practice of selecting timber for specific purposes and functions within the structure of a vessel.

One interesting aspect of the dowels of the al-Balid planks is that their material is different from that used for the planks, with two samples of dowels from planks Wo98A and BA0604128.73 being identified as white mangrove (*Avicennia marina*). Because mangrove wood is dense and strong, it was traditionally used in the region for making fasteners where a great deal of strength is required (Varadarajan 1998: 64; Vosmer 2007: 96). Mangrove dowels proved to be particularly effective for the construction of the replica of the 19th-century sewn *beden seyad* (Ghidoni 2019: 369). Similarly, Yemeni shipwrights chose bamboo for making the dowels fastening some of their sewn *sanbūq*s because of its strength (Bowen 1952: 204).

The wood used for the sewing-hole plugs in the al-Balid timbers is also informative. At present, botanical analysis has identified the species of three plugs from planks Wo45, BA0704156.1477 and Wo70 as *Ficus* sp., palm wood and teak. Although all three species have different characteristics, the former two are both a soft wood. Trees from the *Ficus* family are generally too small for use as ship planks; their wood is neither strong nor durable (PlantUse 2016), however, one of its main features is its softness. Similarly, the palm could also provide a relatively soft wood from its core because its density decreases from the outer wall of the trunk towards the centre (Butterfield and Meylan 1980: 48).

Soft material such as *Ficus* and palm wood is ideal for plugging sewing holes for two main reasons. Firstly, soft wooden pegs prevent the risk of cutting or damaging the cordage when driven into sewing holes, thanks to its softness, which makes it compressible. Similarly, it is less likely to damage the hole or cause splitting along the grain. Overall, it is obvious how crucial this is since the integrity of sewn-boat hull depends on the sewing. Secondly, using a soft wood means that a plug can expand more than one made from a hard wood when wet, filling every gap in sewing holes and further waterproofing the hull. Botanical analyses on the timbers from Quseir al-Qadim produced results similar to those from al-Balid. According to Gale, (2011: 224) one peg from plank 6 of the Quseir al-Qadim timbers may belong to the *Salicaceae* family, possibly poplar (*Populus* sp.) or willow (*Salix* sp.). The former is relatively soft, light and porous; willow is generally grouped with poplar since they share similar characteristics such as a soft, fine-textured wood and straight grain (TRADA 2019).

Evidence from the al-Balid timbers indicates that the selection of wood for use as hole plugs and dowels was not accidental. Instead, boatbuilders were aware of the various physical properties of different species and would have intentionally opted for timbers, within available resources, with specific qualities to achieve a particular purpose. These data further confirm the ingenuity of Indian Ocean carpenters and rope workers in solving technical problems with available materials.

7.2.6 Teak and Indian Ocean Boatbuilding

The variety of timber species in the al-Balid timbers challenges the assumption of the exclusiveness of teak in medieval Indian Ocean boatbuilding. Because of its durability, strength and resistance to parasites, teak has, indeed, been the ideal boatbuilding timber in the region and was commonly used until recently (Agius 2005: 30; Al-Hijji 2001: 38; Lorimer 1915: 2319; Miles 1919: 412; Villiers 1948: 399). This relatively recent evidence, as well as the few textual sources mentioning teak in the medieval period, placed great emphasis on it creating, among scholars, the general assumption that boatbuilding in the region relied almost exclusively on this type of wood (Hourani 1963: 71, 89-90; Lewis 1973: 247-248, 257; Moreland 1939: 184).

For example, Lewis (1973: 257, note 9) refers to Marco Polo's description of the boats of Hormuz in support of the prevailing notion that all the Indian Ocean vessels were built of teak. In fact, Marco Polo never mentions the wood species and remarks that "it is a hard wood, of which they are made, of a certain kind brittle as pottery" (Moule and Pelliot 1938: 124). Anyone who has ever had experience with teak and its qualities knows well that Marco Polo's description is not indicative of this wood, which is definitely not brittle. Similarly, Barbosa's account of Hormuz and its vast reserve of "wood (which also they bring from outside)" (Dames 1918: I, 97) is seen by Lewis as a clear reference to teak imported from India (1973: 257, note 9). This tendency to identify every generic timber described in textual sources as teak also occurs in Hourani (1963: 90), who reports Theophrastus' (ca. 300 BCE) description of a particular type of wood used in the Island of Tylus (Bahrain): "a kind of wood of which they build their ships, and that in seawater this is almost proof against decay; for it lasts more than 200 years if it is kept under water, while, if it is kept out of water, it decays sooner, though not for some time." This somewhat generic description, as well as the fact that Bahrain lacks wood with those characteristics, is enough to persuade Hourani that Theophrastus is referring to teak (1963: 90). However, as remarked by Potts (1995: 567), mangrove has similar qualities and is widely found in the Gulf, where it can reach a considerable size and be used in boatbuilding. The assumption that teak was the dominant material of Indian Ocean watercraft is so strong that even East African medieval vessels are assumed to have been made of imported teak (Horton 1987: 92).

Evidence from al-Balid, while corroborating historical sources mentioning teak, undermines its assumed dominance in western Indian Ocean shipbuilding but expands our knowledge of Indian Ocean boatbuilding materials, providing a glimpse of the wide range of wood species, with different distribution and characteristics, that were employed (**Error! Reference source not found.**). This wide range of timber was already highlighted by the Belitung shipwreck, which indicated four different wood species used in its construction: *Afzelia africana* for planking, frames, stem post and dunnage; *Afzelia bipindensis* for the keelson; teak (*Tectona grandis*) for through-beams; and juniper (*Juniperus procera*) for ceiling planks (Flecker 2008: 285, Table 1). Botanical analysis carried out on the Quseir al-Qadim timbers could not provide definitive identification of the species but pointed to different types of wood not native to Egypt, while excluding teak (Gale and der Veen 2011: 223-225).

The diversity of boatbuilding materials revealed by archaeological data mirrors that of ethnographic records of Indian Ocean vessels, particularly on its western shore, where using a wide range of wood was common practice in regions where timber was scarcely available (Agius 2005: 29-35; Al-Hijji 2001: 38-41; Staples 2018: 207-209). Omani boatbuilders used a wide assortment of wood to plank the *kambārī*s of Dhofar, ranging from locally available *arīr* (*Delonix elata*), mango (*Mangifera indica*) or white mangrove (*Avicennia marina*) (Agius 2005: 31; Alian 2006: 7-8; Vosmer 1997: 231). Yemeni *sanbūq*s had mostly teak planking until the 1970s (Bowen 1952: 210; Prados 1996: 104) and Chittick informs us that Somali shipwrights imported timber from Indian and East Africa for their sewn *beden*s (Chittick 1980: 302). Mangrove was, meanwhile, the primary timber used in the construction of the East African *mtepe* (Hornell 1941: 59).

7.3 Sewing material

Material employed in the sewing of the al-Balid timbers also reflects the heterogeneity revealed by the wood analysis. The sewing cordage was identified as coir and doum palm (*Hyphaene thebaica*).

7.3.1 Coir

Five cordage samples from the al-Balid dataset was tentatively identified as coir (Belfioretti and Vosmer 2010: 111). References to coir as a primary material for sewing cordage are nearly ubiquitous in medieval and later Portuguese textual sources and it appears to have been used throughout the Indian Ocean. In the 12th century, Ibn Jubayr reports that the *jalbah*s built in ʿAydhab, Red Sea, "are stitched with cords of coir [*qinbār*[48]], which is the husk of the coconut (Hourani 1963: 91). Marco Polo provides a similar description a century later about the vessels of Hormuz, "sewn with coarse thread, which is made of the husks of the trees of nuts of Indie" (Moule and Pelliot 1938: 124). A 16th-century Chinese source also remarks on the use of coir in the fastening of Maldivian boats (Ptak 1987: 686), and that it was used for the sewing cordage of ships from Malabar, southern India (Stanley 1869: 240) and East Africa (Dames 1918: I, 27; Prins 198667).

Various authors even describe the making of coir ropes, such as Abū Zayd al-Sīrāfī (Al-Sīrafī and Ibn Faḍlān 2014: 121), Ibn Jubayr (Hourani 1963: 92) and Ludovico de Varthema (De Varthema et al*.* 1863: 165), but the most detailed account is perhaps that provided by Ibn Baṭṭūṭa in the 14th century, which states that the material is "... the hairy integument of the coconut, which they tan in pits on the shore, and afterwards beat out with bars; the women then spin it, and it is made into cords" (Agius 2007a: 150; Ibn Baṭṭūṭa 1968: IV, 121). It is noteworthy that the same practice is still in use on Pemba Island, Tanzania (Eric Staples personal communication, 2009) (Figure 7.5).

Coir has always played an essential role in Indian Ocean boatbuilding for sewing cordage and rigging (Chittick 1980: 301; Hornell 1941: 56; Shaikh et al*.* 2012: 152; Varadarajan 1998: 50; Vosmer 1997: 232). Its great advantage over other fibres, such as date palm, for example, is its durability in salt water (Severin 1985: 279). A 16th-century Portuguese account of Indian products dedicates a significant section on the benefits of coir, remarking that it is the perfect material for caulking because, when

[48] *Qinbār* (also *qunbār*) is the Arabic term for coir (Agius 2007a: 148-149; Vosmer 1997: 231).

Figure 7.5: Rope making process in Pemba Island, Tanzania. Women remove the coconut husk and place it in muddy pits mud in brackish water (A). After a period of 6–10 months, when they are removed, the husk fibre has become loose and a shiny golden colour (B). They then beat the fibre with wooden mallets to make it stringy (C) and twist it by hand into ropes (D). (Photo courtesy of Eric Staples)

immersed in sea water, it swells and does not rot (Da Orta and Ficalho 1891: 236–237). Despite the fact that Belitung-wreck fibre was tentatively identified as hibiscus, the construction team of *Jewel of Muscat* opted instead to use coir for both the wadding and sewing rope after testing the strength and longevity of both materials in sea water (Vosmer et al. 2011: 414). The advantages of coir over other fibres makes it the ideal choice for fastening the hulls of vessels in the region, and encouraged Arabs to sail to sources of coconut, such as the Lakshadweep Islands, to obtain its precious fibre (Al-Sīrafī and Ibn Faḍlān 2014: 121). Southern India, the Lakshadweep and Maldives islands were the primary sources of this material in the Indian Ocean (Dames 1918: II, 90-91), but Ibn Baṭṭūṭa informs us about the presence of coconut plantations in Oman, at the city of Ẓafāri'l-Ḥumūḍ (al-Balid) in the 14th century (Ibn Baṭṭūṭa 1962: II, 387). It is significant to note that the local name of the last sewn craft of Dhofar, the *kambārī*, derives from the Arabic term *qinbār*, meaning coir, alluding to the material of its sewing cordage (Agius 2007a: 148-149; Vosmer 1997: 231).

7.3.2 Doum Palm

A sample from the sewing cordage of timber Wo86, identified as doum palm (*Hyphaene thebaica*), expands the range of fibrous materials used by medieval boatbuilders to fasten the hulls of Indian Ocean vessels. This is also the first evidence for the use of doum palm as a sewing rope, although its wood was particularly appreciated by ancient Egyptian builders and boatbuilders (Ward 2000: 17). Evidence of the use of this material in Yemen occurs from the 3rd millennium BCE (de Moulins and Phillips 2009: 119) onwards.

Medieval textual sources, while not explicitly mentioning coir, are particularly vague about sewing materials, generically described as fibre by al-Idrīsī (Hourani 1963: 97); twine by John of Montecorvino (Yule 1914: 66), a kind of grass by Jordanus (1863: 54), generic cord by Cabral (Greenlee 1938: 65) and thread (Dames 1918: II, 107-108). Perhaps, some of these refer to doum palm.

Hyphaene compressa, which is very similar to *Hyphaene thebaica* and belongs to the same genus, is widespread in East Africa, particularly along the coast of Kenya and Tanzania (Amwatta 2004: 185). Generally called East African doum palm, and locally known as *mkoma*, it was widely used in the region for multiple purposes, including baskets, thatching and ropes (Maundu and Tengnäs 2005: 265). The nomadic communities of Lake Turkana, Kenya, beat the immature leaves with a wooden bat to separate the fibres in order to make rope (Amwatta 2004: 186). In East Africa, the *mkoma* palm was particularly crucial in sewn-boat construction, its leaves being the primary material for the wadding and caulking of the *mtepe* and *dau la mtepe*, as well as for their woven-mat sails (Hornell 1941: 67; Lydekker 1919: 89-91).

The presence of doum palm in the al-Balid timbers further reflects the diversity of materials used in Indian Ocean boatbuilding, which was suggested earlier by timber species identified. Archaeological evidence, such as that of the Belitung and Phanom-Surin wrecks, once again confirms the use of a wide range of materials for this purpose. The cordage and wadding of the Belitung wreck were tentatively identified as hibiscus and paperbark (*Melaleuca*) respectively[49], both from Southeast Asia (Flecker 2010: 117). Shipwrights that built the Phanom-Surin ship instead used *Arenga pinnata* (sugar cane) (Abhirada Komoot, personal communication, March 2020), a material widely used in the region for making rope and fastening ships since at least the medieval period (Ming-liang 2010: 139). A similar variety is also suggested by the material of the wadding of the al-Balid timbers. When preserved, it is relatively easy to recognise fibre rope, probably made of coir, date palm or doum palm, but impressions in the luting indicate the use of grass, leaves, and generic palm fibre.

7.4 Luting, Coating and Antifouling material

7.4.1 Bitumen

7.4.1.1 Luting

Preliminary chemical analysis on the luting indicates bitumen as the only material used for this purpose in the al-Balid timbers. However, historical sources mention a variety of substances. Abū Zayd al-Sīrāfī writes, in the 10th century, that oil mixed with other substances was used to caulk the seams and waterproof the holes of the sewn boats

[49] Later research and experimentation on the material has called into question this identification (Tom Vosmer, personal communication, December 2020).

of Siraf (Al-Sīrafī and Ibn Faḍlān 2014: 127). In the 16th century, Portuguese sources mentioned the use of various matter, such as pitch, bitumen and resin, in the sewn boats they encountered on the western coasts of India and Africa (Agius 2007a: 151; Moreland 1939: 177; Stanley 1869: 241). Ships that sailed along the East African coast, from Kilwa to Sofala, during the 16th century were caulked with black "pitch" mixed with resin and incense, according to D'Almeida (Prins 1986: 67).

However, Forbes calls for caution when studying textual evidence and ethnographic records, noting a general confusion in sources when dealing with bituminous materials (Forbes 1955: 3-4). Terms such as bitumen, tar, pitch and resin are often used indiscriminately for substances that look very similar in terms of colour and physical properties but are, in fact, produced from different materials. Since it is virtually impossible to distinguish all these substances with the naked eye, references to pitch and tar might actually indicate bitumen, and vice versa. For example, Hornell sometimes uses the term "pitch" to describe the bitumen coating of Iraqi *quffa*s (1920: 67), which are riverine "coracles" used along the Tigris and Euphrates whose distinctive feature is that they are waterproofed with bitumen from natural seeps in Hit, Iraq (Answorth 1888: 196; Chesney 1850: 636; Hornell 1938: 155).

Archaeological data for sewn vessels of the Indian Ocean also point to the variety of materials used for luting. Evidence of a dark substance, tentatively interpreted as bitumen, was also visible on all the Quseir al-Qadim planks, on both the surfaces and edges of the timbers, but no scientific analysis has been carried out to confirm the identification (Blue et al. 2011: 181). Traces of bitumen were also found encrusted on one of the through-beams of the Belitung wreck (Burger et al. 2010: 284). However, its builders mostly used a mixture of lime and other substances to seal the hull planking, posts and through-beams (Flecker 2000: 207). The wide variety of luting materials used is also indicated by records of Modern era Indian Ocean sewn boats (Hornell, 1942: 12; Hill, 1958: 208; Severin, 1985: 283; Agius, 2002: 153; Vosmer et al*.,* 2011: 416): Pâris mentions that resin impregnated the wadding on the inside of the hull of the *beden seyad*, a sewn fishing boat documented in Muscat in 1839 (1843: 15); the boatbuilders of Lamu, Kenya, used a paste made with mangrove bark to lute the seams of the *mtepe* planking (Lydekker 1919: 91); and, more recently, Chittick reported the luting process of the *beden*, in Hafun on the northeast coast of Somalia. The material, described as pitch, was melted in tin or metal pots and poured into the planking seams from the inside of the hull. The boatbuilders then covered this luting with wadding before stitching the planking (Chittick 1980: 301).

7.4.1.2 Coating

Bitumen also appears to be the only material to have been used to coat the hull of the al-Balid vessels, although mixtures of both bitumen and resin were the most common material used to coat sewn watercraft in the western Indian Ocean (Hourani 1963: 150). The practice of using bitumen, tar or pitch is also suggested by a number of illustrations in the *Maqāmāt* of al-Ḥarīrī (Nicolle 1989: 176-177, fig. 22; Bibliothèque Nationale, Ms Arabe 6094, fol. 68) and Persian miniatures (Eastman 1950: 156, pl. XII; Weismann 2002: 139, fig. 21; Bibliothèque National de France, Suppl. Persan 641 f. 59) depicting black hulls. Despite Procopius claiming, in the 6th century, that no substances coated the sewn boats of India and the Gulf, references to various materials appear as early as the Pre-Islamic period (Agius 2007a: 150-151). In the 10th century (Late Tang Period), there are also Chinese references (*Lingbiao Luyi* by Liu Xun) to resin "from the olive tree", giving the hull the appearance of being varnished (Ming-liang 2010: 139).

Evidence of bitumen coating from al-Balid also provides insights into the persistence of this practice in the Indian Ocean boatbuilding context during the medieval period, which, in the Gulf, dates back to the Neolithic. The discovery of bitumen fragments on the 6th-millennium BCE site of As-Sabiyah (H3) in Kuwait bears impressions of reed bundles associated with barnacles on their opposite surface, indicating that this material was used to waterproof reed vessels during this period (Carter 2002: 22-23). Ancient boatbuilders continued to use bitumen to waterproof the hulls of ships in the Bronze Age, as indicated by archaeological evidence from the 3rd-millennium site of Ra’s al-Jinz, the easternmost area of Oman. Here, impressions on bitumen slabs point to its use for both reed and wooden boats that were fastened with ropes (Cleuziou and Tosi 1994: 750). Scholars assumed that from the Iron Age bitumen was gradually replaced by other substances for coating watercraft until it disappeared in the Islamic era (Vosmer 2007: 193).

While two planks from al-Balid are too few to suggest that coating hulls with bitumen was a common practice in the Indian Ocean during this period, the large number of timbers from the dataset that retain traces of it on their edges and under the wadding certainly reflect its extensive use in the 10th–15th centuries. Bitumen-coated vessels have persisted in Iraq (Thesiger 1954: 277; Ochsenschalger 2004: 177-185), where they are still in use in the marshlands in the southern region of the country (Jeffrey Rose, personal communication, February 2017) (Figure 7.6(A)). Five sewn *baggarā*s from Iran, which were recently acquired by Qatar Museums, were coated inboard and outboard with a thick layer of bitumen, proving that its use for this specific purpose persisted in a maritime context until at least the second half of the 20th century (Cooper et al. 2020) (Figure 7.6(B)).

Figure 7.6: Boats coated with bitumen still in use in the marshlands of southern Iraq (A)(Photo courtesy of Jeffrey Rose). The hull of an Iranian *baggarā* covered with bitumen (B)(Photo: Author)

7.4.1.3 Bitumen Source

The chemical signature of the bitumen on the al-Balid dataset appears to suggest that the substance was collected from oil seeps in Khuzestan, southwestern Iran. However, Iraqi sources cannot be ruled out for some of the samples (Jacques Connan, personal communication, March 2020). Very little is known about the use and trade of bitumen in the medieval period but, according to evidence of the al-Balid timbers, it appears to have been an important commodity in the Indian Ocean, at least in boatbuilding. The possibility of an Iranian origin would match the information provided by the only documentary source on the topic. In the early 14th century, the Dominican missionary Jordanus remarked that "in Persia are springs, from which flows a kind of pitch, which is called *kic* (*pix, dico, seu Pegua),*[50] with which they smear the skins in which wine is carried and stored" (Jordanus 1863: 10). Although wine here is mentioned instead of boats, there is certainly a possibility that the bitumen used to seal the hulls of the al-Balid vessels may have been sourced from such springs.

One aspect emerging from the preliminary chemical and mineralogical analyses of samples of the luting and coating of the al-Balid timbers is that the bitumen is not pure but mixed with other materials (Jacques Connan, personal communication, 6 March 2019). The practice of mixing bitumen with additional materials in a boatbuilding context dates back to the 6th millennium in the Gulf (Carter 2002: 22-23; Connan et al. 2005: 57-59). Adding oil, animal fat, sand, lime and vegetal elements to bitumen helped to modify its working properties, making it lighter, more pliable and adhesive (Cleuziou and Tosi 2000: 64; Vosmer 2001: 237). The presence of a mixture in the luting of the al-Balid planks confirms that this practice was also well established in the medieval period. Identification of the inclusions found in the bitumen mixture would also provide an opportunity to determine whether this amalgam has changed since its early use in the Neolithic.

7.4.2 Fish Oil

Various medieval sources mention the use of fish oil to coat the hulls of ships sailing in the Indian Ocean.[51] In the 13th century Ibn Jubayr praised the quality of shark oil as

[50] Yule, the translator of Jordanus, states that the term *kic* is most probably a mispronunciation of *kīr*, meaning bitumen in Farsi; the same author was not able to translate the text in the parenthesis.

[51] References to the use of fish oil in boatbuilding are very early in the Gulf and date back to the 3rd millennium BCE. It is mentioned in an administrative text of the Third Dynasty of Ur from Girsu (CT 7-31) as one of the materials required for the building and repairing the boats of Magan (northern Oman in cuneiform sources) that

a wood preservative, stating that it makes the timber soft and flexible (Agius 2007a: 151). A similar product was also extracted from whales and mixed with other substances, as remarked by Abū Zayd in the description of the sewn Arab ships built in Siraf in the 10th century (Al-Sīrafī and Ibn Faḍlān 2014: 127; Hornell 1970: 234). Whale oil was widely used in the 12th century, as indicated by the cartographer and geographer al-Idrīsī, who provides an account of the process required for extracting the oil, stating that the substance was "renowned in al-Yaman, Aden, the coasts of Fāris, 'Umān, and the sea of India and China" (Hourani 1963: 97).

Maritime communities along the coasts of Arabia continued to use fish oil to pay the bottom of the last traditional wooden vessels in the region (Miles 1919: 404-405; Hornell 1942: 12; Agius 2002: 175; Lorimer 1915: 2319). In 2010, oil extracted from sardines and shark' livers was still manufactured for boatbuilding purposes in al-Ashkharah, a fishing town on the eastern coast of Oman (Author, personal observation, Oman 2010). In the case of sardine oil, fish were piled on the beach and left rotting in the sun until the oil started to drip into jars or trenches dug in the sand (Miles 1919: 404; Donaldson 1979: 85). Shark-liver oil, meanwhile, involved boiling the livers in cauldrons for about an hour until it became a thick liquid (Agius 2002: 175; Miles 1919: 405). Although both sardine and shark-liver oil were used as a wood preservative for hull planking, the oil obtained from sharks was considered to be of higher quality (Miles 1919: 404).

sailed from Oman to Mesopotamia and the Gulf, and perhaps to the Indus Valley, during the Bronze Age (Cleuziou and Tosi 1994: 746).

7.4.3 Lime-Based Compound (Chunam)

Possible traces of antifouling made of lime and fat, as suggested by timber Wo37 from al-Balid, corroborates information provided by historical sources. References to this practice date back to the medieval period in Arab, Indian and Chinese ships, as mentioned by al-Masʿūdī (1861: 365) and Marco Polo (Yule 1871, III: 196). The use of a lime-based substance is also indicated by archaeological evidence from shipwrecks from China and Southeast Asia (Flecker 2001: 224; 2007: 85; Li 1989).

Chunam was a distinctive feature of Indian Ocean watercraft, which were periodically coated with this material (Agius 2002: 175; Lorimer 1915: 3219; Vosmer 2007: 194; 2017: 187; Weismann et al. 2014: 22). Traditionally made by heating animal fat (*shaham*),[52] usually mutton mixed with quicklime obtained from burnt shells and corals, and fish oil, this white substance coated the hulls of wooden vessels outboard below the waterline.

7.5 Material Trade in the Indian Ocean: new Light on Material Suppliers

One of the most important implications of evidence from the al-Balid timbers is the less predominant role that India played as a supplier of boatbuilding materials. Wood species native to the Red Sea, the Horn of Africa and East Africa indicate that these regions played a crucial role in providing timber for the construction of Indian Ocean medieval sewn vessels (Figure 7.7). The scarcity of textual sources regarding the commercial contacts between the Arab world and Africa led some scholars, such as

[52] *Chunam* is often called *shaham* (animal fat in Arabic) in parts of Arabia, because of its primary ingredient (Author, personal observation, Oman 2005).

Digby (1982: 144), to place considerable importance on India, stating that Arabian communities “were heavily dependent to India”. Alpers (1976: 24) remarked that "it is quite clear that East Africa never played as important a role in the history of the Indian Ocean". However, the archaeological record provides more solid data towards the involvement of other geographical entities, other than India, in the Indian Ocean material trade network during the 9th–15th centuries. The Belitung shipwreck, for example, already indicated the importance of African wood in Indian Ocean boatbuilding since most of its components were made of tropical African mahogany (*Afzelia africana*) (Flecker 2008: 385).

The Dahlak archipelago at the entrance of the Red Sea might have been a possible candidate for supplying and shipping timber and sewing cordage for use in the al-Balid vessels. The largest of the islands, Dahlak Kebir, was an important trading town with a large and cosmopolitan population, a sheltered harbour and a possible slipway for boats (Insoll 1997: 384; Margariti 2009: 156-157). The presence of Chinese and Arabic wares highlights the involvement of Dahlak Kebir in both international and local maritime networks (Insoll 1997: 387). Most interestingly, contacts between Eritrean coastal settlements and the Ethiopian interior, among the sources of some of the al-Balid timbers, occur from the 10th century (Insoll 2003: 58). Wood would have been transported from inland forests to the islands and, from there, it would have reached the large centres of Arabia and the Gulf.

Figure 7.7: Map illustrating possible timber trade networks from the interior to the centres along the coast of East Africa, Horn of Africa and the Red Sea (green arrows), and to al-Balid (red arrows). (Map: Author).

The northern coast of Somalia (Somaliland) could also have been involved in the timber trade. One of the city ports of Somaliland, Zeila, was also an international trading centre and strategically located on the route connecting the coastal area to the highlands of Ethiopia (González-Ruibal et al*.* 2017: 138, 143; Insoll 2003: 59). Described by Ibn Baṭṭūṭa as a “city with a great bazaar” (Ibn Baṭṭūṭa 1962: II, 373), this port flourished between the 12th and 16th centuries (González-Ruibal et al*.* 2017: 138). The local trade network between the coast and the interior would have provided Zeila with access to the timber resources of Ethiopia to trade with Arab and Gulf merchants.

Similarly, the Somali coast north of Mogadishu may also be one of the places to consider because of the presence of Muslim commercial settlements during the medieval period (Insoll 2003: 61). Unfortunately, very little archaeological investigation has been carried out in this area.

Lastly, the Swahili coast in East Africa is undoubtedly another possible wood supplier. Contacts between this region and the Arab/Islamic world occurred as early as the 8th century (Ricks 1970: 344), and ships from Oman and Siraf regularly sailed to East Africa in the 10th century (Hourani 1963: 80). Boatbuilding timber was widely available in the region, either along its coast or interior (Insoll 2003: 143), and wood generally was a bulk item exported from East Africa to the Gulf where it "roofed great cities in the Middle East" (Horton 1987: 89). It is most likely that the timber imported into Siraf from East Africa, mentioned in textual sources, comprised not only mangrove poles to be used as roof beams (Chittick 1977: 192) but also boatbuilding wood. In the 16th century, Portuguese writer and officer Duarte Barbosa states that one of the advantages of the port of Moçambique (Mozambique) is its large availability of wood (Dames 1918: I, 15-16).

The Gulf also participated actively in the trade of boatbuilding materials. Whether bitumen was sourced from Iran or Iraq, the luting and coating components of the al-Balid timbers suggest the existence of a local-range trading network connecting the bitumen springs to the coast. In this case, local maritime communities would have either used it in the building of their boats or transported it to shipyards along shores of the Gulf and Arabia.

7.5.1 Utilitarian Goods and Material Trade

The variety of species identified among the al-Balid timbers underlines the diversity and richness of Indian Ocean material trade during the medieval period. References to commercial activities associated with east and northeast Africa often exclusively mention exotic or luxury goods such as gold, ivory and rock crystal, or the slave trade (Alpers 1976: 24; Digby 1982: 149-150; Horton 1987: 86; Insoll 2003: 54, 59; Ricks 1970: 351). Indeed, as remarked by Horton (1987: 86), the commerce of these exotic and luxury commodities reveals the existence of a complex cosmopolitan trading network starting from southern Africa and ending in the Mediterranean basin. However, ships from these regions also carried less high-profile merchandise, such as timber, fibres and luting substances intended for boatbuilding.

There are a number of historical sources that imply the significance of the trading of utilitarian goods in the Indian Ocean during the medieval period. For example, the constant need for boatbuilding materials along the Arabian coast led local maritime communities to travel long distances to obtain coconut products such as fibres to make sewing cordage and wood for planking their boats (Al-Sīrafī and Ibn Faḍlān 2014: 119-121). Portuguese sources provide further clues as to the importance of controlling the sources of boatbuilding materials. Barbosa remarks that “Moorish” merchants of Cananor, southern India, exerted their influence over the Lakshadweep Islands, forcing their ruler to pay a tribute of ship shrouds and ropes every year (Dames 1918: II, 104-105). According to Varadarajan (1998: 10), the annexation of the islands by the Mushaka dynasty of Kerala in the 11th century could have been Malabar’s attempt to control the coir industry.

Collectively, evidence from the al-Balid timbers, along with that provided by the Belitung wreck and a few other historical accounts, clearly tell us that utilitarian goods played a role that was as significant as that of exotic and luxury merchandise. Timber, fibres and luting substances belong to a hidden trading system, mostly neglected by textual sources that provide only a glimpse of the trade in the region and obscured by a small number of "superhighways" connecting the littoral with "high-profile" commodities (Horton 2004:75). The variety of species of the al-Balid timbers provides information about this hidden trade confirming its valuable contribution in the broader Indian Ocean. Along with their precious and highly valuable counterparts, boatbuilding materials prompted the creation of multiple maritime trade networks and routes in the Indian Ocean, thus boosting the emergence of commercial entities along its littoral. More importantly, they enabled maritime communities to construct vessels in timber-deficient regions such as Arabia, the Red Sea and the Gulf, which in turn made these commercial systems in the area possible (Staples 2018: 205).

7.6 Origin of the Vessels

Determining the boatbuilding location of the al-Balid ships is a particularly difficult task. While deducing that commercial entities involved in the material trade with the site is relatively easy, thanks to the identification of sources of materials such as wood, fibre and luting substances, establishing where these timbers were originally assembled or repaired is more challenging. As noted in Chapter 2, historical sources provide extremely limited information about boatyards in the Indian Ocean, with most of the references actually implied rather than explicitly stated in texts (Agius 2007a: 67; Margariti 2007: 122). Neither is there any archaeological evidence of shipyards in the Indian Ocean to date; archaeologists have never surveyed or discovered sites with boatbuilding facilities in the Indian Ocean. Moreover, a relatively homogeneity in boatbuilding techniques in the region during the medieval period makes the question of a boat's origin even more difficult to answer. Sewing techniques, for example, were probably very similar throughout the western Indian Ocean and cannot be used to distinguish boats from various regions.

The al-Balid timbers, however, might offer insights into the geographical areas and maritime communities involved in the construction of the vessels to which they formerly belonged. Trying to answer this question helps indicate whether other geographical entities possessed the technical skills to build ships and sail them. Knowing where these boats came from would deepen knowledge about which coastal centres were involved in various Indian Ocean maritime trade networks and could provide an insight into the connections that sites like al-Balid, and more generally the Arab world, had with the rest of the Indian Ocean. But the evidence is still too fragmented and scarce, while knowledge of medieval Indian Ocean vessels is still too limited. Therefore, the al-Balid timbers cannot provide a definitive answer to the question of the origin of the vessels. Perhaps, it can be concluded, for example, that the nailed planks of the citadel's gate originally belonged to a ship built in India because its fastening method is similar to that of more recent watercraft from there. But even this would be mere speculation based on recent ethnographic records, while technology and techniques could have changed several times over the centuries separating the timbers from the Modern era. Therefore, I do not mean to make any definitive claims as to where these vessels where built, but instead to suggest possibilities and formulate hypotheses.

7.6.1 Construction Features

As seen in Chapter 5, some construction features of the timbers, such as oblique dowels and wooden plugs, match those of 19th–20th-century sewn vessels from Arabia, the Red Sea, the Gulf and East Africa, perhaps suggesting that those from al-Balid were built in one of these regions; these features are present in watercraft used there recently, while they are rarely found in India, for example. However, ethnographic analogies should be considered with caution because of the significant time span of the evidence.

7.6.2 Al-Balid's Trading Partners

Archaeological finds in al-Balid should be taken into consideration in order to gain an idea of the sources of goods imported by the port. Ceramic finds indicate that products were imported from a variety of different geographical areas, including Iran, Yemen, India, China and East Africa (Newton and Zarins 2014: 269; Pavan et al. 2018: 219; Zarins 2007: 314-316). Relationships appear particularly strong with Iran (Pavan et al. 2018: 219) and India, as indicated by the presence of an Indian community at the city (Newton and Zarins 2014: 263), and East Africa, as shown by Gray Tana ware (Newton and Zarins 2017: 90) and the discovery of a number of coins from Kilwa, Kenya, dated to the 14th century (Pavan et al*.* 2018: 230). According to Costa (1979: 148), al-Balid acted as an important centre of trade between India, Arabia and East Africa, while Chinese sources indicate that the coastal ports of the Hadhramaut, such as Mirbat, southern Oman, controlled the ivory trade from Africa to Southeast Asia (Wheatley 1959: 111-112).

7.6.3 Timber Species

While the material culture discovered at al-Balid provides information about the commercial partners of the port and its connections with the broader Indian Ocean, it cannot confirm which ships carried goods, or who built them. Determining the origin of the al-Balid vessels according to wood and cordage species used to assemble their hulls is particularly challenging because timber was widely traded in the Indian Ocean and wood native to a specific region would not necessarily indicate that a boat was built there. Hence, the presence of teak in the al-Balid timbers does not necessarily indicate Indian shipyards, as scholars have often assumed (Digby 1982: 155-156; Lewis 1973: 257, note 9; Margariti 2007: 122).

The al-Balid timber species nonetheless offer some useful insights as to where the ships were built. Rather than trying to determine the origin of a vessel by identifying the wood species of its planking, it would be better to exclude boatbuilding places on the same basis. For example, the presence of African wood would exclude Indian origins and, likewise, wood native to India would refute African origins, since both these regions are rich in high-quality boatbuilding timber and would not, therefore, require its importation (Vosmer et al. 2011: 413–414). It is, therefore, safe to assume that vessels built in India would probably not have used wood species native to the African Horn or East Africa. Similarly, teak-planked boats are likely to exclude African origins.

Teak planks could have belonged to either Indian or Arab vessels, with the latter being built in either in Arabia or Malabar, southern India, by Arab communities. African timbers might likewise indicate that boats were built or repaired in Africa by communities of Arab or Indian traders and boatbuilders who had settled there. Because of the significant presence of wood native to the Horn of Africa and East

Africa in the al-Balid dataset, these boats could have also been built or repaired there by local maritime communities. As noted in the previous section, there were political and economic centres in Africa, such as those along the Swahili coast, Somaliland and the Red Sea, which were deeply involved in international maritime trade networks. At least some of the al-Balid timbers may have belonged to ships owned and sailed by Swahili merchants, who had become actively engaged with the sea from at least the beginning of the 2nd millennium, and were involved in long-distance voyages by the 13th century, if not earlier (Fleisher et al*.* 2015: 107). Similarly, coastal towns of Somaliland, as well as the Dahlak archipelago, also indicate active involvement in the Indian Ocean maritime trade (González-Ruibal et al*.* 2017: 138; Margariti 2009: 158) and could potentially be considered to be good boatbuilding candidates for the al-Balid timbers. Doum-palm fibre sewing cordage that was identified in one of the timbers also alludes to an African link, or even points to southern Arabia.

7.6.4 Luting material

The presence of bitumen in the al-Balid timbers might suggest other boatbuilding areas, such as both coasts of the Gulf or, perhaps, northern Oman. Archaeological excavations at Qalʿat al-Bahrain indicate that the site imported bitumen for millennia until the 16th century, the sources of which were exclusively Iranian during the medieval period (Connan et al*.* 1998: 177-178). While it is true that bitumen could have been exported from other regions, there is no evidence of its trade[53] outside the Gulf during the medieval period (Stern et al. 2008: 424).

[53] There is evidence of Iranian bitumen from Sri Lanka, but only as a coating on the inside of ceramic vessels exported from the Gulf (Stern et al. 2008).

The use of bitumen as luting, along with a lack of evidence of bitumen exports outside the Gulf, may suggest that the al-Balid timbers bearing this substance may have come from boats that were built, repaired or re-sewn in the Gulf, in the vicinity of Iranian sources. Other places in the Indian Ocean, such as East Africa and India for example, could have used resin as luting instead; this was largely available in those areas, and of good quality (Edye 1835: 361; Regert et al. 2008: 669, 674-675 Table 2).

7.6.5 Timber Quality and Adaptability of Sewn Boats

What is particularly interesting with respect to the range of tree species identified among the al-Balid timbers is the presence of the inferior-quality wood used for planking, such as *Ziziphus spina-christi* and acacia. This evidence may suggest boatbuilding places with scarce timber, where shipwrights had no other choice than to use what was available locally. It is safe to assume that East Africa, as well as southern India, both of which had abundant timber resources, would have had no need to import wood, particularly inferior species, for planking. Areas such as Arabia, the Gulf and the Red Sea, where these timber species are found, could instead be possible candidates, meaning that the boatbuilders of al-Balid could have either built or repaired at least some of the vessels.

7.7 Material Recycling

Evidence from the al-Balid timbers provides interesting information regarding the forms of reuse of wood in the Indian Ocean in the medieval period. Decorations on the former inner side of nine planks are likely to be linked to their being recycled in the citadel. Since boats generally have decorations on the outside of their hulls, evidence from these timbers suggests that these painted motifs belonged to a later period, after the planks were stripped from the vessels. There is, in fact, a specific reason for considering this: the absence of rebates makes planks flat and so better suited for being painted and decorated. The builders of the al-Balid citadel removed most of the sewing and luting from the surface and plugged the stitching and frame-lashing holes with wooden pegs.

Six timbers painted with geometrical and floral motifs suggest a use as ceiling planks or beams, resembling those seen in Omani forts and castles such as Nizwa and Jabrin. The decoration on plank Wo56-Wo60-Wo73 shows a panel with Arabic text and resembles those painted on each of three exposed faces of ceiling beams in Jabrin castle (17th century), Oman (Baldissera 1991: 34, 41) (Figure 7.8(A,C-D)). These are usually verses of the Quʾrān that are dedicated to the Imam and the castle, or prayers (Baldissera 1991: 35). Similarly to those in Jabrin, the inscribed text on this plank is also brightly coloured and painted on a coloured background, evidence that suggests the builders of the citadel recycled the timber in the ceiling of one room of the citadel, most probably to line one of the ceiling-beam faces.

On the other side to the Arabic inscription on timbers Wo56-Wo60-Wo73, there is a small stylised figure painted in red (Figure 3.45). Although it is found on the former outer surface of the plank, it is unlikely to be a decoration on the hull of a vessel as it would have been exposed to sunlight and sea water causing the paint to fade, and it is, in fact, well preserved. In addition, the surface of the plank appears to have been chiselled or adzed in that section, as indicated by the presence of tool marks and a reduction in its thickness.

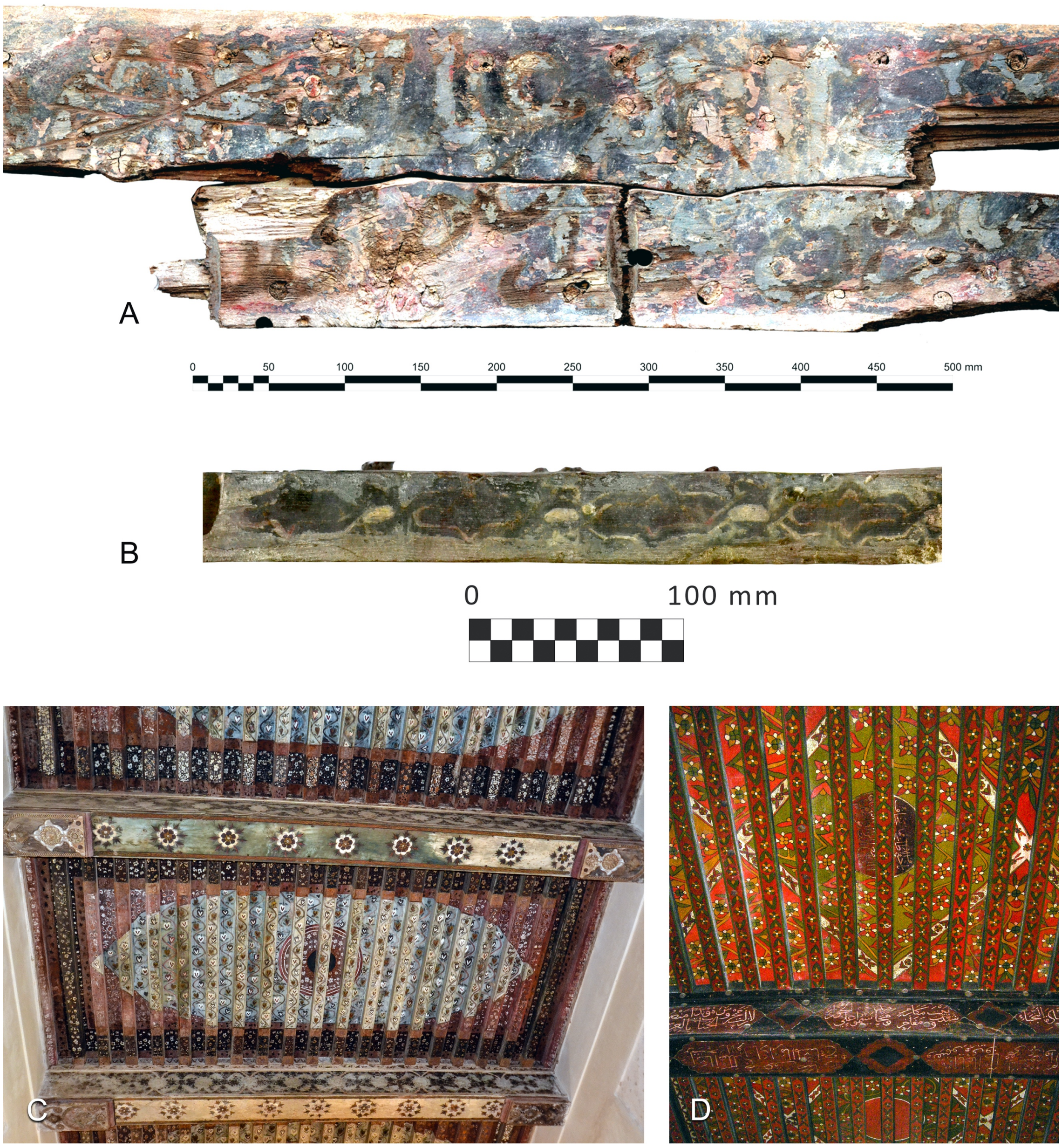


Figure 7.8: Planks Wo56-Wo60-Wo73 (A) and Wo71 (B) showing Arabic text and abstract decorative motifs similar to those painted on the ceiling of the Sun and Moon Hall in Jabrin castle, Oman (C-D). (Photos: Author)

Decorative motifs on timbers Wo71 and Wo72 are on one of their edges, suggesting that they constituted one of the smaller beams aligned longitudinally to the length of the room, between the largest structural beams (Figure 7.8(B-D)). Once again, the analogies between the evidence from these two al-Balid timbers and those from Jabrin castle are striking, with both showing repetitive floral or geometric motifs.

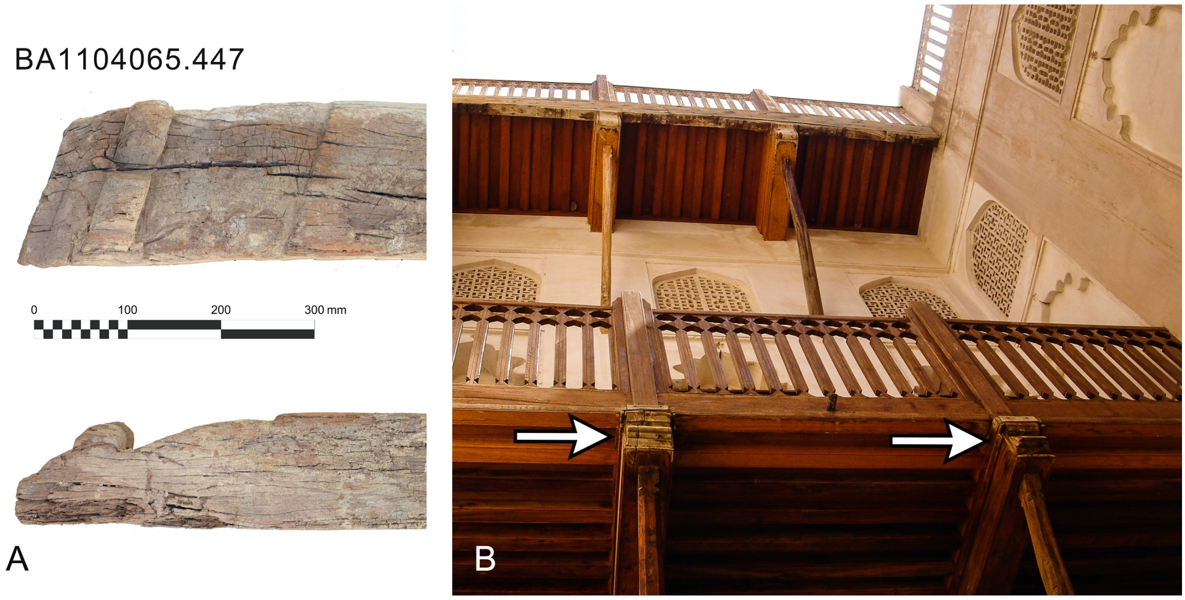


Figure 7.9: A balcony in the internal courtyard at Jabrin castle, supported by beams with decorated ends. (Photo: Author)

Similarly, the floral and intricate motifs carved at the ends of the two large beams (Figure 3.37 and Figure 3.39), discovered in the citadel and the mosque of al-Balid, point to later modification. The ends of these, seen in the previous section, also show elaborate carved incisions and decorations, suggesting late intervention in a terrestrial context. Decoration of a beam is rare in boatbuilding. As far as the author is aware, there is no archaeological, ethnographic or historical evidence of decorations on the ends of through-beams in western Indian Ocean watercraft. Beams, especially through-beams, are particularly useful in making fast the cables used for sailing, and decorations would make this impractical and could even damage the rope or reduce the space of the beam where lashing is done.

Moreover, beam Wo105, which has one end preserved, shows no evidence of decoration. Jabrin castle again provides similar evidence — the beams supporting the balconies facing the internal courtyard have their ends carved with a motif similar, but less elaborate, to that on BA1104065.447 (Figure 7.9).

7.7.1 Recycling Practice

The recycling of ships' parts in architecture is an ancient practice widespread in the region throughout history, from pharaonic Egypt (Creasman 2013; 2014: 25-26; Haldane 1988: 142-143, 151; Ward 2000: 107-109; Ward and Zazzaro 2010: 28) through Roman times (Sidebotham 2008: 310; Sidebotham and Zych 2010: 19-21; 2012: 147-151) and the medieval period (Blue 2002; 2006; Blue et al. 2011; Kalus and Guillot 2005: 27-29) to the Modern era (Agius et al. 2016: 147; Prins 1982: 97-99; 1986: 87-89). The author of this thesis observed nailed planks that were used as shelves in demolished houses in Mirbat, southern Oman (Figure 7.10), while Omani fishermen continue to use boat beams, planks and frames in their huts on the beach (Author, Personal observation, Oman 2016).

Figure 7.10: Abandoned buildings in Mirbat, southern Oman (A). Most of the timber used for shelves and beams was recycled from boats (B). (Photos: Author)

What is significant is that the al-Balid and Qalhat ship timbers were recycled in the most important buildings, respectively the citadel and the Friday Mosque, and while many of them had a structural function and were employed to support and strengthen the walls of the citadel (Borgese et al. 2019: 6-10), others were chosen for aesthetic purposes, to decorate the rooms of the citadel. Evidence from Jabrin indicates that these decorations usually occurred in the most important rooms, such as the library, courtrooms and audience halls (Baldissera 1991: 34, 41), suggesting a similar custom in the case of al-Balid.

7.7.2 Availability and Material Economy

It might appear curious that the people of al-Balid and Qalhat choose old, worn and often broken timbers for use in their most luxurious buildings. The primary reason for the reuse of ship parts would have certainly been the scarce availability of wood in the region. However, while a lack of timber applies in the case of Qalhat, wood would have been relatively readily available around al-Balid, which is located in a privileged ecological area on the Arabian Peninsula. The southwest summer monsoon affects Dhofar with two-to-three months of rain between June and August, making it the greenest region in southern Arabia with a wide range of trees and plants suitable for construction (Ghazanfar 1992: 191; Ghazanfar and Fisher 1998: 291-292; Miller et al. 1988).

There are other examples in the Indian Ocean timber recycling in either terrestrial or maritime contexts from places with abundant wood resources, such as the guardroom ceiling of the Mombasa fort, Kenya, which is made with planks from sewn boats (Prins 1982: 97-99; 1986: 87-89). Similarly, southern Indian boatbuilders often reused old boat elements to repair sewn craft of the Kerala backwaters or build new ones (Author, personal observation, Alleppey 2013).

Perhaps, as remarked by Creasman (2013: 154) in the case of ancient Egypt, carpenters took advantage of the durability of wood by reusing it regularly. Another benefit of reusing of ship timbers, particularly beams and planks, is that they already have a relatively regular shape suitable for terrestrial construction and do not necessitate expensive and labour-intensive activities, such as those required to fell a tree, saw planks or carve a beam from a log. This would undoubtedly have been an option that was taken into consideration by al-Balid's builders. Moreover, since some of these timbers were painted, signs of damage and wear associated with their previous use would have been covered by the decoration.

7.7.3 Boat Symbolism

The people of al-Balid and Qalhat might also have valued the ship timbers for their previous use in a maritime context and what that represented, apart from the obvious economic advantage of recycling them. This was sometimes the case in ancient Egypt, where there is evidence of the reuse of building materials, such as monumental stone that was moved for ideological motives (Brand 2010: 2-3), such as "pious recycling" (Creasman 2013: 155). Perhaps Arab maritime communities might have considered these planks and beams as being particularly meaningful precisely because they had belonged to ships, which are often imbued with symbolism (Braginsky 2007: 51; Kobyliński 1995: 11; Manguin 2001: 2; McCaughan 2013: 54). In the Islamic world, the theme of the ship (*fulk*) is closely linked to the Ark of Nūḥ (Noah) and associated with the greatness of Allah (Braginsky 2007: 51). The concept of a boat alluding to some spirituality or life is ubiquitous in maritime cultures (Vosmer 2007: 352-356); it is a cultural symbol connected to the unfamiliar and unknown environment of the ocean, and often suggestive of the "journey of life" (McCaughan 2013: 54; Agius 2013b: 94).

These ship timbers might have symbolised long voyages, the challenges of sailing, distant lands, favourable trade episodes and profit to some of the people of al-Balid, and merchants and captains living in these ports may have employed them in their buildings as memories of a glorious past. Symbolism embedded in boats may have played a significant role in the recycling of maritime remains in al-Balid and Qalhat, instead of sourcing new material.

7.8 Conclusion

Overall, the al-Balid timbers offer important new insights into the materials used in Indian Ocean boatbuilding during the medieval period. This information concerns the maritime use of the material, as well as the modalities of its recycling in a terrestrial context.

Species of wood identified in the al-Balid dataset reveal the variety of timber used to build vessels in the region, while alluding to the existence of various material trade networks connecting the coasts of the Indian Ocean, which also yield insights into possible trading centres managing the flow of goods. The exchange of utilitarian commodities is the most overlooked in historical sources and the archaeological record, but played an essential role in shaping the economy, social life and politics of the Indian Ocean throughout history.

Evidence at al-Balid also provides information concerning another aspect of medieval Indian Ocean boatbuilding that is relatively unknown: those who built and owned the boats. While this topic is complex, it nevertheless indicates possible areas of provenance of the vessels sailing to and from al-Balid. Data support the prevailing notion about India as one of the main shipbuilding candidates, but it also highlights new geographical areas, such as the Horn of Africa, the Red Sea and the Swahili coast, and even raises the possibility that some of these vessels could have been built in timber-deficient regions, such as on the Arabian Peninsula and in the Gulf.

However, perhaps the most significant aspect revealed by the variety of species of the al-Balid timbers is the adaptability of sewn-plank construction. Timbers native to different geographical areas, with a wide range of characteristics and qualities, along with a variety of sewing materials, highlight the advantage that sewn boats can easily be built and repaired almost everywhere along the Indian Ocean littoral by exploiting local resources. This implies less standardisation in sewn boats, which has been often assumed by scholars to follow the “teak and coir” paradigm, and shows that boatbuilders could use different materials for similar functions and achieve the same results. Coastal communities could make sewing rope from a variety of fibres and plants that are easily found all over Indian Ocean regions, even in barren and arid areas. A wide range of materials, such as bitumen, resin and burnt lime, would serve as luting and coating, while boatbuilders could obtain oil and fat from fish and various ruminants even in the most arid regions to pay and preserve the hulls of their ships. It is, in fact, this adaptability of sewn-plank construction that is the predominant factor for its widespread use in the Indian Ocean in the Premodern Islamic period, as well as its long survival in the region.

8 Conclusion

The study of the al-Balid timbers has generated significant new knowledge regarding Indian Ocean boatbuilding and seafaring during the medieval period. It has produced valuable insights into a number of aspects of sewn-plank construction, including sewing techniques, materials and technology. Equally importantly, it has also shown a glimpse of the maritime communities and societies — the people behind the boats — that were involved in building and sailing of these vessels and, at the same time, has deepened our knowledge about the trade networks and broader connections within the coastal entities of the Indian Ocean littoral.

8.1 Indian Ocean Medieval Sewn Vessels

Varieties of Technique

One crucial aspect emerging from this research is the variety of sewing techniques of these medieval vessels. Within this diversity, the planks from al-Balid can be grouped into two main types based on their features. The single-wadding technique is recognisable through its similarity with sewn boats recorded in the region over the last two centuries. This sewing pattern is the most common in the western Indian Ocean, stretching from the Gulf to East Africa and as far as western India. The other sewing type is known as the double-wadding technique and is observed in both the Belitung and Phanom-Surin shipwrecks and, more recently, on the eastern coast of India and in Sri Lanka. This evidence is crucial because it takes our knowledge far beyond historical sources, which provide no detailed information regarding how medieval shipwrights fastened the planking of their vessels.

Another outcome emerging from a comparative chronological analysis of the timbers is a strengthening of the hypothesis formulated by Vosmer (2017; 2019) of a possible development from a double-wadding to a single-wadding technique. However, data remain scarce and more evidence is required to confirm this hypothesis definitively. Except for this possible shift in sewing techniques, the al-Balid timbers do not show any particular variation in technical patterns over time that would suggest development. This does not mean that Indian Ocean boatbuilders and rope workers relied on static technology but instead indicates the success of a method that shipwrights had probably refined for centuries, and which required no particular changes because it simply suited its purpose.

Along with sewn-fastening methods, the al-Balid timbers also indicate the use of nails, evidence that confirms what had already been indicated by other archaeological data, such as the timbers from Quseir al-Qadim (Blue 2006; Blue et al. 2011) and the Thaikkal-Kadakkarappally shipwreck (Tomalin et al. 2004), that nailed boats were in use in the western Indian Ocean before the arrival of the Portuguese. It, therefore, refutes the assumption that the adoption of nailed construction was an imitation of European vessels, but it could have likely been influenced by Chinese, Southeast Asian, or Indian boatbuilding traditions or even developed independently in the region.

Lastly, there is one timber showing a mortise-and-tenon method. While it cannot be confirmed that this was a part of a boat, it nevertheless indicates a further fastening technique used to join timbers during that period. While that sample may not have belonged to hull planking, it might have been another structural boat element, perhaps suggesting the use of different joining methods to fasten different parts of a vessel.

The implication of the variety of fastening techniques displayed by the al-Balid timbers is that it provides a picture — although still limited — of the diversity of boatbuilding practices in the region, as opposed to an assumption of the unchanged nature of medieval sea craft (Hourani 1963: 88; Johnstone and Muir 1962: 63). Above all, it reveals that the study of these boats is a complex topic that cannot be expressed with the simple statement that medieval vessels were sewn until the coming of the Portuguese, and showed no technical or technological changes before their arrival (Bowen 1952: 200; Moreland 1939b: 190; Johnstone and Muir 1962; Hornell 1970: 237). Evidence from al-Balid warns about this complexity and serves as a reminder to treat this topic with caution because knowledge of these sewn craft is still limited.

Variety of Material

The variety of techniques indicated by the timbers is also echoed by the results of materials' analyses, particularly regarding wood species. Medieval boatbuilders used wood of different qualities from several regions throughout the 11th–15th centuries, and similar evidence is provided by the sewing materials, indicating the use of various vegetal fibres for the same purpose. Bitumen seems to be the exception to this information concerning variety as it is the only luting substance found on ship timbers from al-Balid. Nevertheless, preliminary chemical and mineralogical analyses appear to indicate the presence of various ingredients added to bitumen to create a different range of mixtures, revealing new boatbuilding activities that can be researched when investigating Indian Ocean sites.

Identification of the material of the al-Balid timbers, particularly wood species, confirmed what was already suggested by the Belitung wreck, which was built with different types of wood, adding precious data to the limited information provided by historical sources.

Species' variety alludes to broader material networks in the Indian Ocean during this period. These commercial connections signify a longue durée that shaped the Indian Ocean world and linked its peoples for centuries, that had gone on since early times to compensate for the unbalanced distribution of resources in the region. The continuous flow of materials from one ecological zone to another prompted the emergence, and supported the survival, of the recipients of these commodities: the various ports along the coast, as well as the interior of the Arabian Peninsula and the Gulf. Similarly, it would have boosted the growth of centres supplying these materials, particularly on the Swahili coast and Horn of Africa, and their links with their relevant interiors to where many of the timbers are native.

Moreover, the variety and provenance of these materials, particularly the wood, also strongly points towards the adaptability of sewn boats, which can be built and repaired with a wide range of materials even in desert areas with limited plant species. The fact that many timbers show evidence of multiple repairs also highlights the versatility of this construction method, which is probably the strongest reason for its longevity in the region.

8.2 The Multidisciplinary Approach

A further aspect underlined by this thesis is the validity of a multidisciplinary approach for the study of these ship timbers, which shows how important the study of archaeological material is in providing information about the maritime past of the Indian Ocean. However, this could not have been achieved without the support of other disciplines, such as ethnography, experimental archaeology, textual and iconographic sources that worked in concert with archaeology within a comparative approach to provide a broader context for these timbers.

8.2.1 Ethnographic Analogies

This research has also highlighted the striking similarity between medieval sewn vessels and those documented in the Indian Ocean in the 19th and 20th centuries, thus justifying the use of the analogy but without drawing simplistic equivalents. This similarity is remarkable because it confirms the strong link between past and present boatbuilding practices in the region. Other scholars (Agius 2002; Hornell 1970; Hourani 1963; Moreland 1939; Vosmer 2007; 2019) have noted this aspect of the Indian Ocean maritime world, but the scarcity of archaeological data made their studies predominantly based on often vague historical sources, either textual, iconographic or both. The al-Balid and Qalhat timbers have provided fresh new collections of archaeological data that have allowed a comparison with pictorial and literary evidence, confirming hypotheses assumed since earlier studies. One obvious outcome of the similarities between medieval and Modern era sewn boats is the significant role of ethnography in the study of the maritime past of the Indian Ocean, and perhaps elsewhere.

Construction Technique and Sequence

Ethnographic analogies from 19th–20th century boats with similar fastening systems have offered clues as to the interpretation of most of the features of the al-Balid and Qalhat timbers, providing essential information about the construction stages and sequence. Apart from helping to explain the sewing process and techniques, sewn boats recorded in East Africa, Arabia and India also suggested the function of particular hole patterns in the timbers, pointing to the use of temporary frames and moulds during the hull assemblage of these Premodern Islamic boats. Other elements, such as dowels, occurring in a considerable number of timbers, and the use of bitumen as luting, also persisted in the construction of sewn boats in the region until recently, pointing to the ingenuity of boatbuilders in solving problems related to sewn-plank construction and confirming the effectiveness of this method.

Comparing ethnographic records with the ship timbers also provided insights into boat parts, such as frames, keel and posts that are not preserved in the archaeological record from al-Balid. Series of holes in the centre of the planks reveal the fastening technique of frames, telling us about their spacing and size, and deepening our understanding of these vessels from a structural point of view. The bevelled edges of some planks point instead to garboards, which in turn give insights into the keels of the boats; the presence of diagonal ends suggests the angle of the stem and sternposts, offering clues about the shape of the hull. Similarly, one can estimate the approximate size of the vessels by looking at the thickness of the timbers and the length of the beams, which provide possible interpretations about their function. In turn, ships' sizes indicate the various maritime activities carried out at al-Balid.

Technology

The study of the al-Balid timbers has also yielded useful information about medieval technology. Marks on timbers' surfaces reveal the tools that shipwrights used to shape them, as well as their approximate size. This is particularly important in the light of the absence of boatbuilding tools in the archaeological record and historical sources.

Lastly, marks on the timbers also indicate striking similarities between medieval and Modern era boatbuilding in the region, where similar tools are still in use. Most of these tools would have probably been simple and predominately made of wood, particularly those employed in sewing, which could be the main reason for their absence in the archaeological record. The metal parts could have, perhaps, been recycled in other artefacts because they were considered valuable, which may also be a reason for their absence on the site.

8.2.2 Experimental Archaeology

Along with ethnography, other disciplines played a vital role in this research. Boat reconstruction projects such as *Sohar* (Severin 1982; 1985), *Jewel of Muscat* (Staples 2019; Vosmer 2010; Vosmer et al. 2011), the al-Hariri boat (Staples 2019) and the *beden seyad* (Ghidoni 2019), all carried out in Oman, have shown the potential of an experimental approach that helps archaeologists build experience about sewn-plank construction while becoming familiar with recognising technical features in the archaeological record.

These projects also provide information about boatbuilding that cannot be grasped from archaeological data, such as various construction processes as well as the time required for each building stage. My involvement in both *Jewel of Muscat* and the al-Hariri boat enabled me to:

- interpret the stitching pattern and sequence of timbers;
- determine the advantages and disadvantages of different techniques used;
- produce a range of possible explanations for the double-wadding method being abandoned in favour of a single-wadding pattern;

- explain the function of bitumen as luting substance to waterproof the hull;
- extract information regarding the tools used to shape the timbers.

Overall, the experimental approach provides archaeologists with a better understanding of the handling of materials, the workforce and many of the activities required in the construction of a sewn vessel, all of which bring the human element to the fore and fulfil the real target of maritime archaeology: the communities who built and used these boats.

8.3 Future Directions in the Study of Indian Ocean Medieval Vessels

8.3.1 The Importance of Secondary Contexts

In light of the scarcity of archaeological evidence and the absence of underwater programs in the region, ship timbers recycled in terrestrial and secondary contexts become increasingly crucial for the study of the maritime past. Archaeological and ethnographic evidence indicates that the practice of recycling maritime material culture was widely spread in the region. Therefore, it is necessary to investigate excavated coastal Islamic sites with particular attention to their storage facilities for similar evidence, such as wood remains that might have been overlooked during previous excavations. Maritime archaeologists should carry out such surveys to seek other ship components that are not present in the al-Balid and Qalhat collections.

One issue regarding ship findings from secondary archaeological contexts is that they might often go unnoticed by researchers because scholars not trained in maritime archaeology will not always recognise nautical finds, particularly if they are extremely fragmented and removed from their usual context. Moreover, archaeologists who worked on coastal sites of the Indian Ocean, particularly in earlier periods, may not have had a nautical focus when investigating them. For example, the earliest ship timber from al-Balid was discovered as early as 1979 (Costa 1979: 134), while teams excavating the site found various sewn planks in 1999, according to date on their tags. These artefacts were moved to the site's storage facilities without being adequately documented until 2009–2010 when Belfioretti and Vosmer (2010) published a preliminary study on a selection of samples.

The importance of these secondary contexts is also due to the fact that the al-Balid and Qalhat timbers presented in this thesis are only a fraction of the wooden remains that are still buried under the collapsed buildings of both sites. Al-Balid has provided the largest collection of ship timbers in the Indian Ocean at present, but only a small area of this large site has been excavated. Many wooden elements are visible in the masonry of the site, and more samples are expected to be found during future excavations, with the potential of discovering other boat parts such as masts, spars, rigging, rudders, oars, etc. The same applies to Qalhat, where several timbers are still inset in the walls of its buildings (Author, personal observation, April 2018).

However, apart from the apparent value of these finds in providing information about many aspects of medieval boatbuilding and seafaring, they also bear other important advantages. Firstly, their recycling in a secondary context probably contributed to their state of preservation. Shipwrecks tend to degrade very quickly underwater if they are not covered by sediment within a short time, particularly in the tropical waters of the Indian Ocean, which are infested with wood-boring organisms.

Moreover, investigating pieces of material culture on land is relatively inexpensive and logistically easy compared to the underwater excavation of a shipwreck. Their documentation requires no expensive budget since no particular facilities, such as boats or diving gear, are needed while conservation treatments are much easier and more affordable. Because of their distribution and the relatively low cost of their investigation, it is clear that maritime finds in terrestrial contexts represent a tremendous source of information that can be exploited by archaeologists while waiting for the discovery of fairly well-preserved shipwrecks in the Indian Ocean, and the implementation of underwater archaeology projects.

8.3.2 Al-Balid and Qalhat: What to Do Next?

Despite the large amount of data produced by the al-Balid timbers and, partly, by those from Qalhat, more work on this maritime material culture is required. So far, only a selection of timbers has been sent for species identification and radiocarbon dating analyses but by extending such analyses to all the specimens a more accurate chronological context would be determined for these finds, and possibly highlight other trends of development. It could also help in determining whether there were changes in materials through time, which could reflect shifts in Indian Ocean maritime networks.

These series of actions should be immediate due to the rapid degradation of the timbers. If not properly stored in a controlled environment, they could be affected by mould in a short space of time, which could cause disintegration of the wood. Similarly, the fibrous material of sewing cordage and wadding deteriorates even faster without proper interventions and treatments. Hence, an extensive conservation program for these timbers should also be a priority to prevent the loss of these precious artefacts and vital information.

Lastly, because of its invaluable role in the study of the maritime past of the Indian Ocean, ethnographic research should be implemented in the region, particularly on the sewn boats of southwest India. Despite being the last craft of the Indian Ocean that are fastened with ropes, very little research has been carried out and limited information has been published recently (Rajamanickam 2004; Ransley 2009; Shaikh 2019; Shaikh et al. 2012). Although these watercraft are no longer built, shipwrights and rope workers continue to repair them with modern materials, while communities along the backwaters of Kerala and Goa use them for fishing or carrying small cargo between the villages scattered along their banks. Researchers should focus on documenting these boats by recording their features in detail through both traditional and modern methods and, more importantly, interview the people who repair and use them. Again, these ethnographic surveys are urgent due to the rapid disappearance of both sewn vessels and boatbuilders skilled in sewn-plank construction. The latter are the last custodians of a dying tradition that, with different forms and techniques, persisted in the western Indian Ocean for at least four thousand years.

Appendix–A – Timber Recording Forms

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 8/05/17**

TIMBER ID:	823 B-3/98-1235	**LOCATION:**	Citadel NW?
WOOD SPECIES:	*Celtis africana* (Hackberry)		
DATE:	Cal AD 1117 - 1222 (Cal BP 833 - 728) (68.4%) Cal AD 1042 - 1104 (Cal BP 908 - 846) (27%)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	464	**WIDTH:**	28-82-143	**THICKNESS:**	45-44-39

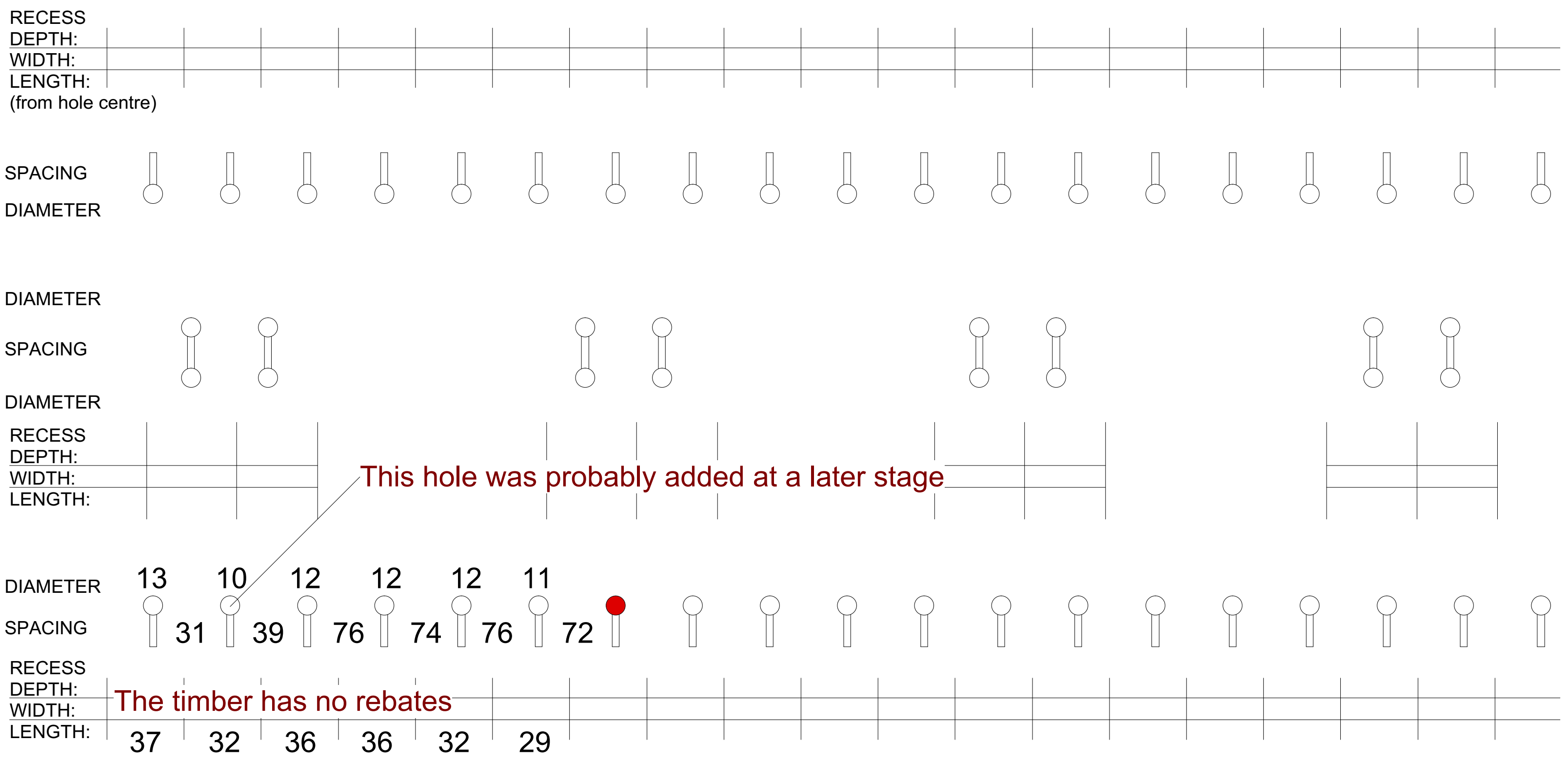
			TOP	**BOTTOM**	**FRAME**
HOLES				8	
OVERALL NUMBER:		8			
DIAMETER (Average):				11	
PLUGS	**WOOD**			6	
REBATES			NO	NO	
ROPES					
DOWELS				**1**	
DOWEL DIAMETER				12	
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This is a fragment of a thick plank or a stem/sternpost. It features no rebates on either surface, perhaps indicating a double-wadding sewing technique. The timber is not in good condition and one of the surfaces is very degraded. Hole spacing is relatively regular with an average of 75 mm, and the holes are placed 33 mm from the edge.


823 B-3/98-1235
0 50 100 150 200 250 300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: 823.B3.98.1235 DATE: 8/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 10/5/17**

TIMBER ID:	BA.01.11.01	**LOCATION:**	South Citadel (Wall)?
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:	Cal AD 1028 - 1184 (Cal BP 922 - 766)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	828	**WIDTH:**	246-285-296	**THICKNESS:**	52-55-20

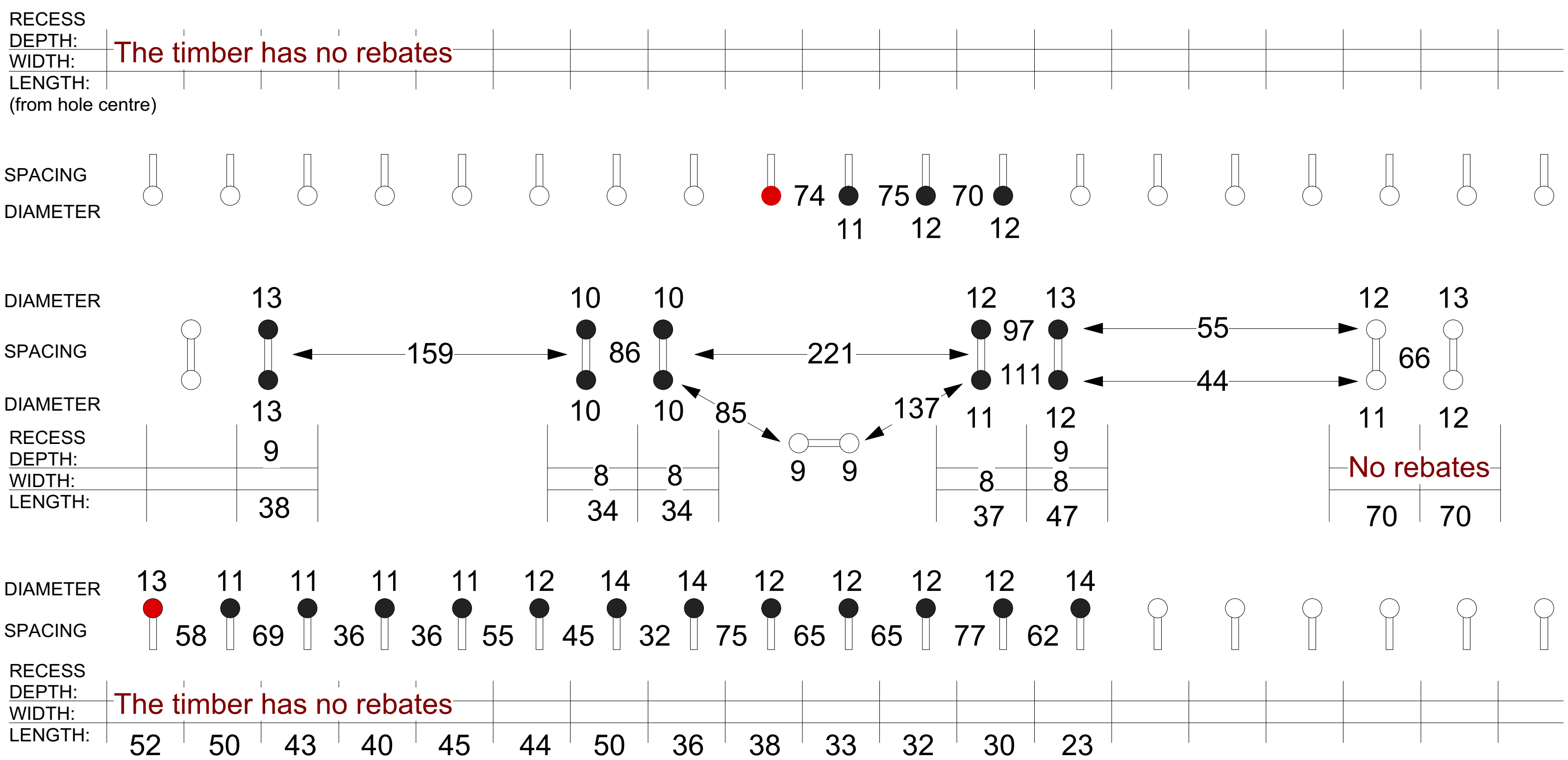
		TOP	BOTTOM	FRAME
HOLES		4	13	14
OVERALL NUMBER:	31			
DIAMETER (Average):		12	12	11
PLUGS	**WOOD**	3	10	10
REBATES				5
DOWELS			**2**	
DOWEL DIAMETER			12	
DOWEL SPACING			411	
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				Bitumen

COMMENTS:
Both surfaces of this timber are deteriorated and reveal the wood grain. Since most of the surface is missing and only one edge is preserved, the estimated thickness and width of the plank would exceed 60 mm. Holes are quite regular with a diameter of between 11 and 14 mm. The frame-lashing cordage is recessed in rebates in the centre of the plank, and indicates frames with moulded dimension of 66, 86 and 97 mm, and a spacing of 159, 221 and 55 mm. Two dowel channels, with a diameter of 11-12 mm, are visible on the lower faying edge and are 411 mm apart. Traces of a black substance identified as bitumen are visible on the lower faying edge.

BA01.11.01

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA.01.11.01 DATE: 10/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole (red)
- Worn elongated hole (blue)
- Plug preserved (black)
- No plug preserved (open circle)

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 13/05/17**

TIMBER ID:	BA090458.1010	**LOCATION:**	Citadel East Wall?
WOOD SPECIES:	Tectona grandis (teak)		
DATE:	N/A		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	703	**WIDTH:**	198-182-50	**THICKNESS:**	47-48-49

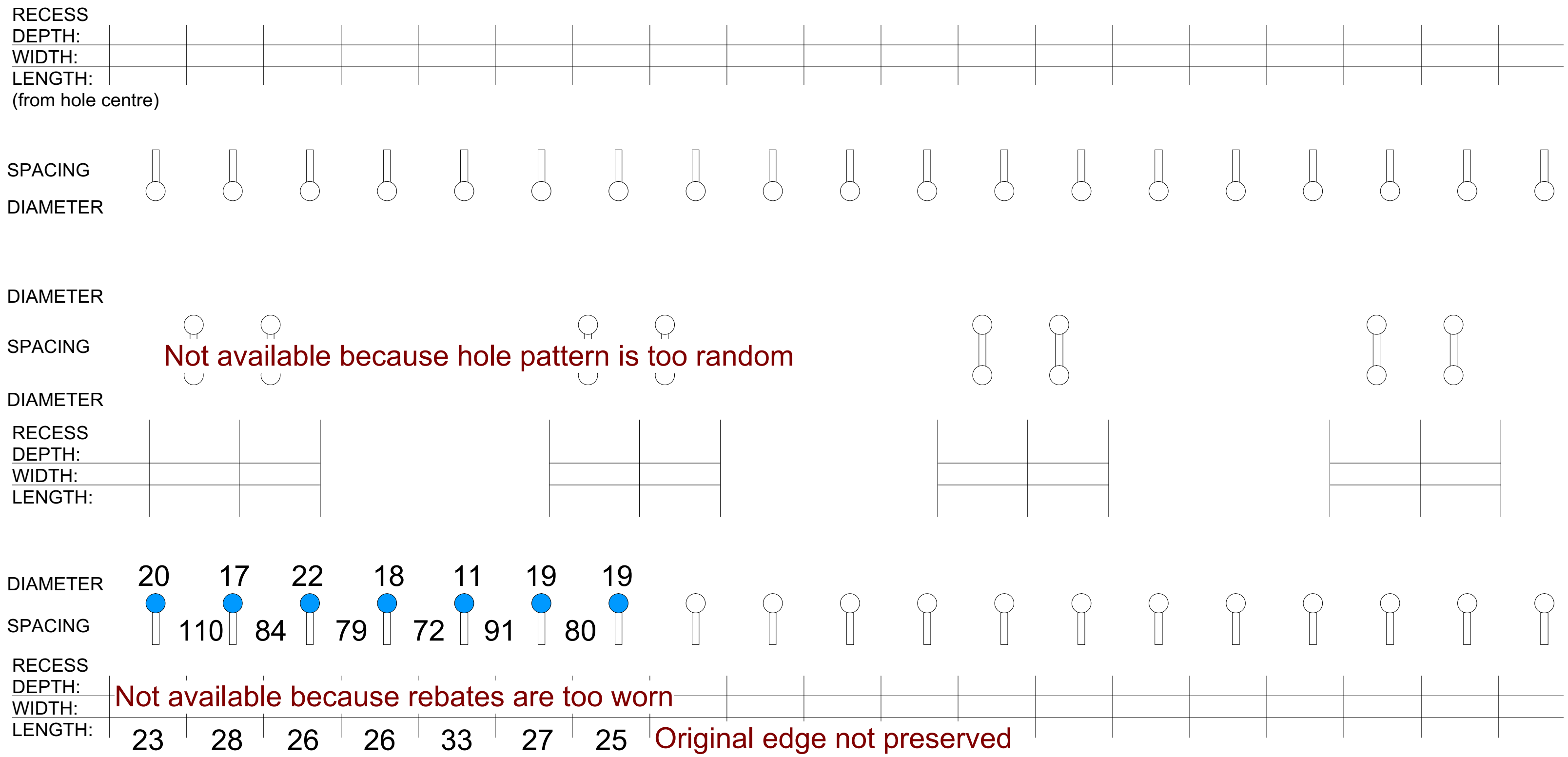
		TOP	**BOTTOM**	**FRAME**
HOLES			7	10?
OVERALL NUMBER:	17			
DIAMETER (Average):			19	
PLUGS	**WOOD**			
REBATES			7	
DOWELS				
DOWEL DIAMETER				
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This thick and very deteriorated plank features elongated sewing-holes along the wood grain, similar to those found in BA0604148.70. The plank has not retained any original edge. Due to its poor state of preservation the hole pattern is difficult to interpret, particularly in the centre of the plank where the holes suggest the presence of frame-lashings. Rebates are worn and barely visible. This timber was found during the 2001 excavation of the citadel led by Dr. Michael Jansen. A tag attached to the timber is inscribed, “E. Wall,” but it is not clear if “E” stands for the Eastern or Exterior wall.


BA090458.1010
OUTER SIDE
INNER SIDE
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA090458.1010 DATE: 10/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 9/05/17**

TIMBER ID:	BA0604128.73	**LOCATION:**	Citadel (north east)?
WOOD SPECIES:	*Possible species include Tiliaceae, Sterculiaceae, Tamarix*		
DATE:	Cal AD 1290 - 1410 (Cal BP 660 – 540)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	642	**WIDTH:**	72-119*-87	**THICKNESS:**	28-28-24

* The assemblage comprises three planks sewn together. 119mm refers to the overall width including all planks.

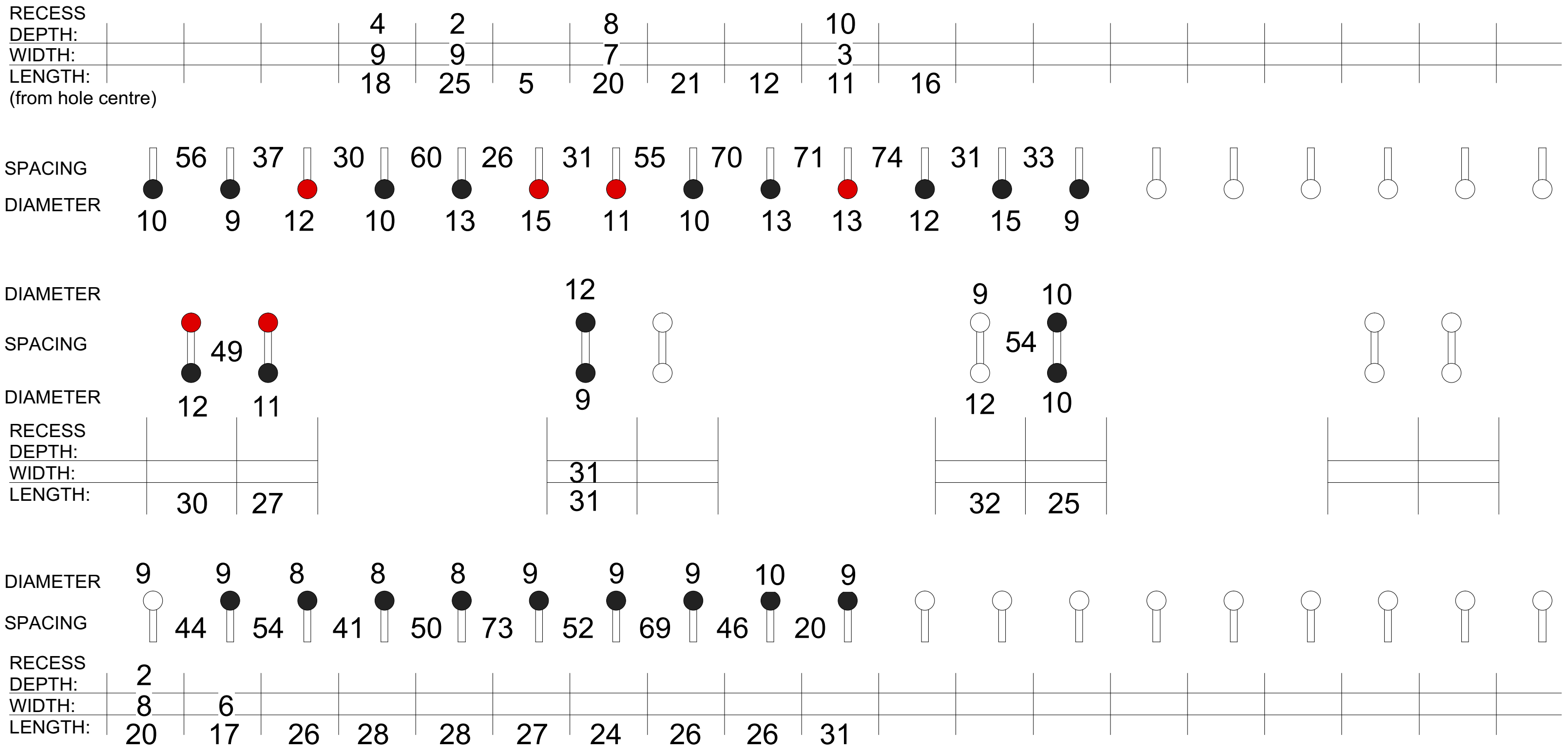
			TOP	BOTTOM	FRAME
HOLES			14	15	9
OVERALL NUMBER:		38			
DIAMETER (Average):			12	9	11
PLUGS	**WOOD**				
REBATES			8	12	2
DOWELS			5	4	
DOWEL DIAMETER			6-7-6-7-5	11-7-7-7	
DOWEL SPACING			60-117-121-130	53-275-154	
SCARFS			√		
WADDING: Single					
BEVEL					

	OUTER SIDE	INNER SIDE	EDGE TOP	EDGE BOTTOM
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN			Bitumen	

COMMENTS:
This timber consists of three planks sewn together: two adjacent planks, and one connected with a diagonal scarf. Its surface is degraded and cracked. A large portion of sewing is preserved on the inner side of the plank, measuring 38 cm in length, and showing the traditional stitching pattern of the western Indian Ocean. This consists of an “IXIXIXI” pattern, with 6 vertical and 3 diagonal stitches. The cordage is 2 mm thick. The wadding rope diameters range between 4 and 6 mm. The wadding seems to be made of coir ropes running longitudinally along the seam. Frame-lashings are small, rendering the pattern confusing and difficult to interpret. Frame cordage is 7 mm thick. Dowels are thin and long, and are made of what looks like hard wood. It appears that a new series of holes were added at a later stage, drilled very close to the previous sewing holes. These probably indicate a repair. The inner surface of the plank displays traces of a black substance, probably bitumen, which covers part of the timber and the wadding.


BA0604128.73
SINGLE WADDING PATTERN
0
50
100
150
200
250
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA0604128.73 DATE: 9/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 10/05/17**

TIMBER ID:	BA0604128.74	**LOCATION:**	Citadel (North east)?
WOOD SPECIES:	N/A		
DATE:	Cal AD 1400 - 1460 Cal AD 1420 - 1440		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	318	**WIDTH:**	112* – 89	**THICKNESS:**	27-27-26

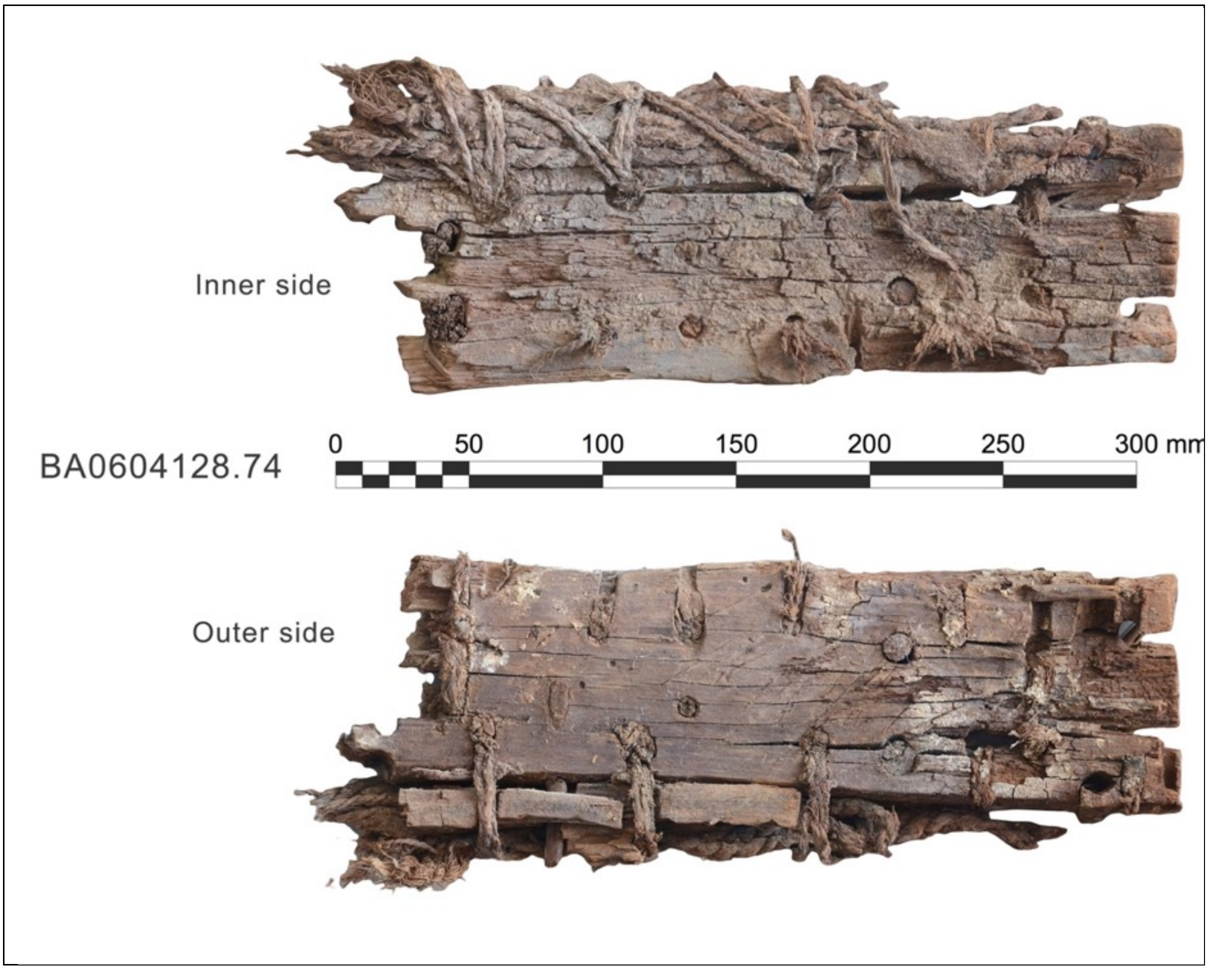
* The timber consists of two planks sewn together. 112mm refers to the overall width including both planks, while 89 is the width of just one plank with both edges preserved.

			TOP	**BOTTOM**	**FRAME**
HOLES			6	5	6
OVERALL NUMBER:		17			
DIAMETER (Average):			8	10	11
PLUGS	**WOOD**		4	5	6
REBATES			6	5	2
DOWELS			3	**3**	
DOWEL DIAMETER			11-13	7-7	
DOWEL SPACING			107-150	232	
SCARFS					
WADDING: Single			Width: 32	Length: 210	Rope Thickness:
BEVEL					

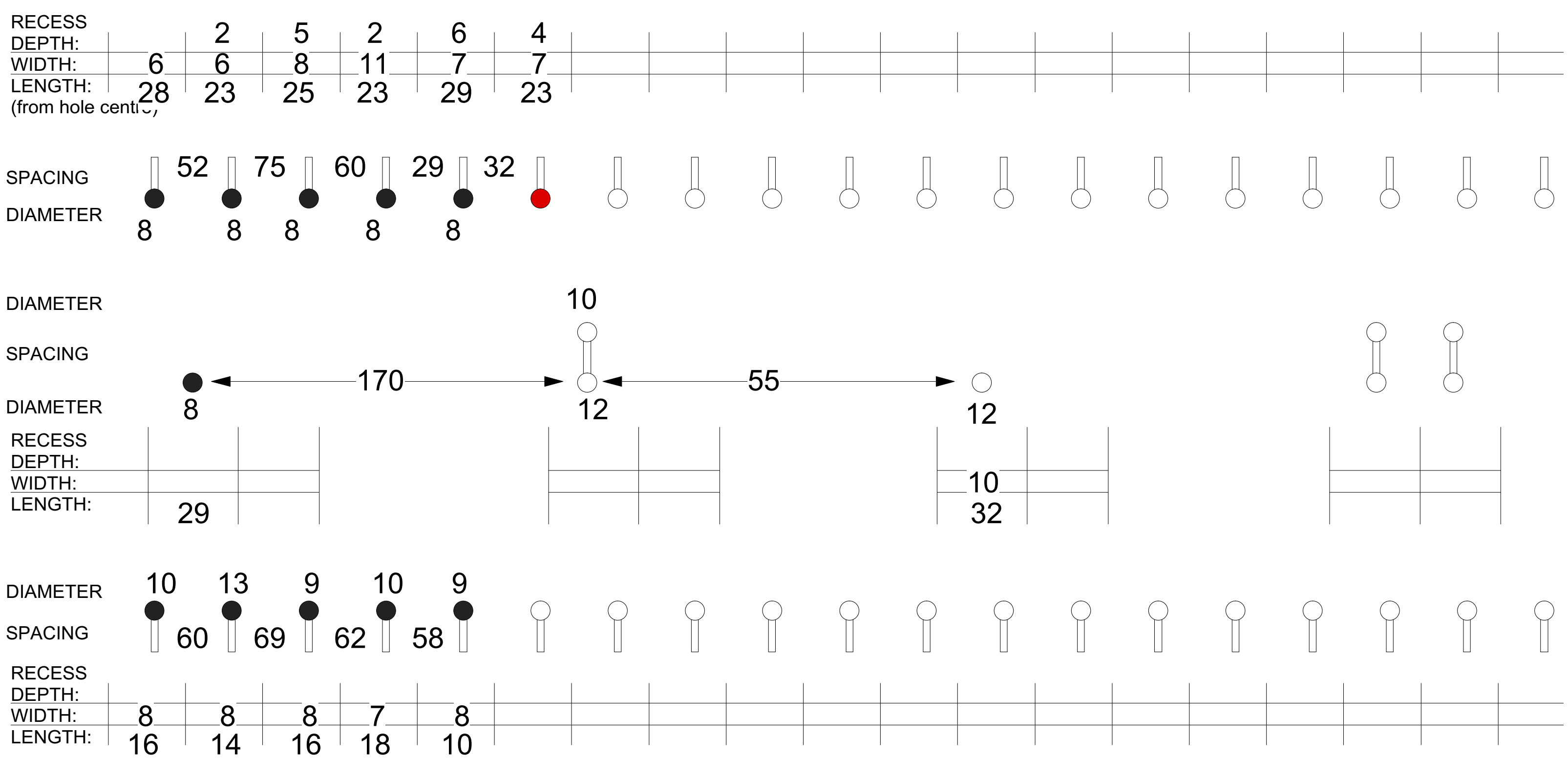
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:

This timber is heavily degraded, and split along the stitching-holes at the lower edge. A large section of wadding is still in place, displaying the typical western Indian Ocean sewing technique. The wadding consists of fibre ropes, 6-7 mm thick, while the sewing cordage is slightly thinner at 4-5 mm. The sewing-holes at the top edge are smaller and are not as evenly spaced as those at the bottom. Rebates are shallow (2-5 mm) and are as wide as the sewing holes (7-11 mm). Four pairs of holes aligned vertically in the centre of the plank indicate frame-lashings. One complete portion of frame-lashing cordage is still recessed in the rebate, showing that the frame was lashed with three rounds of rope. One frame-lashing has no rebate. The plank has three dowels on each edge. Those at the top edge are larger than those at the bottom and their spacing also differs. The timber is similar to BA0604128.73, with regard to its thickness, hole spacing, and hole diameter.


Inner side
BA0604128.74
0
50
100
150
200
250
300 mm
Outer side

AL-BALID TIMBER STITCHING HOLES RECORDING FORM* ID: BA0604128.74 DATE: 8/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

● Partial/broken hole

● Worn elongated hole

● Plug preserved

○ No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 9/05/17**

TIMBER ID:	BA0604145.175	**LOCATION:**	Citadel
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:	Cal AD 1160 - 1260 (Cal BP 790 - 690)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	461	**WIDTH:**	136–147–149	**THICKNESS:**	39-37-39

		TOP	**BOTTOM**	**FRAME**
HOLES		5	6	14
OVERALL NUMBER:	25			
DIAMETER (Average):		9	10	10
PLUGS	**WOOD**	5	2	14
REBATES		5	2	5
DOWELS			3	
DOWEL DIAMETER			12 - 10 - 12	
DOWEL SPACING			237 - 102	
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS	Chisel/Adze			
METAL ELEMENTS		2 Nails		
DECORATION				
RESIN/BITUMEN			Bitumen	Bitumen

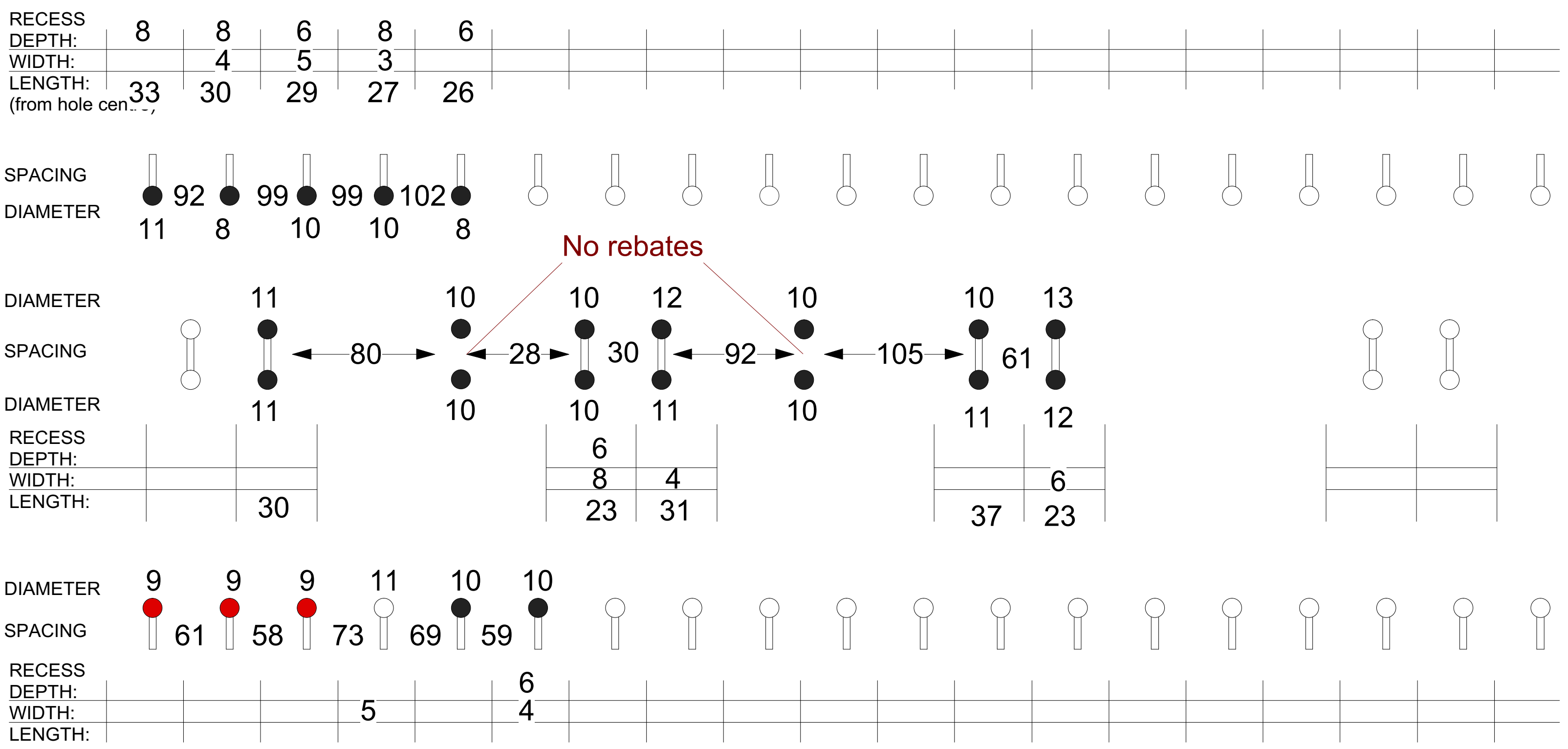
COMMENTS:

This plank is well preserved, with one original edge (top). The top edge sewing-holes are more regularly spaced than those along the bottom edge. The sewing cordage is well preserved and is still recessed in rebates at the top edge. The series of holes in the centre of the plank indicate frame-lashings, but the pattern is confusing, with some pairs of holes recessed and others without rebates—probably indicative of repairs. There are three dowels on the same edge, one of which was driven through one of the sewing-holes.

Bitumen is found on the inner side of the plank between its edge and the sewing-holes. The substance, used as luting under the wadding, contains small fragments of shells and grains of sand, and bears impressions of reeds, grass, and palm leaves.


BA0604145.175
OUTER SIDE
INNER SIDE
0
100
200
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA0604145.175 DATE: 9/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 13/05/17**

TIMBER ID:	BA0604148.70	**LOCATION:**	Citadel
WOOD SPECIES:	*Tectona grandis* (teak)		
DATE:	N/A		

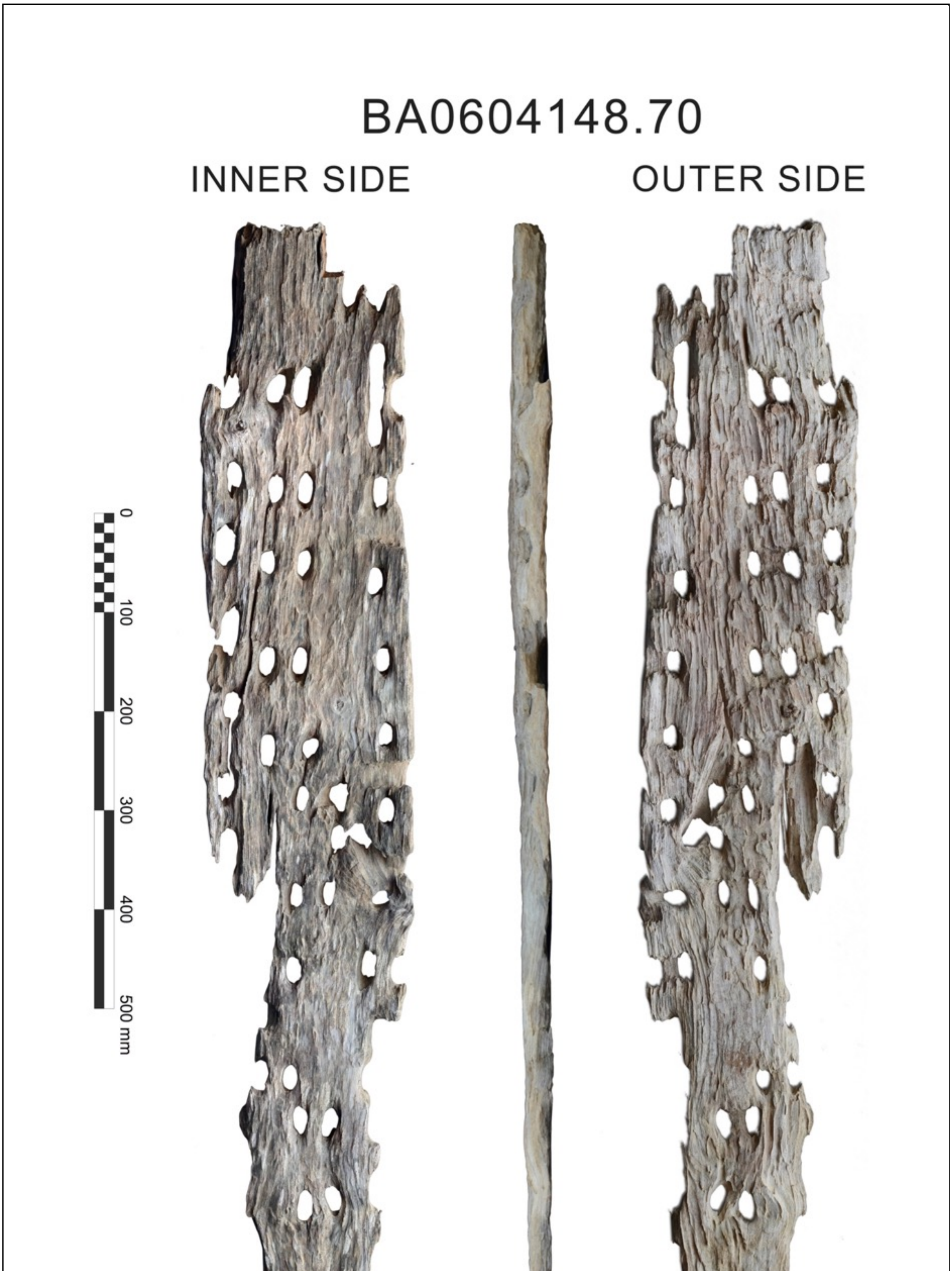
OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	1202	**WIDTH:**	226	**THICKNESS:**	43

		TOP	**BOTTOM**	**FRAME**
HOLES		7	8	18?
OVERALL NUMBER:	33			
DIAMETER (Average):		18	18	15
PLUGS	**WOOD**			
REBATES				
DOWELS			**3**	
DOWEL DIAMETER				
DOWEL SPACING			95-250-355	
SCARFS				
WADDING				
BEVEL				

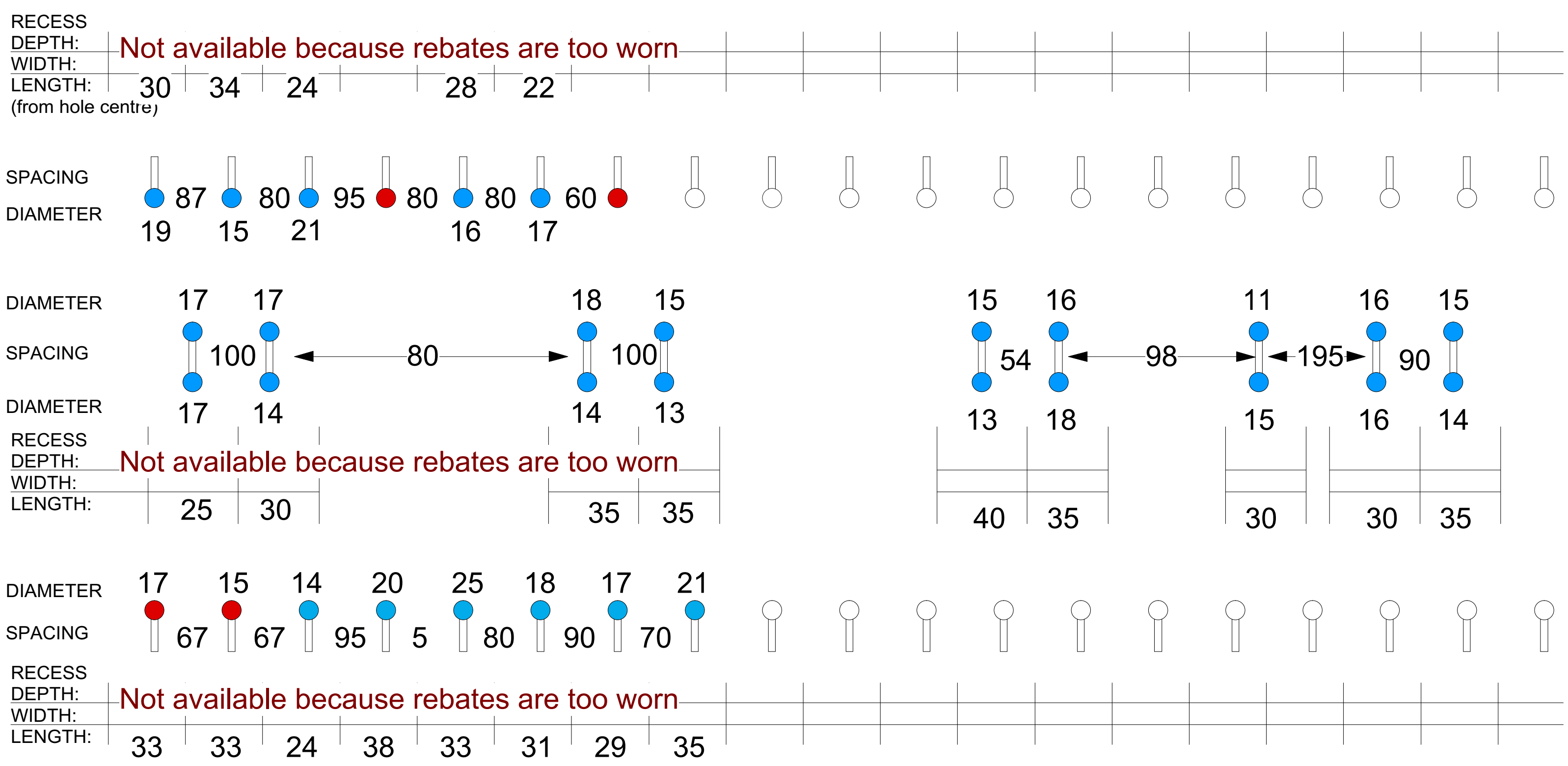
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:

This thick and very deteriorated plank features elongated sewing-holes along the wood grain. The plank has not retained any original edge. Due to its poor state of preservation the hole pattern is difficult to interpret, particularly in the centre of the plank where the holes suggest the presence of frame-lashings. Rebates are worn and barely visible.


BA0604148.70
INNER SIDE
OUTER SIDE
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA0604148.70 DATE: 9/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 10/5/17**

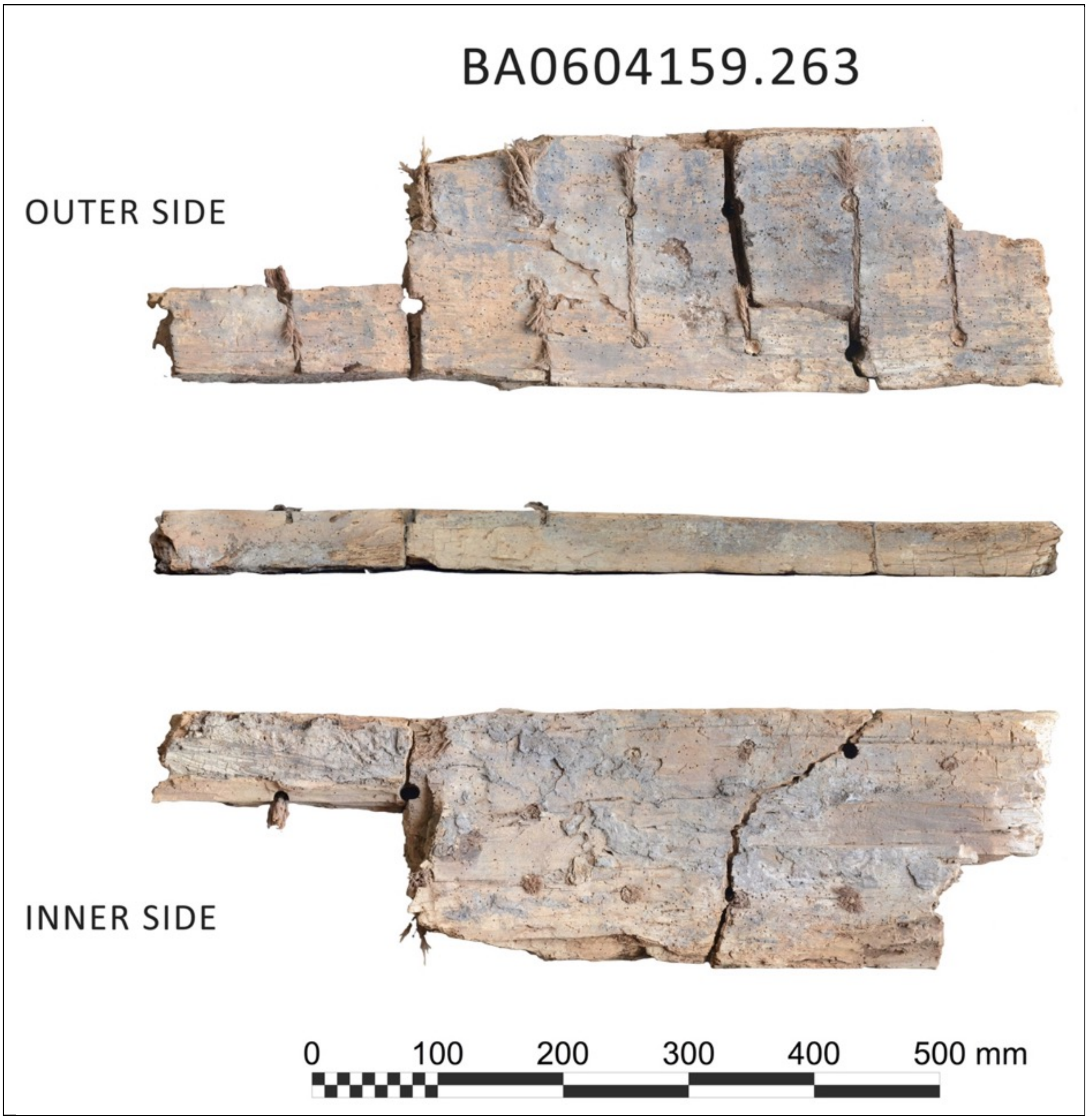
TIMBER ID:	BA0604159.263	**LOCATION:**	Citadel
WOOD SPECIES:	*Leguminosae Caesalpiniaceae*		
DATE:	See BA0604172.69		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	723	**WIDTH:**	207-201-69	**THICKNESS:**	46-49-51

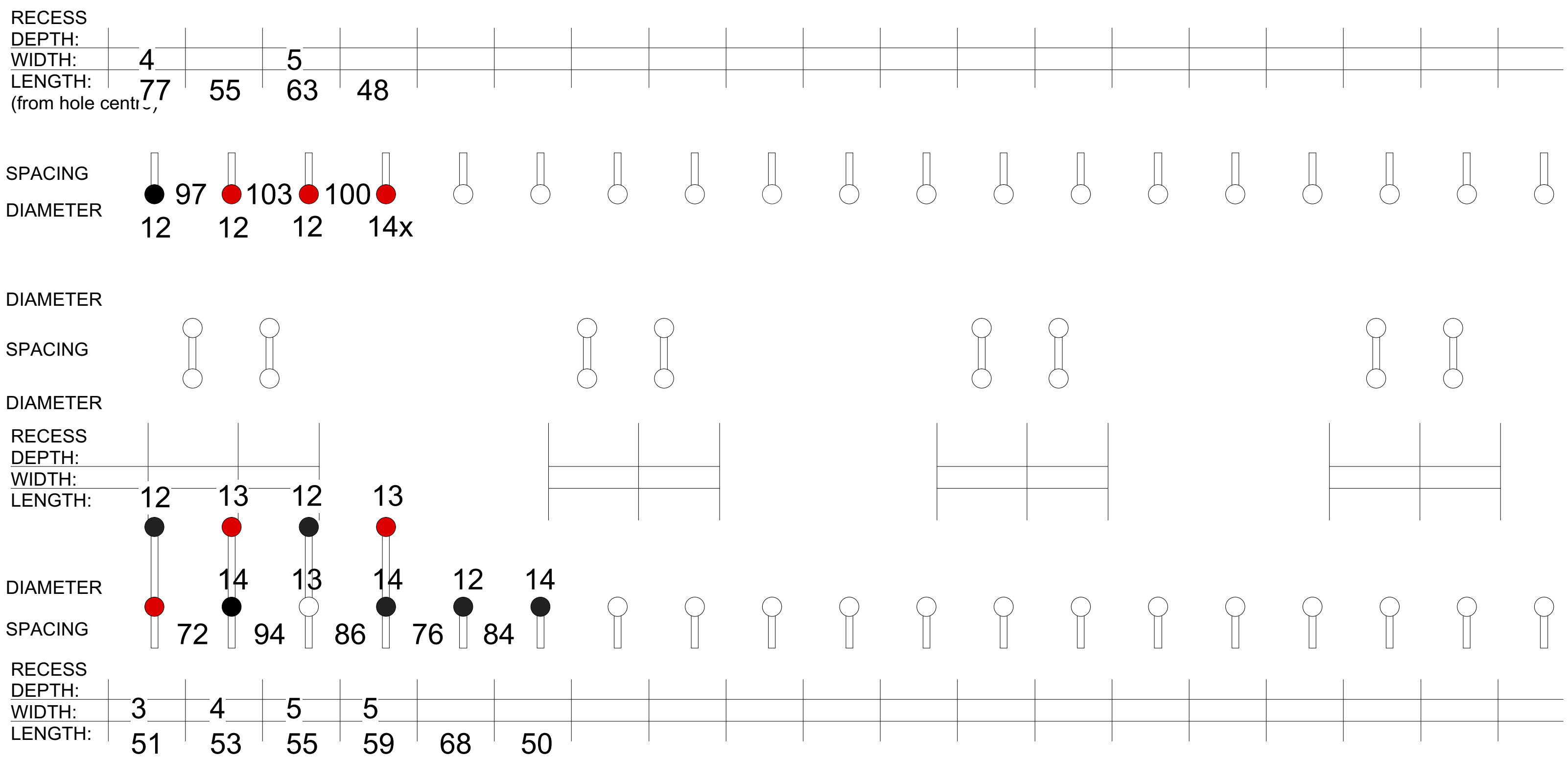
			TOP	**BOTTOM**	**FRAME**
HOLES			4	6	4 ?
OVERALL NUMBER:		14			
DIAMETER (Average):			12	13	12
PLUGS	**WOOD**		1	4	13
REBATES			5	4	4
DOWELS				**1**	
DOWEL DIAMETER				15	
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN		Bitumen?		

COMMENTS:
A very thick plank that was contiguous with BA0604172.69. The diameter of the sewing-holes, and their spacing, are fairly regular. The sewing-hole arrangement is similar to that of plank Wo71, with rebates extending from the sewing-holes towards the centre of the plank, and connecting to another row of holes in a way that suggests frame-lashings. This pattern appears to be limited to one section of the plank. The same hole arrangement continues onto plank BA0604172.69. This pattern might indicate the lashing of other structural elements to the inside of the plank, such as a beam shelf, thwart, or inwale. Around the centre of its inner side, the plank features a coat of what appears to be bitumen. This coating bears impressions of ropes, reeds, palm leaves, and grass, indicating the former presence of wadding next to the bitumen.


BA0604159.263
OUTER SIDE
INNER SIDE
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA0604159.263 DATE: 10/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 10/5/17**

TIMBER ID:	BA0604172.69	**LOCATION:**	Citadel
WOOD SPECIES:	*Terminalia* sp.		
DATE:	Cal AD 1210 - 1310		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	481	**WIDTH:**	132-195-108	**THICKNESS:**	46-47-43

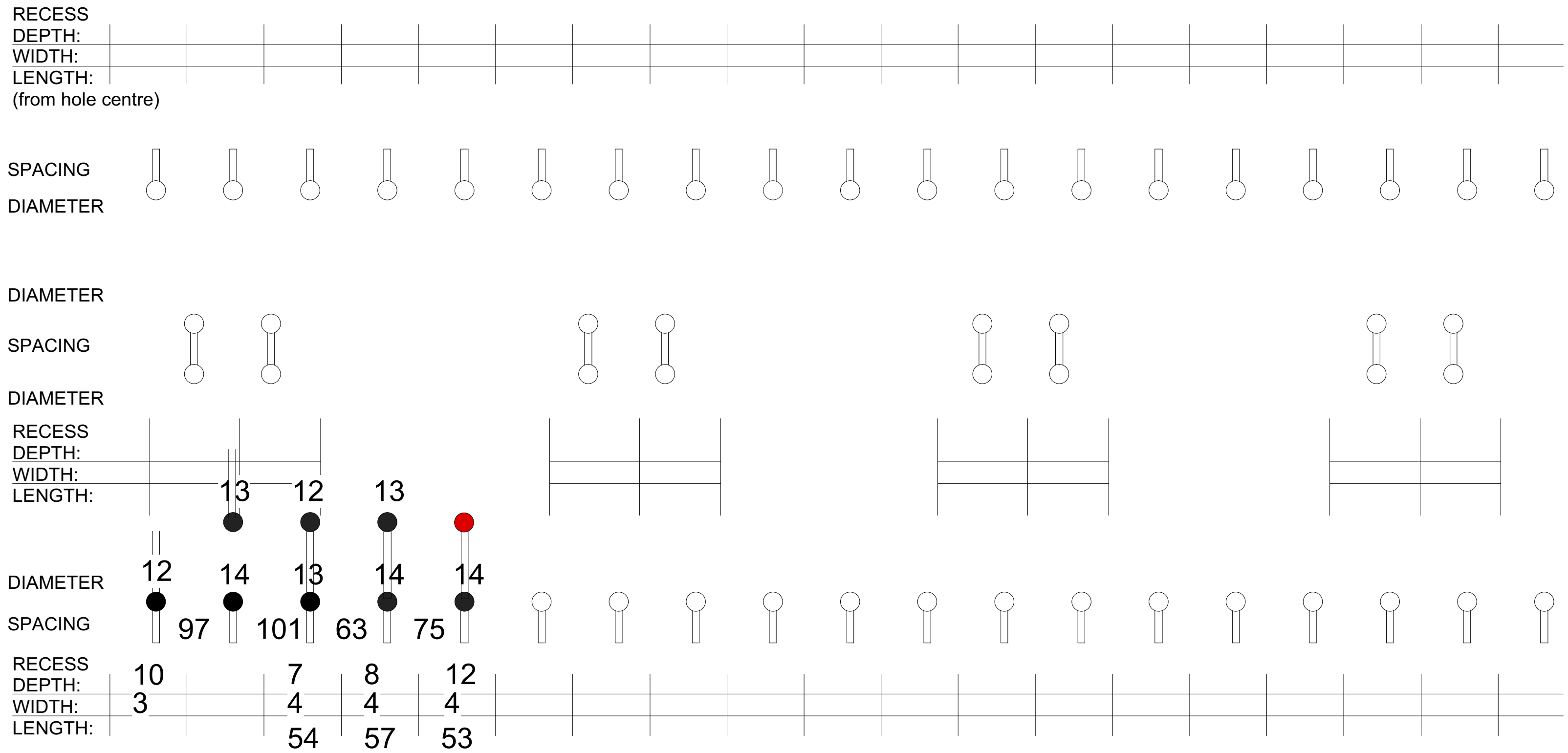
			TOP	**BOTTOM**	**FRAME**
HOLES				7	5
OVERALL NUMBER:		12			
DIAMETER (Average):				13	13
PLUGS	**WOOD**			5	3
	FIBRE				
REBATES				5	4
DOWELS				2	
DOWEL DIAMETER				14	
DOWEL SPACING				346	
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN		Bitumen (?)		

COMMENTS:
This thick, somewhat deteriorated plank is contiguous with BA0604159.263, with which it shares a similar hole pattern. (See BA0604159.263) As with BA0604159.263, the plank has traces of bitumen on its inner surface.


BA0604172.69
OUTER SIDE
INNER SIDE
0
100
200
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA0604159.263 DATE: 10/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE:**

TIMBER ID:	BA0704156.1477	**LOCATION:**	Citadel
WOOD SPECIES:	*Leguminosae Caesalpiniaceae*		
DATE:	Cal AD 1280 - 1400 (Cal BP 660 - 550)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	652	**WIDTH:**	128-136-97	**THICKNESS:**	30-25-22

		TOP	**BOTTOM**	**FRAME**
HOLES		1	8	4?
OVERALL NUMBER:	13			
DIAMETER (Average):			13	12
PLUGS	**WOOD**		3	2
REBATES			2	1
DOWELS			1	
DOWEL DIAMETER			14	
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL				

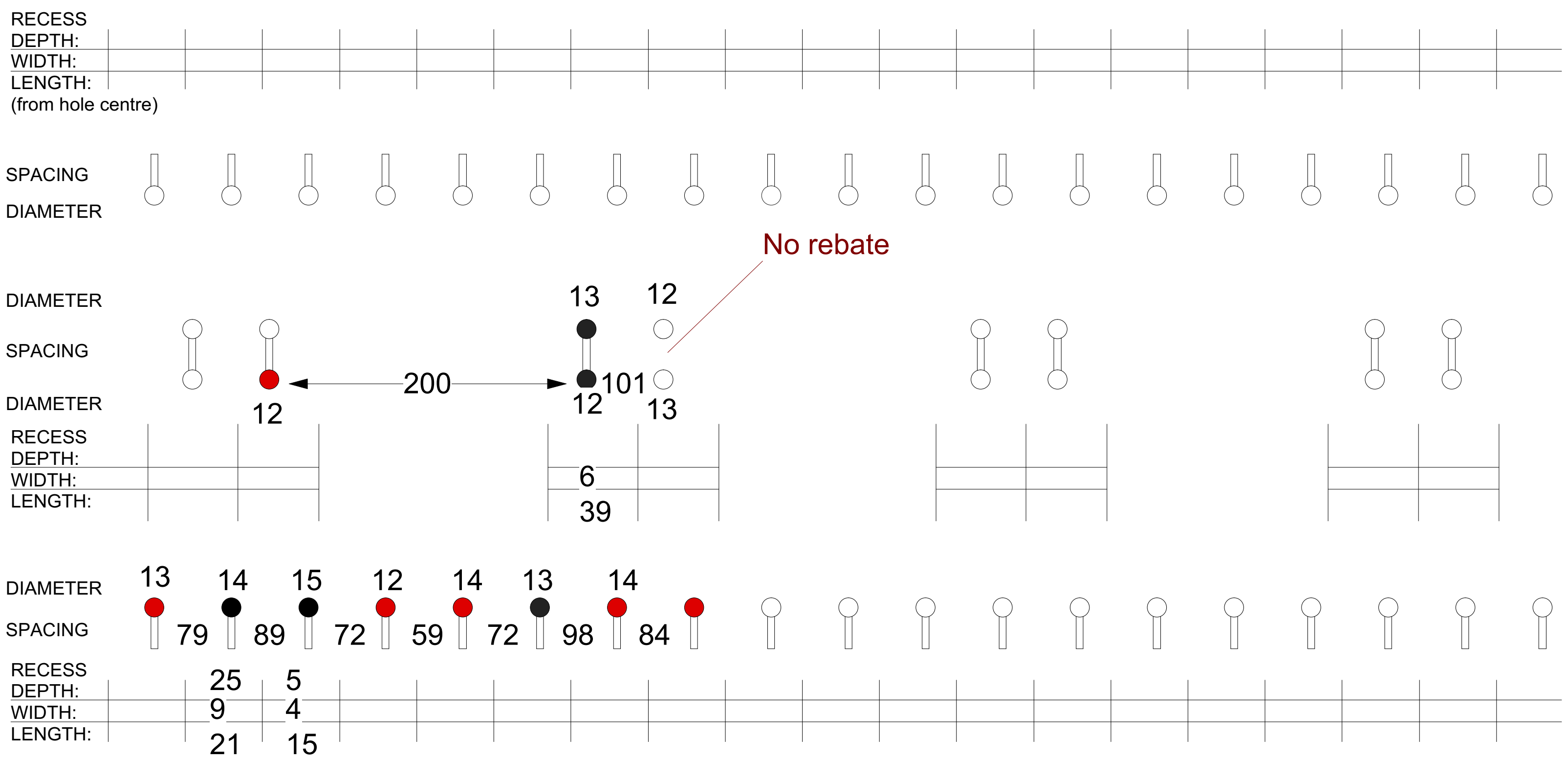
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS			nail	nail
DECORATION	Carved motifs			
RESIN/BITUMEN				

COMMENTS:

This thin plank features semi-regularly spaced sewing-holes, and frame lashings. The outer surface is decorated with geometric motifs (squares and triangles) carved in a zigzag pattern. The outer surface contains small holes probably caused by shipworms (*Teredo navalis*), while the inner surface is generally degraded. Fibres from the sewing cordage still adhere to the inside of some of the holes, and to a few wooden plugs. The outer plank surface retains two frame-lashings still recessed in rebates. One pair of holes in the middle of the plank is not connected by a rebate.

BA0704156.1477

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA0704156.1477 DATE: 9/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 14/05/17**

TIMBER ID:	BA 1104065.449	**LOCATION:**	Citadel
WOOD SPECIES:	*Tamarix* sp. (Tamarisk)		
DATE:	Cal AD 990 - 1050 (Cal BP 960 - 900) Cal AD 1090 - 1120 (Cal BP 860 - 830) Cal AD 1140 - 1150 (Cal BP 810 - 800)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	684	**WIDTH:**	111 – 124 - 105	**THICKNESS:**	24-25-27

			TOP	**BOTTOM**	**FRAME**
HOLES					
OVERALL NUMBER:		13		13	
DIAMETER (Average):				14	
PLUGS	**WOOD**			6	
REBATES				NO	
DOWELS					
DOWEL DIAMETER					
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS	Nails x2			
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This timber has not retained any original edge. Sewing-holes are relatively large, and not associated with rebates. Two rows of sewing-holes are visible on the surface. Holes farther from the edge of the plank are better preserved, showing plugs and bits of sewing cordage. Holes closer to the edge are only partially preserved. There are no rebates between the sewing-holes and the timber's edge, perhaps indicating a double-wadding stitching pattern. Because of the lack of rebates and frame lashings, it is impossible to determine which are the outer and inner sides of the plank. The plank displays a large rebate on the edge opposite the sewing-holes. This rebate might be the result of the timber having been recycled for another use in the citadel of al-Balid. Two nail shanks with square sections are visible on the right side of the plank.
Note: This timber was restored by conservator Carmela Corvaia (Western Australian Museum) in 2013.

BA110465.449

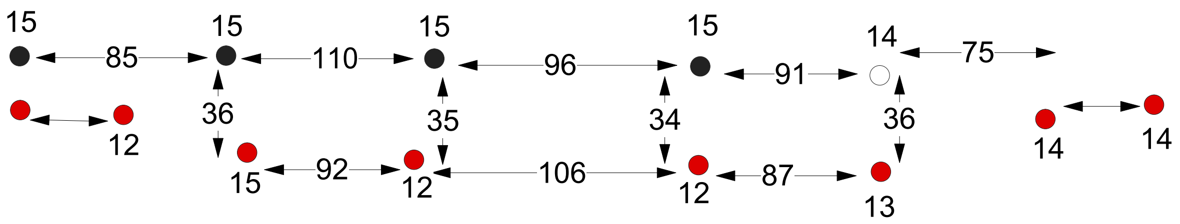
AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: BA1104065.449 DATE: 14/5/17

RECESS
DEPTH:
WIDTH:
LENGTH:
(from hole centre)

Original edge not preserved.

SPACING

DIAMETER



DIAMETER

SPACING

RECESS
DEPTH:
WIDTH:
LENGTH:

Original edge not preserved. The timber has no rebates.

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 9/05/17**

TIMBER ID:	BA 1104065.450	**LOCATION:**	Citadel
WOOD SPECIES:	*Ziziphus spina-christi*		
DATE:	Cal AD 1020 - 1170 (Cal BP 930 - 780)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	679	**WIDTH:**	86–97–91	**THICKNESS:**	31–26–21

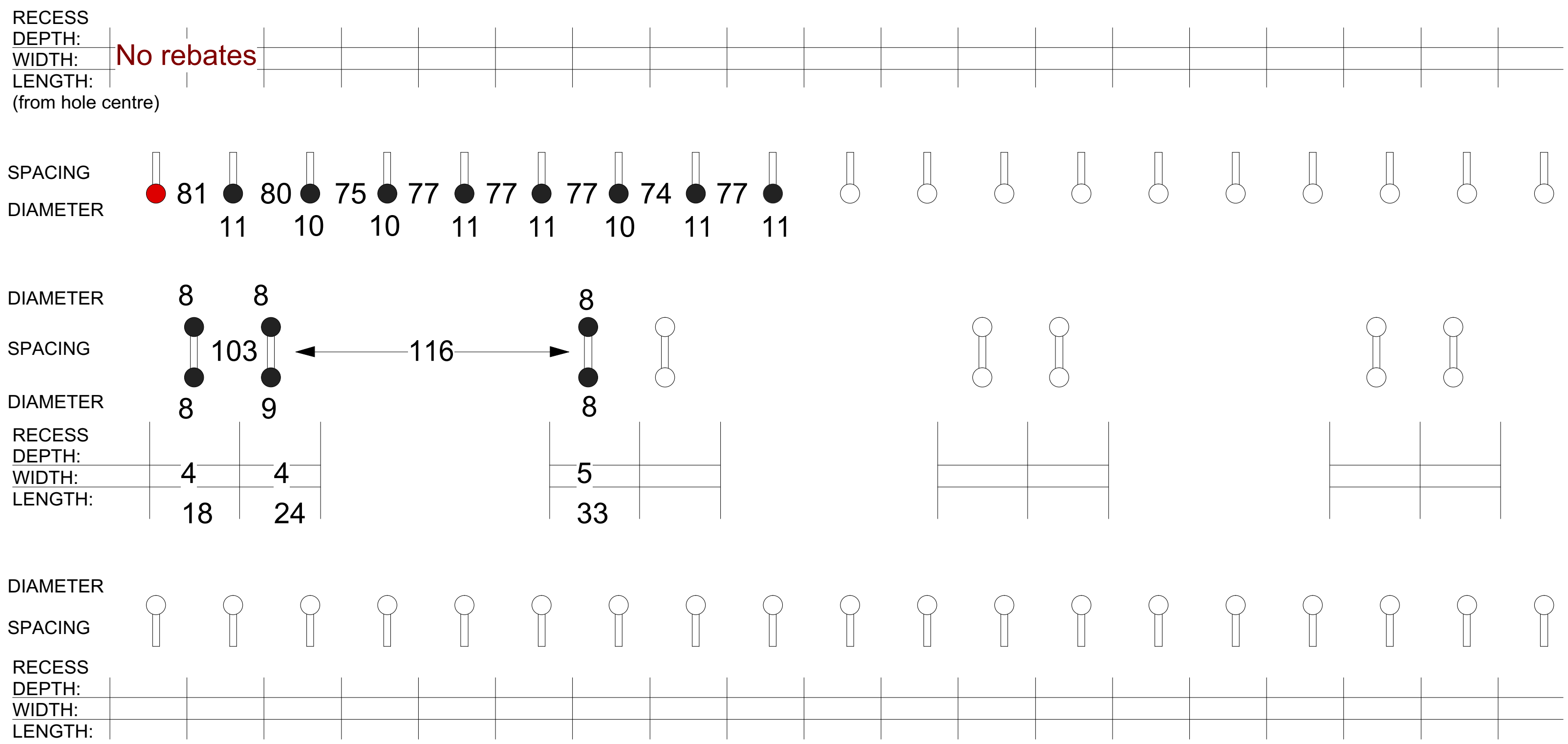
			TOP	**BOTTOM**	**FRAME**
HOLES			8		6
OVERALL NUMBER:		14			
DIAMETER (Average):			11		8
PLUGS	**WOOD**		8		6
REBATES					
DOWELS					
DOWEL DIAMETER					
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION	Carved Motifs			
RESIN/BITUMEN	Bitumen		Bitumen	

COMMENTS:
This thin plank features sewing-holes very close to the edge, suggesting that the timber was probably modified when it was recycled for use in the citadel of al-Balid. The plank has no rebates, suggesting a double-wadding sewing technique. The spacing of the sewing-holes is regular, and all but one hole retain wooden plugs with cordage fibre. Three stitching holes in the centre of the timber indicate frame-lashings but the pattern is confusing and difficult to interpret. The lashing cordage is two stranded, and 4 mm thick. Two of these lashings are recessed in rebates, thus identifying the outer side of the plank. The timber is decorated on its outer surface with carved triangles painted in black and white. Bitumen on the edge of the timber, and between the sewing-holes and the edge, indicates the presence of luting under the wadding to seal the seams of the vessel. Both sides of the plank manifest small holes and grooves caused by shipworms.


BA1104065.450
INNER SIDE
OUTER SIDE
0 50 100 150 200 250 300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM* ID: BA04065.450 DATE: 9/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 10/05/17**

TIMBER ID:	BA1104065.454	**LOCATION:**	Citadel
WOOD SPECIES:	*Ziziphus spina-christi*		
DATE:	Cal AD 1020 - 1160 (Cal BP 930 - 790)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	719	**WIDTH:**	52-72-71	**THICKNESS:**	31-30-30

		TOP	BOTTOM	FRAME
HOLES			20	4
OVERALL NUMBER:	24			
DIAMETER (Average):			7	6
PLUGS	**WOOD**		17	4
REBATES			19	3
DOWELS			4	
DOWEL DIAMETER			8-6-6-6	
DOWEL SPACING			177-146-159	
SCARFS				
WADDING				
BEVEL				

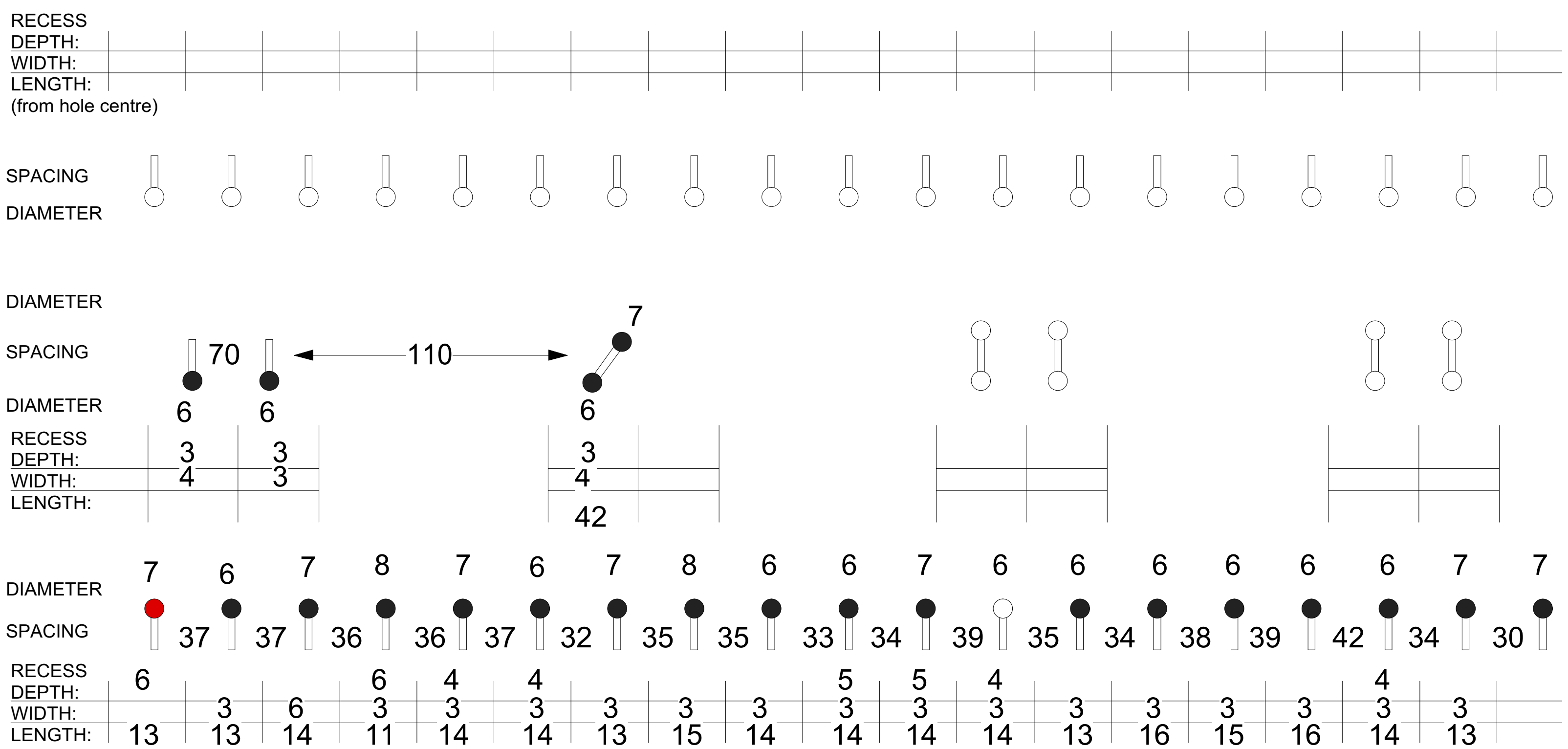
	OUTER SIDE	INNER SIDE	EDGE TOP	EDGE BOTTOM
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN			Bitumen(?)	

COMMENTS:

This timber features regularly spaced sewing-holes of similar diameter located very close to the edge of the plank (less than 2 cm). The plank is heavy and the wood is hard. A frame-lashing at one end of the plank is arranged diagonally to the timber length. The outer surface is degraded and contains small holes and channels bored by shipworms. Traces of bitumen are visible on the lower faying edge, while a thick layer of bitumen covers the inner side of the plank between its edge and the sewing-holes. Impressions of thin strips of leaves (palm leaves?) and grass in the bitumen indicate that these materials were used as wadding.


BA1104065.454
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM* ID: BA04065.450 DATE: 9/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 10/05/17**

TIMBER ID:	Jansen.Husn.99.01	**LOCATION:**	Citadel
WOOD SPECIES:			
DATE:			

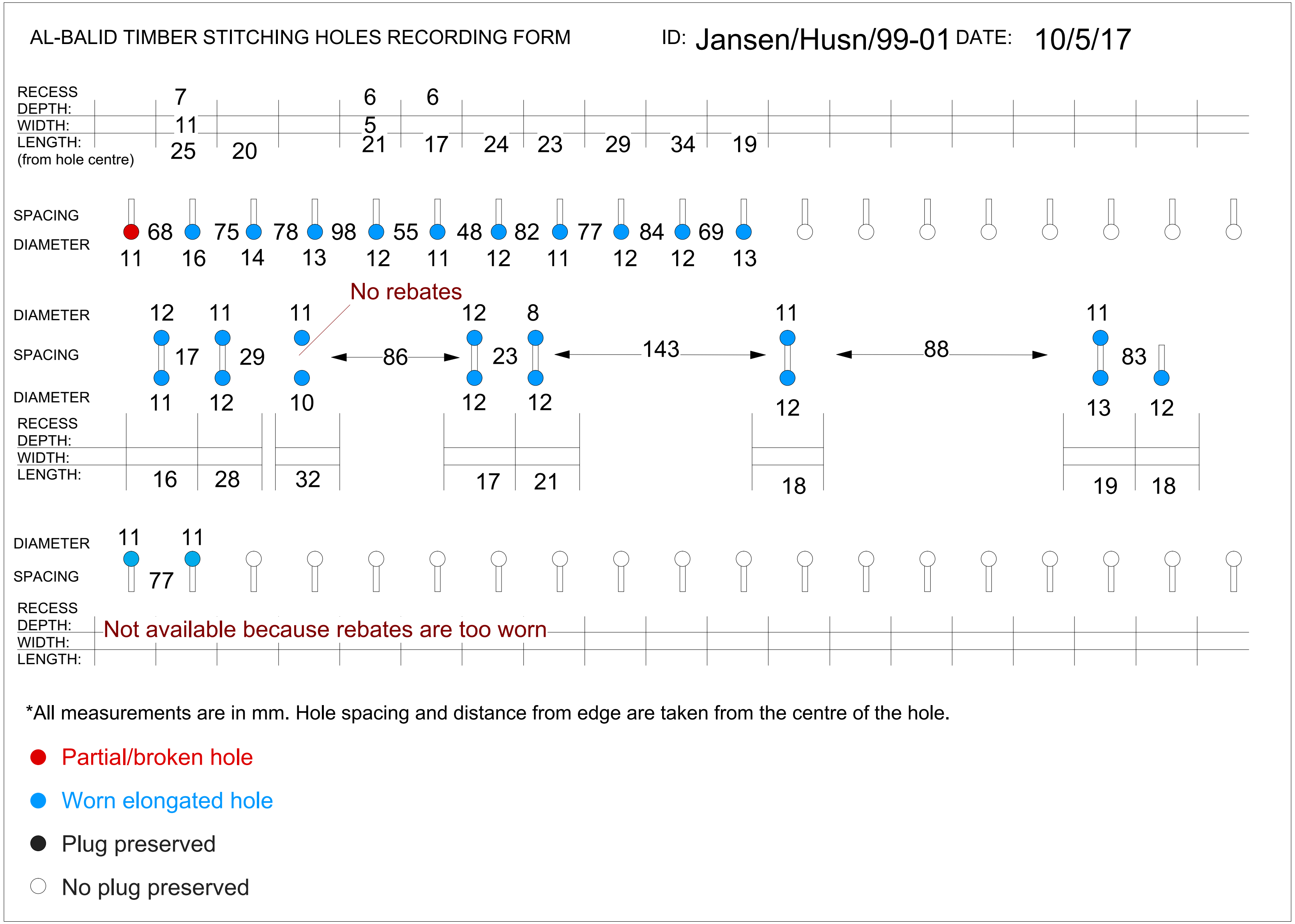
OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	851	**WIDTH:**	140-154-97	**THICKNESS:**	21-22-22

			TOP	**BOTTOM**	**FRAME**
HOLES			11	2	17(+6?)
OVERALL NUMBER:		36			
DIAMETER (Average):			12	11	12
PLUGS	**WOOD**				
REBATES			8	2	8
DOWELS			1		
DOWEL DIAMETER			12		
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This timber is heavily degraded. The exposed and uneven wood grain makes it difficult to determine the plank's actual thickness, and the stitching-holes have distorted with time. The top edge appears to be the original faying edge, while only a small section of what appears to be the original lower edge is preserved at the bottom of the plank, along with two holes associated with rebates. Because the timber's surface is extremely worn, it is impossible to determine the depth and width of the rebates. The frame-lashing pattern in the centre of the plank is confusing, suggesting either that the plank was repaired or that the frame to which it was attached was replaced.
Note: This timber was discovered during the excavation of the citadel of al-Balid in 1999-2001, directed by Dr. Michael Jansen.


JANSEN.HUSN.99-01
INNER SIDE
OUTER SIDE
0
100
200
300
400
500 mm


AL-BALID TIMBER STITCHING HOLES RECORDING FORM
ID: Jansen/Husn/99-01
DATE: 10/5/17
RECESS DEPTH:
WIDTH:
LENGTH: (from hole centre)
7
11
25
20
6
5
21
6
17
24
23
29
34
19
SPACING
DIAMETER
68 75 78 98 55 48 82 77 84 69
11 16 14 13 12 11 12 11 12 12 13
No rebates
DIAMETER
12 11 11 12 8 11 11
SPACING
17 29 86 23 143 88 83
DIAMETER
11 12 10 12 12 12 13 12
RECESS DEPTH:
WIDTH:
LENGTH:
16 28 32 17 21 18 19 18
DIAMETER
11 11
SPACING
77
RECESS DEPTH:
WIDTH:
LENGTH:
Not available because rebates are too worn
*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.
Partial/broken hole
Worn elongated hole
Plug preserved
No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 31/10/17**

TIMBER ID:	Wo37	**LOCATION:**	Citadel, Room A2
WOOD SPECIES:			
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	228	**WIDTH:**	50-60-61	**THICKNESS:**	38-36-35

		TOP	**BOTTOM**	**FRAME**
HOLES			2	
OVERALL NUMBER:	2			
DIAMETER (Average):			11	
PLUGS	**WOOD**			
REBATES			2	
DOWELS			1	
DOWEL DIAMETER			11	
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL			117-107˚	

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN	Bitumen *Chunam(*?)			

COMMENTS:

This small fragment features a bevelled edge with straight ends, and it was probably altered when recycled for use in the citadel. The rebates between the sewing-holes and the plank's edge are very deep (17 mm) and their width narrows towards the holes. Traces of bitumen are visible on the outer surface around the sewing holes and near the broken edge of the plank, suggesting that the exterior of the vessel was coated with bitumen. Additionally, a white substance resembling clay or lime covers the bitumen. This is likely the remains of a traditional antifouling material known as "*chunam*" that is made of burnt lime and animal fat, and is widely used in the western Indian Ocean.

Wo37

AL-BALID TIMBER STITCHING HOLES RECORDING FORM

ID: Wo37

DATE: 9/5/17

RECESS
DEPTH:
WIDTH:
LENGTH:
(from hole centre)

SPACING

DIAMETER

DIAMETER

SPACING

DIAMETER

RECESS
DEPTH:
WIDTH:
LENGTH:

DIAMETER 11 11

SPACING 95

RECESS		
DEPTH:	14	17
WIDTH:	4	4
LENGTH:	26	27

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 13/5/17**

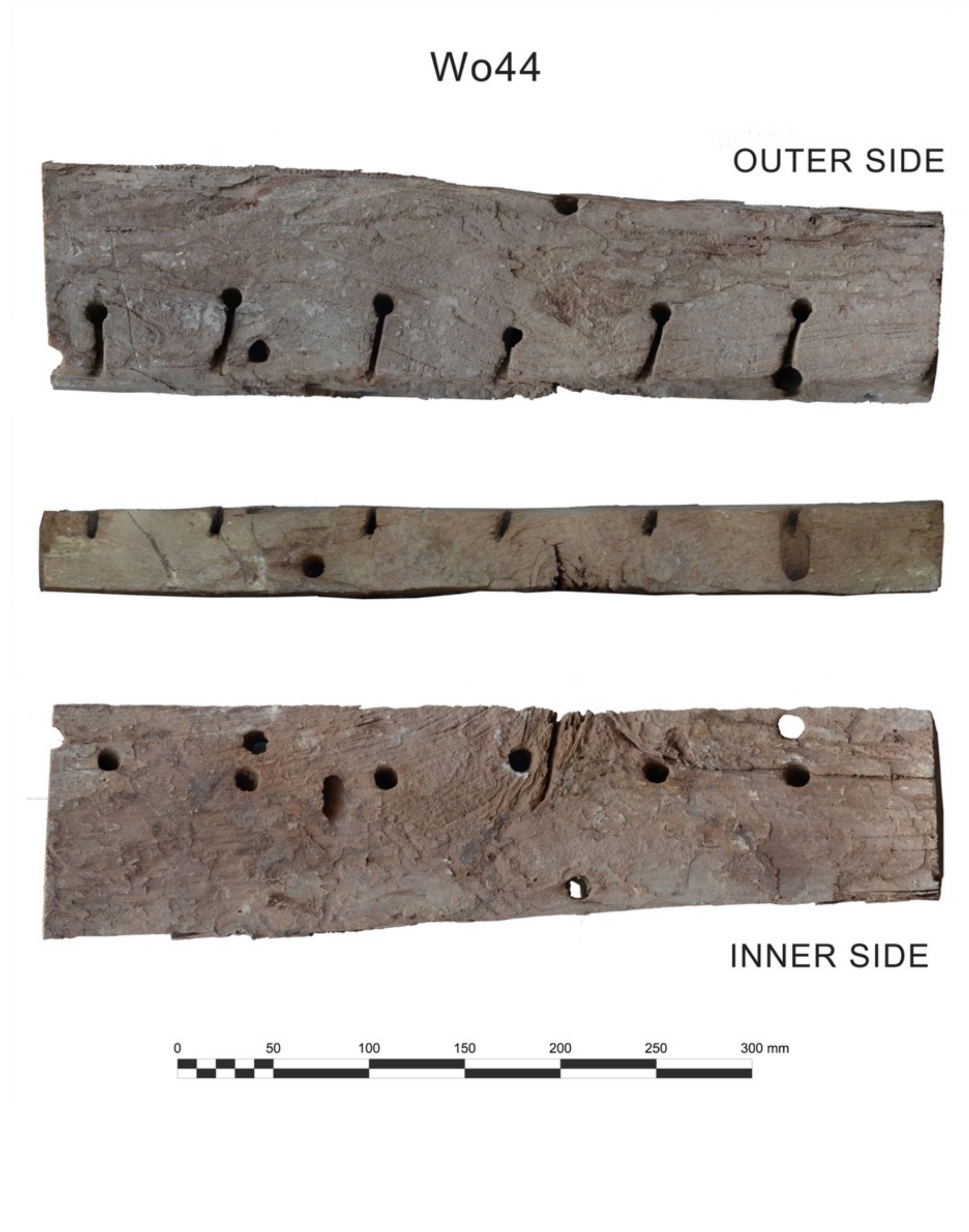
TIMBER ID:	Wo44	**LOCATION:**	Citadel , Room A2
WOOD SPECIES:			
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	470	**WIDTH:**	124-109-100	**THICKNESS:**	42-43-50

			TOP	**BOTTOM**	**FRAME**
HOLES			1	6	
OVERALL NUMBER:		7	11	11	
DIAMETER (Average):					
PLUGS	**WOOD**				
REBATES				6	
DOWELS				1	
DOWEL DIAMETER				12	
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL				104˚	

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This timber is 50 mm thick--one of the thickest of dataset. The diameter and spacing of the sewing-holes are regular. Rebates are deep (13-16 mm) and narrow (3-5 mm), and they are set at an 80˚ angle to the edge of the plank. Three holes on the bottom edge of the timber were likely added when the timber was recycled, or were used for temporary lashings during the assembly of the hull. The lower edge is bevelled 76˚ from the inner surface.


Wo44
OUTER SIDE
INNER SIDE
0
50
100
150
200
250
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM   ID: Wo44   DATE: 13/5/17

RECESS
DEPTH:
WIDTH:
LENGTH:
(from hole centre)

SPACING
DIAMETER

DIAMETER
SPACING
DIAMETER

RECESS
DEPTH:
WIDTH:
LENGTH:

DIAMETER	12		11		10		10		11		11
SPACING		72		80		68		78		73	

RECESS						
DEPTH:	14	16	14	13	15	11
WIDTH:	4	4	3	5	7	3
LENGTH:	31	39	37	23	40	38

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE:** 08/05/17

TIMBER ID:	W054	**LOCATION:**	Citadel, Room A2
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:	Cal AD 1117 - 1222 (Cal BP 833 - 728) (68.4%) Cal AD 1042 - 1104 (Cal BP 908 - 846) (27%)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	738	**WIDTH:**	234–221–190	**THICKNESS:**	58–56–45

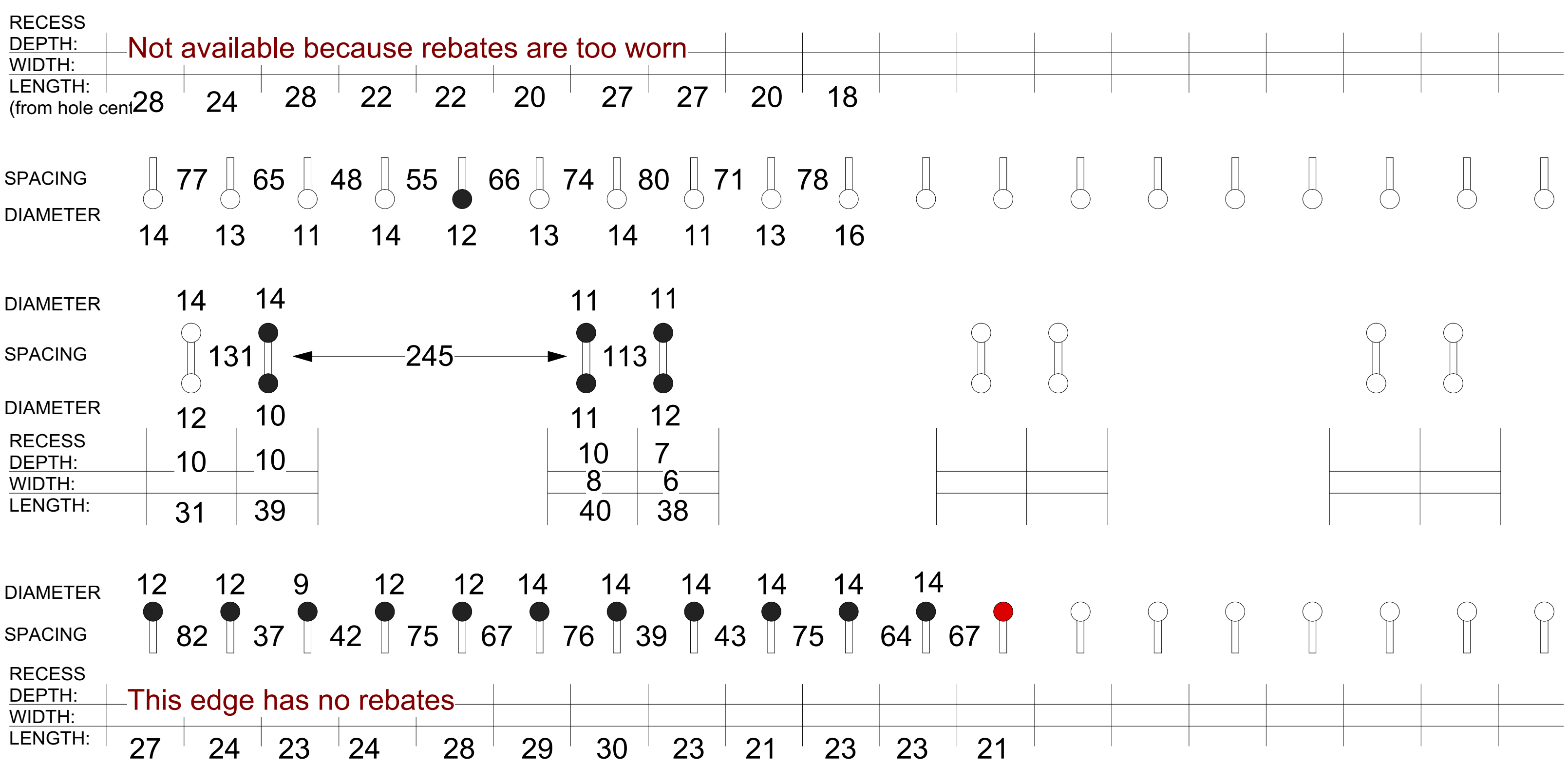
			TOP	**BOTTOM**	**FRAME**
HOLES			10	11	8
OVERALL NUMBER:		29			
DIAMETER (Average):			13	12	12
PLUGS	**WOOD**		1	9	3
REBATES			3		4
DOWELS			3		
DOWEL DIAMETER			11 – 12 -13		
DOWEL SPACING			203 - 248		
SCARFS					
WADDING					
BEVEL				136˚	

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS	Adze			
METAL ELEMENTS				
PIGMENT				
DECORATION				
RESIN/BITUMEN				Bitumen

COMMENTS:
This is a very thick and dark timber with degraded surfaces. The bevelled edge (136˚ from the outer surface) and the lack of rebates on one edge suggest that the timber is probably a garboard. Tool marks show that an adze was used to reduce the thickness of the plank near one end, The frame-lashing holes in the centre of the timber are spaced 245 mm apart, and indicate frame moulded dimensions of 113-131 mm. On the outer surface, there is a deep saw cut from the lower edge to approximately the centre of the plank. Bits of rope are still recessed in the rebates of the frame lashings. The distance between the lashing-holes and the edge is between 18 and 28 mm, but the plank's advanced state of deterioration makes it impossible to determine the depth and width of the rebates.


Wo54
OUTER SIDE
INNER SIDE
0 50 100 200 300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo54 DATE: 8/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 4/5/17**

TIMBER ID:	Wo56–Wo60–Wo73	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	870	**WIDTH:**	216–200–204	**THICKNESS:**	40

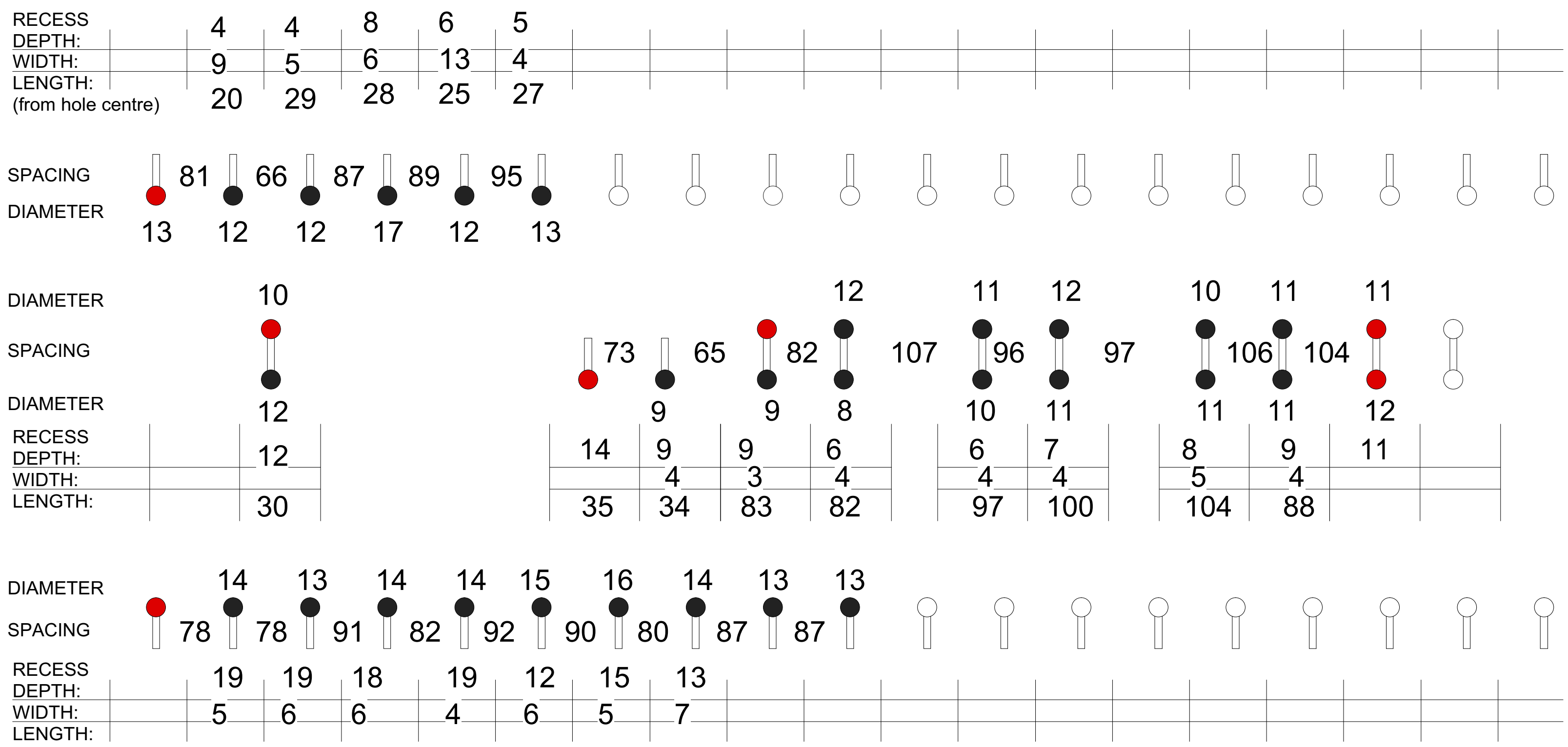
			TOP	**BOTTOM**	**FRAME**
HOLES			6	10	
OVERALL NUMBER:		16			
DIAMETER (Average):			13	14	
PLUGS	**WOOD**		4	6	
REBATES			5	6	
DOWELS			3	2	
DOWEL DIAMETER			13-14	14	
DOWEL SPACING			257-276	240	
SCARFS					
WADDING					
BEVEL				77˚	

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS	Adze, Saw			
METAL ELEMENTS				
PIGMENT		Grey		
DECORATION		Arabic Text		
RESIN/BITUMEN				

COMMENTS:
This large portion of a sewn-boat plank consists of three timbers. Wo56 and Wo60 connect along a large transverse crack in the centre of the plank—the crack apparently having been caused by a large dowel. Timber Wo73 connects to Wo56 and Wo60 along a large crack along the length of the plank. One edge of Wo56/Wo60 is relatively straight and is probably the original faying edge, while the opposite edge features a bevel of 77˚ with the inner side. The crack along the centre of the plank is sewn in a single-wadding pattern--the same technique used for the plank-to-plank fastenings. Wooden plugs and bits of cordage and fibre are still preserved in most of the holes and rebates. A large, damaged portion of the outer surface reveals the underlying wood grain. The plank features adze and saw marks; the latter were probably caused when the timber's thickness was reduced during recycling, or perhaps when removing barnacles. The inner surface of the plank is covered with a dark grey pigment and decorated with Arabic text of a lighter grey colour. A red abstract motif, resembling a flower or a bird, is painted on the outer face of Wo73.


Wo56-Wo60-Wo73
OUTER SIDE
INNER SIDE
Wo73
Wo73
Wo60
Wo60
Wo56
Wo56
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo56-Wo60-Wo73 DATE: 4/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 07/05/17**

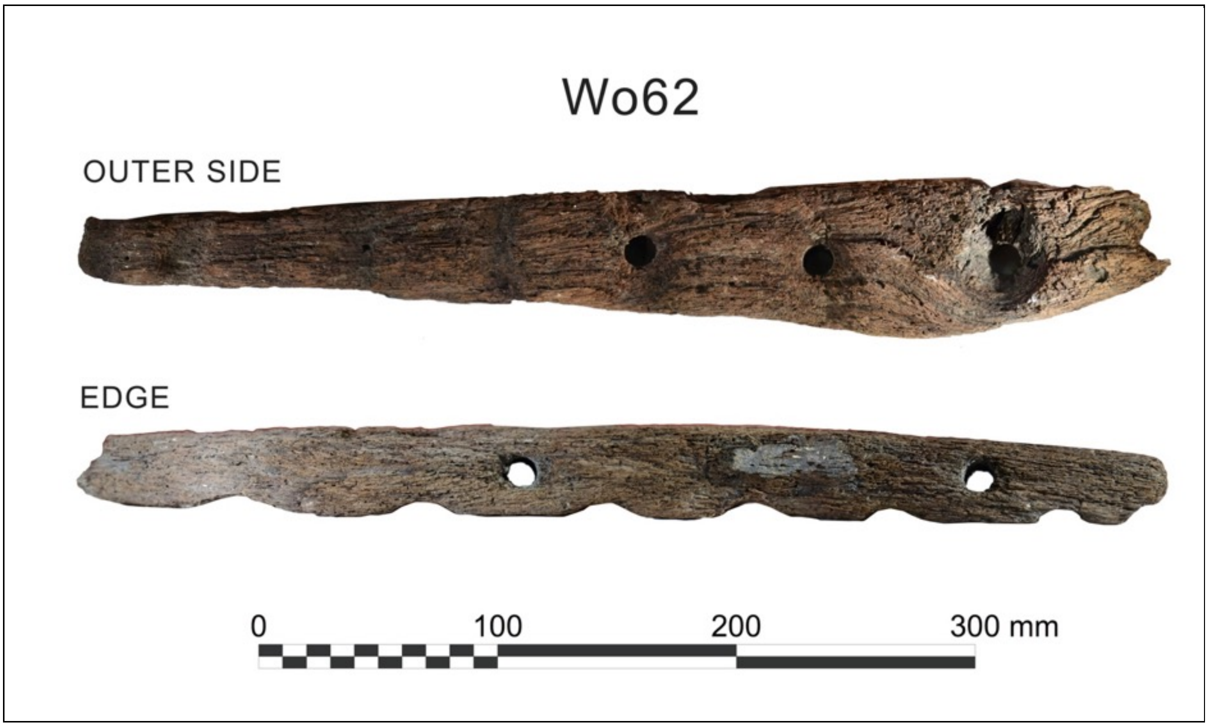
TIMBER ID:	Wo62	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:			
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	455	**WIDTH:**	67-48-31	**THICKNESS:**	38-40-27

		TOP	**BOTTOM**	**FRAME**
HOLES				
OVERALL NUMBER:	3	3		
DIAMETER (Average):		13		
PLUGS	**WOOD**			
REBATES				
DOWELS		2		
DOWEL DIAMETER		16-13		
DOWEL SPACING		190		
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This small fragment features four sewing-holes in the outer surface and two dowel holes along one edge. Only a small portion of the original edge is preserved. Shallow, wide grooves on the outer surface, between the sewing-holes and the edge, indicate the presence of rebates. The wood is spongy and frail, with a very degraded surface.


Wo62
OUTER SIDE
EDGE
0
100
200
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo62 DATE: 7/5/17

RECESS
DEPTH:
WIDTH:
LENGTH:
(from hole centre)

Not available because rebates are too worn, and the original edge is not preserved.

SPACING 76 77

DIAMETER 14 13 13

DIAMETER

SPACING

DIAMETER

RECESS
DEPTH:
WIDTH:
LENGTH:

DIAMETER

SPACING

RECESS
DEPTH:
WIDTH:
LENGTH:

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 7/5/17**

TIMBER ID:	Wo63	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:	*Tamarix sp.* (Tamarisk)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	538	**WIDTH:**	182–186–188	**THICKNESS:**	44–51–52

			TOP	**BOTTOM**	**FRAME**
HOLES			4	6	6
OVERALL NUMBER:		16			
DIAMETER (Average):		13	13	13	15
PLUGS	**WOOD**		3	3	
REBATES					1
DOWELS				1	
DOWEL DIAMETER				13	
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

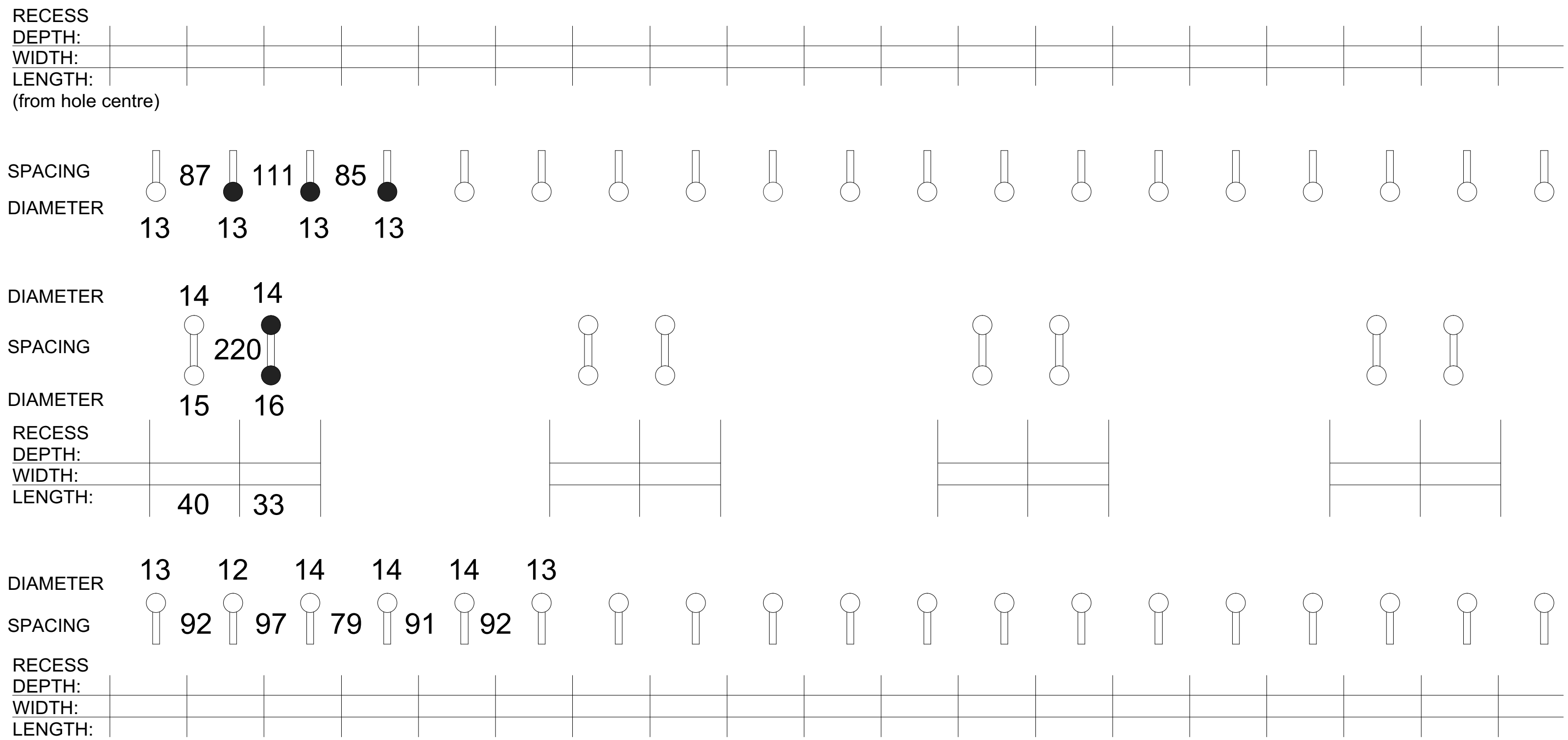
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:

This is an extremely degraded and frail timber, with fibrous, spongy wood. A fragment of shell, probably from a barnacle, is imbedded in the outer surface. Two pairs of holes in the centre of the plank suggest frame-lashings, but their wide spacing (220 mm) indicates a frame with a very large moulded dimension. Thus, it could be that the lashing was related to another element such as a thwart (as seen in the Omani *kambārī*). Because of the timber’s poor state of preservation, and the fact that the plank was cut along the sewing-holes, the rebates are barely visible.

Wo63

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo63 DATE: 7/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 7/5/17**

TIMBER ID:	Wo64	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:			
DATE:			

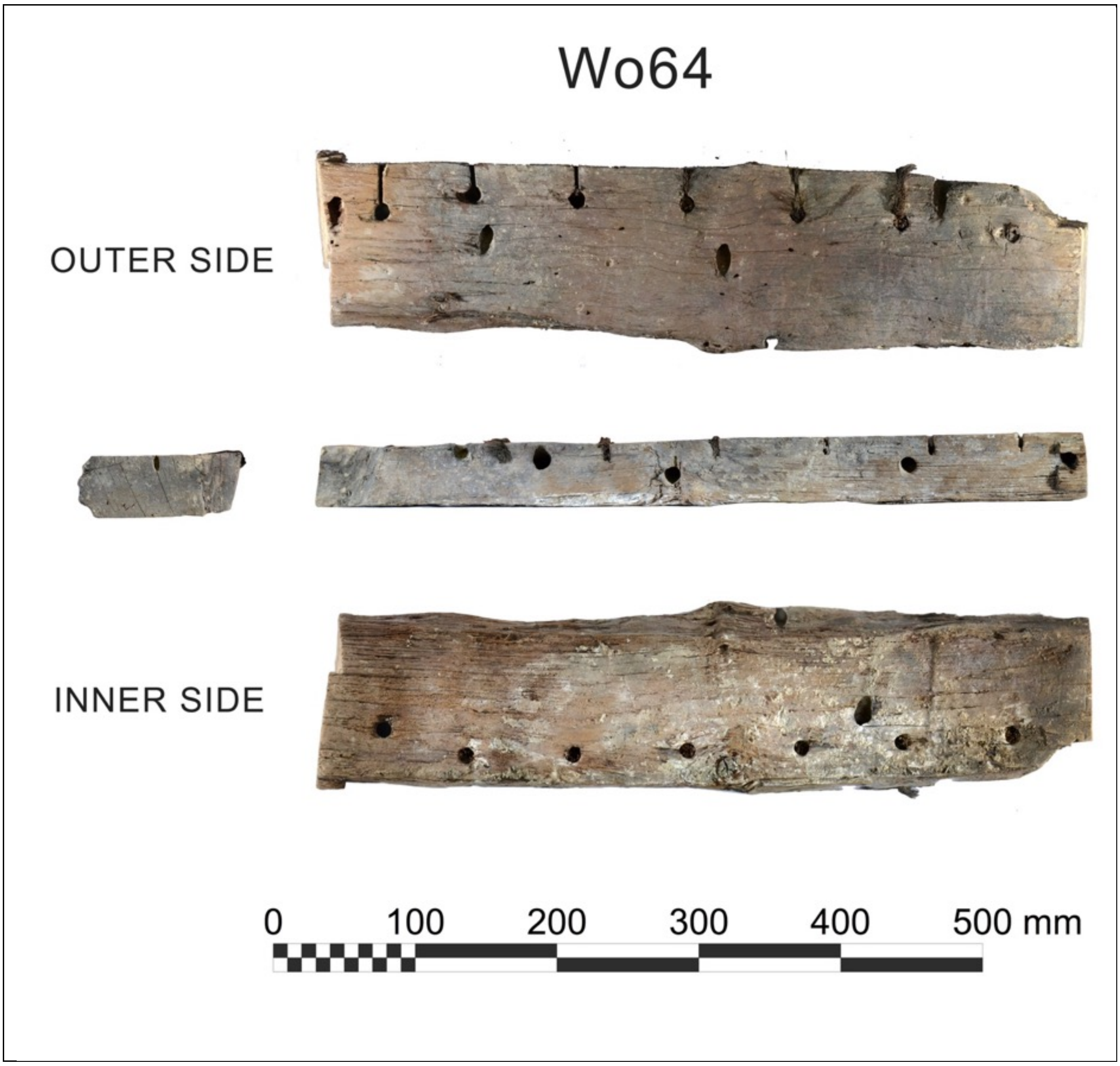
OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	535	**WIDTH:**	115–132–86	**THICKNESS:**	49–47–47

		TOP	**BOTTOM**	**FRAME**
HOLES		7	1	
OVERALL NUMBER:	8			
DIAMETER (Average):		10		
PLUGS	**WOOD**	6		
REBATES		6		
DOWELS / Channels		5		
DOWEL DIAMETER		11-10-11-10		
DOWEL SPACING		110-165-94-56		
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS			Saw	
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:

This thick plank features regularly spaced stitching-holes, all of which have rebates, except one at top right corner of the plank. The rebates are deep (10 mm) and narrow (3 mm). The edge with the sewing-holes is partially preserved and shows a small diagonal scarf on the corner. Five dowel channels are visible on the edge of the timber, four of which were driven obliquely from the outer surface. The fifth could have been added later to repair the plank.


Wo64
OUTER SIDE
INNER SIDE
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo64 DATE: 7/5/17

RECESS DEPTH:	11	10	5	7	11	11	
WIDTH:	3	3	3	4	3	4	
LENGTH: (from hole cen	29	21	22	24	32	33	33

SPACING		63	72	77	75	71	78
DIAMETER	11	10	11	10	10	10	10

DIAMETER

SPACING

DIAMETER

RECESS DEPTH:
WIDTH:
LENGTH:

DIAMETER

SPACING

RECESS DEPTH:
WIDTH:
LENGTH:

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE:**

TIMBER ID:	Wo65	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:			
DATE:			

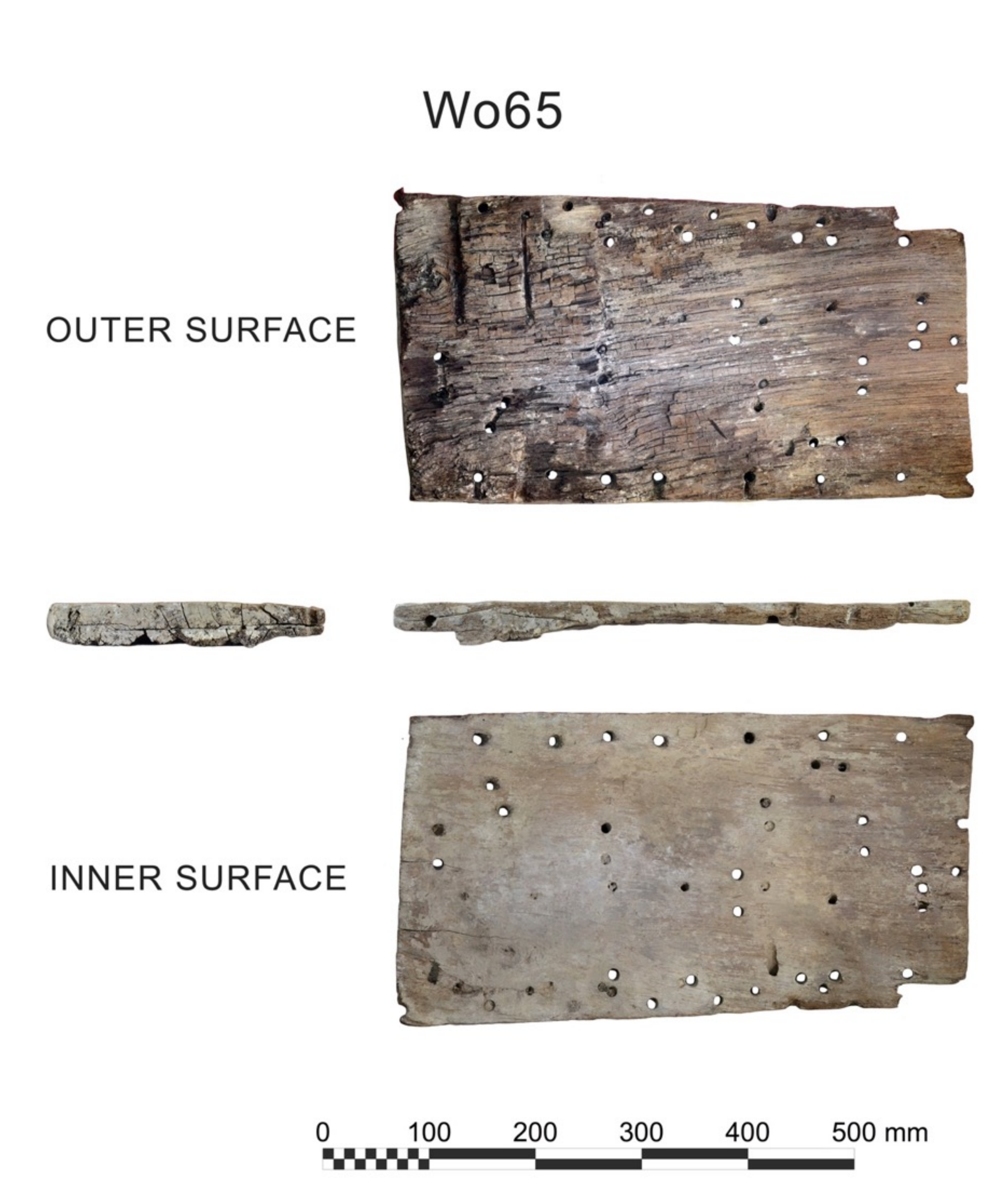
OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	530	**WIDTH:**	285	**THICKNESS:**	26-42-45

		TOP	**BOTTOM**	**FRAME**
HOLES		8	7	16(?)
OVERALL NUMBER:	53			
DIAMETER (Average):		10	10	10
PLUGS	**WOOD**	12		
REBATES		4		
DOWELS		2	2	
DOWEL DIAMETER		10-11	10-11	
DOWEL SPACING		256	318	
SCARFS				
WADDING				
BEVEL				

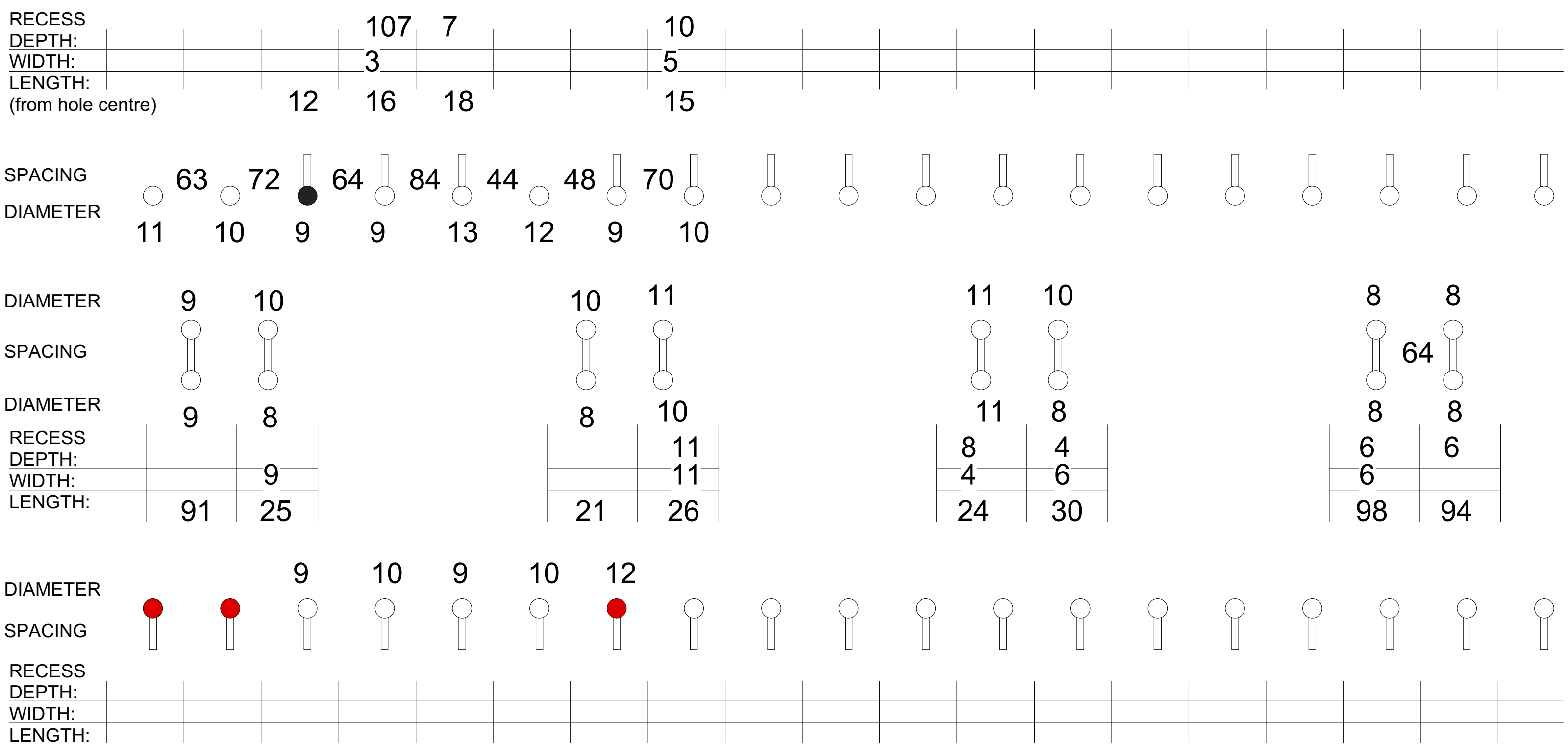
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:

This timber's straight edges were probably cut when the piece was recycled for secondary use. The top edge has regularly spaced stitching-holes and associated rebates, but the hole arrangement in the bottom edge is confusing and features no rebates. The outer surface is damaged, making it difficult to measure the depths of the rebates. The seemingly random hole pattern in the centre of the plank is also confusing. It appears that there are two rows of matching holes resembling those of frame lashings: one near the top edge with short stitches; and one with long, recessed, regularly-spaced stitches. The presence of so many holes might indicate that the plank was repaired multiple times.


Wo65
OUTER SURFACE
INNER SURFACE
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo65 DATE: 7/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE:** 03/05/17

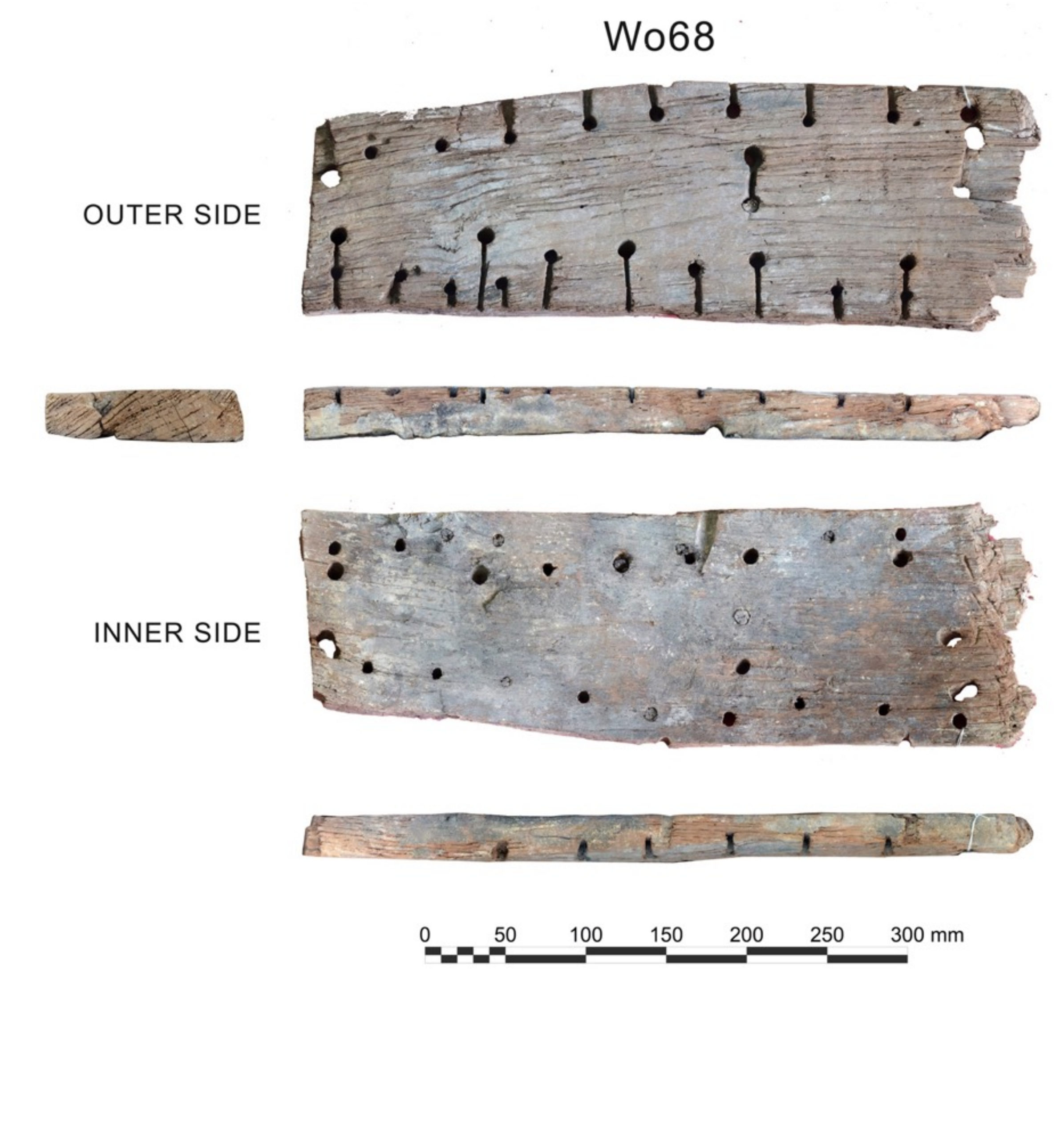
TIMBER ID:	Wo68	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:	*Acacia* sp. (Acacia)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	565	**WIDTH:**	153 - 125	**THICKNESS:**	27 - 30

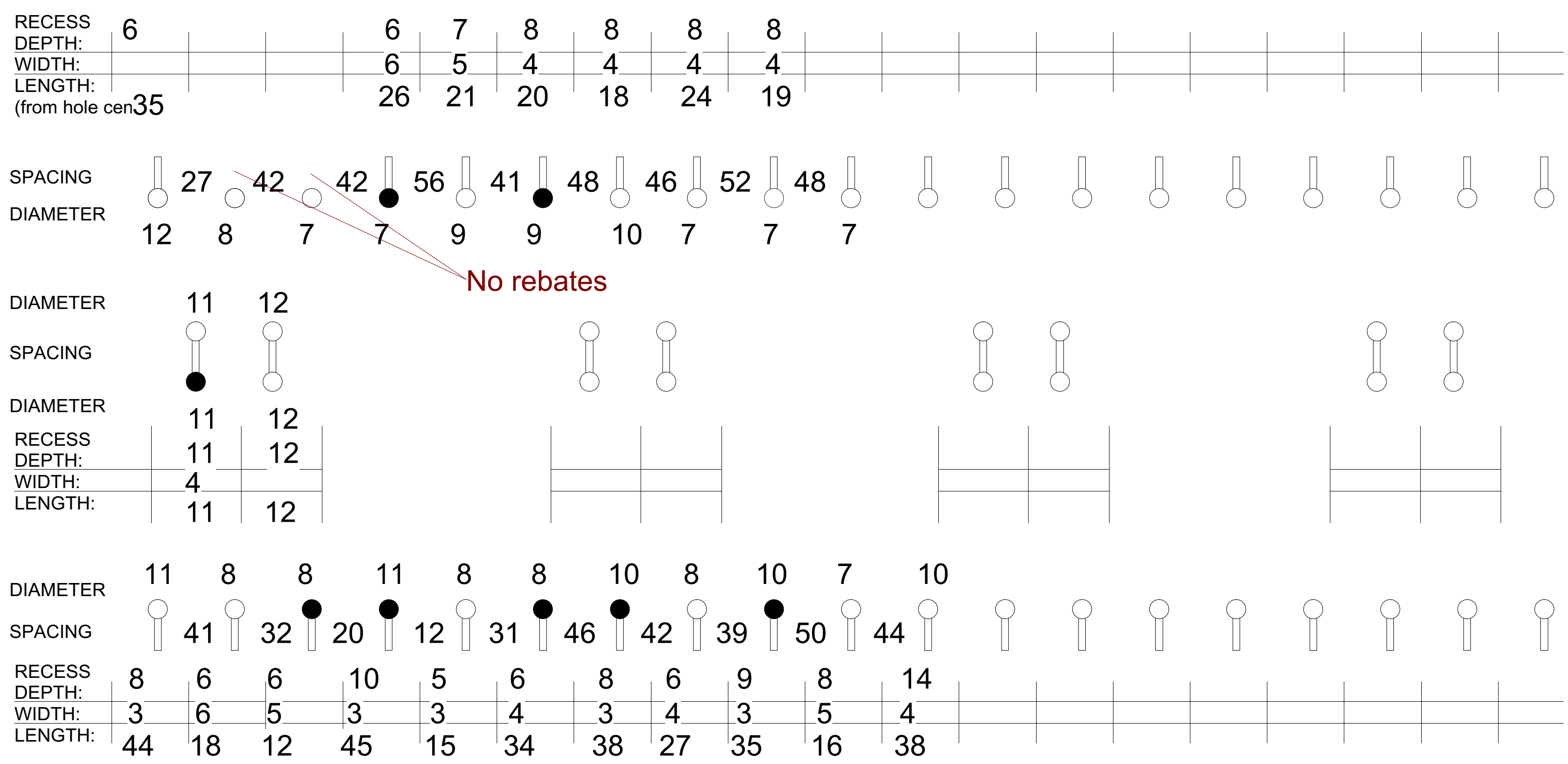
	TOP	**BOTTOM**	**FRAME**
HOLES	10	11	4
OVERALL NUMBER: 25			
DIAMETER (Average):	8	9	11
PLUGS: **Wood**			
REBATES	6	11	
DOWELS	1		
DOWEL DIAMETER:	11		
DOWEL SPACING			
SCARFS			
WADDING			
BEVEL			

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS		Chisel, Adze		
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This thin plank retains both original edges, and features fairly regularly spaced stitching-holes. The hole-spacing at the top edge is more consistent, while the bottom seems to have two distinct rows of holes of different sizes. The stitching-hole arrangement on the bottom edge might indicate a repair or an attempt to reinforce the fastening between the planks. Two pairs of holes along the centre of the plank indicate the lashing of a frame with a side dimension of 115 mm. The inner surface of the plank is covered with a grey thin substance, which is perhaps a coating of fish oil.


Wo68
OUTER SIDE
INNER SIDE
0 50 100 150 200 250 300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo68 DATE: 3/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 4/5/17**

TIMBER ID:	Wo69	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:			
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	288	**WIDTH:**	60	**THICKNESS:**	45

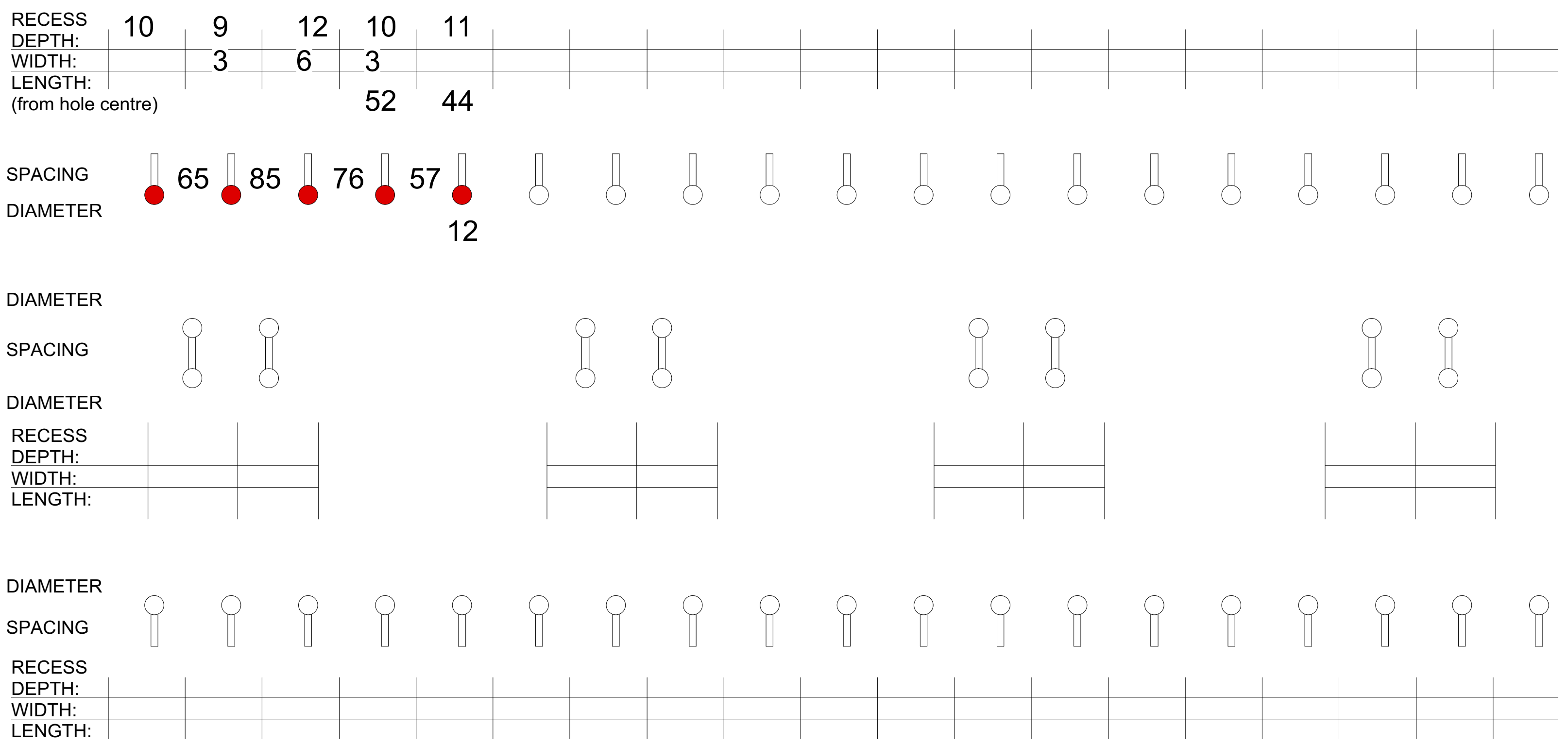
		TOP	**BOTTOM**	**FRAME**
HOLES				
OVERALL NUMBER:	2	2 (partial)		
DIAMETER (Average):		13		
PLUGS	**WOOD**			
REBATES		3		
DOWELS		1		
DOWEL DIAMETER		11		
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
This is a very thick fragment with deep, narrow, and long rebates. Only two holes are partially preserved, each with an estimated diameter of 13 mm. The spacing between the holes has been determined by measuring the distance between the centres of the rebates. However, since these are slightly angled, the sewing-hole spacing might be different. Traces of a white substance on the inner surface could be interpreted as a burnt-lime luting compound, or as plaster applied to the timber when it was recycled for use in the citadel of al-Balid.


Wo69
OUTER SIDE
INNER SIDE
0
50
100
150
200 mm
x

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo69 DATE: 4/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 4/5/17**

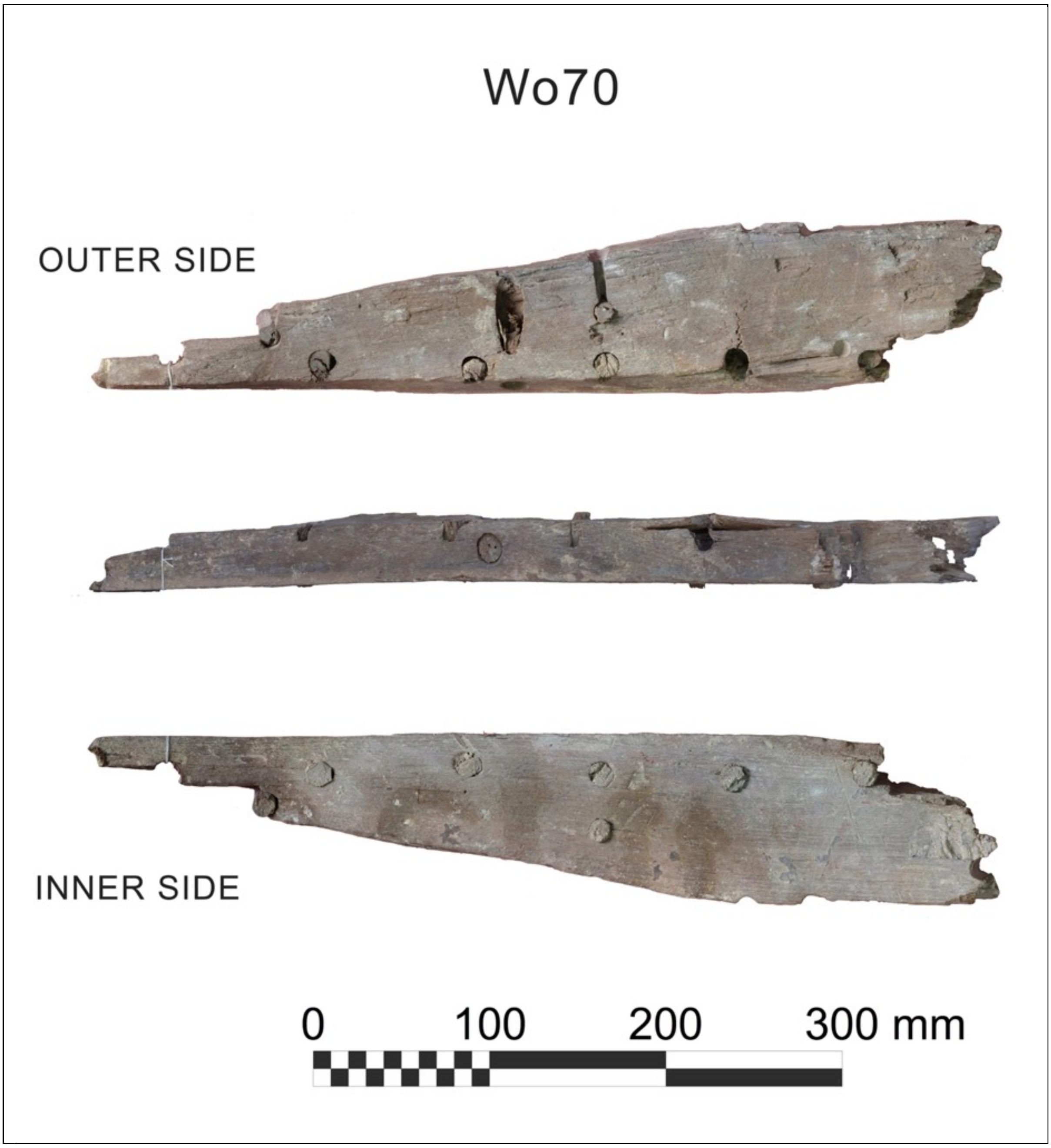
TIMBER ID:	Wo70	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:	*Tectona grandis* (teak): hole plug		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	520	**WIDTH:**	97	**THICKNESS:**	37-40

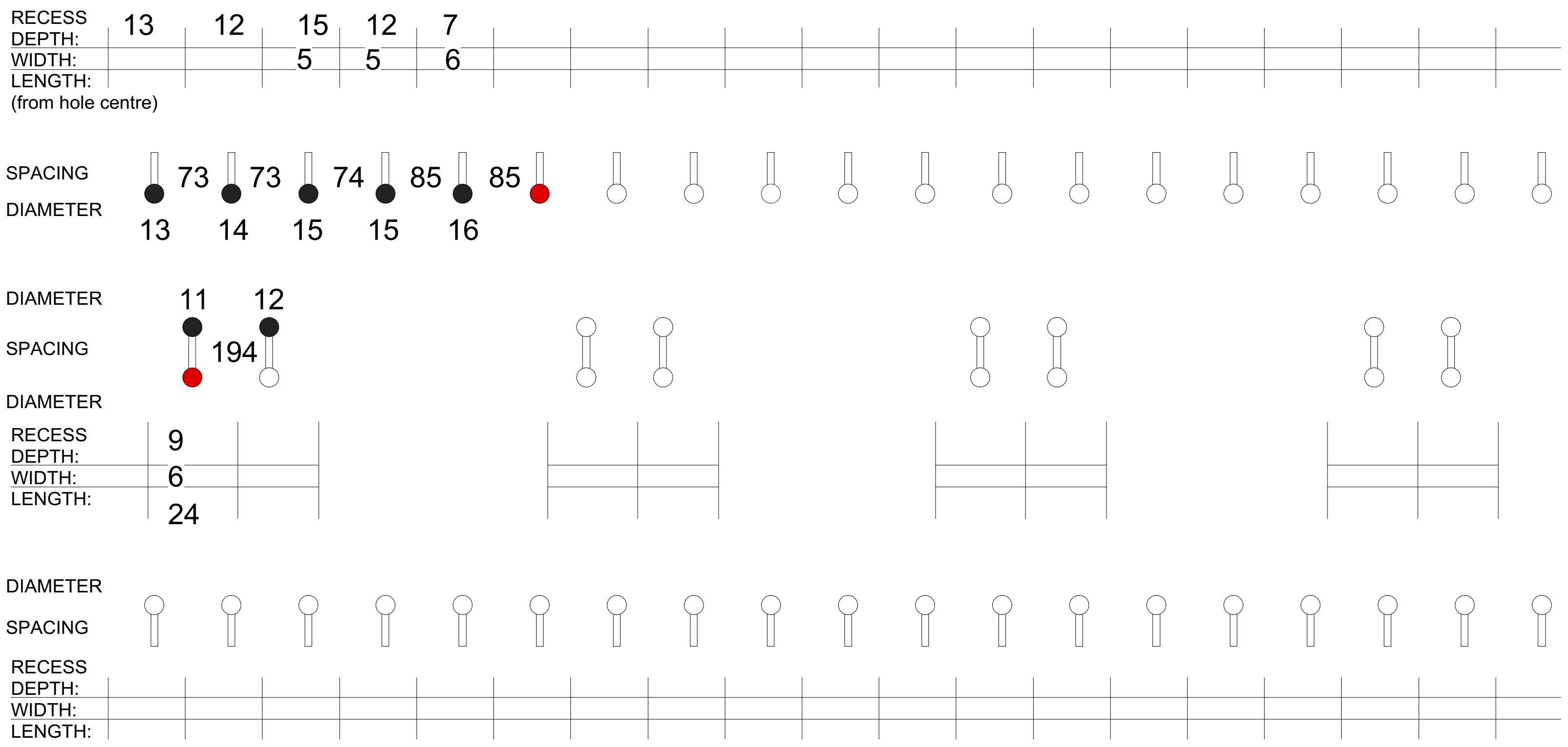
			TOP	**BOTTOM**	**FRAME**
HOLES			6		3
OVERALL NUMBER:		8	15		
DIAMETER (Average):			13-15		12
PLUGS	**WOOD**		5		1
REBATES			6		1
DOWELS			1		
DOWEL DIAMETER			15		
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS	Adze			
METAL ELEMENTS	Nail near top edge			
DECORATION		Arabic Text?		
RESIN/BITUMEN				

COMMENTS:
This thick, sewn-plank fragment features a top surface that was cut at an angle of 108˚ near the stitching-hole line. The holes are regularly spaced and their diameter is relatively large. The rebates are barely visible with a depth of 12-15 mm and a width of 5 mm.
Three holes indicate a frame-lashing. Two of these holes are connected with a rebate.
Plugs preserved inside the holes appear to be made of a fibrous wood resembling bamboo.
The oblique dowel is large and appears to be made of the same wood used for the plugs.
Traces of decoration, probably Arabic text, are visible on the inner side of the timber, and the calligraphy appears to be similar to that shown in planks Wo56, Wo60 and Wo73, with which timber Wo70 shares thickness, hole spacing, and diameter. Marks of what looks like an adze are visible on both surfaces of the timber.


Wo70
OUTER SIDE
INNER SIDE
0
100
200
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo70 DATE: 4/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 6/5/17**

TIMBER ID:	Wo71-Wo72	**LOCATION:**	Citadel, Rooms A1-A2
WOOD SPECIES:	*Albizia lebbeck* (Lebbeck tree)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	2508	**WIDTH:**	126-130-113	**THICKNESS:**	41-46-36

		TOP	**BOTTOM**	**FRAME**
HOLES		30		8 (?)
OVERALL NUMBER:	38			
DIAMETER (Average):		13		12
PLUGS	**WOOD**	11		
REBATES		24		
DOWELS		10		
DOWEL DIAMETER		14		
DOWEL SPACING		249–242–237–244-241-251-241-241-228		
SCARFS				
WADDING				
BEVEL			64˚	

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS	Saw/adze?	Saw/adze?	Saw	
METAL ELEMENTS		Nail		
DECORATION			Red abstract motives	
RESIN/BITUMEN				

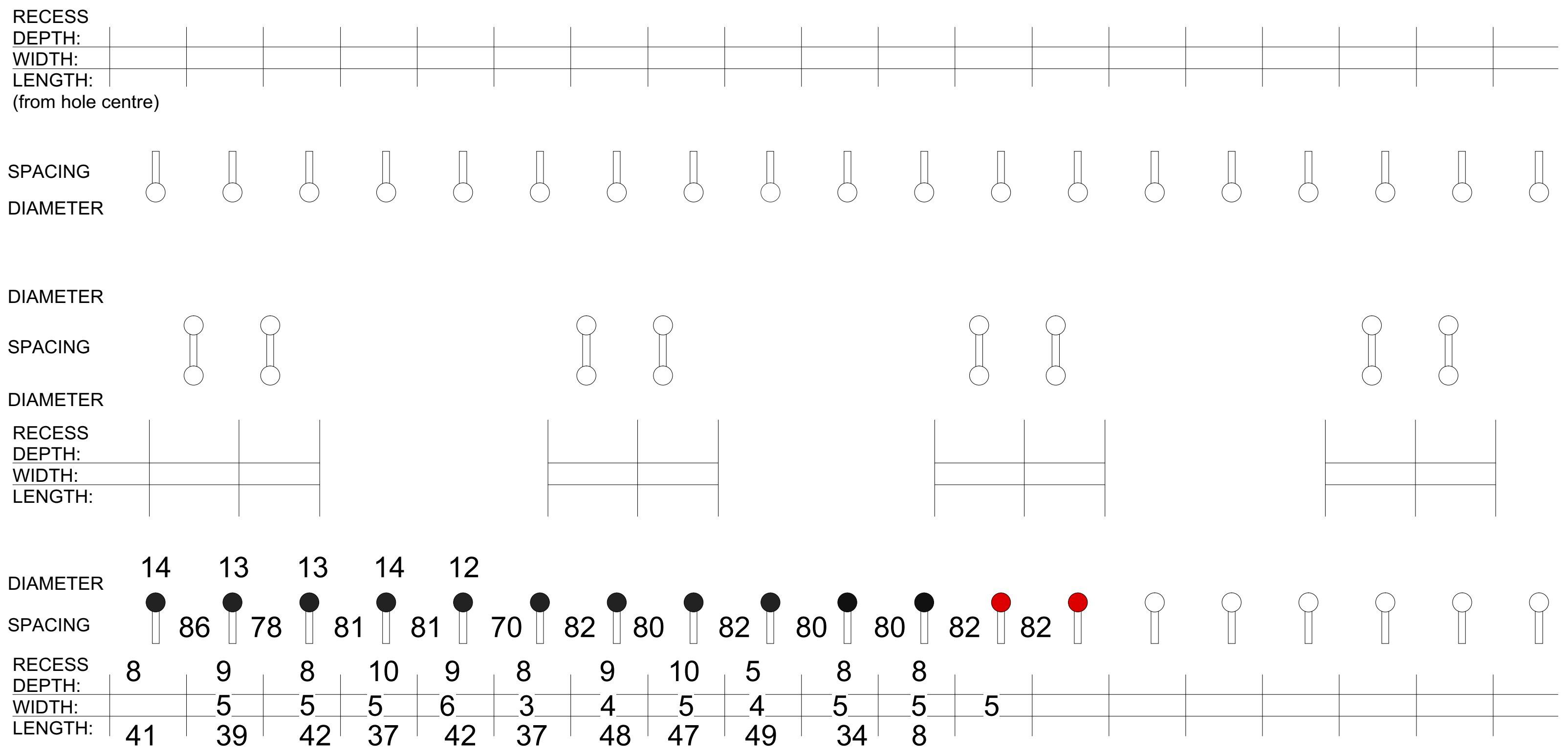
COMMENTS:
Timbers Wo71 and Wo72 connect to form a long and well-preserved thick plank. The edge opposite the sewing-holes has a 64˚ bevel (from the inner face) and is painted with abstract motifs, in a way similar to the ceiling frames in some of the rooms of Jabrin Fort, Oman. Sewing-holes are regularly spaced and evenly distant from the plank edge. One partial hole on the bottom edge associated with a rebate might indicate a frame-lashing. Four holes in the inner face of the timber show traces of corrosion (orange colour around the hole perimeter) suggesting the presence iron fastenings, most probably used by the builders of the citadel when they recycled the plank. The rebates are deep and narrow, and appear to extend beyond the sewing-holes towards the centre of the plank, where they gradually disappear, probably due to a later reduction of the plank thickness. This evidence is similar to that displayed on timbers BA0604172.69 and BA0604159.263. The surfaces of the plank appear to have both parallel saw-lines and the hewing cuts of an adze. Saw marks are also visible on the edge of the plank.

Wo71

Wo72


Wo 71
1000 mm
500
0
Wo 72

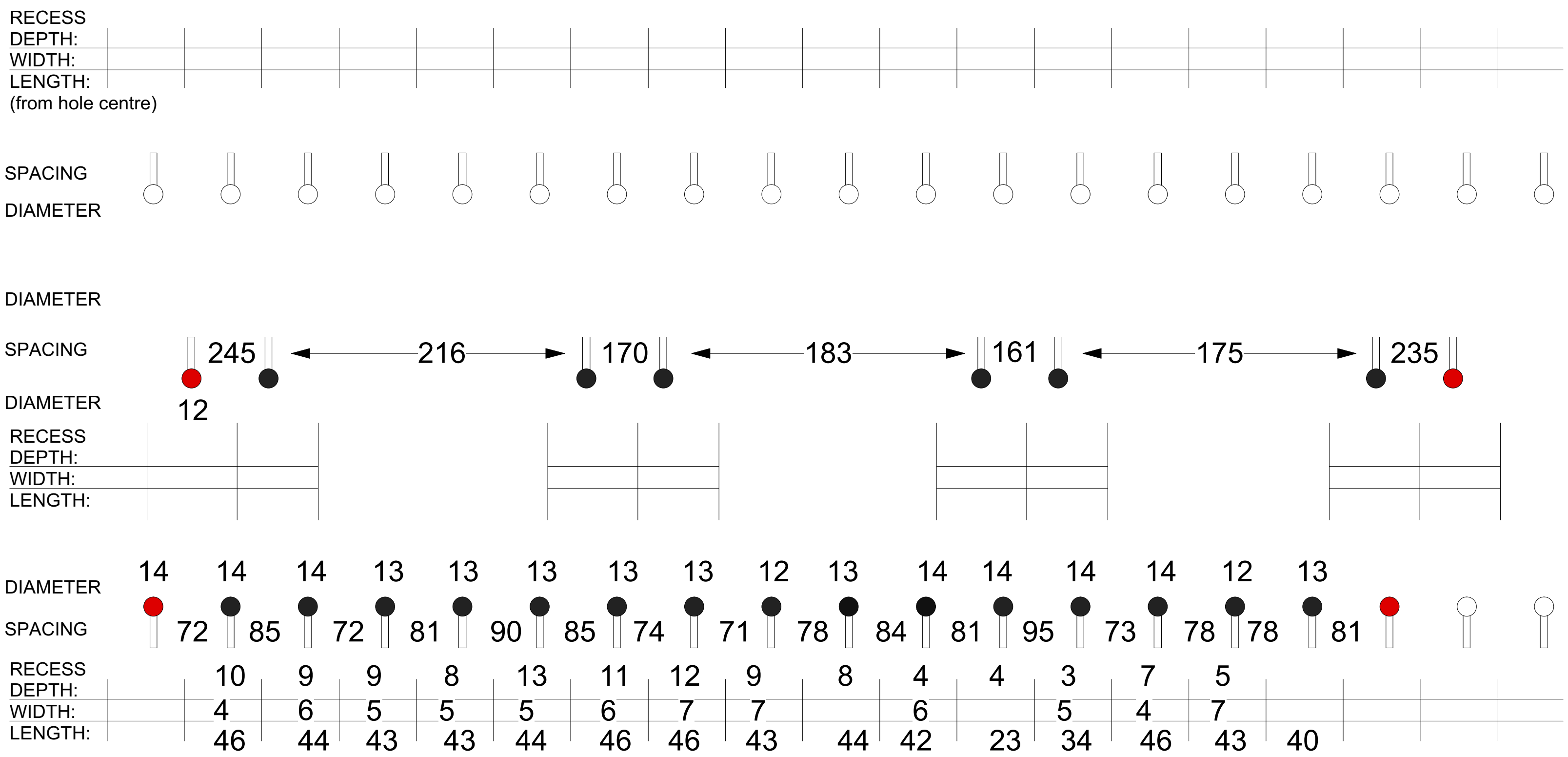
AL-BALID TIMBER STITCHING HOLES RECORDING FORM   ID: Wo71   DATE: 6/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo72 DATE: 6/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 08/05/17**

TIMBER ID:	Wo82	**LOCATION:**	Citadel, Room A1
WOOD SPECIES:	*Celtis africana* (Hackberry)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	480	**WIDTH:**	143-163-113	**THICKNESS:**	23-22-22

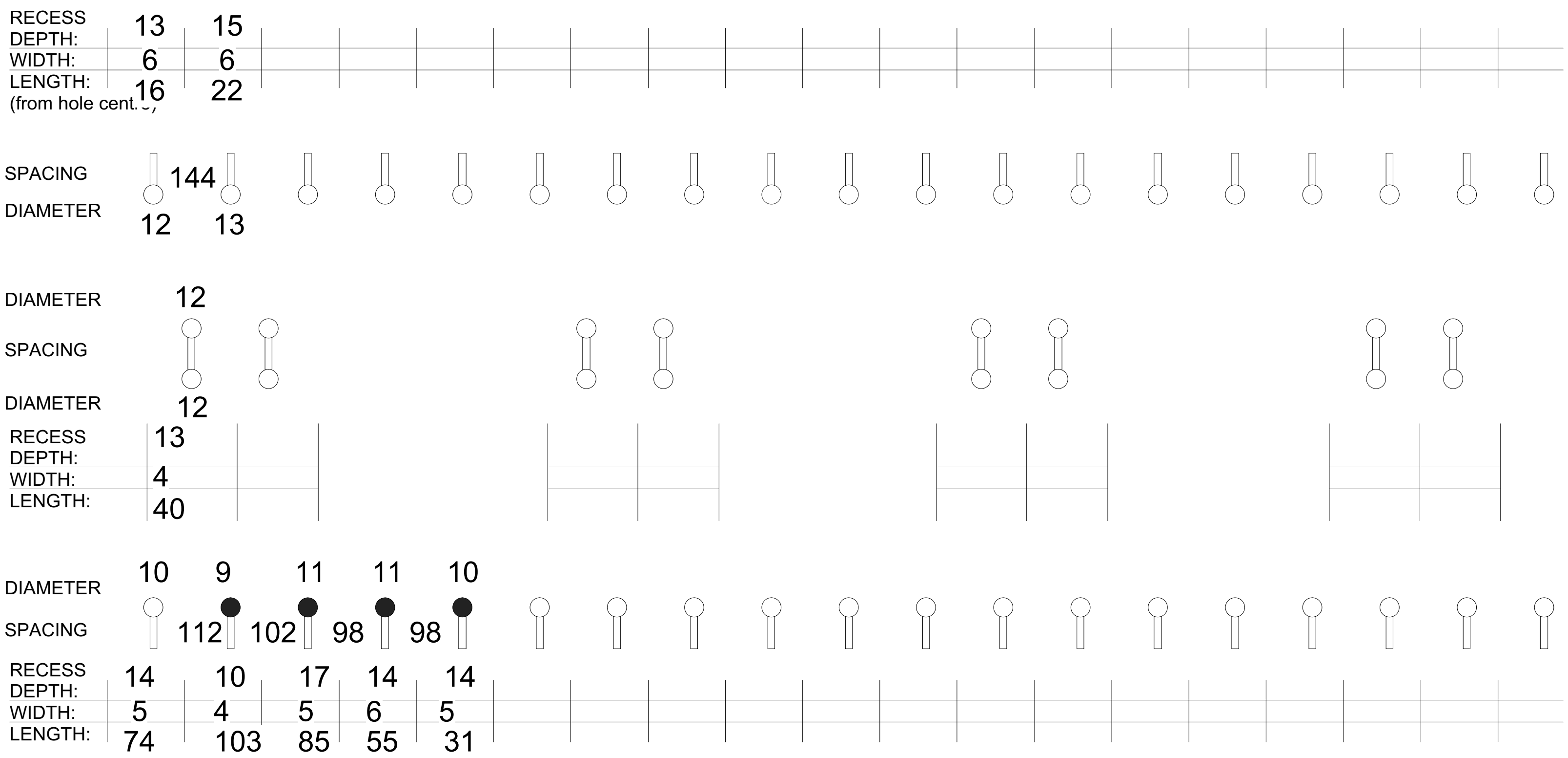
		TOP	**BOTTOM**	**FRAME**
HOLES		2	5	2
OVERALL NUMBER:	9			
DIAMETER (Average):		13	10	12
PLUGS	**WOOD**		4	
REBATES		2	5	1
DOWELS		1		
DOWEL DIAMETER		15		
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS		Saw		
METAL ELEMENTS		5 nails		
DECORATION				
RESIN/BITUMEN				

COMMENTS:
The outer surface of this thin plank features an abundance of holes bored by shipworms. The rebates are narrow, deep and unusually long (exceeding 100 mm), and the stitching-holes are regularly spaced. The original edges are not preserved, except perhaps for a small section at the top edge. The straight edges at each end of the plank indicate that the its length was reduced when it was recycled for use in the citadel of al-Balid.


Wo82
OUTER SIDE
INNER SIDE
0
50
100
150
200
250
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo82 DATE: 8/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 08/05/17**

TIMBER ID:	Wo83	**LOCATION:**	Citadel, Room A1
WOOD SPECIES:			
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	417	**WIDTH:**	139-134-116	**THICKNESS:**	25-22-24

			TOP	**BOTTOM**	**FRAME**
HOLES			4		4
OVERALL NUMBER:		8			
DIAMETER (Average):			11		12
PLUGS	**WOOD**		1		
RECESSES			4		
DOWELS				**1**	
DOWEL DIAMETER			13	13	
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL					

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS		saw		
METAL ELEMENTS		3 nails		
DECORATION				
RESIN/BITUMEN				

COMMENTS:
The outer surface of this thin plank is severely deteriorated, but the stitching-holes are regularly spaced and are of consistent diameter. The inner side shows traces of a grey pigment, and features a series of incised straight and diagonal lines that were probably made when the plank was recycled for use in the citadel of al-Balid. Saw marks are also visible on the inner surface.

Wo83

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo83 DATE: 8/5/17

RECESS DEPTH:	18	11	12	
WIDTH:	6	7	6	6
LENGTH: (from hole centre)	52	30	26	28

SPACING: 98, 100, 96

DIAMETER: 11, 11, 11, 11

DIAMETER: 14, 11

SPACING: 373

DIAMETER: 12, 10

RECESS DEPTH:		12
WIDTH:		
LENGTH:	21	37

DIAMETER: 13

SPACING

RECESS DEPTH:

WIDTH:

LENGTH:

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 13/5/17**

TIMBER ID:	Wo84	**LOCATION:**	Citadel, Surface
WOOD SPECIES:			
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	525	**WIDTH:**	140-148-189	**THICKNESS:**	29-35-36

		TOP	**BOTTOM**	**FRAME**
HOLES			5	2
OVERALL NUMBER:	7			
DIAMETER (Average):	12		13	12
PLUGS	**WOOD**			
REBATES			2	1
DOWELS				
DOWEL DIAMETER				
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:

The deteriorated surface of this heavy fragment exposes the wood grain. The bottom edge of the plank is preserved and the holes are placed 36-40 mm from the edge. The sewing-holes have the widest spacing (92-113 mm) recorded in the al-Balid dataset. The poor preservation of the plank's surface makes it difficult to determine the width and depth of the rebates. In the centre of the plank, on the right side, a pair of holes 34 mm apart indicate a frame-lashing. No dowels or any other elements are visible on the timber's surface.

Wo84

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo84 DATE: 13/5/17

RECESS
DEPTH:
WIDTH:
LENGTH:
(from hole centre)

SPACING

DIAMETER

DIAMETER 12

SPACING

DIAMETER 12

RECESS
DEPTH:
WIDTH:
LENGTH: 34

DIAMETER	14	15	11	12	11
SPACING	92	111	106	113	
RECESS DEPTH:					
WIDTH:					
LENGTH:	29	40	39	38	36

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 11/5/17**

TIMBER ID:	Wo85	**LOCATION:**	Citadel, MI22-MI23
WOOD SPECIES:	*Tamarix* sp. (Tamarisk)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	783	**WIDTH:**	134-138-72	**THICKNESS:**	52-45-33

		TOP	**BOTTOM**	**FRAME**
HOLES		3	13	9
OVERALL NUMBER:				
DIAMETER (Average):	12	12	11	11
PLUGS	**WOOD**	2		2
REBATES		2	11	4
DOWELS			4	
DOWEL DIAMETER			11-11-13-11	
DOWEL SPACING			125-168-174	
SCARFS				
WADDING				
BEVEL				

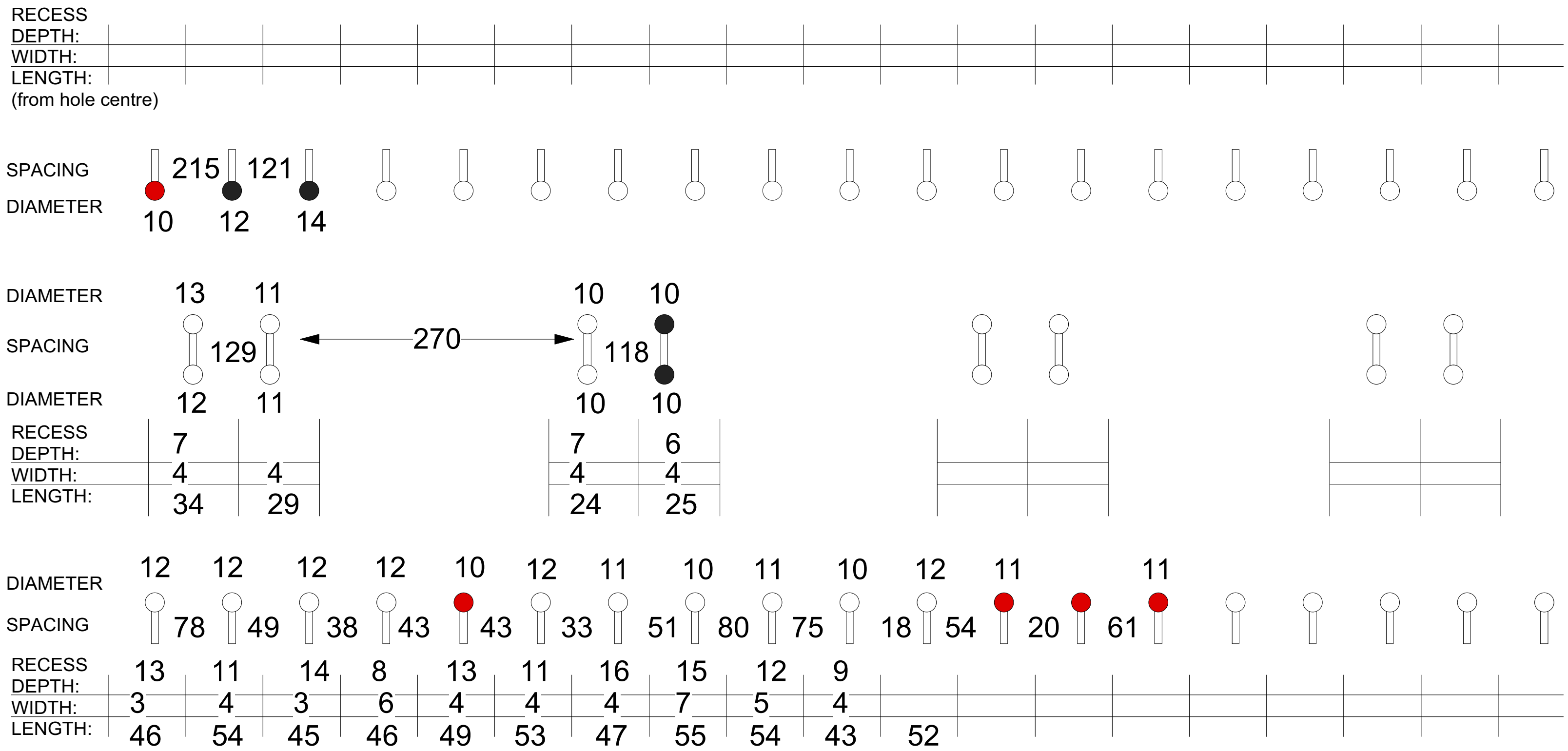
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:

The wood grain is exposed on this thick and very deteriorated timber. A section of the original edge is visible in the lower faying edge. The timber appears to have two different sewing-hole patterns. One consists of a series of large holes (12 mm), regularly spaced (75-88 mm), and somewhat far from the edge of the plank. The second series of sewing-holes are more closely spaced and are closer to the plank's edge, and might be evidence of a repair. The rebates between the sewing-holes and the plank's edge are deep (9-16 mm) and narrow (3-7 mm). Pairs of holes in the centre of the plank, each connected by a rebate, indicate the lashings of two large frames, spaced 270 mm apart and with moulded dimensions of 108 and 119 mm.

Wo85

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo84 DATE: 13/5/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 30/10/17**

TIMBER ID:	Wo86	**LOCATION:**	Citadel, M60, North east corner
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	1443	**WIDTH:**	120-82-121	**THICKNESS:**	35-37-36

		TOP	**BOTTOM**	**FRAME**
HOLES		8	31 (4 on diagonal edge)	
OVERALL NUMBER:	39			
DIAMETER (Average):		10	10	
PLUGS	**WOOD**	4	18	
REBATES			26	
DOWELS			4	
DOWEL DIAMETER			10-12-12-9	
DOWEL SPACING			326-837-281	
SCARFS				
WADDING				
BEVEL			84-80-81˚	

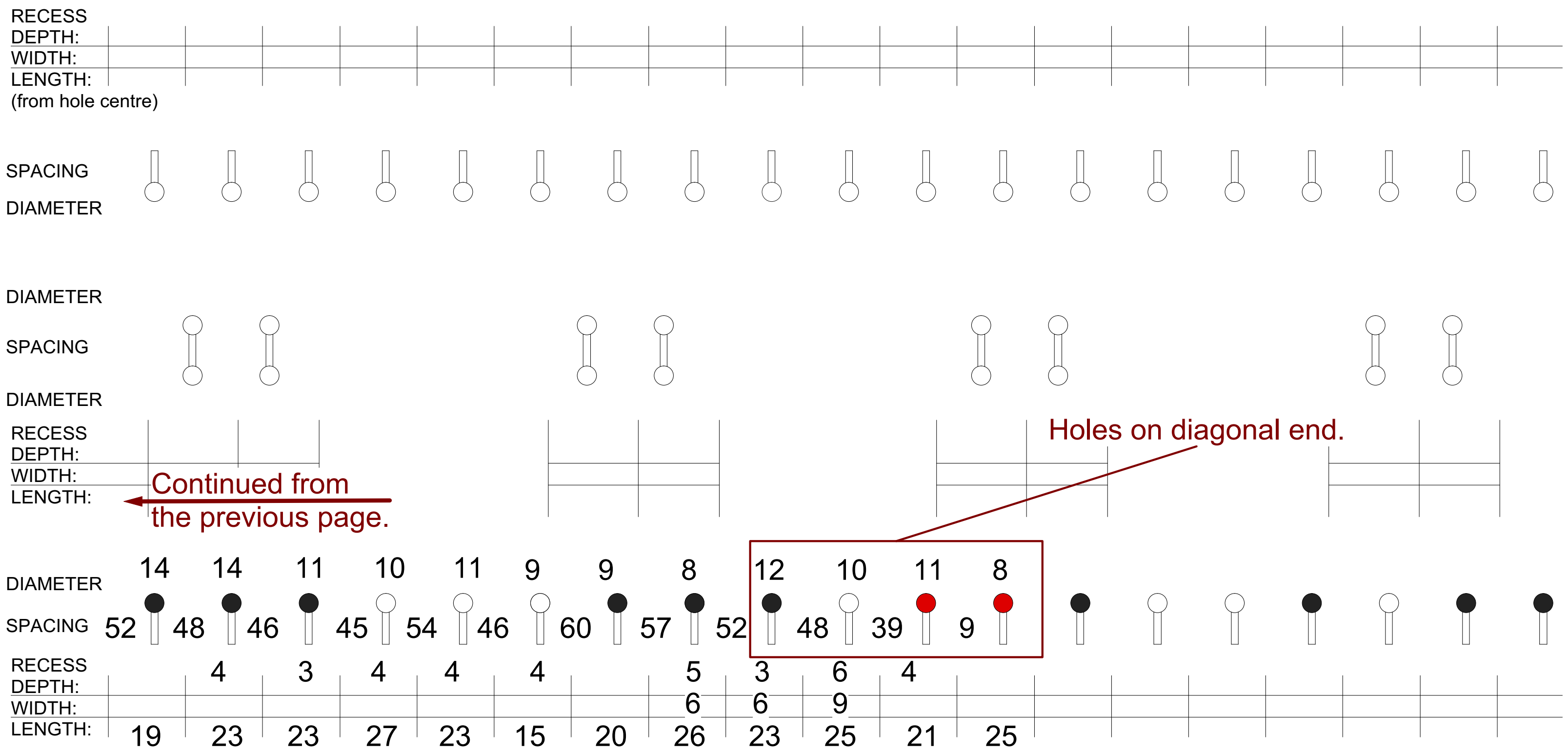
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN		Bitumen		Bitumen

COMMENTS:

This thick, heavy timber features regularly spaced stitching-holes and retains an original edge bevelled to between 80° and 84˚. The piece broke along the wood grain, and the upper edge is not preserved. A few holes are visible near the broken edge, but it is difficult to determine whether they were for stitching or were part of a frame-lashing. The diameter of the sewing-holes is fairly consistent and the holes were drilled at an angle matching the edge's bevel. The timber features a diagonal end, but it is difficult to determine whether it is a scarf joining two planks of the same strake, or a hood end connecting the plank to either the stern or stem post. The end of the plank was fastened with cordage in the single-wadding technique and with two dowels. Traces of bitumen are visible on the inner side of the plank, between the sewing holes and the edge, indicating the presence of luting under the wadding and between the plank's seam. Impressions on the bitumen reveal the materials used for the wadding, such as reeds, thin strips of palm leaves, and grass.

Wo86

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo86 (B) DATE: 30/10/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 31/10/17**

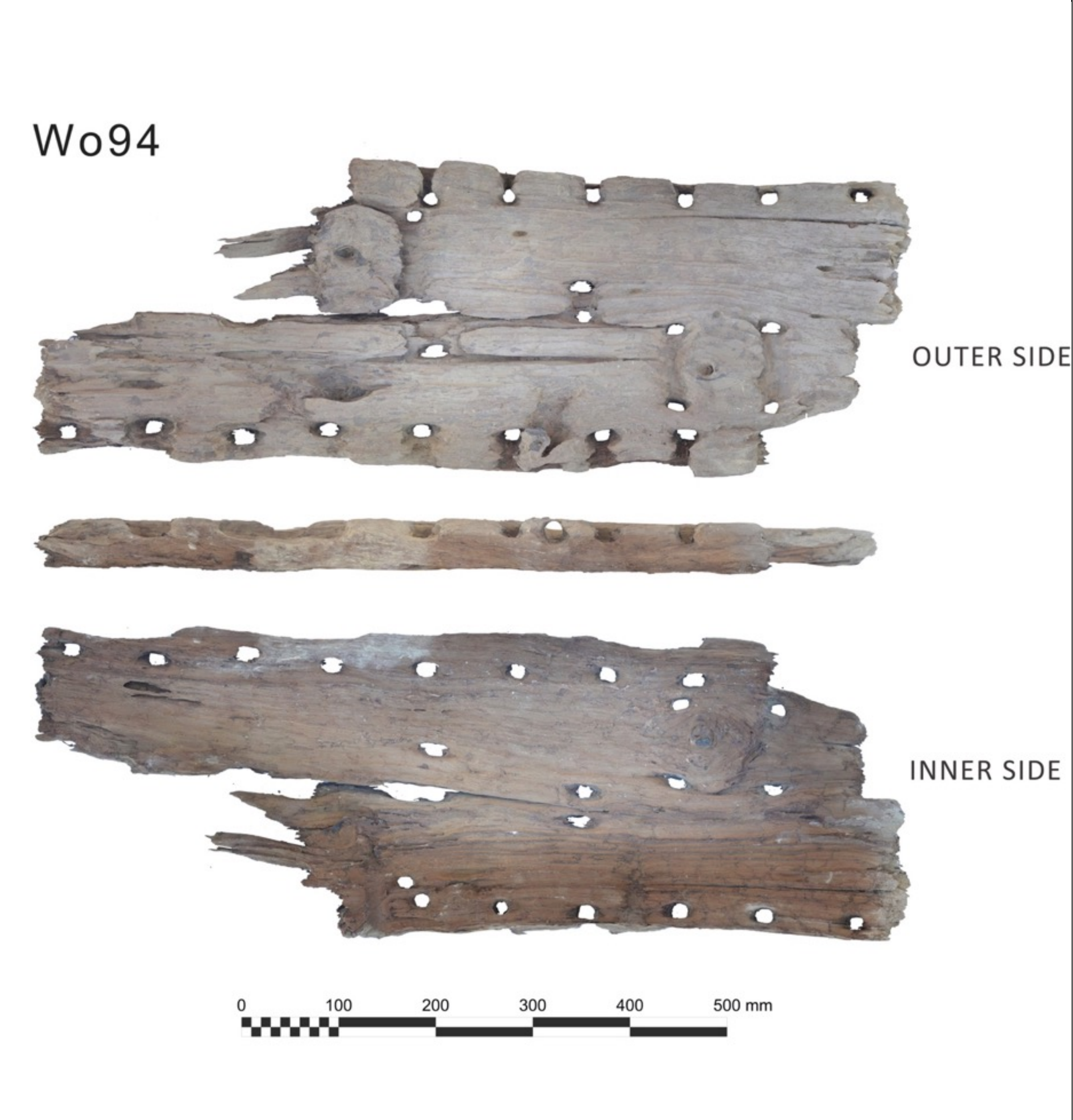
TIMBER ID:	Wo94	**LOCATION:**	Citadel, M148S (eastern wall)
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	889	**WIDTH:**	303-312-134	**THICKNESS:**	54-56

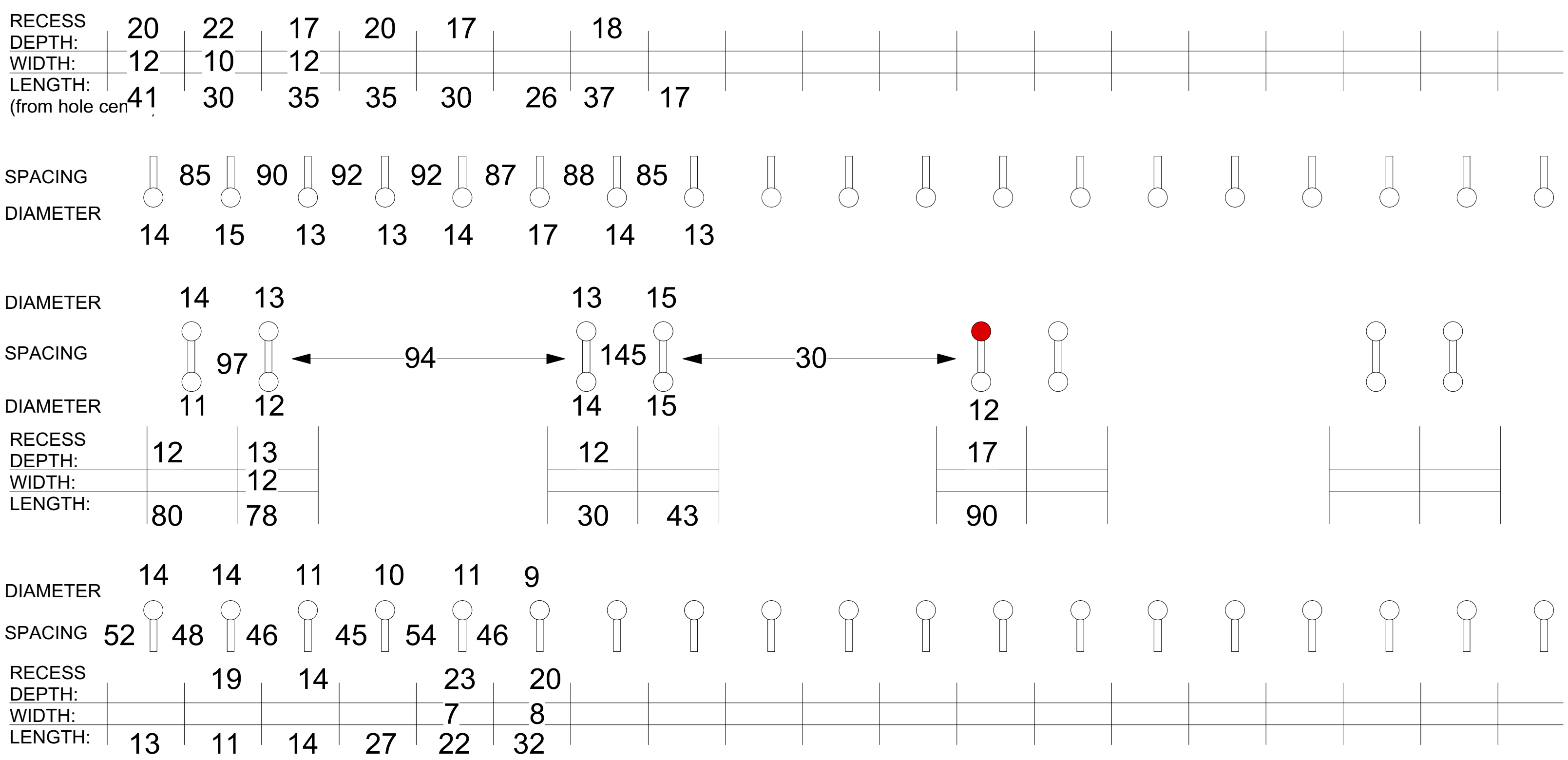
		TOP	**BOTTOM**	**FRAME**
HOLES		8	6	9
OVERALL NUMBER:	24			
DIAMETER (Average):		14	15	13
PLUGS	**WOOD**			
REBATES		8	6	6
DOWELS		1	2	
DOWEL DIAMETER		22	18	
DOWEL SPACING			265	
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
One of the largest timbers in the al-Balid dataset, this piece measures 30 cm in width and is nearly 6 cm thick. The size of the plank suggests that it came from a large cargo ship. The timber was discovered in the east wall of the citadel, and was used as a levelling course. The surface without the rebates (i.e., the former inner surface) is the most damaged and its wood grain is exposed. Stitching-holes are regularly spaced and unusually large, probably because they have stretched along the wood grain. Rebates are degraded, making it difficult to determine their precise depth and width. Frame-lashings are clearly visible on the surface, revealing a frame dimension of 78-80 mm, and lash-spacings between 30 to 94 mm.


Wo94
OUTER SIDE
INNER SIDE
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo94 DATE: 30/10/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 24/03/18**

TIMBER ID:	Wo98A	**LOCATION:**	Citadel, M182 (southern gate)
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:	Cal AD 1304 - 1364 (Cal BP 646 - 586) (57.7%) Cal AD 1384 - 1422 (Cal BP 566 - 528) (37.7%)		

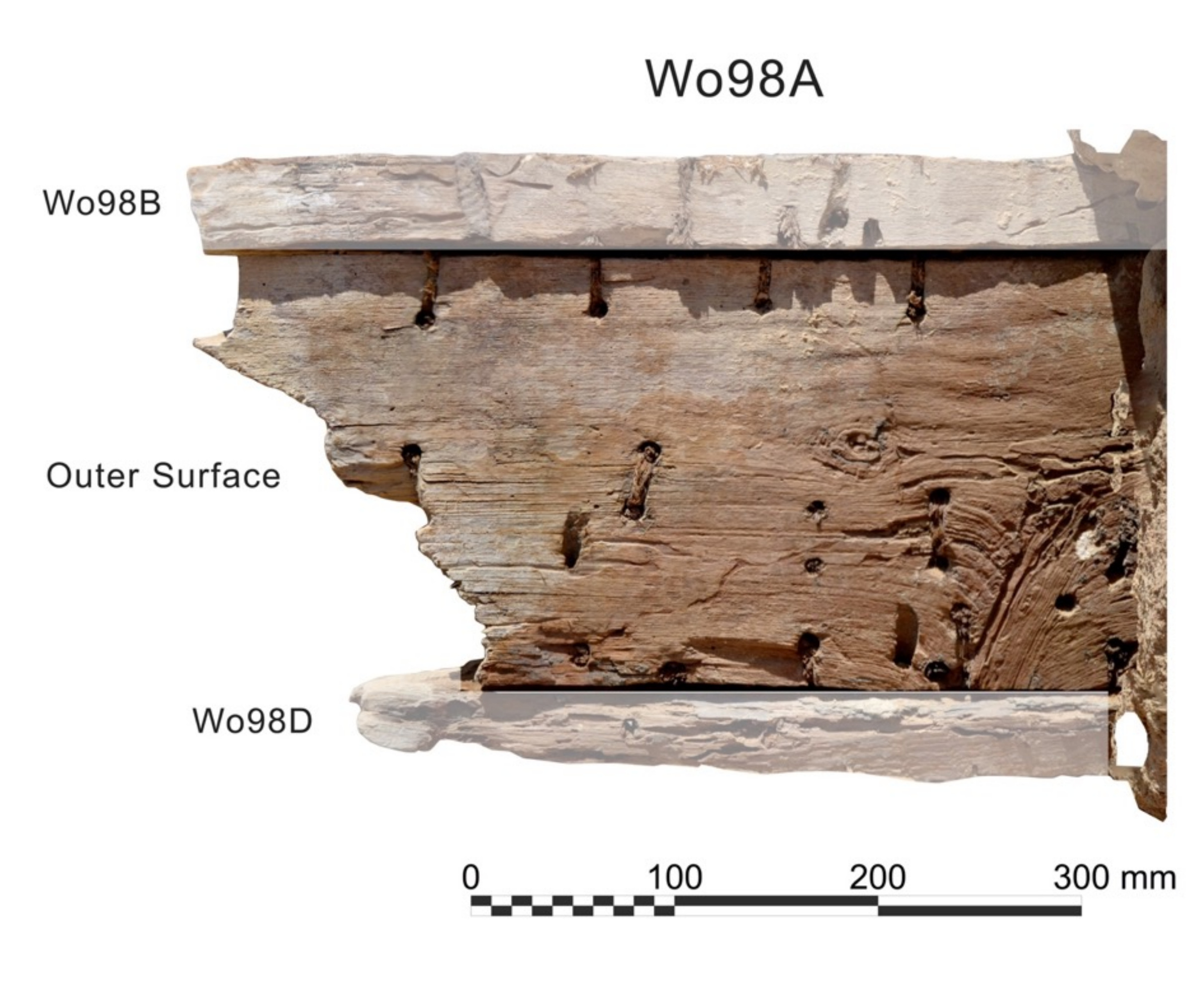
OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	>3,500mm	**WIDTH:**	215	**THICKNESS:**	30

		TOP	**BOTTOM**	**FRAME**
HOLES		4	5	8
HOLE SPACING:		81	73	
DIAMETER (Average):		10	11	10
PLUGS	**WOOD**	4	5	8
REBATES		4	1	4
DOWELS			2	
DOWEL DIAMETER			10	
DOWEL SPACING			177	
SCARFS				
WADDING				
BEVEL				

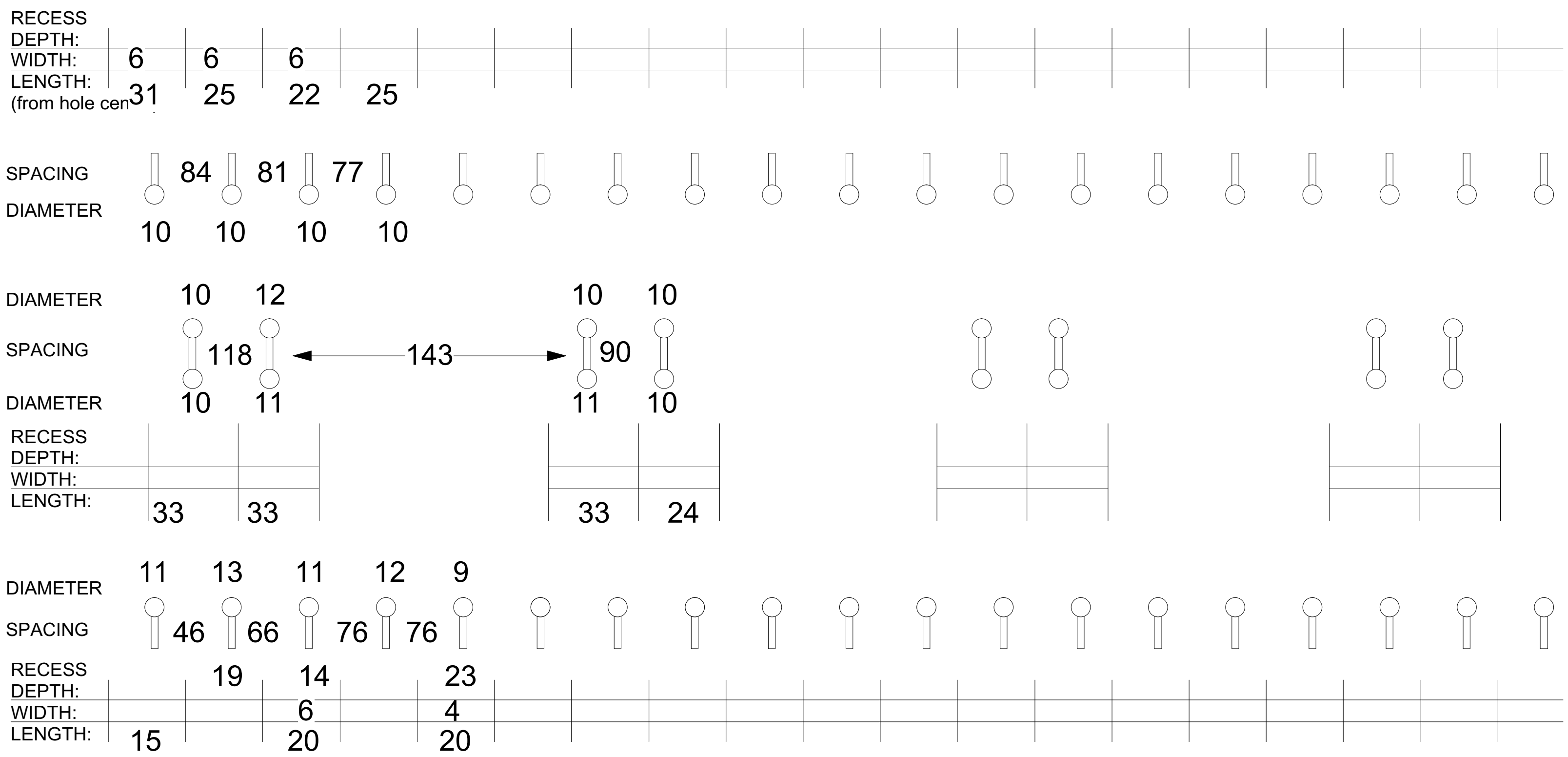
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN			Bitumen	

COMMENTS:

This large plank was recycled as part of the locking system for the southern gate of the al-Balid citadel. Its length cannot be determined precisely because it remains *in situ* within the wall, but it is estimated to be longer than 3.5 m. The piece retains one of its original edges. This is one of only two planks showing evidence of sewn-, dowel-, and nail-fastenings. The nails have disintegrated, but the plank retains the triangular rebates into which the nail heads were recessed--on the surface opposite the sewing rebates. The sewing-holes, dowels, and the nail rebates are relatively evenly spaced. Bits of the fibre cordage used to stitch the plank are still inset into the rebates. A thin layer of bitumen covers the top edge, and the section between the sewing-holes and the inside edge of the plank.


Wo98A
Wo98B
Outer Surface
Wo98D
0
100
200
300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo98A DATE: 30/10/17



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 24/03/18**

TIMBER ID:	Wo98	**LOCATION:**	Citadel, M182 (southern gate)
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:	Cal AD 1300 - 1369 (Cal BP 650 - 581) (63.3%) Cal AD 1380 - 1418 (Cal BP 570 - 532) (31.8%)		

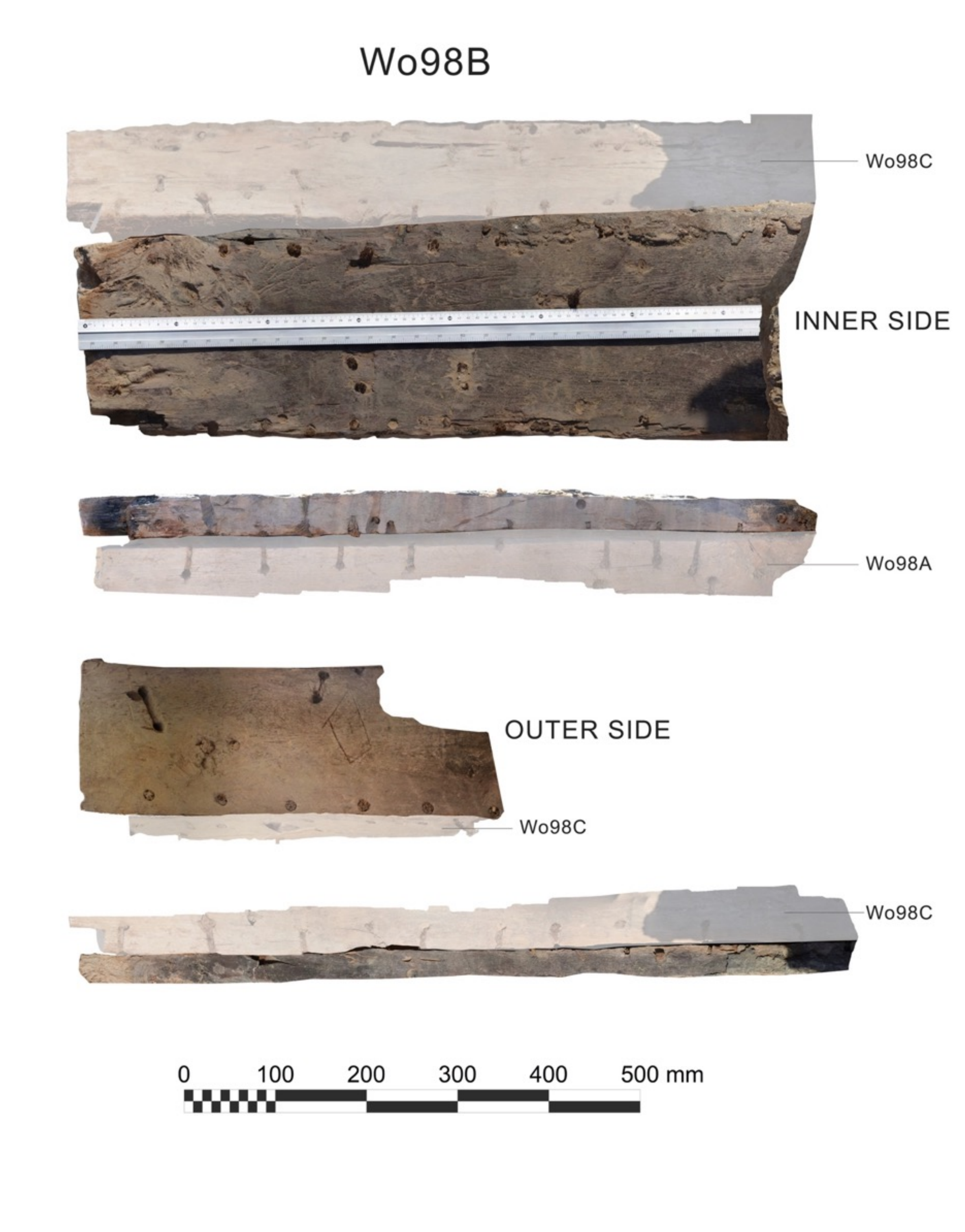
OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	>3,500	**WIDTH:**	243	**THICKNESS:**	46

		TOP	**BOTTOM**	**FRAME**
HOLES		8	6	8
OVERALL NUMBER:	24			
DIAMETER (Average):		11	13	13
PLUGS	**WOOD**			
REBATES		NO	Yes*	
DOWELS		1		
DOWEL DIAMETER		11		
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL				

* The first five holes are without rebates.

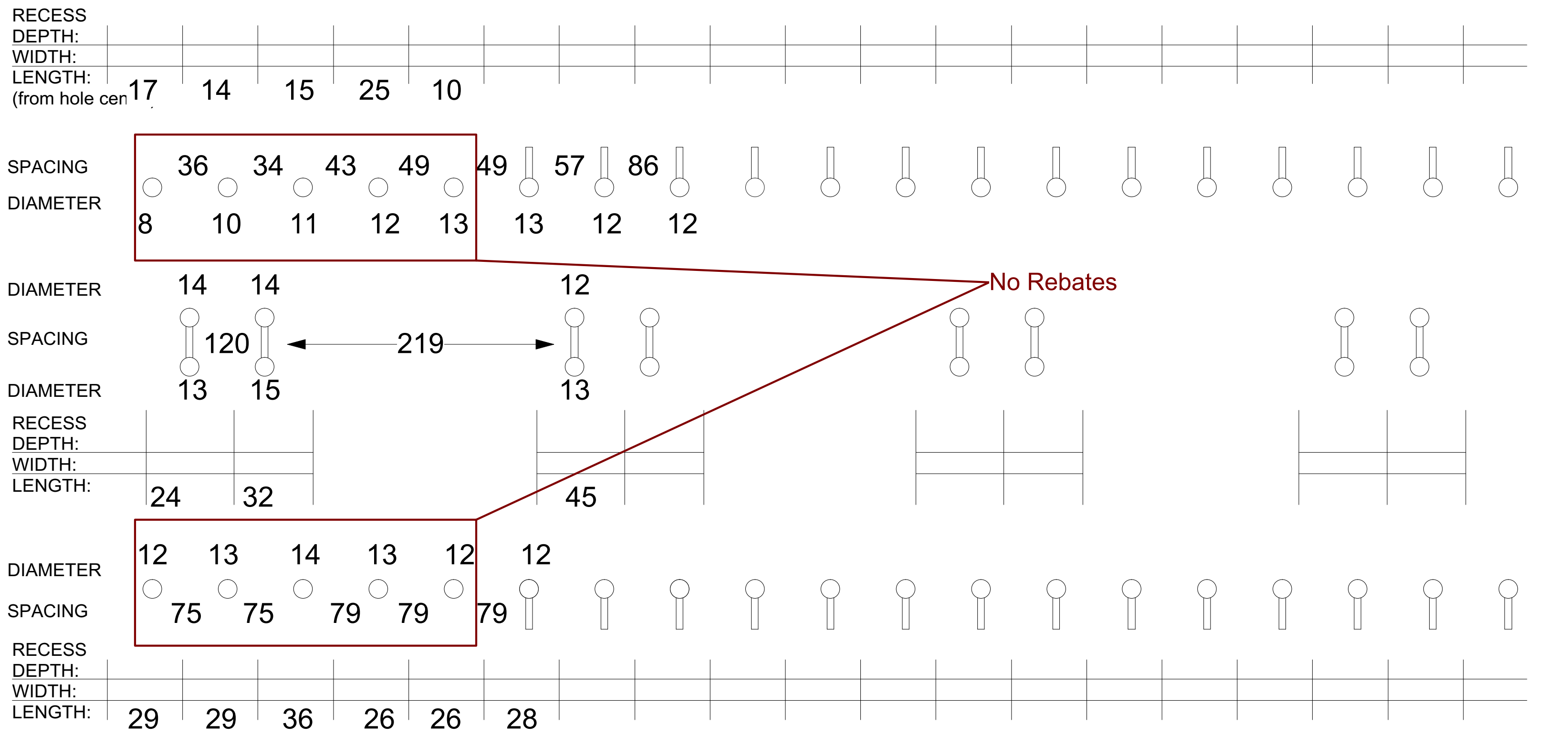
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
PIGMENT				
DECORATION				
RESIN/BITUMEN		Bitumen		Bitumen

COMMENTS:
This large plank was recycled as part of the locking system for the southern gate of the al-Balid citadel. Its length cannot be determined precisely because it remains *in situ* within the wall, but it is estimated to be longer than 3.5 m. The timber was fastened using the single-wadding technique, but the first five sewing-holes of the plank are not associated with rebates, perhaps suggesting that the boat from which it came had short sections of double-wadded planking. A thin layer of bitumen covers the top edge and the section between the sewing-holes and the inside edge of the plank.



Wo98B
Wo98C
INNER SIDE
Wo98A
OUTER SIDE
Wo98C
Wo98C
0
100
200
300
400
500 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo98B DATE: 23/03/18



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

AL-BALID TIMBER DOCUMENTATION FORM **DATE: 24/03/18**

TIMBER ID:	Wo98C	**LOCATION:**	Citadel, M182 (southern gate)
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:	Cal AD 1320 - 1350 (Cal BP 630 - 600) Cal AD 1390 - 1430 (Cal BP 560 - 520)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	>3,500	**WIDTH:**	200	**THICKNESS:**	29

			TOP	**BOTTOM**	**FRAME**
HOLES			8	3	8
OVERALL NUMBER:		19			
DIAMETER (Average):			10	11	10
PLUGS	**WOOD**				
REBATES					
DOWELS			4		
DOWEL DIAMETER			9		
DOWEL SPACING			198-149-358		
SCARFS					
WADDING					
BEVEL					

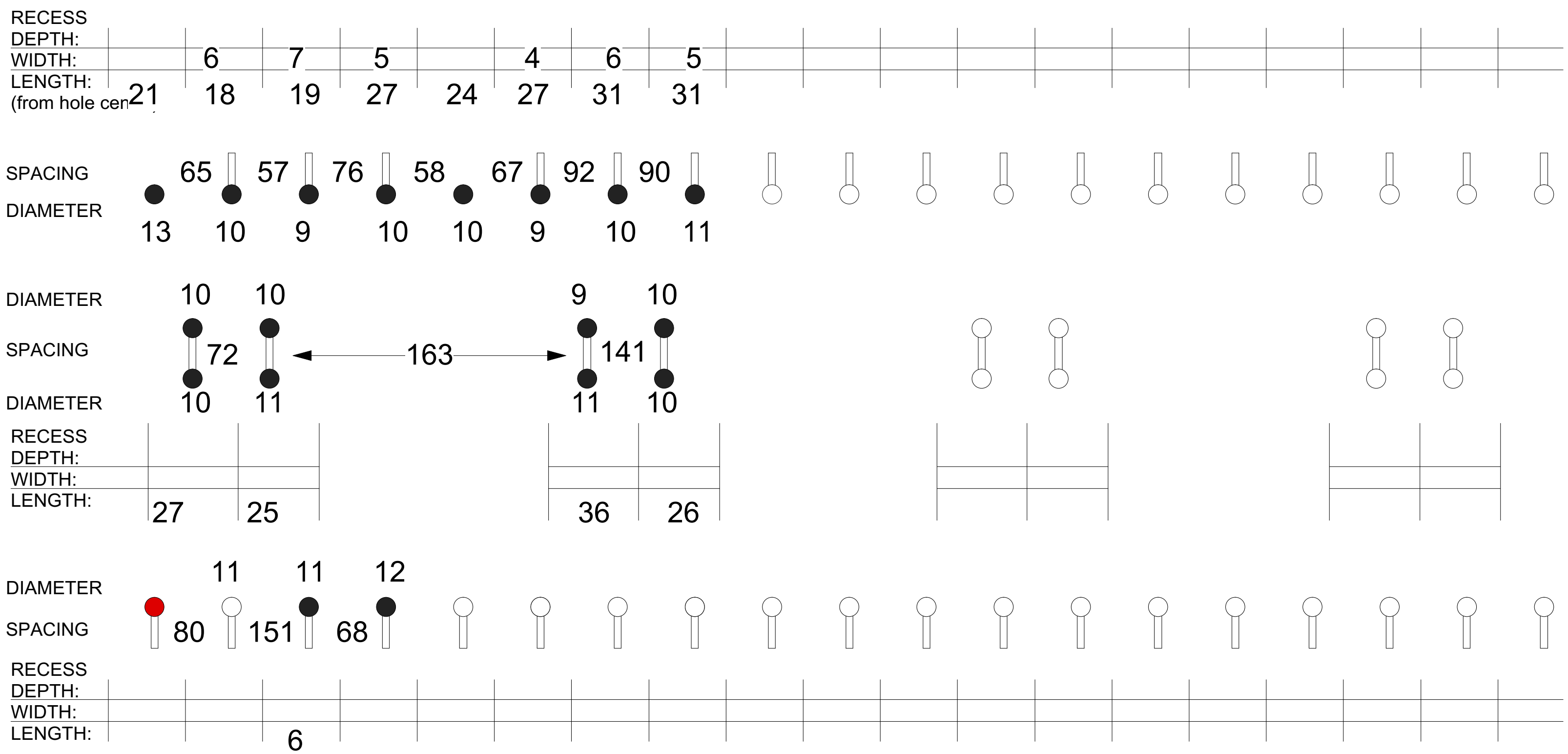
	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN		Bitumen		

COMMENTS:

This large plank was recycled as part of the locking system for the southern gate of the al-Balid citadel. Its length cannot be determined precisely because it remains *in situ* within the wall, but it is estimated to be longer than 3.5 m. Similar to Wo98A, this timber shows evidence of sewn-, dowel, and nail-fastenings. Traces of metal are preserved in one of the triangular rebates into which the nail head was recessed--on the surface opposite the sewing rebates. The sewing-holes, dowels, and the nail rebates are relatively evenly spaced. Bitumen covers the top edge and the section between the sewing-holes and the inside edge of the plank.


Wo98C
Outside
Inside
0 50 100 150 200 250 300 mm

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Wo98C DATE: 23/04/18



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

QALHAT TIMBER DOCUMENTATION FORM **DATE: 26/03/18**

TIMBER ID:	3210	**LOCATION:**	Building B12 Room F (28/11/13) B, Pre 606 US00RG 08
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:	Cal AD 1430 - 1522 (Cal BP 520 - 428) (82.6%) Cal AD 1590 - 1620 (Cal BP 360 - 330) (12.2%)		

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	938	**WIDTH:**	124-146-95	**THICKNESS:**	51-59-43

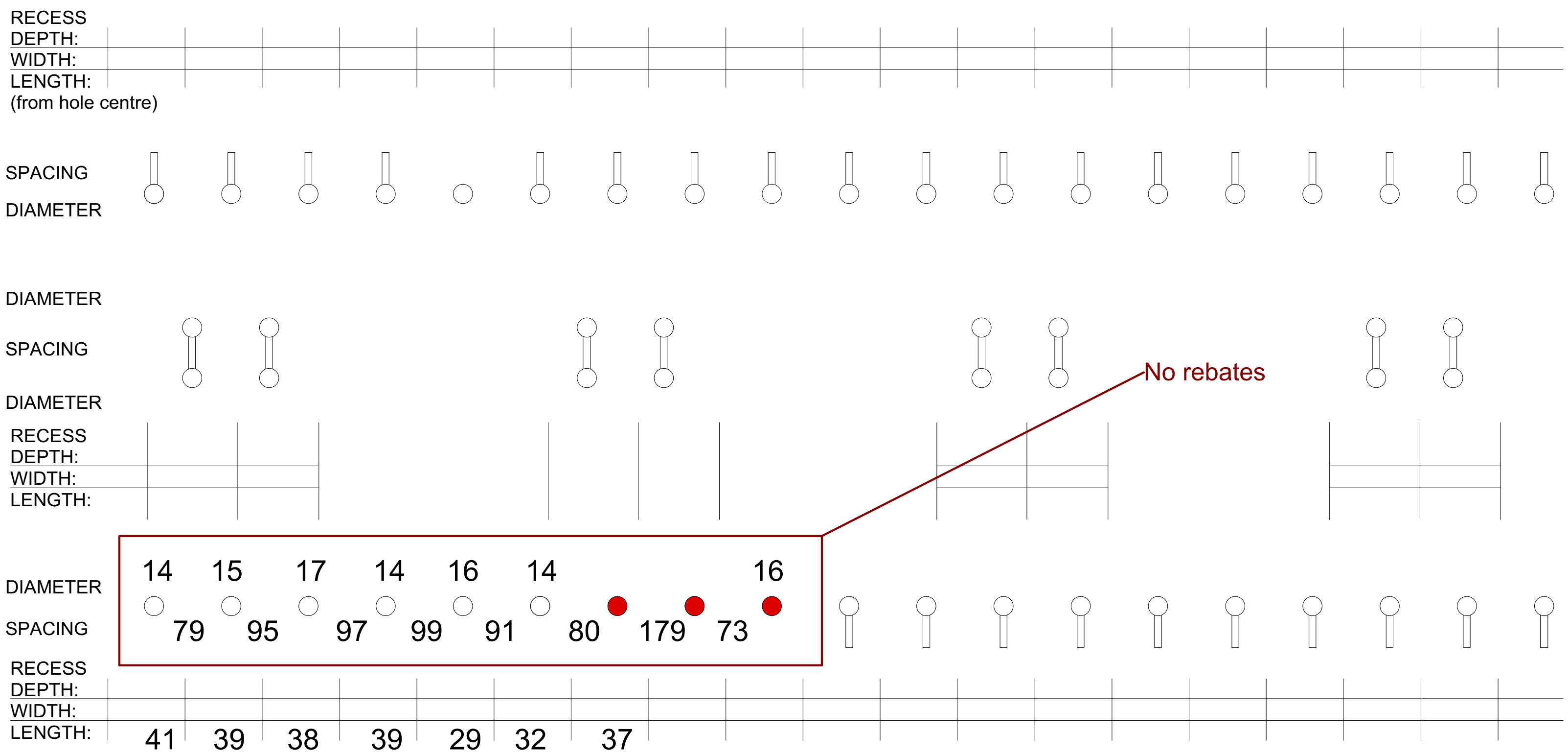
			TOP	**BOTTOM**	**FRAME**
HOLES				9	2 (+1?)
OVERALL NUMBER:		12			
DIAMETER (Average):				14	18
PLUGS	**WOOD**				
REBATES			NO	NO	NO
COIR FIBRE					
ROPES					
DOWELS					
DOWEL DIAMETER					
DOWEL SPACING					
SCARFS					
WADDING					
BEVEL			41˚-66˚		

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
For a detailed description, see Chapter 4.

TIMBER 3210n
(Qalhat)

QALHAT TIMBER STITCHING HOLES RECORDING FORM ID: 3210 DATE: 18/03/27



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

QALHAT TIMBER DOCUMENTATION FORM **DATE: 26/03/18**

TIMBER ID:	Qalhat-1	**LOCATION:**	N/A
WOOD SPECIES:	*Tectona grandis* (Teak)		
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	414	**WIDTH:**	175	**THICKNESS:**	N/A

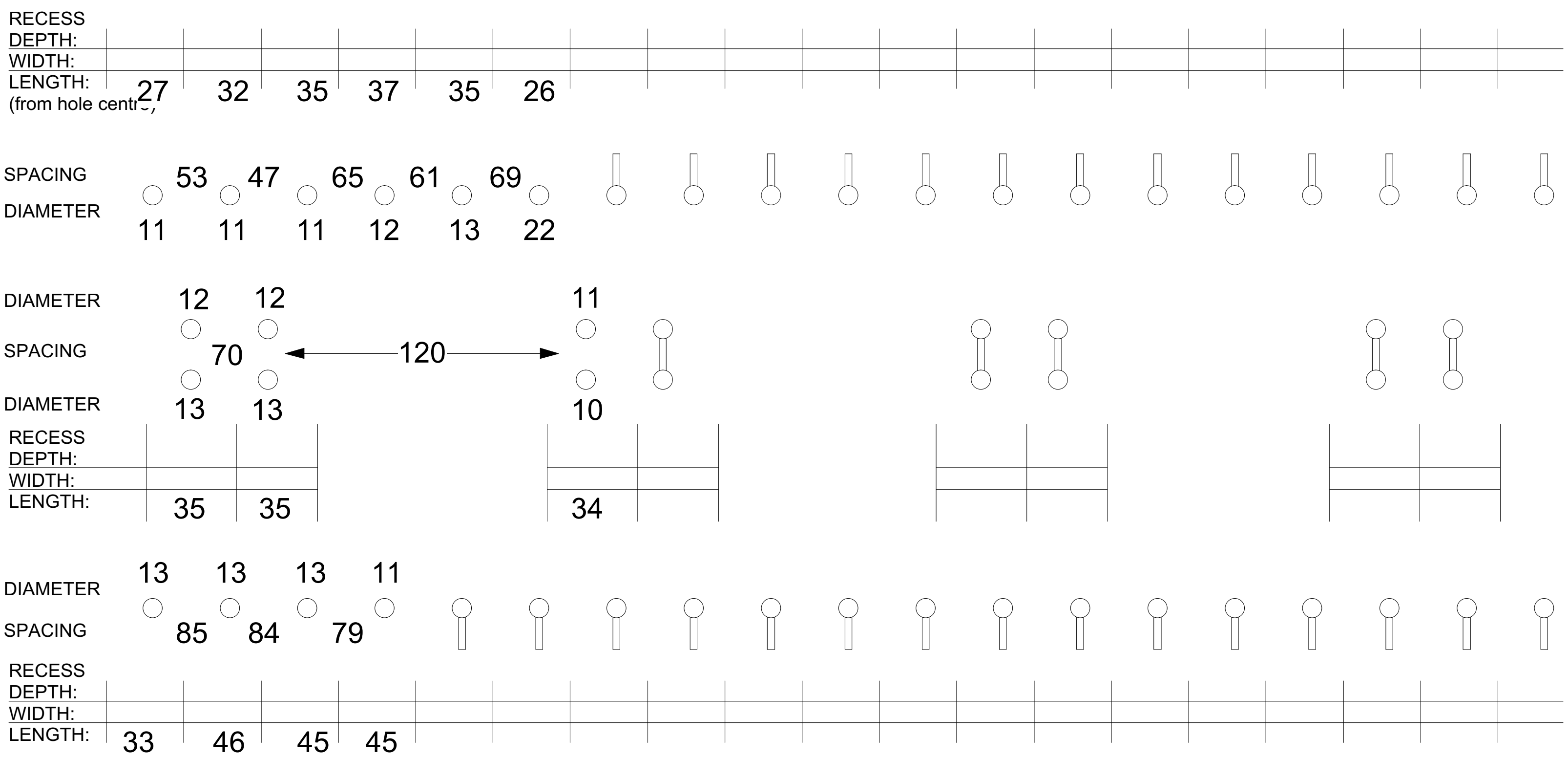
		TOP	BOTTOM	FRAME
HOLES		6	4	
OVERALL NUMBER:	4			
DIAMETER (Average):	8	13	12	
PLUGS	**WOOD**			
REBATES		NO	NO	
DOWELS		2		
DOWEL DIAMETER		12, 16		
DOWEL SPACING		242		
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	INNER SIDE	EDGE TOP	EDGE BOTTOM
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

COMMENTS:
For a detailed description, see Chapter 4.

Timber Qalhat-1

QALHAT TIMBER STITCHING HOLES RECORDING FORM ID: Qalhat-1 DATE: 20/5/19



*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

QALHAT TIMBER DOCUMENTATION FORM **DATE: 26/03/18**

TIMBER ID:	Qalhat-2	**LOCATION:**	Survey, near Great Mosque
WOOD SPECIES:			
DATE:			

OVERALL MEASUREMENTS (mm)(End-Centre-End)					
LENGTH:	345	**WIDTH:**	54-42-37	**THICKNESS:**	26-26-21

		TOP	**BOTTOM**	**FRAME**
HOLES		4		
OVERALL NUMBER:	4			
DIAMETER (Average):		8		
PLUGS	**WOOD**			
	FIBRE			
REBATES		NO		
DOWELS				
DOWEL DIAMETER				
DOWEL SPACING				
SCARFS				
WADDING				
BEVEL				

	OUTER SIDE	**INNER SIDE**	**EDGE TOP**	**EDGE BOTTOM**
TOOLS MARKS				
METAL ELEMENTS				
DECORATION				
RESIN/BITUMEN				

CUTTING METHOD: Plain Sewn

COMMENTS:
For a detailed description, see Chapter 4.

Timber Qalhat-2

AL-BALID TIMBER STITCHING HOLES RECORDING FORM ID: Qalhat-2 DATE: 26/3/18

RECESS
DEPTH:
WIDTH:
LENGTH:
(from hole cen 14 12 12 12

SPACING 64 64 64
DIAMETER
8 8 8 8

DIAMETER
SPACING
DIAMETER
RECESS
DEPTH:
WIDTH:
LENGTH:

DIAMETER
SPACING
RECESS
DEPTH:
WIDTH:
LENGTH:

*All measurements are in mm. Hole spacing and distance from edge are taken from the centre of the hole.

- Partial/broken hole
- Worn elongated hole
- Plug preserved
- No plug preserved

Appendix–B – Radiocarbon Dating Analysis

BETA
Consistent accuracy delivered on time

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beta@radiocarbon.com
www.radiocarbon.com

Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

July 26, 2017

Alessandro Ghidoni
University of Exeter
5 Playmoor Drive Pinhoe
Exeter, Devon EX1 3ST
United Kingdom

RE: Radiocarbon Dating Results

Mr. Ghidoni,

Enclosed are the radiocarbon dating results for three samples recently sent to us. The report sheet contains the Conventional Radiocarbon Age (BP), the method used, material type, and applied pretreatments, any sample specific comments and, where applicable, the two-sigma calendar calibration range. The Conventional Radiocarbon ages have been corrected for total isotopic fractionation effects (natural and laboratory induced).

All results (excluding some inappropriate material types) which fall within the range of available calibration data are calibrated to calendar years (cal BC/AD) and calibrated radiocarbon years (cal BP). Calibration was calculated using one of the databases associated with the 2013 INTCAL program (cited in the references on the bottom of the calibration graph page provided for each sample.) Multiple probability ranges may appear in some cases, due to short-term variations in the atmospheric 14C contents at certain time periods. Looking closely at the calibration graph provided and where the BP sigma limits intercept the calibration curve will help you understand this phenomenon.

Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result.

All work on these samples was performed in our laboratories in Miami under strict chain of custody and quality control under ISO/IEC 17025:2005 Testing Accreditation PJLA #59423 accreditation protocols. Sample, modern and blanks were all analyzed in the same chemistry lines by qualified professional technicians using identical reagents and counting parameters within our own particle accelerators. A quality assurance report is posted to your directory for each result.

Our invoice will be emailed separately. Please forward it to the appropriate officer or send a credit card authorization. Thank you. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely ,

Darden Hood
Digital signature on file

Beta Analytic
RADIOCARBON DATING
Consistent accuracy delivered on time

DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74th Court
Miami, Florida, USA 33155
PH: 305-667-5167 FAX: 305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Mr. Alessandro Ghidoni — Rerport Date: July 26, 2017

University of Exeter — Material Received: July 19, 2017

Sample Information and Data	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes Calendar Calibrated Results: 95.4 % Probability High Probability Density Range Method (HPD)	
Beta - 469877	**823_B3_98-1235**	**880 +/- 30 BP**	IRMS δ13C: -25.7 o/oo

Submitter Material: Woody Material

(68.4%) 1117 - 1222 cal AD (833 - 728 cal BP)
(27.0%) 1042 - 1104 cal AD (908 - 846 cal BP)

Analyzed Material: Wood
Pretreatment: (wood) acid/alkali/acid

Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 89.62 +/- 0.33 pMC
Fraction Modern Carbon: 0.8962 +/- 0.0033
D14C: -103.76 +/- 3.35 o/oo
Δ14C: -111.00 +/- 3.35 o/oo(1950:2017)
Measured Radiocarbon Age: (without d13C correction): 890 +/- 30 BP
Calibration: BetaCal3.21: HPD method: INTCAL13

Results are ISO/IEC-17025:2005 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

BETA Beta Analytic
RADIOCARBON DATING
Consistent accuracy delivered on time

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beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Mr. Alessandro Ghidoni — Rerport Date: July 26, 2017

University of Exeter — Material Received: July 19, 2017

Sample Information and Data	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes Calendar Calibrated Results: 95.4 % Probability High Probability Density Range Method (HPD)	
Beta - 469878	**BA.01.11.01**	**920 +/- 30 BP**	IRMS δ13C: -25.9 o/oo
Submitter Material: Woody Material		**(95.4%) 1028 - 1184 cal AD**	**(922 - 766 cal BP)**

Analyzed Material: Wood
Pretreatment: (wood) acid/alkali/acid

Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 89.18 +/- 0.33 pMC
Fraction Modern Carbon: 0.8918 +/- 0.0033
D14C: -108.21 +/- 3.33 o/oo
Δ14C: -115.41 +/- 3.33 o/oo(1950:2017)
Measured Radiocarbon Age: (without d13C correction): 930 +/- 30 BP
Calibration: BetaCal3.21: HPD method: INTCAL13

Results are ISO/IEC-17025:2005 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), “present” = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Beta Analytic
RADIOCARBON DATING
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beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Mr. Alessandro Ghidoni — Rerport Date: July 26, 2017

University of Exeter — Material Received: July 19, 2017

Sample Information and Data	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes Calendar Calibrated Results: 95.4 % Probability High Probability Density Range Method (HPD)
Beta - 469879	**Wo54**	**880 +/- 30 BP** IRMS δ13C: -24.7 o/oo

Submitter Material: Woody Material

(68.4%) 1117 - 1222 cal AD (833 - 728 cal BP)
(27.0%) 1042 - 1104 cal AD (908 - 846 cal BP)

Analyzed Material: Wood
Pretreatment: (wood) acid/alkali/acid

Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 89.62 +/- 0.33 pMC
Fraction Modern Carbon: 0.8962 +/- 0.0033
D14C: -103.76 +/- 3.35 o/oo
Δ14C: -111.00 +/- 3.35 o/oo(1950:2017)
Measured Radiocarbon Age: (without d13C correction): 880 +/- 30 BP
Calibration: BetaCal3.21: HPD method: INTCAL13

Results are ISO/IEC-17025:2005 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

BetaCal 3.21

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13)

(Variables: d13C = -25.7 o/oo)

Laboratory number	**Beta-469877**
Conventional radiocarbon age	**880 ± 30 BP**

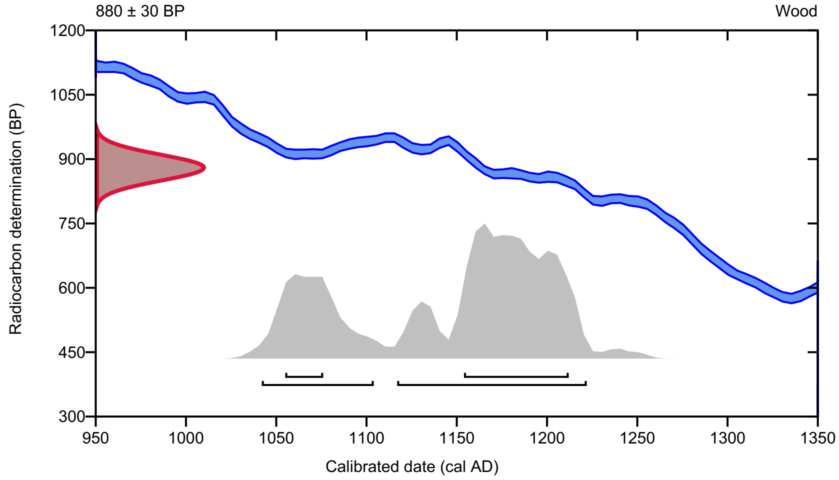
95.4% probability

(68.4%)	1117 - 1222 cal AD	(833 - 728 cal BP)
(27%)	1042 - 1104 cal AD	(908 - 846 cal BP)

68.2% probability

(53.8%)	1154 - 1212 cal AD	(796 - 738 cal BP)
(14.4%)	1055 - 1076 cal AD	(895 - 874 cal BP)

823_B3_98-1235



Database used
INTCAL13

References
References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL13

Reimer, et.al., 2013, Radiocarbon55(4).

BetaCal 3.21

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13)

(Variables: d13C = -25.9 o/oo)

Laboratory number **Beta-469878**

Conventional radiocarbon age **920 ± 30 BP**

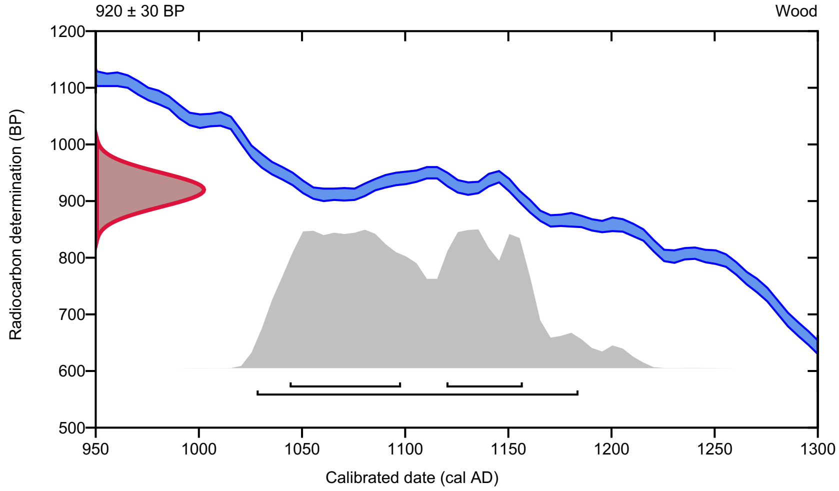
95.4% probability

(95.4%)	1028 - 1184 cal AD	(922 - 766 cal BP)

68.2% probability

(41.9%)	1044 - 1098 cal AD	(906 - 852 cal BP)
(26.3%)	1120 - 1157 cal AD	(830 - 793 cal BP)

BA.01.11.01



Database used

INTCAL13

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL13

Reimer, et.al., 2013, Radiocarbon55(4).

BetaCal 3.21

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13)

(Variables: d13C = -24.7 o/oo)

Laboratory number **Beta-469879**

Conventional radiocarbon age **880 ± 30 BP**

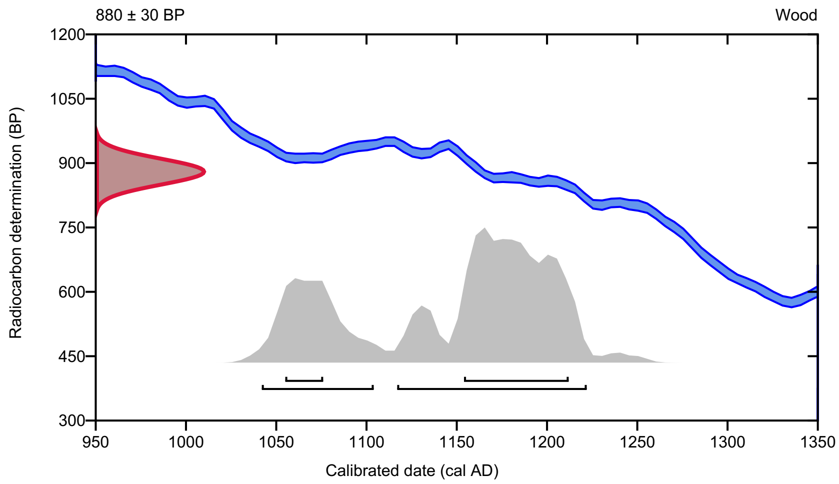
95.4% probability

(68.4%)	1117 - 1222 cal AD	(833 - 728 cal BP)
(27%)	1042 - 1104 cal AD	(908 - 846 cal BP)

68.2% probability

(53.8%)	1154 - 1212 cal AD	(796 - 738 cal BP)
(14.4%)	1055 - 1076 cal AD	(895 - 874 cal BP)

Wo54



Database used

INTCAL13

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL13

Reimer, et.al., 2013, Radiocarbon55(4).

BETA
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Mr. Darden Hood
President

Mr. Ronald Hatfield
Mr. Christopher Patrick
Deputy Directors

The Radiocarbon Laboratory Accredited to ISO/IEC 17025:2005 Testing Accreditation PJLA #59423

Quality Assurance Report

This report provides the results of reference materials used to validate radiocarbon analyses prior to reporting. Known-value reference materials were analyzed quasi-simultaneously with the unknowns. Results are reported as expected values vs measured values. Reported values are calculated relative to NIST SRM-4990B and corrected for isotopic fractionation. Results are reported using the direct analytical measure percent modern carbon (pMC) with one relative standard deviation. Agreement between expected and measured values is taken as being within 2 sigma agreement (error x 2) to account for total laboratory error.

Report Date: July 26, 2017
Submitter: Mr. Alessandro Ghidoni

QA MEASUREMENTS

Reference 1

Expected Value: 129.41 +/- 0.06 pMC

Measured Value: 129.46 +/- 0.37 pMC

Agreement: Accepted

Reference 2

Expected Value: 0.44 +/- 0.10 pMC

Measured Value: 0.44 +/- 0.03 pMC

Agreement: Accepted

Reference 3

Expected Value: 96.69 +/- 0.50 pMC

Measured Value: 96.94 +/- 0.29 pMC

Agreement: Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Darden Hood Date: July 26, 2017

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ISO/IEC 17025:2005-Accredited Testing Laboratory

March 14, 2019

Mr. Alessandro Ghidoni
University of Exeter
5 Playmoor Drive Pinhoe
Exeter, Devon EX1 3ST
United Kingdom

RE: Radiocarbon Dating Results

Dear Mr. Ghidoni,

Enclosed are the radiocarbon dating results for three samples recently sent to us. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable. The Conventional Radiocarbon Ages have all been corrected for total fractionation effects and where applicable, calibration was performed using 2013 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

Reported results are accredited to ISO/IEC 17025:2005 Testing Accreditation PJLA #59423 standards and all chemistry was performed here in our laboratory and counted in our own accelerators here. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2005 Testing Accreditation PJLA #59423 program participated in the analyses.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result. The reported d13C values were measured separately in an IRMS (isotope ratio mass spectrometer). They are NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the results, please consider any communications you may have had with us regarding the samples.

Our invoice will be emailed separately. Please forward it to the appropriate officer or send a credit card authorization. Thank you. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,

Digital signature on file

Ronald E. Hatfield Director

Beta Analytic Inc
4985 SW 74 Court
Miami, Florida 33155
Tel: 305-667-5167
Fax: 305-663-0964
info@betalabservices.com

REPORT OF RADIOCARBON DATING ANALYSES

Alessandro Ghidoni — Report Date: March 14, 2019

University of Exeter — Material Received: February 26, 2019

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes Calendar Calibrated Results: 95.4 % Probability High Probability Density Range Method (HPD)	
Beta - 519639	**Wo98B**	**580 +/- 30 BP**	IRMS δ13C: -26.7 o/oo

(63.6%)	**1300 - 1369 cal AD**	**(650 - 581 cal BP)**
(31.8%)	**1380 - 1418 cal AD**	**(570 - 532 cal BP)**

Submitter Material: Woody Material
Pretreatment: (wood) acid/alkali/acid
Analyzed Material: Wood
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 93.03 +/- 0.35 pMC
Fraction Modern Carbon: 0.9303 +/- 0.0035
D14C: -69.66 +/- 3.47 o/oo
Δ14C: -77.39 +/- 3.47 o/oo(1950:2,019.00)
Measured Radiocarbon Age: (without d13C correction): 610 +/- 30 BP
Calibration: BetaCal3.21: HPD method: INTCAL13

Results are ISO/IEC-17025:2005 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Beta Analytic
TESTING LABORATORY

Beta Analytic Inc
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ISO/IEC 17025:2005-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Alessandro Ghidoni		Report Date:	March 14, 2019
University of Exeter		Material Received:	February 26, 2019

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes Calendar Calibrated Results: 95.4 % Probability High Probability Density Range Method (HPD)	
Beta - 519640	**Wo98A**	**570 +/- 30 BP**	IRMS δ13C: -26.2 o/oo

(57.7%)	**1304 - 1364 cal AD**	**(646 - 586 cal BP)**
(37.7%)	**1384 - 1422 cal AD**	**(566 - 528 cal BP)**

Submitter Material:	Woody Material
Pretreatment:	(wood) acid/alkali/acid
Analyzed Material:	Wood
Analysis Service:	AMS-Standard delivery
Percent Modern Carbon:	93.15 +/- 0.35 pMC
Fraction Modern Carbon:	0.9315 +/- 0.0035
D14C:	-68.50 +/- 3.48 o/oo
Δ14C:	-76.24 +/- 3.48 o/oo(1950:2,019.00)
Measured Radiocarbon Age:	(without d13C correction): 590 +/- 30 BP
Calibration:	BetaCal3.21: HPD method: INTCAL13

Results are ISO/IEC-17025:2005 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Alessandro Ghidoni	Report Date: March 14, 2019
University of Exeter	Material Received: February 26, 2019

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes Calendar Calibrated Results: 95.4 % Probability High Probability Density Range Method (HPD)	
Beta - 519641	**3210n**	**410 +/- 30 BP**	IRMS δ13C: -25.9 o/oo

(82.6%)	**1430 - 1522 cal AD**	**(520 - 428 cal BP)**
(12.2%)	**1590 - 1620 cal AD**	**(360 - 330 cal BP)**
(0.6%)	**1577 - 1583 cal AD**	**(373 - 367 cal BP)**

Submitter Material: Woody Material
Pretreatment: (wood) acid/alkali/acid
Analyzed Material: Wood
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 95.02 +/- 0.35 pMC
Fraction Modern Carbon: 0.9502 +/- 0.0035
D14C: -49.76 +/- 3.55 o/oo
Δ14C: -57.66 +/- 3.55 o/oo(1950:2,019.00)
Measured Radiocarbon Age: (without d13C correction): 420 +/- 30 BP
Calibration: BetaCal3.21: HPD method: INTCAL13

Results are ISO/IEC-17025:2005 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

BetaCal 3.21

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13)

(Variables: d13C = -26.7 o/oo)

Laboratory number **Beta-519639**

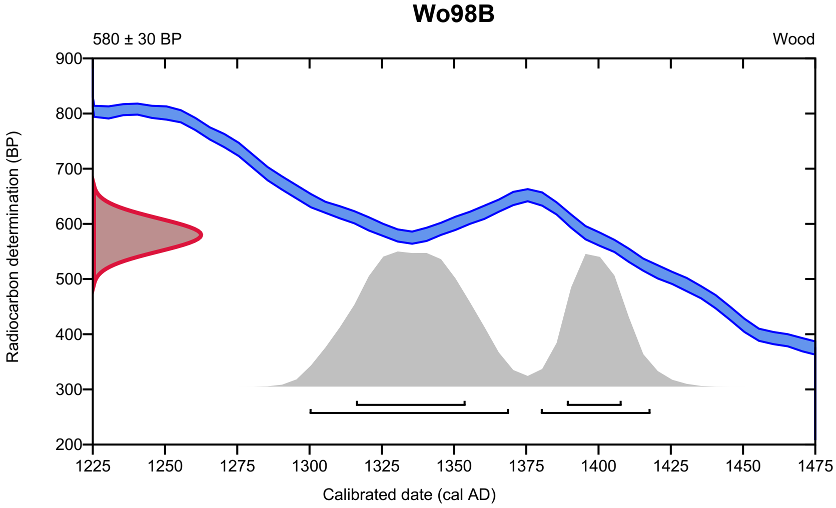
Conventional radiocarbon age **580 ± 30 BP**

95.4% probability

(63.6%)	1300 - 1369 cal AD	(650 - 581 cal BP)
(31.8%)	1380 - 1418 cal AD	(570 - 532 cal BP)

68.2% probability

(46.2%)	1316 - 1354 cal AD	(634 - 596 cal BP)
(22%)	1389 - 1408 cal AD	(561 - 542 cal BP)



Database used

INTCAL13

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL13

Reimer, et.al., 2013, Radiocarbon55(4).

BetaCal 3.21

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13)

(Variables: d13C = -26.2 o/oo)

Laboratory number **Beta-519640**

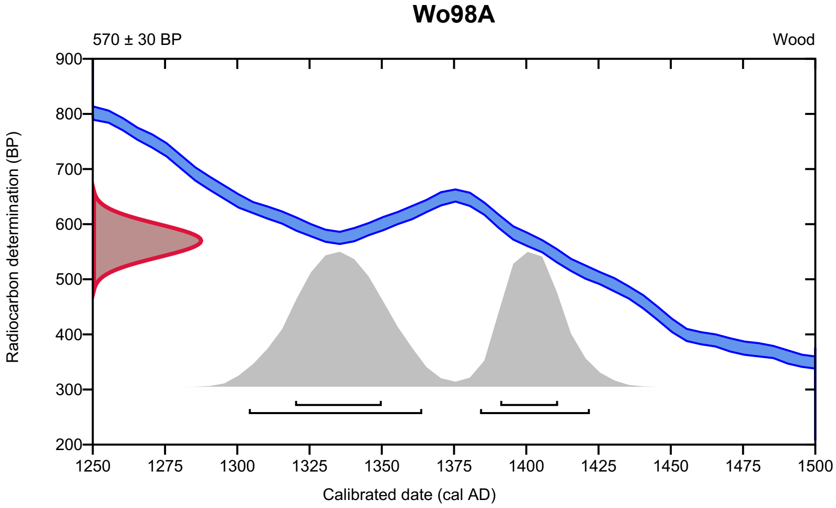
Conventional radiocarbon age **570 ± 30 BP**

95.4% probability

(57.7%)	1304 - 1364 cal AD	(646 - 586 cal BP)
(37.7%)	1384 - 1422 cal AD	(566 - 528 cal BP)

68.2% probability

(40.9%)	1320 - 1350 cal AD	(630 - 600 cal BP)
(27.3%)	1391 - 1411 cal AD	(559 - 539 cal BP)



Database used
INTCAL13

References
References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL13

Reimer, et.al., 2013, Radiocarbon55(4).

BetaCal 3.21

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13)

(Variables: d13C = -25.9 o/oo)

Laboratory number **Beta-519641**

Conventional radiocarbon age **410 ± 30 BP**

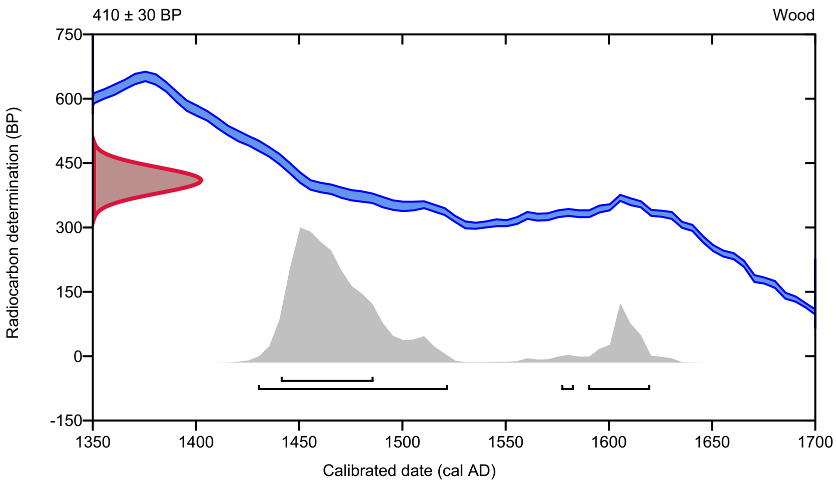
95.4% probability

(82.6%)	1430 - 1522 cal AD	(520 - 428 cal BP)
(12.2%)	1590 - 1620 cal AD	(360 - 330 cal BP)
(0.6%)	1577 - 1583 cal AD	(373 - 367 cal BP)

68.2% probability

(68.2%)	1441 - 1486 cal AD	(509 - 464 cal BP)

3210n



Database used
INTCAL13

References
References to Probability Method
Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.
References to Database INTCAL13
Reimer, et.al., 2013, Radiocarbon55(4).

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Quality Assurance Report

This report provides the results of reference materials used to validate radiocarbon analyses prior to reporting. Known-value reference materials were analyzed quasi-simultaneously with the unknowns. Results are reported as expected values vs measured values. Reported values are calculated relative to NIST SRM-4990B and corrected for isotopic fractionation. Results are reported using the direct analytical measure percent modern carbon (pMC) with one relative standard deviation. Agreement between expected and measured values is taken as being within 2 sigma agreement (error x 2) to account for total laboratory error.

Report Date: March 14, 2019
Submitter: Mr. Alessandro Ghidoni

QA MEASUREMENTS

Reference 1

Expected Value: 129.41 +/- 0.06 pMC
Measured Value: 129.05 +/- 0.40 pMC
Agreement: Accepted

Reference 2

Expected Value: 41.14 +/- 0.10 pMC
Measured Value: 41.00 +/- 0.18 pMC
Agreement: Accepted

Reference 3

Expected Value: 0.51 +/-0.04
Measured Value: 0.50 +/- 0.03 pMC
Agreement: Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Chris Patrick
Digital signature on file

Date: March 14, 2019

Appendix–C – Timber Identification Report

Report on the identification of 11th to 15th century ship timber samples from al-Balid, Oman using scanning electron microscopy

Dr Caroline R. Cartwright

Senior Scientist and Wood Anatomist,
Department of Scientific Research, British Museum

Introduction

Samples of desiccated ship's timbers from Oman were selected and submitted by Alessandro Ghidoni to the author for identification; see Table 1. The following information was provided by Alessandro Ghidoni: "the timbers were discovered in the Islamic site of al-Balid, dated to the 11th-15th centuries AD. They all have been identified as parts of sewn boats. All are planks, except one which could be interpreted as a ship beam. Some were recycled in the buildings of the citadel as lintels, shelves and ceiling planks. Others were simply found scattered in the layers of debris filling the rooms of the citadel. Unfortunately, most of them have been discovered during the restoration of the site, rather than a proper excavation, and have not been properly documented. "

Table 1

Documentation and photographs of the al-Balid samples by Alessandro Ghidoni

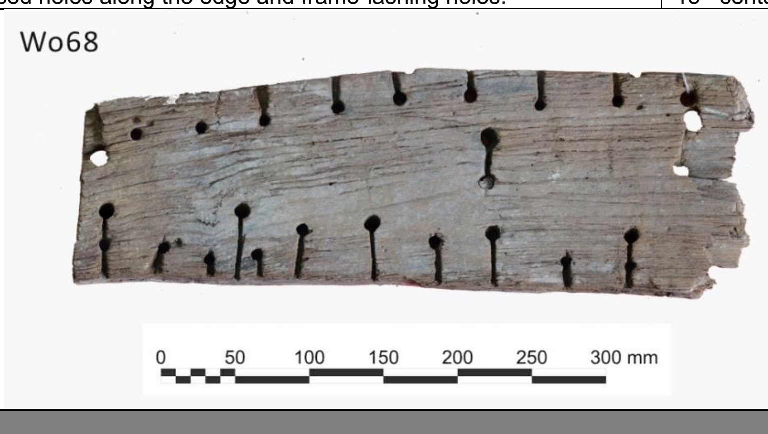
Sample	Context	Date
823.B3.98-1235	There is no documentation about the location of the timber except that it was discovered during the restoration of the site of al-Balid, most probably in 2001-2002. It is a relatively small fragment with stitching holes arranged in a way that suggests a "double wadding" sewn pattern, similar to that observed in the 8th and 9th century shipwrecks discovered in Thailand (Phanom-Surin) and in Indonesia (Belitung).	2 Sigma Calibration Cal AD 1042 to 1104 (27%); Cal AD 1117 to 1222 (68.4%); 1 Sigma Calibration Cal AD 1055 to 1076 (14.4%); Cal AD 1154 to 1212 (53.8%);
		
BA.01.11.01	One of the largest timbers of the collection, it was discovered in 2001 in the north-west corner of the southern entrance of the citadel (husn) of the site of al-Balid. Similarly to the previous timber, it displays the same sewn pattern.	2 Sigma Calibration Cal AD 1028 to 1184; 1 Sigma Calibration Cal AD 1044 to 1098 (41.9%); Cal AD 1120 to 1157 (26.3%);
		

BA0604128.73	Cylindrical wooden peg from plank BA0604128.73 used to connect two adjacent planks in the hull of a boat.	2 Sigma calibration Cal AD 1290 to 1410; 1 Sigma calibration Cal AD 1300 to 1400
		
BA1104065.449	Planks from a sewn boat, displaying holes regularly spaced along the edge, with rope fibres still inside. It was discovered in al-Balid.	Cal AD 990 to 1050 (Cal BP 960 to 900), Cal AD 1090 to 1120 (Cal BP 860 to 830), Cal AD 1140 to 1150 (Cal BP 810 to 800) **Best fit 1020 AD**
		
BA1104065.450	Plank with stitching holes and geometrical decorative motives carved on its former outer surface. It was discovered in al-Balid.	Cal AD 1020 to 1170 (Cal BP 930 to 780)
		
BA1104065.454	Sewn plank with evenly spaced holes. The wood is hard and well preserved.	Cal AD 1020 to 1160 (Cal BP 930 to 790)
		
BA1104065.447	Large beam reused as a lintel over a small window in the wall M89 of Room A9 of the citadel of al-Balid. Because of the shape, notches on the surface and presence of holes with fibre ropes still in situ, it resembles a through-beam, typically used in sewn boats.	No diagnostic material associated with the find. Date range (11-15th centuries AD)
		

Wo45	Wooden peg used to plug the stitching holes on plank Wo45.	No diagnostic material associated with the find. Date range (11-15th centuries AD)
Wo54	Large plank from a sewn boat. The timber was discovered in USS 1, one of the last layers before the abandonment of the southern area of the citadel of al-Balid. It is one of the best examples of planks from sewn boats, with regularly spaced holes along the edge and frame-lashing holes.	2 Sigma Calibration Cal AD 1042 to 1104 (27%); Cal AD 1117 to 1222 (68.4%); 1 Sigma Calibration Cal AD 1055 to 1076 (14.4%); Cal AD 1154 to 1212 (53.8%)

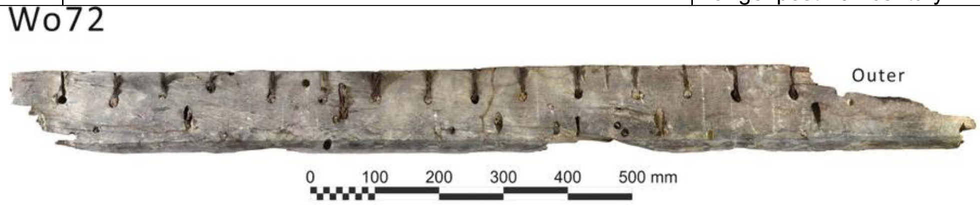
Wo63	Sewn plank made of a very porous wood.	No diagnostic material associated with the find. Date range (11-15th centuries AD)

Wo68	The timber was discovered in USS 1, one of the last layers before the abandonment of the southern area of the citadel of al-Balid. It is one of the best examples of planks from sewn boats, with regularly-spaced holes along the edge and frame-lashing holes.	No diagnostic material associated with the find. Date range (11-15th centuries AD)



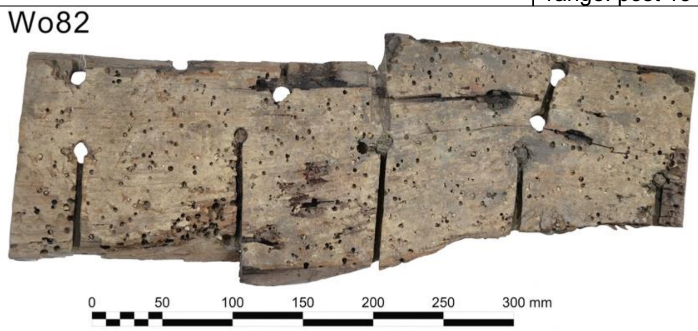
Wo70	Wooden peg used to plug the stitching hole from a ship plank discovered in USS 1.	No diagnostic material associated with the find. Date range (11-15th centuries AD)

Wo72	Long sewn plank with evenly spaced sewing holes and decorative motifs painted along the edge.	No diagnostic material associated with the find. Date range: post 15th century AD.



Wo73	Plank discovered in USS 1 displaying decoration and Arabic text painted on the former outer edge. On the basis of the similarities with evidence from Islamic forts in Oman (Jabrin and Nizwa), the timber was probably reused as a ceiling plank in a citadel room.	No diagnostic material associated with the find. Date range (11-15th centuries AD)

Wo82	Short plank from a sewn boat with the outer surface affected by shipworm.	No diagnostic material associated with the find. Date range: post 15th century AD.



Wo85	Timber from a sewn boat with degraded surface.	No diagnostic material associated with the find. Date range (11-15th centuries AD)

Wo86	Long plank from a sewn boat, discovered in the north-eastern corner of the citadel, in M154 (=M60), a layer of debris used to fill the area before the construction of the tower.	No diagnostic material associated with the find. Date range (11-15th centuries AD)

<table>
<tr><td colspan="3">
</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Wo94</td><td>Large and thick plank discovered in the east wall of the citadel.</td><td>No diagnostic material associated with the find. Date range (11-15th centuries AD)</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Wo98A</td><td>One of the longest planks of the collection – from a sewn boat. It was discovered placed in the top side of a deep recess located in the southern entrance of the citadel (M182), used as a locking system for the gate.</td><td>1304-1364 Cal AD; 1384-1422 Cal AD.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Wo98A</td><td>Cylindrical wooden peg from plank Wo98A used to connect two adjacent planks in a boat hull.</td><td>1304-1364 Cal AD; 1384-1422 Cal AD.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Wo98B</td><td>One of the longest planks of the collection – from a sewn boat. It was discovered placed in the top side of a deep recess located in the southern entrance of the citadel (M182), used as a locking system for the gate.</td><td>No diagnostic material associated with the find. Date range: post 15th century AD.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

Wo98C	One of the longest planks of the collection – from a sewn boat. It was discovered placed in the top side of a deep recess located in the southern entrance of the citadel (M182), used as a locking system for the gate.	1320-1350 Cal AD
		

Methods

For desiccated wood (and charcoal), the application of scanning electron microscopy (SEM) rather than optical microscopy enables illustration of a better depth of field in the preserved cell structure, as well as having the facility to offer high magnification imaging. Because of the three-dimensional nature of wood anatomy, each sample of wood, irrespective of size or condition, was fractured manually to show transverse section (TS), radial longitudinal section (RLS) and tangential longitudinal section (TLS) for examination (Cartwright 2015). Each TS, RLS and TLS sample was then mounted on a double-sided adhesive pad on an aluminium SEM stub for SEM examination; no other sample preparation was required. The samples were examined uncoated in the Hitachi S-3700N variable pressure scanning electron microscope (VP SEM) in the Department of Scientific Research at the British Museum using the backscatter electron (BSE) detector with the accelerating voltage of 15 kV (and occasionally at 10kV or 20kV). For optimal visualisation of diagnostic cellular detail on these samples, the working distance varied from 9.8 mm to 19.6 mm, as dictated by the individual fragment being examined. Magnifications ranged from x25 to x750. The chamber pressure also varied according to the state of preservation of each fragment. Most were imaged using VP, with 40Pa (or 30Pa) chamber pressure, which was used to eliminate surface charging on non-conducting samples. With the BSE detector, 3D mode was preferentially selected to maximize the opportunity to reveal diagnostic features for identification, although Compositional mode was occasionally deployed. The Oxford Instruments energy-dispersive X-ray spectroscopy (EDX) analyser attached to the SEM was used to provide elemental identification and semi-quantitative compositional information where necessary e.g. to determine whether crystals, inclusions and secondary infilling consisted of calcium or silica. The data bar on each of the SEM images that constitute the Figures in this report show the operating condition details including the scale bar in microns or mm.

Identifications were made using the definitions and protocols laid down by the International Association of Wood Anatomists (Wheeler et al. 1989; Wheeler 2011), with modifications made to accommodate the effects of desiccation (Cartwright 2015). In-house reference collection specimens and thin-sections of wood from the Arabian Peninsula and specifically from Oman were consulted for comparative purposes, as were key publications that included Ghazanfar 1992; 2003-2018; Ghazanfar and Fisher 1998; Manzo et al. 2019; Miller and Morris 1988; Tardelli and Raffaelli 2006 (see **References** for a full listing)

Results

Table 2 gives the results of the VP SEM wood identifications.

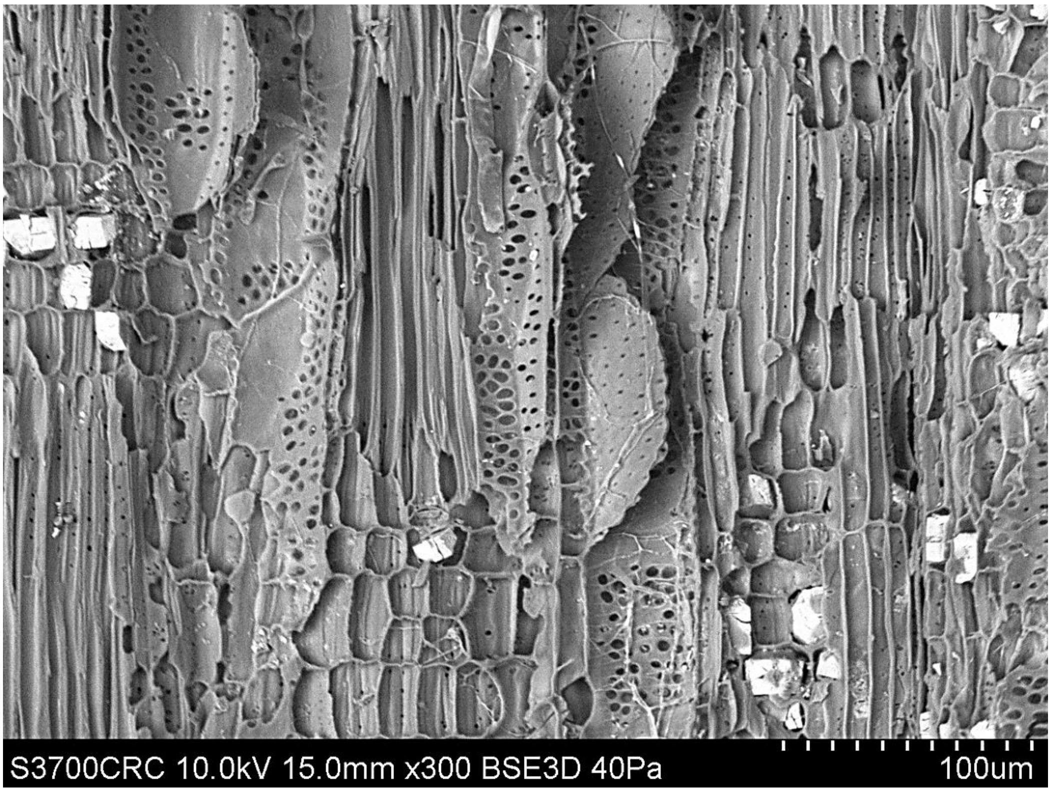
TABLE 2

Identified desiccated wood samples according to context

Sample number	Context and further information	Wood identification
823.B3.98-1235	Small fragment with stitching holes arranged in a way that suggests a "double wadding" sewn pattern, similar to that observed in the 8th and 9th century shipwrecks discovered in Thailand (Phanom-Surin) and in Indonesia (Belitung).	*Celtis africana*, hackberry; Figure 1
BA.01.11.01	One of the largest timbers of the collection, it was discovered in the north-west corner of the southern entrance of the citadel. It displays the same sewn pattern as the previous timber.	*Tectona grandis*, teak; Figure 2
BA0604128.73	Cylindrical wooden peg from plank used to connect two adjacent planks in a boat hull	*Avicennia marina*, white mangrove Figure 3
BA1104065.449	Plank from a sewn boat with holes regularly spaced along the edge, with rope fibres inside.	*Tamarix* sp., tamarisk; Figure 4
BA1104065.450	Plank with stitching holes and geometrical decorative motives carved on outer surface.	*Ziziphus spina-christi*, Christ's thorn / sidr
BA1104065.454	Sewn plank with evenly spaced holes. The wood is hard and well preserved.	*Ziziphus spina-christi*, Christ's thorn / sidr; Figure 5
BA1104065.447	Large beam reused as a lintel over a small window in wall M89 of Room A9 of the citadel. Because of the shape, notches on the surface and presence of holes with fibre ropes still in situ, it resembles a through-beam, typically used in sewn boats.	*Acacia* sp., acacia; Figures 6 and 7
Wo45	Wooden peg used to plug the stitching holes on plank Wo45.	*Ficus* sp., fig; Figure 8
Wo54	Large plank from a sewn boat. The timber was discovered in USS 1, one of the last layers before the abandonment of the southern area of the citadel. It is one the best examples of planks from a sewn boats, with regularly-spaced holes along the edge and frame-lashing holes.	*Tectona grandis*, teak; Figure 9
Wo63	Sewn plank made of a very porous wood.	*Tamarix* sp., tamarisk
Wo68	The timber was discovered in USS 1, one of the last layers before the abandonment of the southern area of the citadel. It is one the best examples of planks from a sewn boat, with regularly spaced holes along the edge and frame-lashing holes.	*Acacia* sp., acacia
Wo70	Wooden peg used to plug the stitching hole from a ship plank discovered in USS 1.	*Tectona grandis*, teak; Figure 10
Wo72	Long plank with evenly spaced sewing holes and decorative motifs painted along the edge.	*Albizia lebbeck*, lebbeck tree; Figure 11
Wo73	Plank discovered in USS 1, displaying decoration and Arabic text painted on the former	*Tectona grandis*, teak; Figure 12

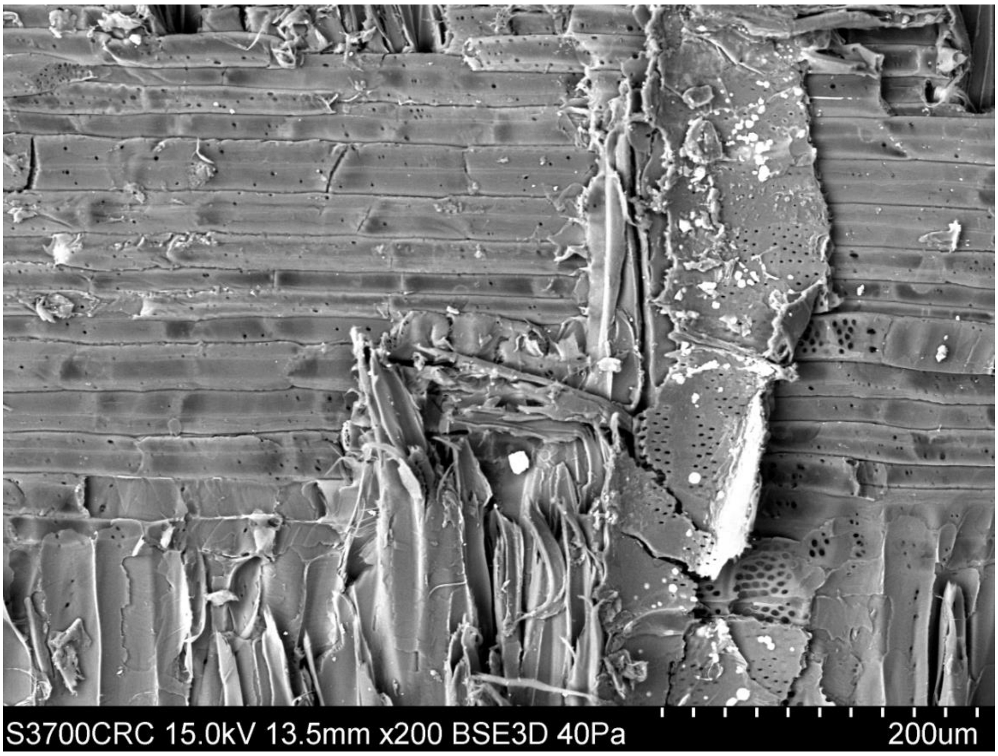
	outer edge. Similarities with the evidence from Islamic forts in Oman (Jabrin and Nizwa) suggest that the timber was probably reused as a ceiling plank in one of the citadel rooms.	
Wo82	Short plank from a sewn boat with the outer surface affected by shipworm.	*Celtis africana*, hackberry
Wo85	Timber from a sewn boat with degraded surface.	*Tamarix* sp., tamarisk
Wo86	Long plank from a sewn boat, discovered in the north-eastern corner of the citadel, in M154(=M60), a layer of debris used to fill the area before the construction of the tower.	Wood is *Tectona grandis*, teak; Figure 13 Stitching ropes are *Hyphaene thebaica,* dom palm fibres; Figure 14
Wo94	Large and thick plank discovered in the east wall of the citadel.	*Tectona grandis*, teak; Figure 15
Wo98A	One of the longest planks of the collection – from a sewn boat. It was discovered placed in the top side of a deep recess located in the southern entrance of the citadel (M182), used as a locking system for the gate.	*Tectona grandis*, teak; Figure 16
Wo98A	Cylindrical wooden peg from plank used to connect two adjacent planks in a boat hull	*Avicennia marina*, white mangrove
Wo98B	One of the longest planks of the collection – from a sewn boat. It was discovered placed in the top side of a deep recess located in the southern entrance of the citadel (M182), used as a locking system for the gate.	*Tectona grandis*, teak; Figure 17
Wo98C	One of the longest planks of the collection – from a sewn boat. It was discovered placed in the top side of a deep recess located in the southern entrance of the citadel (M182), used as a locking system for the gate.	*Tectona grandis*, teak; Figure 18

Figure 1



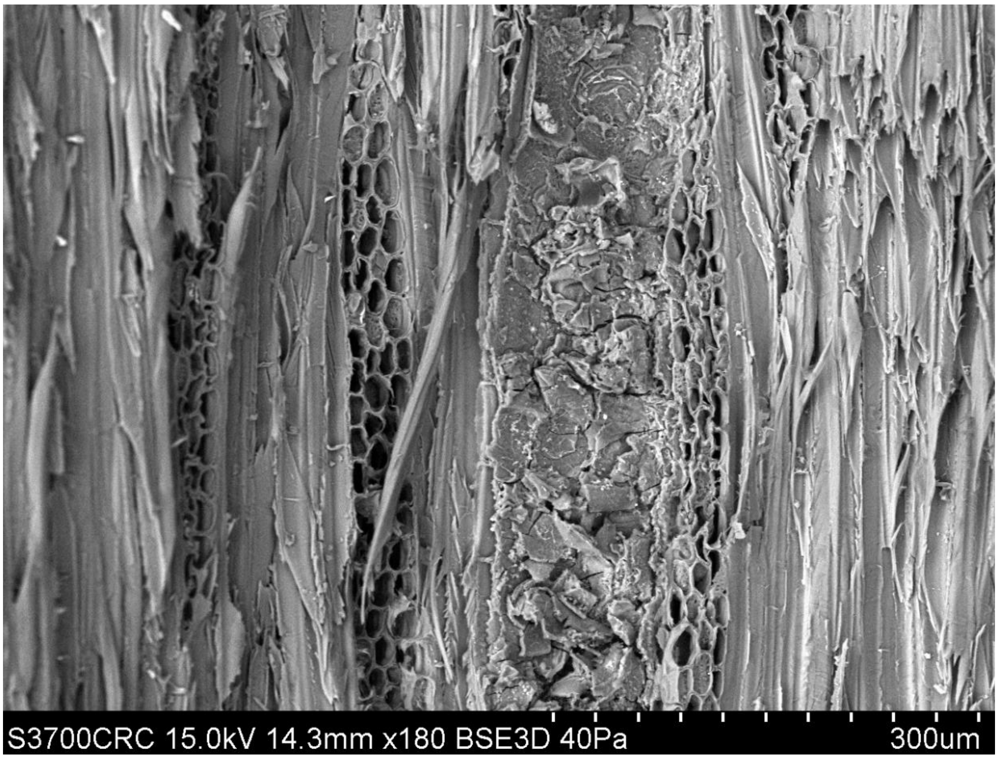
Scanning electron microscope image of a radial longitudinal section of *Celtis africana (*hackberry) wood from 823.B3.98-1235 from a sewn boat. The wood has been affected by fungus; traces of thread-like fungal hyphae can be seen in the vessel cell cavities. SEM EDX showed that the prismatic crystals in parenchyma cells are calcium oxalate. Image C.R. Cartwright © The Trustees of the British Museum

Figure 2



Scanning electron microscope image of a radial longitudinal section of *Tectona grandis* (teak) wood from BA.01.11.01 large timber. Image C.R. Cartwright © The Trustees of the British Museum

Figure 3

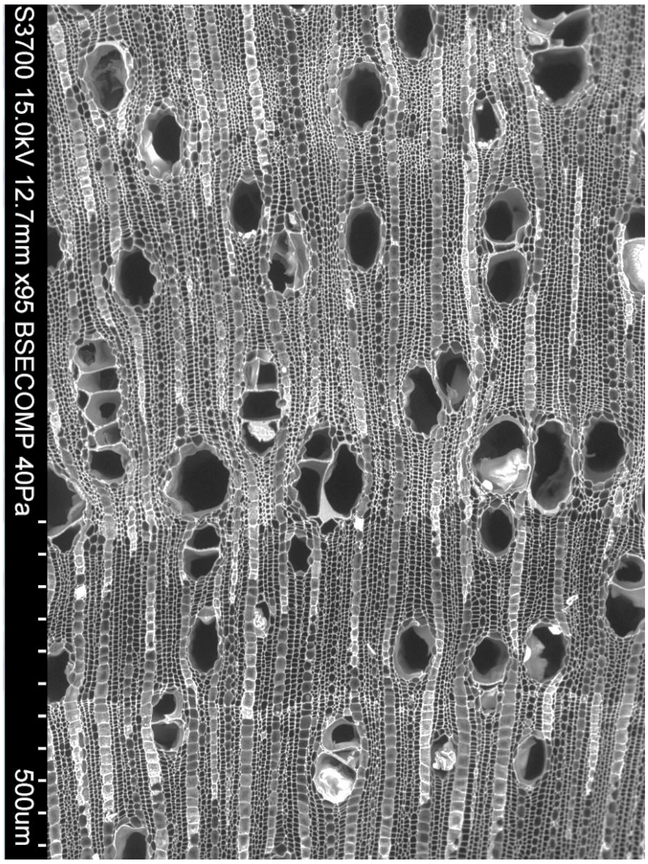


Scanning electron microscope image of a tangential longitudinal section of *Avicennia marina* (white mangrove) wood from BA0604128.73 peg. Image C.R. Cartwright © The Trustees of the British Museum

Figure 4

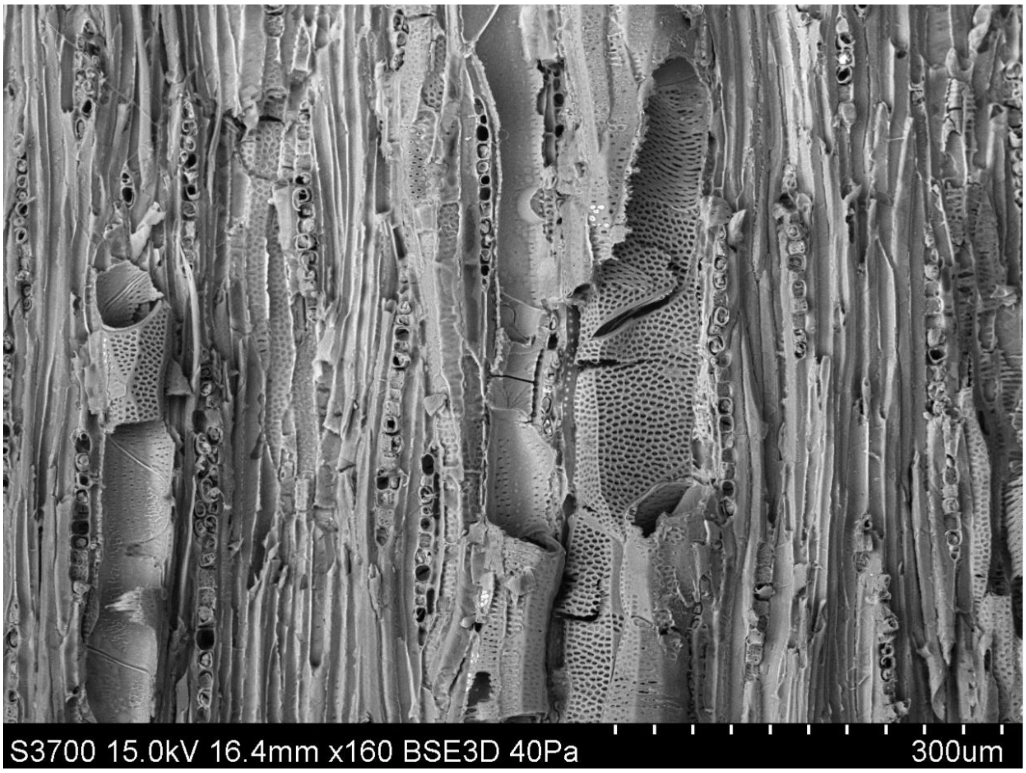
Scanning electron microscope image of a radial longitudinal section of *Tamarix* sp. (tamarisk) wood from BA1104065.449, a sewn boat plank. The wood has been affected by insect damage, whose frass can be seen on the left-hand side of the image. Image C.R. Cartwright © The Trustees of the British Museum

Figure 5



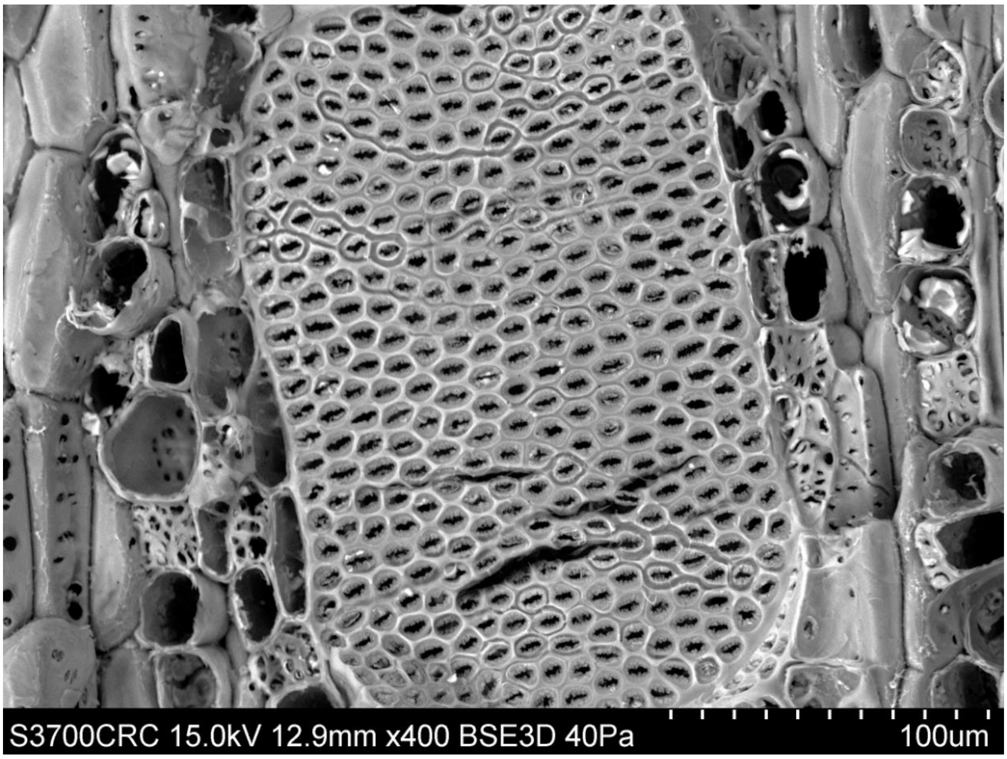
Scanning electron microscope image of a transverse section of *Ziziphus spina-christi* (Christ's thorn / sidr) plank wood from BA1104065.450. Image C.R. Cartwright © The Trustees of the British Museum

Figure 6



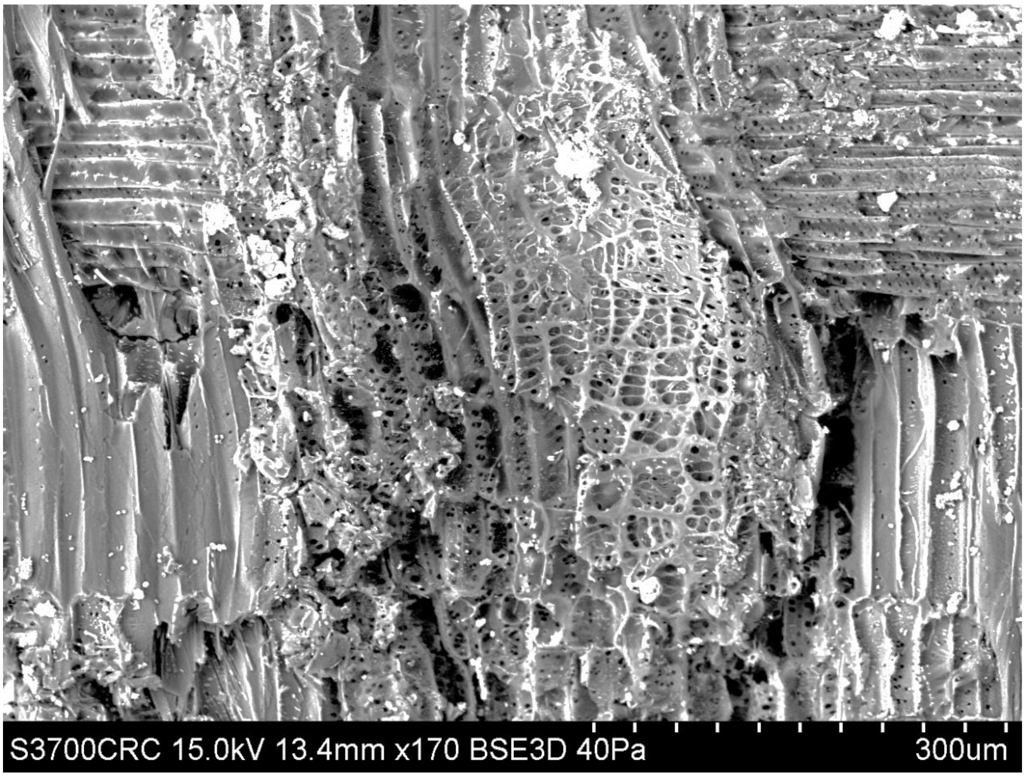
Scanning electron microscope image of a tangential longitudinal section of *Acacia* sp. (acacia) wood from BA1104065.447, a large beam. Image C.R. Cartwright © The Trustees of the British Museum

Figure 7



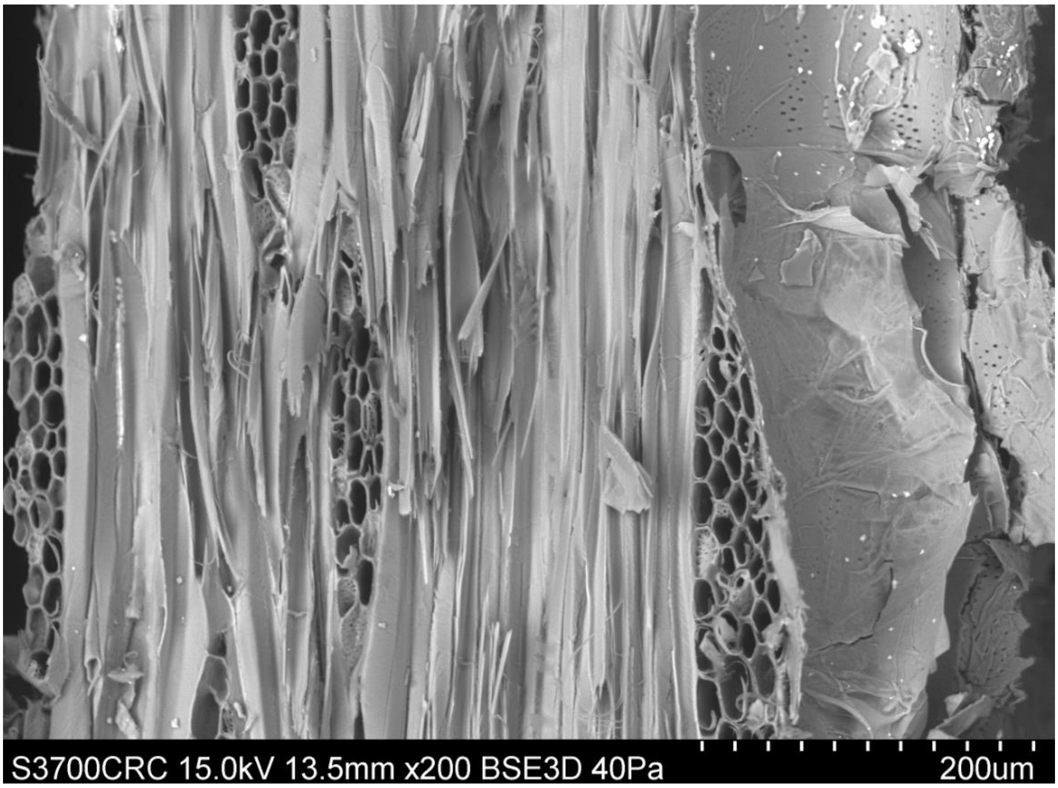
Scanning electron microscope image of the diagnostic vestured pits in a vessel cell wall of this tangential longitudinal section of *Acacia* sp. (acacia) wood from BA1104065.447, a large beam. Image C.R. Cartwright © The Trustees of the British Museum

Figure 8



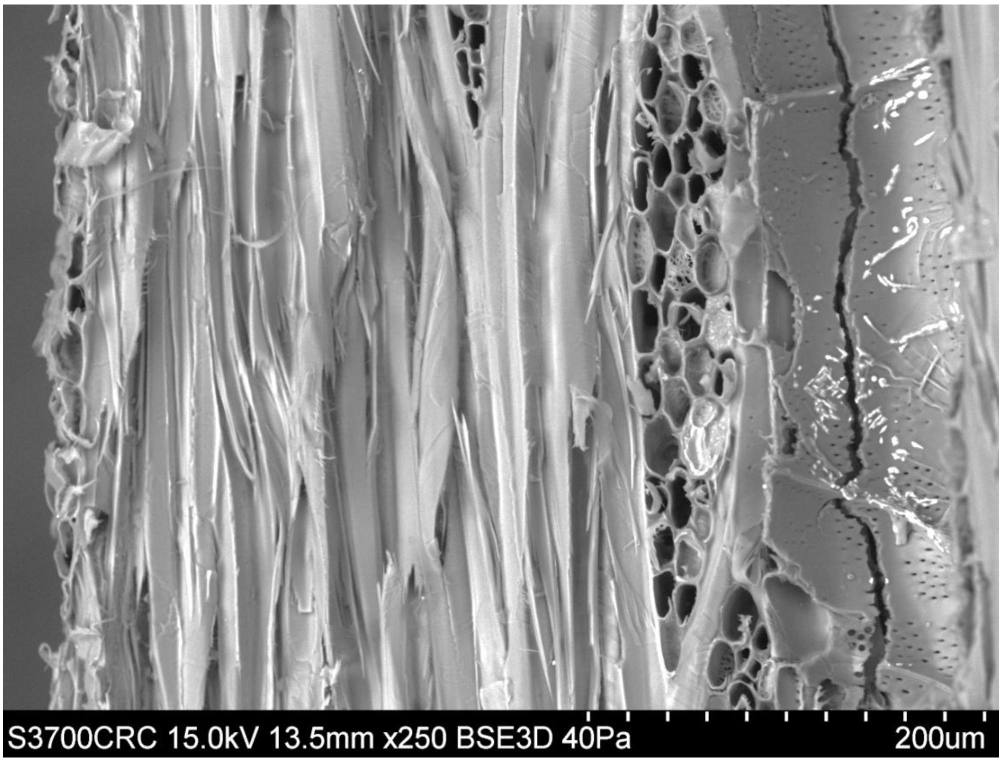
Scanning electron microscope image of a radial longitudinal section of *Ficus* sp. (fig) wood from Wo45 peg. Image C.R. Cartwright © The Trustees of the British Museum

Figure 9



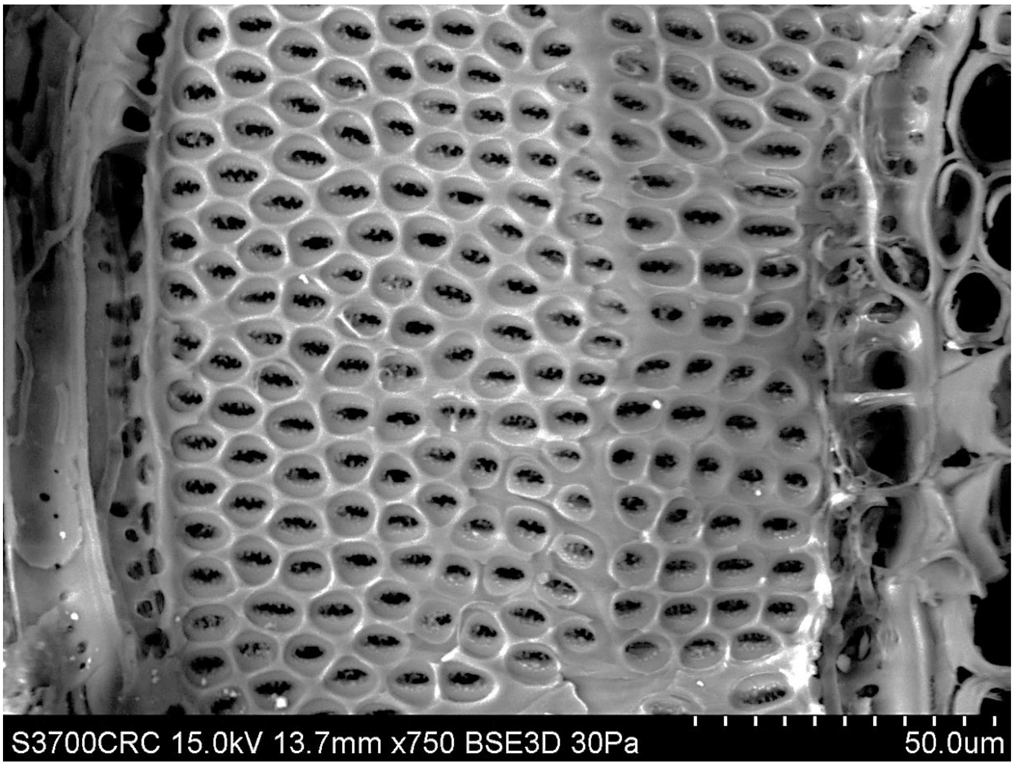
Scanning electron microscope image of a tangential longitudinal section of *Tectona grandis* (teak) wood from Wo54 large plank. Image C.R. Cartwright © The Trustees of the British Museum

Figure 10



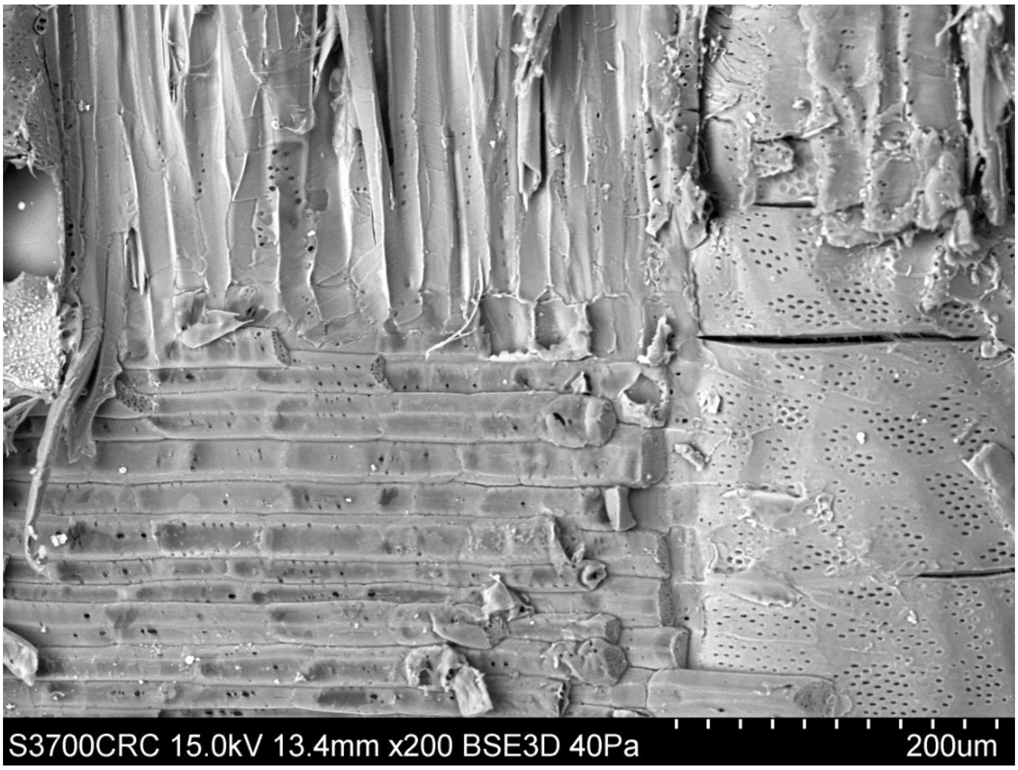
Scanning electron microscope image of a tangential longitudinal section of *Tectona grandis* (teak) wood from Wo70 peg. Traces of fungal hyphae are present on the inner wall of the vessel cells. Image C.R. Cartwright © The Trustees of the British Museum

Figure 11



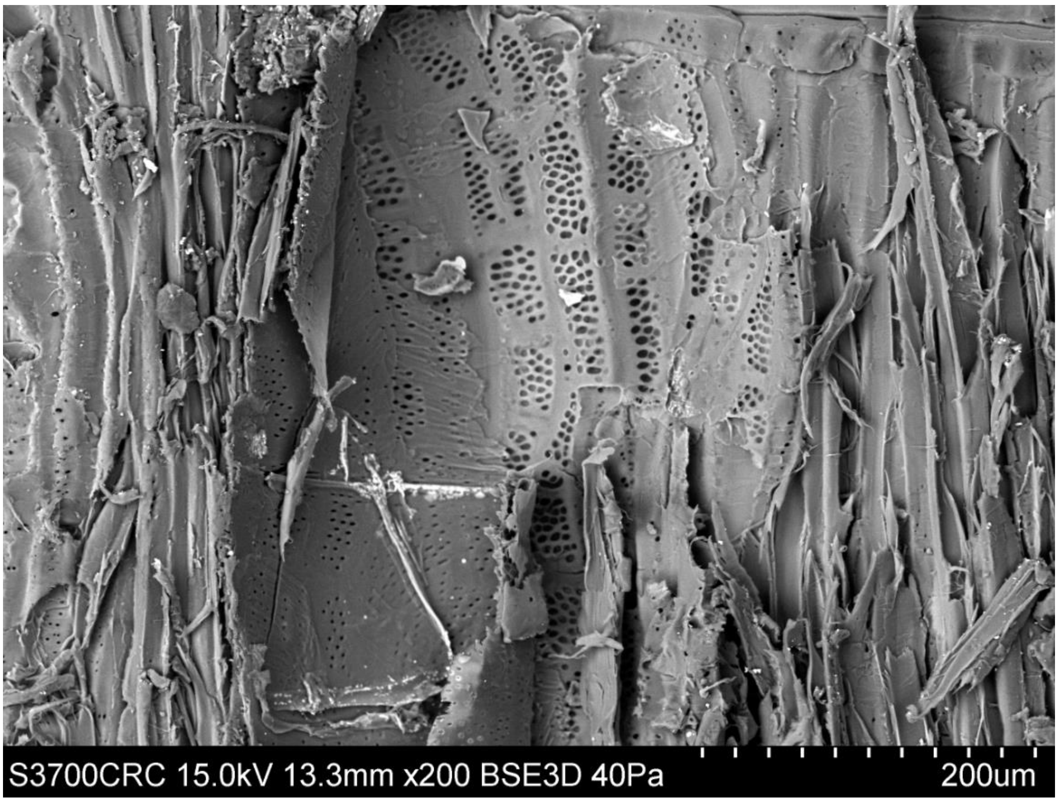
Scanning electron microscope image of the vestured pits of a vessel cell (at x750 magnification) in a tangential longitudinal section of *Albizia lebbeck* (lebbeck tree) wood from Wo72 plank. Image C.R. Cartwright © The Trustees of the British Museum

Figure 12



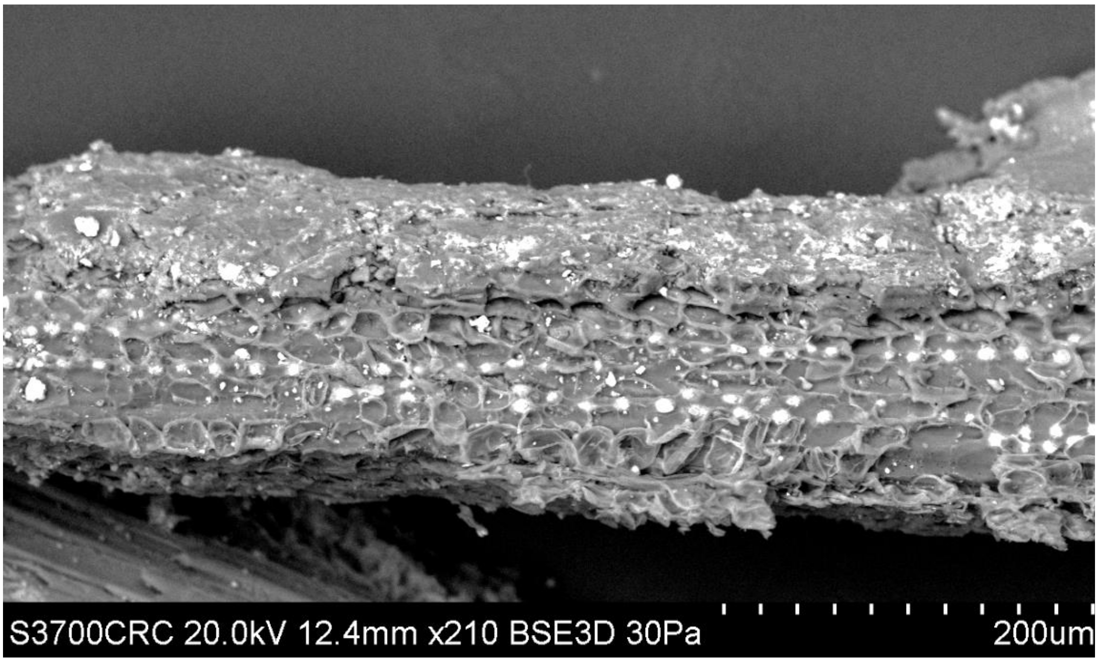
Scanning electron microscope image of a radial longitudinal section of *Tectona grandis* (teak) wood from Wo73 plank. Image C.R. Cartwright © The Trustees of the British Museum

Figure 13



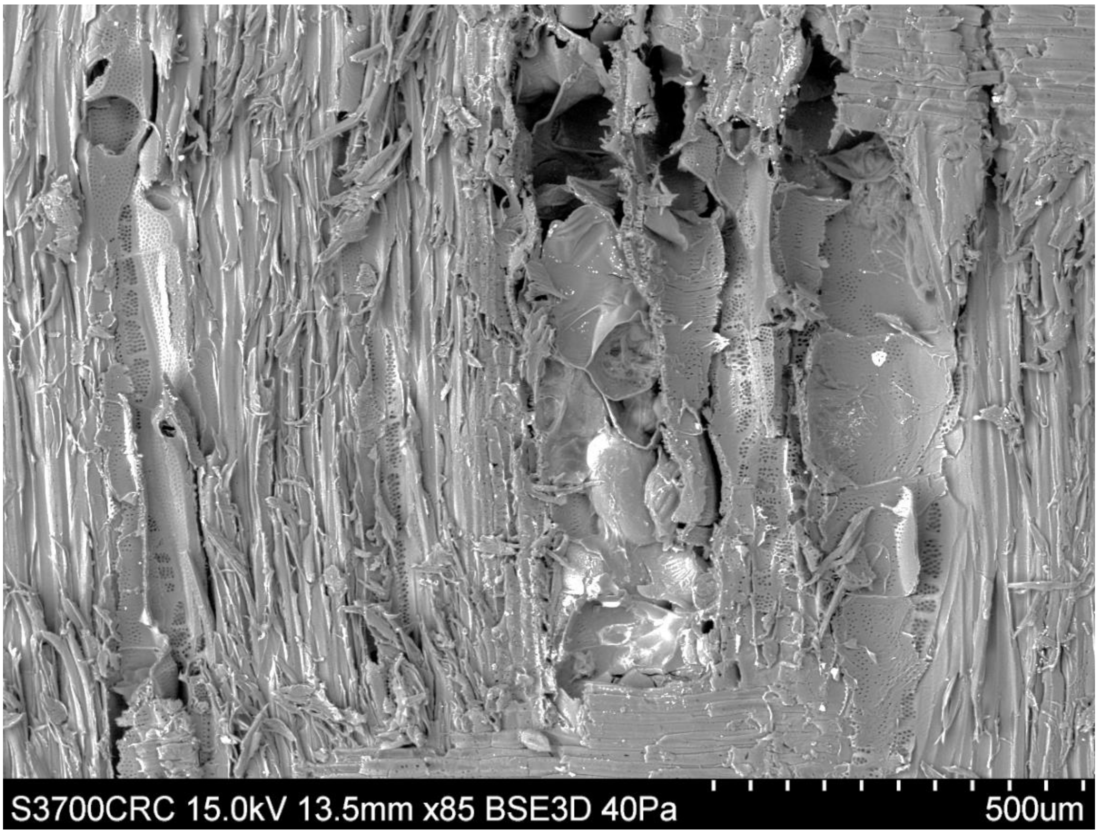
Scanning electron microscope image of a radial longitudinal section of *Tectona grandis* (teak) wood from Wo86 sewn boat plank. Image C.R. Cartwright © The Trustees of the British Museum

Figure 14



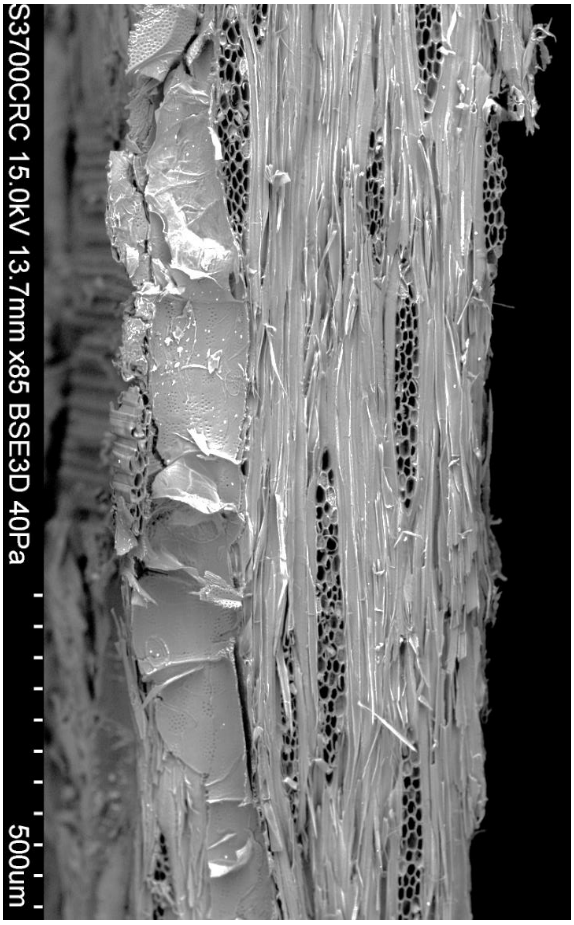
Scanning electron microscope image of a *Hyphaene thebaica,* dom palm fibre from the stitching ropes of Wo86, sewn boat plank. Image C.R. Cartwright © The Trustees of the British Museum

Figure 15



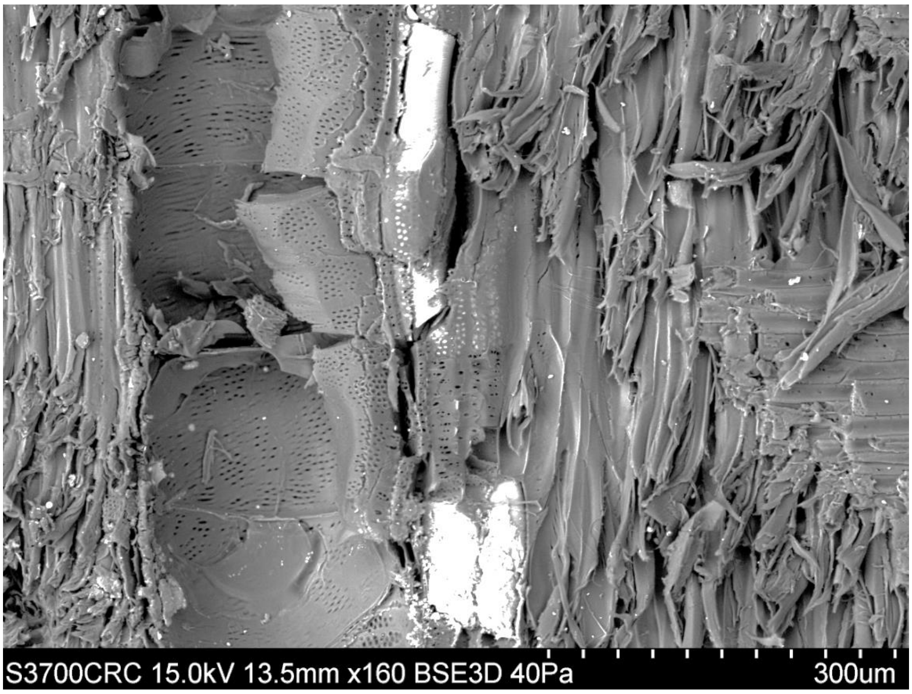
Scanning electron microscope image of a radial longitudinal section of *Tectona grandis* (teak) wood from Wo94 large plank. Image C.R. Cartwright © The Trustees of the British Museum

Figure 16



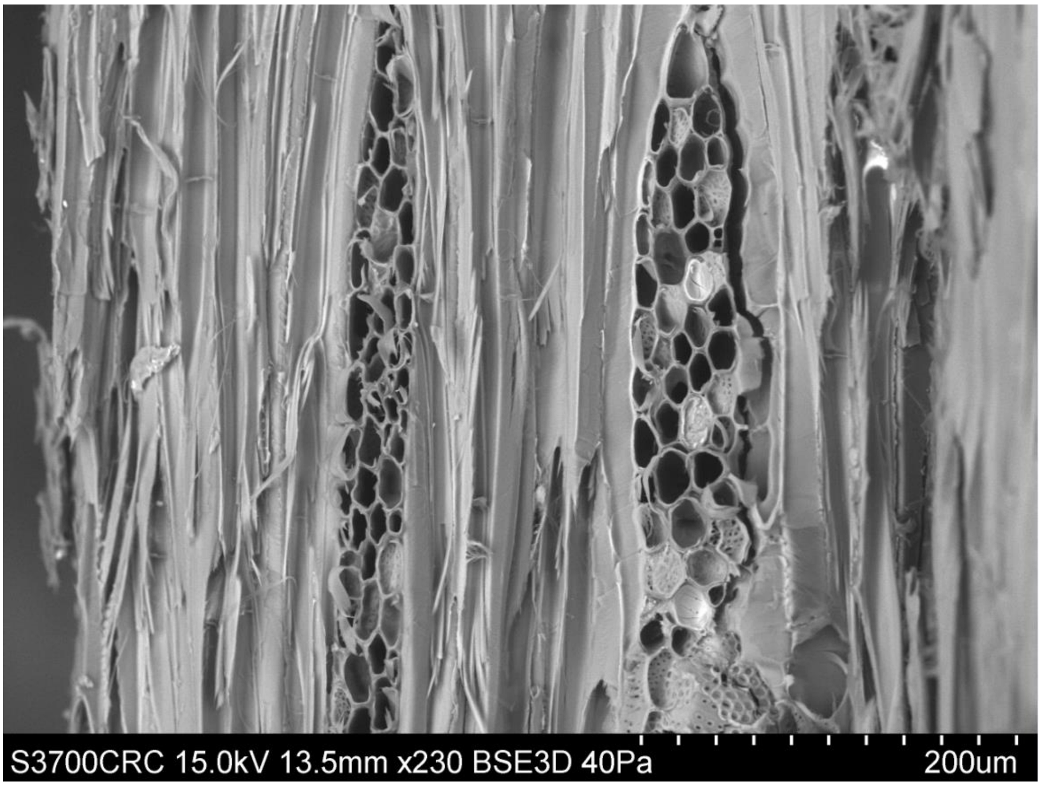
Scanning electron microscope image of a tangential longitudinal section of *Tectona grandis* (teak) wood from Wo98A, a long plank from a sewn boat. Traces of fungal hyphae are present on the inner wall of the vessel cells. Image C.R. Cartwright © The Trustees of the British Museum

Figure 17



Scanning electron microscope image of a radial longitudinal section of *Tectona grandis* (teak) wood from Wo98B, a long plank from a sewn boat. The white areas are salt encrustations. Image C.R. Cartwright © The Trustees of the British Museum

Figure 18



Scanning electron microscope image of a tangential longitudinal section of *Tectona grandis* (teak) wood from Wo98C, a long plank from a sewn boat. Image C.R. Cartwright © The Trustees of the British Museum

A summary of the results is presented in Table 3.

Table 3

Total number of samples	Botanical identification	Planks	Pegs	Stitching rope
9	*Tectona grandis*, teak wood	8	1	
3	*Tamarix* sp., tamarisk wood	3		
2	*Celtis africana*, hackberry wood	2		
2	*Ziziphus spina-christi*, Christ's thorn / sidr wood	2		
2	*Acacia* sp., acacia wood	2		
2	*Avicennia marina*, white / dwarf mangrove wood		2	
1	*Ficus* sp., fig wood		1	
1	*Albizia lebbeck*, lebbeck tree wood	1		
1	*Hyphaene thebaica,* dom palm fibres			1

Discussion and Conclusions

Wood (and wood charcoal) on archaeological sites can often be used to reconstruct past environments, particularly when there is a sequence of botanically rich deposits that testifies to change over time (e.g. Cartwright 2013). Timbers from historical and archaeological maritime contexts (or associations), however, are more indicative of specific selection whereby particular trees and shrubs are chosen because they have wood well-suited to the purpose for which they are intended i.e. to perform well as elements in the construction of ships, boats and dhows. The possibility of (local or regional) political or administrative controls over wood resources cannot be ignored, and the economic value of wood as trading or bartering commodities should not be overlooked. The import of prized timber for building dhows in Oman, particularly of species from India, is a practice that has been observed by the author at Sur since 1992; also see Villiers (1948) for observations regarding dhow wood trade. In both the archaeological and historical past, construction of maritime boats may have taken place in particular areas, and could have utilized timbers from a variety of local and non-local sources. It does not follow that the findspots of maritime boats that have timber surviving for sampling and scientific identification have necessarily used the woody resources of the region of the findspot. However, it may also be that whilst major components of the maritime boats have utilized timbers brought in or traded from a variety of sources (including those imported from other countries), for some of the smaller components, local timbers are likely to have been put to good use. At Ra's al-Hadd, for example, the local *Avicennia marina* mangrove, consistently present in the Bronze and Iron Age archaeological record (Cartwright 1988; 2004; Cartwright and Glover 2002), is reported by local fishing communities at Ra's al-Hadd, Ra's al-Junayz and Sur to have been used for wooden dhow ribs and poles.

Turning to Table 2, there follows herewith (according to listed sequence in Table 2) an examination of each botanical taxon represented by the desiccated wood samples and one fibre sample) in terms of their potentially useful properties and their possible geographical sources. Many of the wood samples have been identified to genus level only, rather than to species level. This is attributable to the cellular condition of the timber samples.

Celtis africana, hackberry produces a good utilitarian timber, but may be susceptible to fungus and insect attack. Figure 1 exemplifies this in the SEM image of a radial longitudinal section of hackberry wood from 823.B3.98-1235 from a sewn boat. Traces of thread-like fungal hyphae can be seen in the vessel cells. *Celtis africana* prefers dry evergreen and riverine forest, but can also occur in Afromontane forest (Cartwright 2013) and upland rainforest. Its native distribution ranges from tropical and southern Africa to the Arabian Peninsula, (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:850978-1#distribution-map).

Tectona grandis, teak wood has long been regarded as very valuable, particularly for boat-building because of its strength and durability, as well as its resistance to rotting, cracking and splitting (Tripati et al. 2016). Tables 2 and 3 (above) demonstrate its popularity amongst with al-Balid boat timbers, with eight out of the nine examples of teak wood representing major plank elements (Figures 2, 9-13, 15-18), and one a plank peg (Figure 10). Teak is not native to Arabia. Usually found growing in monsoon rainforests, teak's native geographical distribution is in south-east Asia, including India, Bangladesh, Cambodia, Laos, Myanmar, Thailand and Vietnam (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:864923-1#distribution-map).

Avicennia marina, white / dwarf mangrove trees colonise sandy estuaries, tidal rivers and mud banks across Arabia and other parts of the world (for more details see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:861130-1). Its wood is hard, durable and heavy, but not always easy to work (for more details see https://uses.plantnet-project.org/en/Avicennia_marina_(PROTA)).

Several species of *Tamarix* are native to Arabia (see Ghazanfar and Fisher 1998, and http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:326334-2).Tamarisk trees do not produce the highest quality timber, may split during cutting, and are susceptible to insect attack. Being tolerant of high temperatures, halophytic (salt-tolerant) and xerophytic (arid-tolerant), tamarisks can adapt to a wide range of ecological conditions. It is likely that *Tamarix nilotica*, amongst other tamarisk species, has been used for the al-Balid ship timbers; this taxon has a wide distribution across Arabia, north-eastern and East Africa (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:828178-1).

Ziziphus spina-christi, Christ's thorn/sidr has a native distribution range from Mauritania to Pakistan (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:719427-1#distribution-map). Found in tree and shrub forms, *Ziziphus spina-christi* inhabits river-banks, desert wadis and scrubland thickets. Some of the more marginal habitats may restrict the straight growth of sidr, resulting in twisted or knotty timber (albeit very dense), with wood suitable for planks more of a rarity. Nonetheless, two of the al-Balid samples have used this wood for planks, no doubt because it is hard, heavy and termite-resistant.

Although there are regional geographical distributions among acacias, microscopical differentiation of species is extremely difficult on account of their anatomical similarities, and there are unresolved and controversial issues regarding taxonomy for acacias outside Australia (Kyalangalilwa 2013). For convenience, these are still referred to as *Acacia* sp. in this report largely because the reassignment either to the genus *Vachellia* or to the genus *Senegalia* is dependent on the species being identified (and it has just been noted above that species-level identification is not feasible here). Some acacias are large trees and are characteristic of the river banks. Others are small trees or shrubs and favour shrubland, semi-desert or desert vegetation (see Ghazanfar and Fischer 1998:142 for more details regarding vegetational and community associations of Arabian acacias). These differences in tree size and shape have an impact on the wood available for particular purposes. Wood from shrubby acacia species is seldom straight-growing, of great length or girth, although it may be hard, heavy, durable and termite-resistant, so if timber from larger acacias can be sourced, good quality planks may be fashioned. *Acacia nilotica* (synonym *Vachellia nilotica*) is likely to have been amongst the acacia species sourced for the al-Balid ship timbers as its wood is strong and durable (nearly twice that of teak) and particularly insect-resistant. The distribution of *Acacia nilotica* (synonym *Vachellia nilotica*) is widespread across Arabia and Africa (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:77089275-1#distribution-map), but other *Acacia* and *Vachellia* taxa are native to Arabia, India, Pakistan and East Africa and, as possible source areas for Indian Ocean ship timbers, these distributions need to be taken into account as well (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:325783-2#distribution-map; http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:30000732-2#distribution-map).

Ficus sp., fig wood is not of the highest quality; it is not very durable and is prone to insect damage, but it is soft, light and easy to carve. Fig trees (with their invasive root systems) prefer to grow where there is a high water table, such as along rivers or in swamps, but may also be found in wadis with sheltered gallery forests on humid mountain slopes, sometimes in crevices where there is accumulated moisture (Ghazanfar and Fisher 1998:166). Several *Ficus* species are native to Oman (see http://www.plantsoftheworldonline.org/?q=Oman%2CFicus), and even more are native to Arabia and adjacent regions (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:327905-2#distribution-map).

The native range of *Albizia lebbeck*, lebbeck trees extends from the Indian subcontinent to Myanmar (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:99109-3#distribution-map). With toleration of drought and some frost, lebbeck trees grow in semi-evergreen monsoon forests, deciduous thickets on mountain slopes, and on river-banks. The wood is moderately hard and fairly durable, but is susceptible to attack by marine borers and termites (see https://www.woodworkerssource.com/show_tree_wood.php?wood=Albizia%20lebbeck). Semaan (2019:509) notes that in the context of boatbuilding, the date of introduction of *Albizia lebbeck* wood into Arabia is unknown.

Hyphaene thebaica, dom (or doum) palm has a native range from tropical West Africa to Egypt and Arabia (see http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:667540-1#distribution-map). In addition to edible fruits and medicinal uses for other parts of the plant, dom palm leaf fibres are strong: often used for ropes, string, basketry, mats and nets (see https://www.prota4u.org/database/protav8.asp?h=M4&t=Hyphaene,thebaica&p=Hyphaene+thebaica#Synonyms).

In conclusion, the results of the scanning electron microscope wood identifications show that major structural elements of the al-Balid boats have utilized timbers imported or traded from a variety of sources, including those brought in from other regions, local timbers could have been used for some of the smaller components.

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