Principles in East Asian Shipbuilding Traditions

by Jun Kimura

Thesis submitted in the fulfilment of the requirement of the degree for Doctor of Philosophy

Department of Archaeology
Faculty of Education, Humanities and Law
Flinders University

Contents

Abstract

The archaeological study of excavated ships has significant potential to contribute to the realm of past seafaring and maritime activities in East Asia. This research assesses ship structure and construction methods, highlighting technological innovations identified in thirteenth and fourteenth centuries' ship remains in China, Korea, and Japan. The existence of diverse shipbuilding traditions has been noted within the region. Endemic features in shipbuilding, however, have been understood as a linear evolutionary development. Innovations generate from not only endogenous growth but also exogenous factors. Technological hybridization concerning the use of a hull component from different traditions is a principle involved in shipbuilding technologies.

One such hull component that has been identified by archaeologists and historians in East Asia is the bulkhead. This component has been linked to technological innovations and its importance needs more study. This research pursues the bulkhead in the structure of oceangoing ships in relation to technological innovations, diffusion, and hybridization which formed regional shipbuilding traditions with other factors, such as environmental elements and material availability. The examination of these factors contributes to a wider understanding of the formation of shipbuilding traditions identified as a "Yellow Sea shipbuilding tradition," an "East China Sea shipbuilding tradition," and a "South China Sea shipbuilding tradition." This framework is developed through reviewing primary and secondary historical resources and sites' reports and studies and archaeological investigations, producing a database of excavated ships in the region.

The "Yellow Sea shipbuilding tradition" is primarily identified in ships showing flat bottoms, operating in the northern waters of the Yellow Sea, yet constructed using two different types of transverse components. The early utilization of bulkheads is archaeologically evidenced in the riverine ships dating back to the Tang Dynasty (618-907 A.D.), compared to early East Asian coastal traders using beams in nearby coastal traders of the Goryeo Dynasty (918-1392 A.D.).

Three case studies of archaeologically recovered East Asian ship remains are the focus of this research: the Quanzhou ship, the Shinan shipwreck, and disarticulated ship timbers from Takashima underwater site. Their structure and construction methods are reviewed in detail. The archaeological examination extends to the assessment of their longitudinal and transverse structure, and the type of timbers

and iron nails used for the hulls. The identified technological innovations on these excavated ships suggest an “East China Sea shipbuilding tradition”, which generally shows v-shaped bottoms, keels and bulkheads, and multiple-layered hull planking. Those ships built according to this tradition actively came to be used in seaborne activities within and beyond the region of East Asia and Southeast Asia.

The “South China Sea shipbuilding tradition” has been defined and is reiterated in this research as a type of hybrid ship integrating East China Sea shipbuilding traditions into Southeast Asian (Austronesian) shipbuilding traditions. While the idea of hybrid ships has been presented in previous research, this study traces the formation of such ships as they evolved from, and related to, adjacent shipbuilding traditions including the “Yellow Sea shipbuilding tradition” and the “East China Sea shipbuilding tradition.”

Declaration of Candidature

'I certify that this thesis does not incorporated without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person expect where due reference is made in the text.'

Singed by Jun Kimura

木村淳

01/December/2011

List of Figures

List of Tables

Acknowledgements

This research would never have been completed without the support from organizations and individuals listed below.

This PhD research has been fully supported by the Endeavour Postgraduate Award provided by Australian Government during the period of 2007-2011 with its administrative assistance from the Austraing International. The Mishima Kaiun Memorial Foundation provided the research with research grant to conduct fieldworks in overseas. Part of result of this research includes the result of the outcomes of a project financially assisted by the Toyota Foundation. Further funding has been obtained through a number of research grants available at Flinders University.

During the fieldwork in China, I obtained full-support from staff of the Quanzhou Maritime Museum (Museum of Overseas History Communication), and I would like to express my gratitude to Dr. Ding, Yuling and Wang, Feng. During the fieldwork in Korea, the staff of the National Research Centre of Marine Cultural Heritage (National Maritime Museum) provided in-kind support, and I want to thank Seong, Nack-Jun and Lee, Chul-han. I have greatly benefited from the staff of Matsuura city for their support during my research in Takashima. A part of the data presented in this research has been obtained through cooperation with Drs. Noshiro, Shuichi and Abe, Hisashi from the Forestry and Forest Products Research Institute and Osawa, Masami from the Kyushu Techno Research Inc. My appreciation extends to experts and members of the following organizations for their support: Asian Research Institute of Underwater Archaeology, Australasian Institute for Maritime Archaeology, École française d'Extrême-Orient, Department of Maritime Archaeology of Western Australian Museum, Institute of Nautical Archaeology at Texas A&M University, Ministry of Marine Affairs and Fisheries of Republic of Indonesia, National Museum of the Philippines, Shipbuilding History Research Centre at Wuhan University, Thai Underwater Archaeology Division of Fine Arts Department.

I especially thank the following individuals for their generous support during the fieldwork, including Randall Sasaki, Amer Khan, and Nicholas Burningham who provided insightful advice and feedback during this research. To colleagues during my candidature, James Hunter, Debra Shefi, Adam Paterson, Jason Raupp, and Robert Stone I owed thanks. I owe a very important debt to Kelvin Rodrigues for his editing work. Finally, Dr. Mark Staniforth, Dr. Jeniffer McKinnon, and Jeremy

Green are acknowledged for their supervision based on their expertise. My appreciation also extends many people who are not listed here and who helped me during the period of the four years of research and during the period extending to the last decade, as some of the data used in this research are from the excavations I participated in more than ten years ago.

Chapter I – Introduction

Archaeology of the Boat developed from an archaeological focus on watercraft, and eventually became known as nautical archaeology (Basch 1972; Greenhill 1976; McGrail 1985; Steffy 1994; McGrail 2001). Maritime archaeology since its early development has attempted to contribute to other disciplines, aiming to be accepted within the academic mainstream of archaeology (Bass 1983; Flatman and Staniforth 2006). Archaeological data from shipwrecks and ship remains within an intradisciplinary framework of nautical archaeology and maritime archaeology show potential to contribute to a wide range of discussions, including their construction technology as cultural indicators extending to evidence of a transportation system for material culture (Maarleveld 1995; Staniforth 2002). The data from the practice of shipwreck archaeology is valuable for our understanding of historical seafaring, human life and behaviour on board, and the development of shipbuilding traditions. The realm of East Asian shipwreck archaeology, however, has lagged behind and few attempts have been made in using shipwreck data from this region for thematic research. This is partly due to circumstances that there are not many regional experts in nautical archaeology and maritime archaeologists focusing on the hull in ship remains. Despite the accumulation of data, there is little understanding of the history of oceangoing ships used in the East Asian region. This research aims to fill that gap by analysing data from excavated ships so as to have a better understanding of the history of ships in the region. More specifically, this study is an examination to clarify the characteristics of the shipbuilding technology used for East Asian oceangoing vessels, focusing on the structure and construction of the hull primarily dating from the thirteenth to the fourteenth century.

I-1 Problem orientation

Representative features and the structure of East Asian oceangoing vessels used in the past have been explained by examining shipwreck remains (Keith and Buys 1981; Green 1998; McGrail 2001: 347-384). The remnants of East Asian oceangoing ships often consist of a bottom hull structure which includes a keel, planks, and bulkheads. In particular, adopting bulkhead construction specifically has been dominant over centuries as a specialized technology to secure the hull and develop seaworthiness for sailing the open sea. Although bulkheads were used before the tenth century, bulkhead construction with the combination of a keel and hull planking appeared after the tenth century and has since become a well-established technology. The completion of this shipbuilding technology is evidenced by the remnants of oceangoing vessels found in China, Korea, and Japan.

The dominance of bulkhead construction became apparent in the fifteenth century, as seen in the common technology prevalent in the ships from Southeast Asia, by observing excavated ships in this region (Manguin 1984).

Figure 1-1 Location of ships remnants dating to the late thirteenth and early fourteenth centuries, and important areas and cities in this research.

The significance of bulkhead construction has been strongly credited as a remarkable Chinese innovation (Needham 1971: 389-392). Nevertheless, details of bulkhead construction have yet to be scientifically argued and sufficiently demonstrated. As such, dispute exists as to the practical role of bulkheads. For example, it is unclear if their function was to provide watertight compartments or, they acted as partitions to hold cargo, or were used as transversal structure, or that they might have been related to a combination of these reasons. This research will investigate the significance of bulkhead construction, by critically reviewing ship remains located in China, Korea, and Japan (Figure 1-1). An intensive archaeological and historical investigation of these shipwrecks that date to the thirteenth and fourteenth centuries will result in a fuller assessment of how bulkheads were used in East Asian oceangoing ships. This research will expand the study of structural components from bulkheads to include other integrated structural components and how they are related to the development of ship construction. The remnants of oceangoing ships will be interpreted to provide evidence of technological integration of fundamental components, including keel, planking, iron nail, and bulkhead construction. By focusing on the functions of these individual components and their relationships to each other, the structural details of East Asian oceangoing vessels and their associated construction methods will become apparent.

Discussing bulkhead construction and the integration of hull components in historical East Asian shipbuilding technology is a consistent theme throughout this research. The research will highlight the cognition behind the integration of hull components that technologically occurred in shipbuilding, rather than only researching the sequence of the construction order of hull components. The present research will consider a developed theory in shipwreck archaeology focussed on the sequence of construction order known as the “philosophy of shipbuilding technology,” discussed by Richard Steffy and other nautical archaeologists as one of the principles for interpreting the development of shipbuilding (Steffy 1994; Hocker 2004). This approach of construction sequence, however, may relevantly function only as Medicentric, Grecocentric or Western norms not applicable for East Asia. Thus, this research will develop a more comprehensive theoretical approach to understanding ship construction practices in the region through a focus on innovation, diffusion and hybridization.

Green (1990) and Manguin (1993) initially suggested the importance of understanding hull components in detail in order to explain shipbuilding technologies distinctively used in two adjacent regions that include East Asia and Southeast Asia. Approaching the regional characteristic of hull components is significant for clarifying the technological diversities of ship constructions. A bias exists in the discussion of traditional East Asian shipbuilding technology where Japan and the Korean Peninsula are likely to be assessed in the contexts of the cultural sphere of the Chinese civilization instead of independently. As such, the detailed study of ship structures existing in these regions is often overlooked. In Japanese and Korean shipbuilding traditions bulkheads are not used but an alternative transversal beam system developed in hull structure and construction methods (Green 1986). This transversal beam system needs to be better identified and related to broader East Asian shipbuilding practices. Through a detailed interpretation of multiple structural components of ship remains this research will clarify the development of regional shipbuilding technologies in East Asia.

I-2 Research aims

The broad aim of this research is to provide a better understanding of the history of ship structure and construction, which formed shipbuilding traditions within the East Asian region. This broad aim will be achieved through addressing the following more specific aims including:

1- Identifying previous historical and archaeological research conducted on East Asian shipbuilding to overview excavated ships in the region and clarify their structural characteristics.
2- Developing a theoretical framework of technological evolution with a focus on innovation, diffusion, and hybridization for understanding shipbuilding in East Asia beyond a linear development theory.
3- Reviewing the technological developments, environmental factors and material availability that contributed to and affected shipbuilding in East Asia.
4- Examining two archaeologically excavated ships and the remains of disarticulated ship timbers dating to the late thirteenth and early fourteenth centuries individually in detail as well as comparatively as an inclusive approach to better define oceangoing shipbuilding traditions in East Asia.
5- Investigating whether an approach focusing on bulkhead structures is the appropriate avenue for understanding the evolution of East Asian shipbuilding traditions.

I-3 Research methods and data collection

Two types of data are approached as resources to address the above research aims. The first data set is historical data related to the time period of ship remains to be addressed in this research. Written information and iconographic resources describing ship configurations, characteristics and construction techniques have been reviewed. The contents of the written information include historical texts, such as travel records, written histories of the time period, iconographic paintings and historical accounts of environmental conditions. Most of these have been identified in previous studies by Chinese and Japanese researchers as secondary sources. Some of the secondary sources were accessed through the National Library of Australia and online as reproduction resources of the original manuscripts. Some iconographic source was reviewed locally in Japan.

The second data set is archaeological data, which includes previously published works of excavated archaeological ship remains. An Excel database was produced from these materials as well as informal conversations with practitioners and professionals in the field of maritime history and archaeology. Some of the archaeological data include unpublished photographs, grey literature, and archaeological drawings at repositories including the: Western Australian Museum, Quanzhou Maritime Museum (Museum of Overseas History Communication) in China, National Research Centre of Marine (Maritime) Cultural Heritage (National Maritime Museum) in Korea, and Buried Cultural Property Investigation Center of Takashima in Japan. Archaeological investigations of the ship remains in three countries include: recording ship lines, detailed recording of hull features and components including taking measurements and identifying fastener patterns, joinery patterns and construction sequence, sampling timbers for wooden species analysis and radiocarbon dating, X-ray and CT-scan analyses of the sampled wooden timbers and metallurgical studies to assess the quality of iron remains.

There are limitations associated with these datasets. While Chinese, Japanese and English historical sources and archaeological reports were accessible and readable, sources in other languages were not reviewed or were translated to the author’s language (Japanese). In terms of the archaeological limitations, there were several. The preservation conditions of the hull remains are less than suitable and some of the original construction details and configurations are non-existent. Further, the excavated hulls were reconstructed, which prevented the disassembly to view certain construction details and configurations.

I-4 Significance of study

Maritime archaeology examines past human interaction with oceans, rivers, and fresh waters (Muckelroy 1978; Flatman and Staniforth 2006). It provides the means to assess various archaeological remains such as, ship cargo and hull remains within maritime archaeology, apart from ship cargo studies, the East Asian regions demonstrate a lack of research on ship hull remains. This research provides the most informative data of excavated ships ever produced for East Asia. An inclusive dataset of the ship remains in East Asia is presented based on an outcome from the Shipwreck ASIA project supported by the Toyota Foundation (Kimura 2010a). This recent project has achieved nautical archaeology highlighting regional themes and issues and is designed to be accessible to international and regional professionals.

The history of East Asian ships and shipbuilding has been reviewed by local researchers and non-local scholars. The outcomes emerged by the two different groups, however, have not been addressed together. There are extensive studies by local researchers, in particular, by looking at newly identified archaeological data, but these studies have not been sufficiently assessed by scholars outside of the regions. On the other hand, we hardly see the adoption of western scholars' approaches and perspectives on these studies which are much more descriptive. This research attempts to mitigate these outcomes and approaches through the archaeological investigation of three individual oceangoing ship remains to achieve a detailed analysis of their structure and construction methods.

Tracing the bulkhead in structure and its development over time clarifies technological evolutions of East Asian shipbuilding traditions. The focus of the specific hull component is pursued with a theory highlighting technological innovations, diffusion, and hybridization, rather than a focus on a linear evolutionary development model. As a consequence, this approach provides a new view regarding the transition of the shipbuilding traditions in the Yellow Sea, the East China Sea, and South China Sea. This challenges the current theoretical thought which postulates the existence of a small number of regional shipbuilding tradition studies.

I-5 Chapter structures

The result of this research is presented in ten chapters, considering the presence of informative data and perspectives. This section overviews the structure of these chapters. Chapter I provides a direction for this study by identifying current issues in the archaeological study of East Asian oceangoing ships. This chapter presents a purpose for this research divided into five specific aims. The method and data collection are defined, specifying the three main objects of this research including the Quanzhou ship in China, the Shinan shipwreck in Korea, and Takashima underwater site in Japan an archaeological approach to address the research aims. The chapter also clarifies the significance of the study.

Chapter II is a literature review, identifying previous historical and archaeological research conducted on East Asian ships. This previous research is outlined including perspectives by scholars from outside of the region and achievements by local groups based on different expertises within the theme of East Asian shipbuilding research. This chapter also reviews historical interpretations on the bulkhead structure.

The first section of Chapter III provides a theoretical framework for this research. A principal theory that has been presented previously in nautical archaeology will be reviewed first. The chapter pursues the nature of technology with a focus on its innovation pattern, diffusion, and hybridization. The second section of this chapter reviews environmental backgrounds of the research area. A geographical factor, in particular, the condition of the waters has been regarded an important factor in the development of East Asian seagoing ships by previous researchers. This section will detail endemic differences in the shipbuilding traditions between the north and the south, within East Asia. In this research the difference is explained with information about distinctive ship structures and historical seafaring in two areas respectively.

Chapter IV outlines archaeologically discovered ship remains from China, Japan, and Korea. By looking at the primitive watercraft and ship remains from these countries before the tenth century, the first section aims at clarifying the technologies underlying the development of shipbuilding in the region, as they are important in leading the construction of oceangoing ships in the following periods. The second section of this chapter provides an inventory of excavated ships by using the data from the Shipwreck ASIA project. This includes ship remains identified in China dating to the period of the Tang and Qing Dynasties with their structural information. This section includes an overview of the Goryeo Period's shipwrecks excavated in Korean waters. It intends to clarify regional diversity in ship structure and construction methods as an example of the distinctiveness of the Korean shipbuilding tradition from the Chinese shipbuilding tradition.

Chapter V describes the details of the Quanzhou ship based on the data from previous research as well as from the investigation conducted during this research. The chapter details site background, overall hull dimension and configuration, the assemblage of the ship's cargo, and hull components. The same information about the Shinan shipwreck is presented in Chapter VI. Chapter VII also attempts to collect the same data regarding ship remains from the Takashima underwater site. However, as the discovered ship timbers are fragments, instead of remaining as an intact hull, the presentation of the information is slightly different from the other two cases.

Chapter VIII is divided into three sections. The first section examines the hull components of the Quanzhou ship and the Shinan shipwreck comparatively in the first section. The reconstructed ship lines obtained from the Shinan shipwreck in this research are specifically used to discuss the sturdiness of the hull. A second section assesses iron nails in all the above three ship remains. A specific specimen of the nail obtained during the investigation of the Shinan shipwreck is highlighted in the comparative assessment. The third section is about the study of wood taxa used in the hulls. The study includes the result of species identification on the timber specimen obtained from the Quanzhou ship during this research, compared to the detailed wood assemblages of the other ships.

Chapter IX is a discussion on the structural characteristics of East Asian oceangoing ships, based on the archaeological data presented above. It attempts to outline general principles of hull components and construction methods identified in those ships. In theory, the principle, which includes the bulkhead structure and construction method, should be commonly observed on all the thirteenth and fourteenth centuries' East Asian oceangoing ships. The discussion in this chapter locates the advent of the principle in a long term perspective of shipbuilding, even including the involvement of shipbuilding technologies developed in Southeast Asia. Finally, how historically the evolution of East Asian shipbuilding has progressed is demonstrated with an idea of "Yellow Sea shipbuilding tradition", "East China Sea shipbuilding tradition", and "South China Sea shipbuilding tradition".

The last chapter places a theory an idea of the development of East Asian oceangoing ships into a chronological scheme and clarifies technological innovations and hybridization underlying regional shipbuilding traditions. These are linked with an approach that traces the historical use of the bulkhead structures in the construction of oceangoing ships. The summary of findings from the detailed examination on the main targeted ships that use bulkheads is presented in terms of the hull structure, and the type of timbers and iron nails. It reinforces the idea of technological innovations that are attributed to the East China Sea shipbuilding tradition, taking into consideration the other archaeological ship data associated with this tradition. Finally, it concludes that technological hybridization is a considerable factor in understanding the "East China Sea shipbuilding tradition". This is suggested through the integration of this East China Sea shipbuilding tradition into the shipbuilding tradition in Southeast Asia. This resulted in the formation of the "South China Sea tradition".

Chapter II - Contexts of East Asian shipbuilding research

Several studies from different fields have contributed to and present understanding of East Asian shipbuilding technology. Their extent allows for a multidisciplinary approach to the theme by referring to historical texts, iconographical resources, ethnographic and archaeological evidence. Throughout the twentieth century, drastic changes occurred in shipbuilding technologies in the region, which included the substantial disappearance of large wooden sailing vessels. Scholars studying this transitional period reviewed and recorded traditional watercraft in East Asia, which were consequences of a global uniformity and modernization of ships' structure and construction. Results from ethnological boat recordings by European and American researchers are widely available, and to review their work is a purpose of this chapter. From the late period of the twentieth century onwards, archaeologically discovered ship remains on land and underwater also started to deserve the attention of by researchers within Asia. In broader themes related to East Asian shipbuilding technology in each country, Wade (2003) briefly reviewed available historical and archaeological resources for the study of traditional East Asian ships. Van Tilburg (2007) reviews such precursors' achievements in his multidisciplinary approach in the study of traditional Chinese ships (junks). This chapter will outline researchers who have contributed to the theme over the last hundred years. It will also provide a review as to how bulkhead structures have been interpreted by researchers. This is necessary, as the present archaeological research attempts to identify the bulkhead structure as an indicator of structural development in oceangoing ships.

II-1 Precursors' approaches and resources

Perspectives from non-Asian researchers

Nautical studies in Asia were recognized as an academic discipline by researchers from Europe who have a perception of the shipbuilding tradition outside of the Eurocentric tradition. In the early twentieth century, traditional vessels used in China caught the attention of some visitors to the region. Ivon A. Donnelly, who lived in China in the early 1900s until the mid 1940s as a British shipping agent, produced a number of descriptions and illustrations of Chinese ships from different regions (Donnelly 1923; 1924; 1930). Classification of the Chinese junks presented in these works is based mainly on the origin of the ships, where they were constructed, or where they were operated. His study highlights the endemic variations of regional ships and decorative motifs on the hull, and thematic topics, such as early activities of Chinese ships and the oculus (the eyes of the ship) (Donnelly 1925; 1926). The *Mariner's Mirror* where many of Donnelly's articles were published has also been a leading journal in the thematic study of Chinese ships (Hornell 1934). It is a valuable resource providing important information about Chinese vessels during the time period spanning from the traditional to the modern in ship construction. Detailed description of structures of wooden Chinese ships, which had already started to vanish in the regions by this time, were published in *the Mariner's Mirror* by Cdr. David. W. Waters (Waters 1938; 1939; 1947).

Some of these non-Asian researchers' work may not be completely motivated by nostalgia for the disappearance of the tradition. The outcomes likely have been derived from a partly bureaucratic mission during the colonization period of China. For those European countries pursuing imperial policies in the country, there was a necessity to understand the detailed water transportation system and the vessels present. A report titled *Junk* (戎克) written by the Society for Chinese Junk during World War II for the Japanese military service is a good example (Kobayashi 1941). The book provides information about regional Chinese sailing vessels, some perspectives regarding their position in the Chinese socio-economy, and the lifestyles of "junkmen". The collective information was probably intended for tactical purpose in terms of Japanese occupation (Kobayashi 1941).

Whatever the motivation, there is no doubt about the contributions that scholarly works produced by western scholars made to the present's knowledge of Asian ships. G. R. G Worcester (1890-1969), a British officer in the Chinese Maritime Customs Service in the early and middle twentieth century, achieved the most remarkable work in the study of wooden sailing Chinese ships. His monograph record over 250 watercraft on the Yangtze River is the most frequently cited, and this early work covers not only fluvial craft but also seagoing ships in China (Worcester 1966, 1971). What distinguishes Worcester's works from the others is his approach to various components of the boats and ships including the detailed study of propulsion, with classification of rigs and sails, the different types of rudders and anchors, fastening methods, caulking techniques, cargo capacity, and even sailors' traditional customs and beliefs. Moreover, his observations extend to construction methods and provide insight on variants in the Chinese ships' construction method, including the order of construction. According to Worcester,

> *The methods employed in building junks vary according to the locality and the type and size of the junk; but essentially the initial operation is to lay the flat planks for the bottom boards side by side on the ground, over a central keel (when such is fitted) and secure them together, that is to say, they are 'pinned'*

> *to each other wirth wrought-iron double-ended nails, the planks being knocked together to form a solid whole. ..., transverse bulkheads or ribs are placed in position on the bottom planks, ... The side planks are then placed in position* (Worcester 1966: 8).

The same explanation refers to a river craft known as the crooked-bow junk (with a size of approximately 17 metres long) engaged in transportation along the Ziliujin River flowing through the Sichuan Province. The above idea has probably been derived from one of the observations on river junk construction during his inspection on the Yangtze River (Worcester 1941: 17-18). The dominance of the above construction manner is more or less suspected. As Worcester mentioned, shipbuilding traditions vary, and moreover skills and knowledge pass onto the next generation by oral or empirical means without specifications, such as the production of plans or lines. The shipbuilding tradition existed only as consistent practice. As such, "…the junkmen's claim [is] that they have been thus fashioned without change in design for many hundreds of years…" (Worcester 1941: 17).

One of the most valuable aspects of ship ethnographical studies lies in the production of a number of drawings and visual resources, including photographs. Some contributions by European scholars are noted in the recording and depicting of the distinctive configuration and appearance of regional Chinese ships (Sigaut 1960; Sokoloff 1982). These works are complementary to all the previous descriptive work done on the subject regarding traditional Chinese ships, as they provide more their colour-visual information.

A volume of nautical technology in the series of books titled *Science and Civilisation in China*, which was published in 1971 by Joseph Needham and his colleagues, was an encyclopaedic resource that helped in the appreciation of a generic Chinese maritime history (Needham 1971). Their project attempted to develop an inclusive understanding of Chinese culture by collaborating with local researchers and ranged from ancient boats and maritime history in China to the present. It used historical documents, artefacts, and iconographic resources. A substantial number of historical texts from China and Japan are listed in the appendix and can be used as a primary inventory for maritime historical study on China. The book contains holistic explanations of boat culture from ancient to modern times and includes their origins and the development of general structures such as rigs, masts, and hulls. In the latter part of the book, Needham also explains the chronological development of Chinese boats and their types, ranging from prehistoric times to the Qing Dynasty (1616-1912 A.D.) in comparison with the history of boats throughout the rest of the world. The book also deals with topics related to historical navigation techniques and the shipbuilding industry. Needham *et al*.'s work has a weakness partly caused by the lack of archaeological evidence at the time. However, his works should be respected in any study on Asian ship construction in terms of the coverage of a certain amount of primary historical texts.

Ship remains in China have been extensively reviewed as a part of an inclusive study of archaeological remains of watercraft in the world (Steffy 1994; McGrail 2001). This resulted from the location of ship remains and shipwrecks during the last quarter of the twentieth century in East Asia. Researchers from the Western Australia Museum have directly assessed the sites and brought underwater and nautical archaeological approaches based on western perspectives into the regions and this began in the 1970s (Green 1986, 2006). Researchers from the museum have contributed to underwater archaeological training programs in China and the study of ship design and construction on archaeological ship remains in the country (Green 1983a; Kenderdine 1995; Burningham and Green 1997; Kenderdine 1997; Green et al. 1998). Their extensive work in some of the Southeast Asian regions, for example, in Thailand, contains important information about shipwrecks found in the country, which could have originated from East Asia (Green et al. 1987). Integrated approaches based on maritime archaeological and ship ethnological perspectives have been conducted on ten Chinese ships that crossed the Pacific Ocean during the twentieth century, according to Van Tilburg (2007). Van Tilburg's approach probably provides the most comprehensive fundamental research scheme into the study of historical Chinese ships by defining the general structure of the vessels from archaeological evidence and applying it to the assessment of historically recorded vessels. Notably, Van Tilburg incorporates some perspectives of sailors' and shipwrights' culture that include unique information on religious behaviour related to shipbuilding and seafaring.

Compared to the study of watercraft in China, there are not many studies by non-Asian researchers on the same topics in Japan and Korea. In Japan, traditional watercraft has been a subject of research among domestic scholars since the early 1900s. With regard to traditional Korean vessels, Needham's study provides descriptive information from an early twelfth century voyage of a Chinese envoy to the Goryeo Dynasty (918-1392 A.D.), known as *Xuanhe Fengshi Gaoli Tujing* (Illustrated record of an Embassy to Goryeo in the Xuanhe reign-period 宣和奉使高麗圖經). It deals with the structure of Korean ships in comparison to Chinese ships dating to the same period (Needham 1971).

As an example of boat-ethnological study, a drawing titled “Corean junk” published in the American Magazine *Harper's Weekly* (*A Journal of Civilization*) published in 1871, was cited in a recent academic volume pertaining to traditional Korean ships (National Maritime Museum of Korea 2008b). In the same report produced by the National Maritime Museum (2008b), there is a brief introduction that the Marine Resources Research Center of the Government-General of Korea recorded several Korean fishing vessels during the Japanese colonization period from 1910 to 1945.

Horace H. Underwood, who lived in Korea as a missionary, conducted extensive study on boat-ethnology on traditional Korea ships. The outcome published in 1934 under the title “Korean Ships and Boats” provides a good overview of Korean ships and shipbuilding (Underwood 1979). This study covers the construction method of these ships, shipbuilding and transportation industries, and ship carpenters’ customs.

Research groups in the field of historical shipbuilding technology and shipwreck study

A chapter of Sean McGrail’s book *Boats of the World* (2001) highlights archaeologically discovered watercraft in East Asia. It relies on information from the proceedings of conferences. Proceedings from past international and regional conferences in East Asia are significant sources to review achievements in the region. In recent conferences where researchers from China, Japan, and Korea delegated papers by collaborating with experts from overseas include the “International Sailing Ships History Conference” in Shanghai 1991, the “International Symposium in Celebration of the 30th Anniversary of the Shinan Wreck Excavation” in Mokpo in 2006, and “Of Ships and Men” in Beijing and Ningbo, in 2009. Apart from these resources, we can access non-English literature resources produced by historians and archaeologists in each country. Below is a brief review of what scholars have achieved in a study of ships in each country.

- China

In China, even though the first discovery of the Quanzhou ship dates back to the 1970s, the study of historical boats and ships did not progress much until the late 1980s. The first publication of the *Transactions of Marine History Research* (1985) by historians and naval engineering groups was a sort of milestone (CSNAME - Marine History Research Group 1985). The articles in the transactions deal with various topics ranging from ancient boats and their outfits to the features of modern naval vessels. Although the contents of most articles are descriptive rather than analytical, they dealt with both archaeological and historical resources. A series of the transactions that has been published until 2002 contains over 200 articles. These articles should be evaluated as important primary sources that were produced by local researchers. A few people from this research group published useful books covering historical shipbuilding technologies and the analysis of shipwrecks discovered in China (Wang 2000; Xi 2000). Most references written by local scholars are only available in Chinese and have not been adequately assessed by foreign maritime archaeologists. These maritime historians, naval engineers and architects, and a few terrestrial archaeologists, have been involved in the assessment of ship remains found at terrestrial sites, such as the Penglai ship remains (Xi 1989; Cultural Relics and Archaeological Institute of Shandong Province et al. 2006).

The Chinese government established the Underwater Archaeological Research Center (UARC) under the National Museum of History (currently the National Museum) in 1986, ahead of enacting the Regulation on the Protection and Administration of Underwater Cultural Relics in 1989 (Zhao 1992; Hoagland 1997, 1999). China sent government officers to the Institute of Nautical Archaeology in the United States to master the principles of underwater archaeological survey methods, and to Japan to learn SCUBA diving. Moreover, the Western Australian Museum, cooperating with the University of Adelaide, set up a one-year maritime archaeological training programme in China to train archaeologists in maritime archaeological techniques (Atkinson 1990). Since this national training began Chinese archaeologists have implemented several surveys and excavations on underwater sites in the Bohai offshore of the Liaoning Province in northern China. The southern Paracel Islands, (known as Xisha Islands among Chinese) in the South China Sea, has been a focal area of research for shipwrecks and cargos. In the beginning, a number of surveys have been carried out in cooperation between the UARC and overseas organizations such as the Western Australian Museum in Australia and the Institute of Underwater Archaeology in Japan (Green and Clark 1993; Green et al. 1993; Kenderdine 1995). Reports of the results of the above underwater archaeological works were published domestically, and the work of the UARC focuses mainly on the assemblages of cargos, rather than hull structures on account of the fact that the remains of these underwater sites consist of only shipwreck cargos (Zhang 2006a). The exception, perhaps, was the discovery of the Nanhai No.I shipwreck offshore of Guangdong Province, since the hull and cargo remains of the Nanhai No.I shipwreck show the most intact condition among the shipwrecks that have been discovered previously. There are plans to conduct the excavation after raising the shipwreck and surrounding sediments with a caisson and moving it inside a museum building. The project is challenging, but it would raise the presence of Chinese underwater archaeology. UCRA has now 45 domestic experts working in the heritage branches and the archaeological department of coastal provinces (Zhang 2006a). UCRA is based in Beijing and also has a regional office in Ningbo, and some of Provinces have underwater survey units. The role of Chinese underwater archaeology extends to overseas more recently. For example, they are internationally cooperating with Kenya for an exploration of Chinese shipwrecks in the country. To sum up, in China, the practices and development of underwater archaeology are in line with national policy, as parts of ocean strategy.

- Japan

Many academic groups in Japan have taken different approaches in the study of maritime history. The majority of their approaches at the early stage were dependent on evidence from ethnological data, iconographic resources, and historical documents. A pioneering study of watercraft in Japan dates back to the 1910s by Nishimura Shinji who adopted cultural anthropological approaches on comparative analysis of ancient boats (Deguchi 1995: 21-22). Nishimura's attempt was to locate the evolution of boats worldwide within a broader perspective based on the cultural diffusion theory focusing on the diffusion route of rafts reaching American continents. Deguchi (1995) evaluates Nishimura's pioneering work, trying a comparative approach with a global scale and points out the fact that Nishimura's works have been referred to because only a few resources are available in English. While some of Nishimura's discussions are highly hypothetical with a lack of rigid scientific data, the pioneering work extending his interest in the remains of archaeologically found dugout canoes has been evaluated by Japanese researchers (Ishii 1957; Shimizu 1975). Nishimura firstly presented the term Kozosen (build up ships) which are commonly used in the concept of the development of traditional Japanese ships (Deguchi 1995: 38). Before the appearance of the "build up ship", Japanese scholars have agreed with the long term use of dugout canoe and a developed type of the dugout canoes based on archaeologically data including ship clay figures and excavated dugout canoes (Ishii 1957; Shimizu 1968, 1975; Okita 2000).

Deguchi conducted boat-ethnological study by focusing on dugout canoes that were still used among the twentieth century's Japanese local societies. Her ethnographical study on dugout canoes extends its discussion to their distribution, endemic characteristics, and their state of evolution of traditional Japanese ships (Deguchi 2001). Another pioneering work has been achieved by Kenji Ishii through an iconographical study in his book titled *Japanese Ships* (Ishii 1957). Kenji Ishii chronologically outlines the history of Japanese ships in each period in the way that examines the primitive types of watercraft based on archaeological resources and the "build up ships" based on iconographic evidence. This evidence encompasses drawings of ships depicted on picture scrolls, wood block prints and historical texts. In the study of indigenous Japanese ships, the approach substantially relying on iconographical resources has been dominant (Ishii 1995b; Adachi 1998). More recent work by a non-Japanese researcher is rather introductory and reviews what Japanese researchers have already presented (Farris 2009).

The study of ships in Japanese maritime history is extensive to not only ships of Japanese origins but also ships from overseas visiting the country. Available iconographical sources regarding these ships are limited until the pre-modern period. Oba (1974; 1980; 1991) initially made inroads into the field through the study of the early eighteenth century picture scroll *Tosen no Zu* (Drawing of Chinese ships 唐船の図). The scroll has a realistic depiction of Chinese oceangoing vessels from different regions and one Dutch ship with their dimensional data, and it provides precise information of structure and configuration. Its artist probably intended to depict those foreign ships visiting Hirado, which was one of only a few ports opened to overseas traders in the seventeenth century. The original scroll consists of the two volumes and is possessed by the Matsuura Historical Museum as part of the collection of the provisional load of Hirado. The National Gallery of Victoria keeps a copy of one volume of the scroll that has been referred to by a few researchers (Guy 1980; Green 1997). Oba has played the editorial role on the collective iconographies of the Chinese residences established in Nagasaki (which is another historical port opened for foreign merchants during the period of national isolation) and they contain drawings of Chinese merchant ships and Dutch ships (Oba 2003). Oba's interest in the ships' iconographies are derived from the study of historical records of the cargo inventories from drifted Chinese merchant vessels to Japanese shores and legally captured foreign vessels. There is a series that studies the historical documents of drifted and wrecked Chinese ships on the coast of Japan published as *Materials' Series of Chinese Ships Cased Away on the Coast of Japanese Islands in the Edo Period* (Tanaka and Matsuura 1986). Based on historical documents, Matsuura (2008a; 2008b) reviewed the role of Chinese traders in the Qing Dynasty period of China and clarified the heyday of Chinese ships in the eighteenth century's coastal trade. Contributions by Japanese researchers on the study of the ships and their role in Chinese water transportation has already been demonstrated by Shiba in the 1960s in his research of Chinese socio-economy during the Song Dynasty (Shiba 1968).

The state of underwater archaeology, which lags behind in East Asia has been reviewed (Hayashida 2006). Only a few avocational societies, such as the Kyusyu

Okinawa Society for Underwater Archaeology, have contributed to underwater archaeological surveys and excavations in the last two decades of the twentieth century. The society was reorganized as a non-governmental organization called the Asian Research Institute of Underwater Archaeology (ARIUA). Its members have identified a few underwater sites including remains of scattered ceramics from possible wreck sites (Nogami 2004). Chinese ceramics including the twelfth-thirteenth centuries' celadon and porcelain possibly from the Song Dynasty's Chinese traders have been identified offshore of Kurakizaki in Amami Island, Kagoshima Prefecture. Hull remains have not been identified at these underwater sites. The discovery of hull remains is limited to the shipwreck sites dating to the last quarter of the nineteenth century around the period of the Meiji Restoration. These sites include the British built steamship *Irohamaru* (1867), the Dutch built wooden sailing ship *Kaiyomaru* (1868), and the U.S. built steamship *Hermann* (1869). Ship timbers identified at the thirteenth century Mongolian fleet wreck site known as the Takashima underwater site are rarely available resources to assess ship structures of the same period. Most timbers recovered from the site during the excavations are extremely deteriorated. However, during the excavation in the 1990s and 2000s, hull timbers including bulkheads probably originated in the Song Dynasty's vessels that have been seized by the Yuan Dynasty (1271-1368 A.D.) of the Mongolian Empire. The hull remains are chronologically comparative resources with the other remains of oceangoing vessels which include the Quanzhou ship discovered in China and the Shinan shipwreck found in Korea.

Korea

It seems that interests in the native watercraft among Korean researchers rose after the 1980s. Materials that were examined from traditional Korean vessels include dugout canoes, ship clay figures, a few iconographies, and a small group of archaeologically discovered coastal ships (Kim 1994; Choi 2006). Korean maritime historians have located the heyday of seafaring during the period of maritime activities of the people from Silla (57 B.C.–935 A.D.) and the invention of turtle ships by Admiral Yi Sun-shin during the naval battle with Japan in the sixteenth century. The remarkable progresses in exploring shipwrecks occurred after the late 1970s. The discovery of the Shinan shipwreck in the offshore waters of the archipelago of Shinan County brought an opportunity and its survey and excavation underwater between 1976 and 1984 showed great success. Associated with the survey and excavation, a conservation centre was established at Mokpo city adjacent to Shinan County. It was later developed as the National Maritime Museum of Korea. Since then the Museum has been a focal place for underwater archaeological research in Korea and has been active in locating unknown shipwrecks in Korean waters. According to reports (National Maritime Museum of Korea 2005a; Kim 2006), twelve underwater seasons of archaeological excavations have been conducted until 2006 in the southern areas and the number of identified sites include: Shinan shipwreck (1976-1984), Wando ship (1983-1984), Jindo ship (dugout-bottom, 1991-1992), Talido ship (or Dalido) ship (1995), Sibidongpado ship (2003-2004), Anjwa shipwreck (2005), and Daebudo ship (2006). In the late 2000s, their focus moved toward the north around Taean County consisting of many small isles. This led to the discovery of the Taean ship (2007-2008). A team from the National Maritime Museum identified another site at the vicinity of the waters in which the Taean ship had been found. The potential around the concerned waters resulted in the establishment of a branch office of the Museum. The Museum was reorganised as the National Research Centre of Marine Cultural Heritage. The organization comprised of four divisions specialised for “exhibition”, “research”, “administration”, and “underwater excavation and conservation”. The organization has been facilitating coherent approaches to discovered shipwrecks. While the chemical conservation was progressing at the hull of the Shinan shipwreck, the post analysis was conducted. Since the completion of the conservation, this shipwreck has been put on display for the public. The significance of artefacts from the Shinan shipwreck, in particular, a number of ceramics, is regarded as evidence of an international network related to the distribution of seaborne ceramics in Japan. For Korean researchers, the study of the above indigenous coastal ships was to elucidate the development of the ships during the Goryeo period.

II-2 Bulkheads as a hull component of East Asian oceangoing ships

Bulkheads in general

Etymology explains that the term “bulkhead” is said to have originated from the Old Norse term “balkr”, meaning “partition” or “bulki” meaning “cargo”. This is composited by the term “head” used for “panel, and the word started to be used around the fifteenth century. In nautical terms, a bulkhead is defined as “a name given to any vertical partition, whether fore and aft or athwartships, which separates different compartments or spaces from one another” (Kerchove 1961). Thus, in the European shipbuilding sense, the bulkhead is described as a ship component that functions to produce a separate space in the bottom of the ship.

The *International Maritime Dictionary* (Kerchove 1961) provides another definition to the term “structural bulkhead”, which is “a bulkhead, generally water- or oil-tight, which forms one of the boundaries of the main compartments and contributes to the strength of the hull. Its depth usually extends through several decks”. The modern nautical terminology secondarily describes the bulkhead by focusing on its effectiveness in the structural role of the hull. The bulkhead is given multiple meanings through interpretive approaches. Perhaps, the multiple aspects may be related to the long history of the development of a bulkhead component since its appearance in the hull of Chinese ships. Its term and concept are clearly defined in the nautical glossary, yet historically it has evolved its own functions. According to modern nautical glossaries, the “bulkhead” and “structural bulkhead” are distinctive of each other. Bulkheads have multiple functions, though the concept and term of structural bulkhead probably advanced in later periods in modern European nautical shipbuilding technology. Here, we will pursue the different functions of bulkhead according to its chronological development.

Bulkhead as partition

A question arises as to when vertical partitions appeared in the history of watercraft. Concerning this issue, small semicircular partitions were used in primitive watercraft such as an ancient dugout canoe in its bottom, one may ask whether they can be identified as bulkheads or not. Ishii (1995a) introduces an archaeologically discovered dugout canoe in Japan that has partitions inside and interprets this structure as a bulkhead. The date of this dugout canoe goes back to the mid-third century to the end of the seventh century. There were a few old records of such dugout canoes having partitions in Japan, while the actual remains of these dugout canoes are missing (Ishii 1957). Evidence of the partitions in dugout canoes have been reported in Russia and Vietnam (Okorokov 1995; Bellwood et al. 2007; Caira 2008). Some of them have been dated to older periods than the Japanese; for example, one dugout canoe from Russia has been dated to the Iron Ages and another dugout canoe from Vietnam to the prehistoric period. There are differences in the structure of the semicircular partition boards of these primitive watercraft. In the Russian example, the cholne dugout canoe from the vicinity of the Oka River which runs through the city of Ryazan, and this has two semicircular shaped partitions in its inside (Caira 2008). These are described as thwarts that are an integral part of the hull. On the other hand, semicircular partitions observed in the canoes in the northern part of Vietnam are independent components, which could be later introduced after hollowing out. Bellwood (2007) notes the existence of fitted bulkheads in the Dong Xa dugout that has semicircular boards slotted between two uncarved ribs at bow and stern as transom boards. He compared this to the Viet Khe dugout in the National Museum of Vietnam History which also has a fitted bulkhead at one end of it (Figure 2-1). The bulkhead transoms in the Dong Xa dugout and the Viet Khe dugout consisted of at least two vertically extended boards (Bellwood et al. 2007). It is, however, disputable if the partition boards of these primitive dugout canoes would come under the modern criteria of bulkheads as a vertical component to produce a separate space in its hull bottom one from another. On a dugout canoe, the dividing interior space of the hull is in less demand, which suggests that this sort of semicircular board can be distinguished from the underlying idea of a bulkhead used for partition purposes. The partition boards are regarded as part of monocoque of the dugout, not as an independent hull component that is given multi-functional roles.

Figure 2-1 Prehistoric Viet Khe dugout in the National Museum of Vietnam History. *Photo by author*

Partition boards in thirteenth century's Chinese ships had a clear function. Those partitions divided the limited interior space of a hull into independent spaces for passengers and cargoes. People could recognize the usefulness of having partition boards to secure private property and space. Needham's historical study cites the description of the interior structure of the Chinese ships around the period depicted on the well-known travel record by Ibn Battuta, translated as *A Gift to Those Who Contemplate the Wonders of Cities and the Marvels of Travelling* (published in 1355 and also known as "Travel") (Needham 1971: 470). According to this historical text, the ship had four decks where there were compartments for sailors, private cabins for passengers and an upper cabin for merchants. The private cabins were divided into small compartments each with a door lock.

Modern Chinese (hanzi) and Japanese (kanji), which use ideograms in writing, respectively describe a “bulkhead” as “cabin wall” (*Cangbi* 舱(艙)壁) in Chinese and “partition wall” (*Kakuheki* 隔壁) in Japanese. Boat ethnological study on Chinese junks also confirm the primary function of bulkheads as partitions, according its nautical glossary (Worcester 1966). It defines bulkheads as the vessel’s vertical partitions separating various portions beneath the deck. This view is followed in archaeological study on traditional Chinese ships (Tilburg 2007).

Such partitions or walls inside the hull may be considered as common structure in ships. The archaeological study of Mediterranean ships, for example, indicates the use of partitions in the interior structure. The Kyrenia ship, dating to the fourth century B.C., might have had such a partition wall to segregate the holds (Steffy 1994: 52). Archaeologically, the seventeenth century shipwreck *La Belle*, wrecked at Matagorda Bay, on the Texas coast, shows an example of bulkheads functioning as partitions. Their design and installation leave almost no doubt as to its primary purpose of functioning as a partition (T.L. Carrell pers. comm. 2009).

Different from those cabin and hold partitions that can be found on European ships, however, it may be better understood that the East Asian ships’ bulkheads are idiosyncratic, as being structural and serving to divide the hold into compartments as part of construction method. According to Jeremy Green, during the excavation at the Pattaya wreck site in Thailand, which was probably constructed partially by East Asian shipbuilding traditions, there is evidence of longitudinal partitions within two bulkheads’ space that separate the port and starboard part with a central area (Green and Harper 1983; Green and Intakosai 1983).

Bulkhead as watertight compartments

> *It should be appreciated that the fundamental characteristics which differentiates*[sic] *Chinese junks and sampans from all other traditional craft throughout the world is the system of transverse water-tight bulkheads, derived as…, the longitudinally split bamboo* (Needham 1971: 385).

The definition of a bulkhead here needs to be clarified in relation to the role of the bulkhead component functioning in the hull, as it is the reason why the component came to be used. The definition of a ship component is not necessarily discussed by the configuration of the component but also by its structural advantage in the hull. Apart from the partition role, bulkheads have been conceived as a system of watertight compartments, which is a part of the definition of a “structural bulkhead”. Chinese researchers emphasize the innovation of the watertight bulkhead in Chinese naval history and evaluate watertightness as the most significant function, rather than the creation of partition space or to support hull transverse strength (Cai et al. 2010). The advent of the watertight bulkhead in Chinese shipbuilding technology has possibly established by the Tang Dynasty (Xi et al. 2004: 58; Zhang et al. 2004: 258). This view was regarded as authentic when the Quanzhou ship was found in China in 1973, on account of the ship having a series of twelve bulkheads, which demonstrated a coincidence with a ship that had been depicted in the thirteenth century text *Travels of Marco Polo*. While there is an argument concerning the reliability of the content of the travel record, its description about ships being built in China for the India trade at the time has been frequently reviewed in much of the literature. The English translation of the original by William Marsden has been widely cited and is described as follows:

> *Some ships of the larger class have, besides (the cabins), to the number of thirteen bulk-heads or division in the hold, formed of thick planks let into each other (incastrati, mortised and rabbeted). The object of these is to guard a leak, such as striking on a rock or receiving a stroke from a whale, a circumstance that not unfrequently occurs; for, when sailing at night, the motion through the waves causes a white foam that attracts the notice of the hungry animal. In expectation of meeting with food, it rushes violently to the spot, strikes the ship, and often forces in some part of the bottom. The water running in at the place where the injury has been sustained, makes its way to the well, which is always kept clear. The crew, upon discovering the situation of the leak, immediately remove the goods from the division affected by the water, which in consequence of the boards being so well fitted, cannot pass from one division to another. They then repair the damage, and return the goods to that place in the hold from whence they had been taken* (Wright 1854: 347-348).

Another version of William Marsden's translation is interpreted as follows:

> *In such case the water that enters the leak flows to the bilge, which is always kept clear; and the mariners having ascertained where the damage is, empty the cargo from that compartment into those adjoin, for the planking is so well fitted that the water cannot pass from one compartment to another. They then stop the leak and replace the lading* (Yule 1993: 250).

These descriptions suggest that these compartments were partially or entirely used as cargo holds at the time. In the cases where water leakage occurred, they could momentarily prevent the cargo from getting wet since the cargo in the leaking hold could be quickly moved into an adjacent hold. The structure of the bulkheads was an indication of firm construction. It should be noted that the existence of bilge or limber holes beneath the bulkheads is indicated in the text. It is implied that making bilge water flow through holes could function as a way to tell if there is a water leaking hazard. The role of the watertight bulkheads in Chinese merchant ships appears to be related to their function of protecting cargo from being water-soaked, and securing the hull from springing a leak as well. This function would relate the bulkhead's structure to its role as a cargo hold to save the ship's load, and not simply relate its role to decreasing the risk of the ship sinking on the assumption of less water-inundating into the interior of the hull. Whether watertight compartments could function to prevent the cargo from being inundated or the inside hull from being submerged is a different issue. Yet, in either case, it is assumed that there must have been a way that the limber holes could be closed or be able to be closed. In either case, there would be a need to keep the central access to each compartment clear so that the location of the leak could be determined, so that the limber plugs could be sealed or opened in the case of allowing the bilge water to run to the lowest point where it can be pumped.

According to Chinese scholars (Xi et al. 2004; Cai et al. 2010), the invention of bulkheads appears to date back to the reign of the Eastern Jin Dynasty Emperor "Yixi" (義熙) (405-418 A.D.) based on historical evidence. Chinese researchers interpreted the advent of watertight bulkheads in China occurred around 410 A.D.. among (Cai et al. 2010). However, the exact date shown here and the detailed background of the introduction of bulkhead structure and construction method have not been fully examined. As a matter of fact, Chinese researchers have agreed that bulkhead constructions became widespread at least by the Tang Dynasty, taking into consideration that a few shipwrecks dating to this period demonstrate the presence of bulkheads (Xi et al. 2004).

The introduction of watertight bulkheads was evaluated in modern European shipbuilding as one of numerous innovations of naval architecture. The innovation was conceived to have occurred during the last few decades of the eighteenth century in China (Needham 1971: 420-421). A British naval officer John Schank suggested the improvement of the ship's structure by adopting bulkheads. The British engineer Sir Samuel Bentham learned from his experience of studying Chinese ships in Russia about the widely adopted bulkhead structures. Later, Bentham brought the idea of bulkheads to European ships, potentially enhancing the hull strength and securing the ship. His firm belief in and promotion of the effectiveness of bulkheads resulted in the construction of his seven experimental vessels in the late 1790s. They were certainly pioneers in the installation of the watertight bulkhead on European ships.

> *So far as the author can find, transverse water-tight iron bulkheads in iron steamships were introduced by the late Mr. Charles Wye Williams, who first employed them in the "Garryowen," iron steamer, in (it is said) the year 1833-4. Transverse bulkheads made water-tight in wooden ships were introduced in this country by Captain Shanks, about the year 1790, in a vessel called the "Trial," and used by Sir Samuel Bentham, K.S.G., in his seven experimental vessels designed in 1794. Longitudinal bulkheads were introduced by Sir Samuel* (Young 1867: 31).

Moreover, there is a record of the well-known naval architect John Laird who built the steam ship *Nemesis*, that its watertight bulkheads were the first to be used in a warship operating in China.

> *The next striking peculiarity in the construction of the vessel was, that the entire vessel was divided into seven water-tight compartments, by means of iron bulkheads; so that, in fact, it somewhat resembled a number of iron tanks, cased over, so as to assume the external form of one connected vessel. By this means, the occurrence of any accident, such as striking on a rock, or shot-holes, &c, which might occasion a dangerous leak in one compartment, would have no effect upon any other part of the vessel* (Bernard 1844: 8).

The fact that a few British naval architects were influenced by Chinese tradition suggests that the bulkhead structure and construction technology had been commonly employed in China. When discussing the introduction of bulkheads into European shipbuilding technology, however, there is still room to consider the extent to which this introduction meant the direct linkage of technological integration between modern European shipbuilding and traditional Chinese shipbuilding. The purpose of introducing bulkheads in China in 410 may or may not have corresponded with the idea brought in the late eighteenth century in Europe. It is likely that adopting bulkheads in Chinese shipbuilding and European shipbuilding in different periods was recognized as a technological innovation.

Bulkheads as frames

There is almost no doubt that the bulkhead structure can be evaluated as an independent shipbuilding technological phenomenon and a construction method distinguished from the typical European shipbuilding lineage. One significant feature of the structural bulkhead is the strength of the hull. The bulkhead functions as a transverse component. It has been understood that using bulkheads as frames could bring a distinctive construction method. Basch (1972), for example, has mentioned that compared to a conventional theory of European tradition that clinker building necessarily means a plank-first (shell) technique, in China the clinker-built could be fixed to bulkheads which set in position beforehand, that is by using a frame-first technique.

There are some disputable issues in the Basch's perspective. It raises queries as to: whether the function of bulkheads can be identified similar to that of frames as transverse components, and whether the interpretation of clinker building can be identical to the general, and how the hull was built in terms of the sequence of hull construction. These are interrelated issues associated with bulkhead structure.

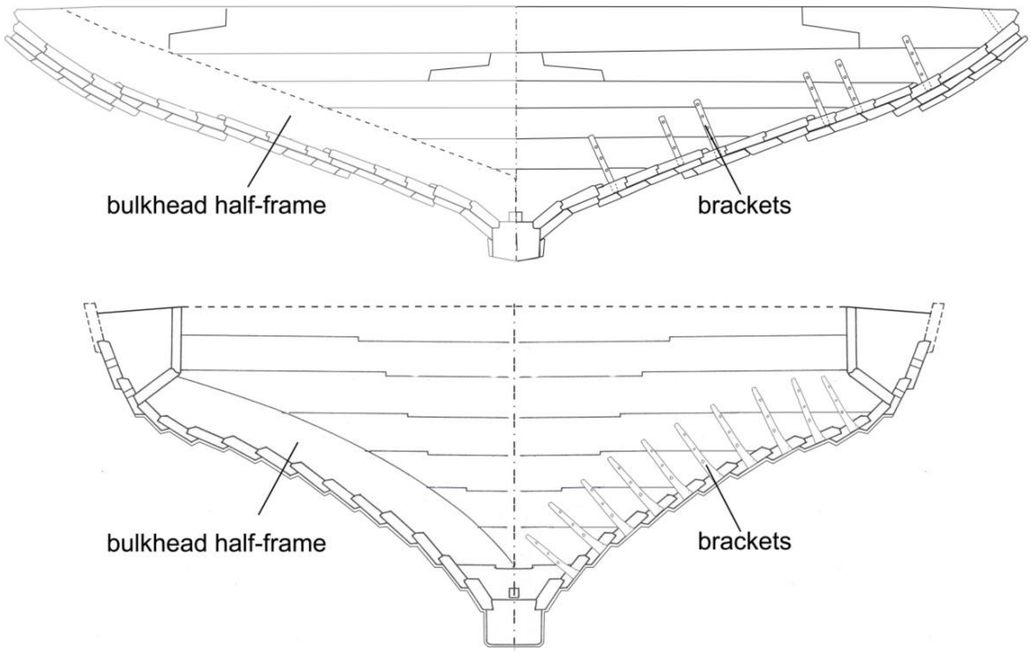

Figure 2-2 Cross-sections of the Quanzhou ship (above) and the Shinan shipwreck (bottom).
Produced by author

Figure 2-2 depicts two images of cross-sections of the late thirteenth and fourteenth centuries' East Asian ship remains. The ships' remains show bulkheads that could function as frames. The structural relationship of these transverse components needs to be clarified in detail.

The planking of these two ships appears to be the clinker-built. However, the clinker planking used in these ships is distinctive from what is typically understood in western naval terminology that defines clinker planking as a method of planking by overlapping the lower edge of each strake onto the upper edge of the strake next below, not rabbeted-carvel seams. Apart from some pioneering works (Worcester 1941, 1966, 1971; Green et al. 1998), very few studies with sufficient research have been done to illustrate hull construction and configuration formed by bulkheads and complex planking in East Asian tradition. The details of hull planking will be reviewed in this research.

Another issue is the construction order of the ships having bulkhead structures, as this issue has been conceived as a typical means to elucidate the development of ships in the European standard approach. Discussing this matter may systematize the theory of the sequence of order of ship construction in East Asian shipbuilding. Apart from the issue, if the sequence of the order is unlikely to represent the solicitation of construction techniques, clarifying the installation of bulkheads before or after building up planking has been a long term concern. The non-Chinese literary text, Ibn Battuta's *Travel*, briefly touched on this naval architectural issue. The description regarding construction methods recorded in the text is summarized based on the Needham's citation of this text as follows (Needham 1971: 469). Chinese shipwrights initially built up two wooden walls (strakes), and between them several thick wooden boards (bulkheads) were fixed firmly by nails driven longitudinally and transversally. The nails were around 1.7-2.0 metres in their lengths. When completing the fastening of the strakes and the bulkheads, shipwrights placed floor timbers on the top of them. Afterwards, the completed part was slipped into the water where the rest of the work could be continued.

During a later period, one of the few historical Chinese texts including a description of nautical technology *Tian Gong Kai Wu (or Thien Kung Khai Wu* 天工開工) written in 1637, which was written by Sung Ying-Hsing, describes the procedure of the construction sequence in a relevant chapter, based on the author's experience of visiting the shipyard:

> *The construction of a boat begins with the bottom. The strakes of the hull (chhiang) are built up on both sides from the bottom (planking) to a height (equivalent to that of the future) deck (chang). Bulkheads (liang) are set at intervals to divide the vessel (into separate compartments), and (the holds have) sheer vertical sides which are (also) called chhiang. The hull is covered at the top (or, surmounted) by great longitudinal members (cheng fang). The (winches for the) halyards (hsien) are fixed above these. The position of the mast just forward of one of the bulkheads is called the 'anchor altar' (mao*

than) (Needham 1971: 412).

凡造船先從底起. 底面傍靠牆. 上承棧. 下親地面. 隔位列置者曰梁. 兩傍峻立者牆. 蓋牆巨木曰正枋. 枋上曰弦. 梁前豎桅位曰錨壇.

The term "liang" translated in Needam's work as a bulkhead, generally means a beam in modern Chinese and Japanese terminology. The liang is also indicative of a frame for an interior structure which includes buildings and crafts in these two languages. The concept that "liang" was a synonym for bulkhead that could be installed as a frame component suggests that the role of the bulkhead at the time was a significant concern when building the basis of the hull. Moreover, as to the construction method, the original Chinese text implies that these frames or bulkheads could be installed after building up a number of strakes, implying a plank-first technique. On the other hand, the sequence of order was re-evaluated based on ethnological evidence of the nineteenth century Chinese junk. Worcester (1966) reports the evidence of a bulkhead-first technique employed in the construction of river junks. The following description is from his report. After laying flat planks secured together by wrought iron double-ended nails to form a solid bottom hull at suitable intervals, and according to the length of the junk and the construction desired, transverse bulkheads were placed in position on the bottom planks. Afterwards, strakes were placed in position, lifted up using ropes and nailed to the bulkheads.

It is not clear whether garboards or wales were placed at the sides prior to installing the bulkheads. The side planks seem to have been fastened together in a way which could nail a member of the strakes to the bulkheads, rather than nail a plank to the bulkheads one by one. It is noted that Worcester emphasized that the actual construction method is related to the locality and the type as well as the size of Chinese ships. Worcester's report contributes to the identification of the sequence of construction. However, whether it determines the significance of the bulkhead structure and construction is a complicated matter. One must take into consideration the variation of technology existing in the different regions of China at the individual, regional, and national levels as well as the long history of the nation.

Finally, bulkhead structure and construction methods are conceived in this research as a representative technology that contributed to the prosperity of East Asian maritime history rather than as a part of the unique Chinese shipbuilding tradition. Most cultural interactions in this region through maritime activities can be evidenced archaeologically by shipwreck resources. The remnants of oceangoing ships identified in East Asia indicate that this technology was attributed to a wide range of ocean voyages, which included trade and military activities. The Shinan shipwreck found in Korea shows the evidence of international trade between China and Japan. The bulkheads remaining from the Takashima underwater site are evidence of the historical invasion of Japan by the Yuan Dynasty (1271-1368 A.D.) of the Mongolian Empire. The bulkhead component is also evident in Southeast Asian shipwrecks at an early date around the thirteenth and fourteenth centuries. The diffusion of the bulkhead structure and construction can be attributed to people's conception of the significance of this component. The significance of the bulkhead is examined not by pursuing simply its origin, but by providing an insight into its development as a technological innovation in East Asian shipbuilding with a consideration of endogenous evolution and integration with external influences. Its structural and functional role can be located by critically reviewing the ship remains dating to periods during the thirteenth and fourteenth century when the process of the growth and innovation to construct East Asian oceangoing ships was accomplished.

Chapter III – Underlying theory and background

Maritime and nautical archaeologists have introduced a method to theorize elements behind ship remains and cargo for their interpretation. Jonathan Adams (2001) suggests seven interrelated attributes that determine the form, structural characteristics, appearance and use of watercraft. They consist of "ideology", "materials", "environment", "purpose", "economics", "tradition", and "technology". All these attributes constrain the structure and construction of the watercraft with mutual influence. However, people who attempt to interpret the attributes need to understand the complexity in their relationships. A conflict of interest, for example, exists between "tradition" and "technology". This is because a conventional aspect of "tradition" tends to minimize the roles variation and innovation play in the construction of boats and ships that require the most advanced technology in a society (Adams 2001: 302). When this conflict occurs, we take into consideration the hierarchy that may exist between the attributes. While there is no doubt that all the above attributes are behind watercraft, maritime archaeologists should ideally clarify their focus as to which attribute fits their research theme. Of the attributes, some represent social and physical constraints and they are more linked to the construction of ships, compared to the others that are related to the designing of ships influenced by various mental templates and ideologies (Gibbins and Adams 2001: 281). To explain the development of the hull under the East Asian shipbuilding technology, this research will clarify the term and concept of "technology" in the study of ship remains. The pursuit of a pattern of the development will be addressed with a focus on technological innovations. This research hypothesizes that such innovations could be often emerged from integration of hull components and observes this as hybridity of shipbuilding traditions. As a result of this research, the significance of the term and concept "environment" will also become apparent. In light of these two concepts, the structure and construction methods in Chinese shipbuilding tradition will be discussed.

III-1 Underlying theory on the development of shipbuilding

Technological development

Technological development facilitates the transition of culture. In shipbuilding, "technology" is defined as the technological means available for constructing the vessel (Adams 2001: 300). Its availability is constrained by materials, tools, and techniques of individuals, which determine the size and complexity of the vessel that one can construct. A watercraft has been recognized as the largest and most complex machinery invention through most of human history (Muckelroy 1978: 3). It is said that "therefore the methods of shipbuilding often represent the technological cutting edge of a society, simply because no other situation is as demanding" (Adams 2001: 301). Technology observed in shipbuilding that refers to innovations is derived from this intuitive idea. According to the idea, technological development brings significant changes to social systems and these are often described as "innovations". One interpretation is that "an innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers 2003: 13).

Technology as innovation

The innovations in archaeology clarify specific individuals, groups, or societies in terms of their idiosyncrasy or advancement from the other. Archaeological assessment determines the specific culture that has chronologically evolved and is temporally located by a relative date in history. In the same manner, the identification of the advent of innovations in shipbuilding technology is an attempt to locate specific ship designs and constructions in a chronological order in history (Steffy 1991). Ordering the innovations in shipbuilding technology is not depicted as a simple linear evolution but as a complex endogenous growth through the improvement of ship structures and construction methods.

The history of technology is presented as a cycle of innovations. Such cycles are attributed to people who choose to pursue different technical methods in order to satisfy particular needs or demands. The needs and demands are presented in the innovating ship design and construction. Identifying the innovation on ship remains is a significant theme in maritime and nautical archaeology. According to Adams (2001), Gawronski (1991: 83) has pointed out that the design of the VOC shipwreck *Amsterdam* had been developed in multi-functional ways to satisfy five different tasks relating to the Dutch East India Company's demands.

Innovation in reality may be less evident as it has been behind shipbuilding practices at various levels ranging from individuals to regions. In archaeologically discovered ship remains, one assesses the degree of human error in shipbuilding practices that includes design faults and ongoing repairs that may cause loss (Adams 2001: 293-294). Vague innovations in archaeological evidence paradoxically remind archaeologists of the significance of innovations that are derived from individual efforts, such as the shipwrights' daily work, and others may be generated from practices of local tradition. Innovation and its practices presumably lead the diffusion of technology that allows shipbuilding. Explaining this cycle is one of the themes in this research that focuses on the bulkhead which is regarded as an innovation underlying the evolution of East Asian shipbuilding technology. This section explores the meaning of innovations and ship hull components' development by appraising them within a theoretical framework.

Nature of innovations

> *It is appropriate to consider innovation in the context of the transmission process because it never takes place in a vacuum, but in the context of a pre-existing culturally transmitted state of affairs, in which new cultural variety is created* (Shennan 1996: 289).

Innovations are addressed specifically with focus on their relevance with the discussion of the development of nautical technology. The reason for this is that this research seeks for a broader perspective in the interpretation of archaeological ships remains beyond the particularistic view that was previously presented in the approach of a philosophy of shipbuilding.

> *[T]he product of an individual shipwright's set of assumptions, cultural and personal biases, and technical experience, could be detected in the details of the ship remains and teased out of the form, dimensions, and tool marks preserved on rotten bits of wood* (Hocker 2004: 1).

While Hocker and others outline the need for a more holistic view of understanding ship construction through archaeology, this concept can be further elaborated and explored. Innovations are perceived to develop the concept, "philosophy of shipbuilding", as a principle to be used in the archaeological interpretation of shipbuilding technology. For this purpose, the significance of innovations are pursued insightfully as individual elements attributing to technology and physical constructs. The following brief summary is a basis of innovations in technological contexts based on Everett Rogers's innovation theory (Rogers 2003).

Innovations include the nature of newness, which is further characterised by the existence of some degree of uncertainty. New technology, representing new ideas, is expected to benefit those would be potential adopters, but this advantage is not always clear for them. Until the potential adopters became practitioners, they would have hardly ascertained whether an innovation is a superior form of technology or technique as an alternative to the previous practice. Cognition of a technological innovation is often coincident with that of uncertainty. When embodying technological innovations, its consequence might be explained thus: "a technology is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome" (Rogers 2003: 36).

This is indicative of what archaeologists observe on remains that may contain information for identifying technological innovations which have been used to deduce cognition or uncertainty that had existed in people's minds. The ideas and practices of innovation may be presented less importantly for those archaeological surveyors who do not intend to interpret or assess the technology by locating them in the development. However, the reason why the presence of innovation might be vague and unclear may also be ascribed to the complexity that technological innovations form a cluster to some degree. This is another way to discuss the nature of technological innovations, indicated as "a technology cluster consisting of one or more indistinguishable elements of technology that are perceived as being closely interrelated" (Rogers 2003: 14). The relationship between these elements sheds light on the complexity of the process involved in the innovations. There is the matter of how to identify boundaries around a technological innovation, or where one innovation ceases and another commences. The knowledge of this helps clarify technological innovations. However, in defining innovations, the interaction and interdependent relationships between innovations consisting of either individual elements or individual innovations should be premised. Perhaps, watercraft is the most representative example to be interpreted from the assembly of technological innovations in such a way that an innovation on fastening methods, adopting new materials and joint techniques could lead to the advent of an improved hull planking. Technological clusters that exist in shipbuilding are a hidden phenomenon in practising archaeological study on ship remains. By regarding hull components as interrelated technological clusters, this research will assess ship construction materials, such as nails and timbers, to locate their significance in the development of the ship components.

Diffusion of innovations

Diffusion theory, recognized as the spread of innovations, is a model adopted by individuals and societies. In archaeology, a theory known as the cultural diffusion model, contributed by Vere Gordon Childe, is a model of chronological implications (Childe 1929). It locates cultural or archaeological objects in temporal diffusion expressed by a chronological timetable with a cultural group. In a way, it is a concept to stress a difference or specify a distinctive culture, and is likely to be used in generalizing cultural groups. Providing the normative view of culture by this generalization allows people to interpret a culture which is more likely unchanging but replaceable, in particular, by influence through contacts between different cultural groups. Its consequence forms a group of artefacts that can be viewed as an expression of cultural ideas or norms (Johnson 1999). However, later, an argument arose regarding its inadequately to explain the formation of culture without considering environmental conditions. While cultural diffusion was regarded as the result of the acceptance of different information and cultural traits, the processes of cultural change or evolution were viewed as human's adaptive response to different environments, as practiced in an processual archaeological approach (Clarke 1968). The explanation of these processes develops with identifying the structure of cultural transmission, with focus on its processes encompassing innovation (Shennan 1996). In the discussion of contemporary archaeological theories, cultural change is appreciated in an integrated theory that can address short-term social dynamism and cultural evolution and treats the long-term persistence of cultural forms (Preucel and Hodder 1996: 217).

In the anthropological study of watercraft, models of diffusion within the chronological development of the dugout canoe of the Austronesian language group have been elucidated (Hornell 1946). Diffusion theory has been used in introducing the idea of anthropological approaches into the interpretation of shipwreck assemblage (Gould in Delgado 1997: 377-380). Deductive approaches that lead to generalization are understood in the second movement in the history of maritime archaeological theory and practice known as "Shipwreck anthropology" (Gould 1983; Gibbins and Adams 2001: 285). A hypothetico-deductive approach is not a dominant position today in maritime archaeology (Gould in Delgado 1997: 380; Gibbins and Adams 2001: 286). This is because of the exclusive view of the hypothetico-deductive model, and also in actual practice, a theoretical approach in maritime archaeology shows more intensive relationships with historical archaeology (Staniforth 2002). The recent achievements at the colonial and post-colonial periods' shipwreck sites are probably related to more extensive connections between archaeology and history in practice.

Such an exclusive viewpoint that all social change can be explained by diffusion alone is not adopted in archaeology or in other disciplines. It is more likely that "…social change is caused by both invention (the process by which a new idea is discovered or created) and diffusion, which usually occur sequentially" (Rogers 2003: 43). What is emphasized in the interpretation of diffusion in contemporary subjects is the focus on adoption processes of innovations by individuals and groups. What people or societies involved in the innovations' adoption process think about innovations are not easily expressed, yet they may be identified by extracting characteristics of innovations related to interrelated factors and people's perception

(Rogers 2003: 1-38). In theory, diffusion of innovations can be interpreted quantitatively and the rate of adoption of a specific innovation in societies follows a certain pattern. The pattern of adoption of the innovation from quantitative data is described as an S-shaped curve calculated by time length with a certain percentage of the members adopting the innovation (Rogers 2003: 272-273). The diffusion is further explained beyond generalisation by focusing on variants existing in innovation and interrelated factors. The "innovations" spread through certain "communication channels" over "time" among the members of a "social system". The paradigm that intends to be shown here is not for the purpose of arguing if the generalisation is applicable, but rather to ascertain if there are interrelated factors involved in generating a complexity in diffusion. While the interrelated factors are probably less directly linked to archaeological evidence remaining on shipwrecks or ship remains, they certainly exist behind the adoption of technological development.

Hybridisation of technologies

> *In many colonial and Asian societies, hybridity tended to be applauded in cultural terms…* (Reid 2010: 307)

One achievement exemplified from technological developments from either endogenous or exogenous growth has resulted in a hybrid hull. As explained above, innovations used for watercraft form a technological cluster in theory. Conceptually, this should range from an innovative idea to fashioning a primitive watercraft to a shipwright tool, physically to practice the idea in a better way. This technological cluster comprising of both tangible and intangible components may not appear to be an assembly of multiple innovations in the primitive types of watercraft. However, it gets to be accounted in the adopting of multiple technologies in hull construction. The technological cluster, in becoming apparent, evolves through integration of hull components. The phenomenon reaching this complex stage can be described as hybridisation. The ships get to show apparently hybridity in their configuration.

In some regions of Asia, the appearance of hybrid ships can be observed in iconography and literature. European people appeared in Southeast Asia by the late sixteenth century and at some stage recognised ships as having features from different regions. There is a historical drawing of a ship that has been depicted as a Chinese ship involved in Southeast Asian waters before 1613. However, this was later corrected to be a non-Chinese ship that should be described as a local construction ship in Southeast Asia known as Malay or Javanese "jong (or junco)" by the Portuguese (Manguin quoted in Guy 1980: 17). The barely depicted ship shows a characteristic Chinese rig; yet on the image there is a quarter rudder clearly drawn, which is identical to ships from Southeast Asia or perhaps Arabia. A bowsprit seems to be drawn and this is also unlikely to be attributed to the Chinese at the time. Another example is an image of the Japanese ship captured offshore in the Philippines in 1600 by Dutch ships (Nagazumi 2001: 58). Despite the image that is recorded as a Japanese ship, the depicted ship has square batten sails made of bamboo and quarter rudders. These features are not characteristic of Japanese ships.

Such misperception by European drawers is probably due to the vagueness associated with multi-nationalities of the merchant ships by the time they employed seamen and ships from different countries. It might have resulted from the drawer's preconception about the similarities between the Southeast Asian and Chinese ships. Perhaps, it may be explain for the depicted ship to some degree shows a hybrid ship's feature integrating hull components from different regions. There is clearer evidence that the Europeans recognised the involvement of hybrid ships in Southeast Asia. The existence of the hybrid ship came to be known widely by a Spanish term "mestizo", equivalently indicative of a hybrid. The fact that the Europeans used mestizo in describing ships is indirectly evidenced in the historical Japanese text titled *Zoho Kai Tsushoko* (Studies on the Intercourse and Trade with the Chinese and Foreigners 増補華夷通商考) written in 1708 by Nishikawa, Joken (Ishii 1995b: 72-76). According to this historical text, the mestizo ships are explained as

> *Rigs and sails of the two masts of the ship are as same as those of Chinese ship, and the depth of the hull as well. Its rudder fits with iron pintles which slips into iron gudgeons, and the stern is alike those ships from Fujian or Tanzhou. Structurally, these ships are also the same ships which used to sail from the Nagasaki to Tenjiku known as a "mestizo" construction vessel. The large type of this ship could carry 2,000,000 kin (unit likely to be equal to 1,200 tonnage capacity, yet conversion calculation is disputable to be discussed) cargos, the middle types of the ship could carry 1,560,00 kin, and the 1,230,000 kin allowed to be loaded into the smaller ones. The ship has a bowsprit where there is a spritsail likewise observed on many Chinese ships voyaging overseas, also having top sails made of cotton used for the sprit sail too (distinctive from the other sails made of bamboo). The length of the ship ranges 15-6 ken (about 28-30 metres) to 20 ken (about 37 metres), likewise those ships from Siam (Thailand). The upper of the ship is painted with red terracotta colour or simply painted by oil, yet the lower part under waterline is painted by substances made from lime and oil, which makes it appear white painting* (author's trans. Gaikoku dashi no Fune, Zoho Kai Tsushoko).

Apart from establishing that foreigners who visited Southeast Asian waters were cognizant of the hybridisation, modern scholars have addressed the existence of hybrid ships in their own way. Needham (1971: 433-439) introduced an idea of affinities and hybrids of ship designs and construction, and discussed an obsolete diffusion theory that locates diffusion in the spread of innovations from one focal point to the other peripherals simply by observing the similarities of features existing between two distant regions. This idea that had been developed by cultural anthropologists was still dominant at the time. Based on the understanding of such view, an early interaction between Chinese ships and indigenous ships in Southeast Asia in structure and construction has become apparent (Needham 1971: 438-439). According to Needham (1971: 438-439), the hybrid ship presents the Indo-China style; its development has been explained by the fact that a keel was perhaps the first feature to be adopted and then the bulkheads were abandoned for frames. The Twaqo or Twakow used are examples of such boats until recently in the waters of Singapore, as they show similarities with Chinese ships from Fujian Province (Waters 1946). What Needham thought when looking at ethnological boat records appears to be the similarities not only in the hull but also in the rigs and sails. Adopting rigs from a distinctive Chinese batten sails on Southeast Asian Singapore's ships has been highlighted as a possible case of hybridisation. Needham, however, has not clearly explained innovative processes of rigging. He has briefly proposed an adaptation theory mentioned by Jean Poujade, introducing "…, that hulls tend to change more easily than rigs…the shipwrights and the sail-maker are quite different people. Hulls, …, are sensitive to commercial contact; rigs, more closely associated with the tradition and life of the sea-faring folk, change only under political dominance" (Poujade quoted in Needham 1971: 439). Furthermore, Needham indicates that Southeast Asian regions have been a focal place for hybridisation for a long time by quoting Poujade's study regarding a ship relief inscribed on the wall relief of the temple of Bayon that was built in the late twelfth century or early thirteenth century. Poujade concluded that most of the particular features of the relief's ship closely show more similarities with Southeast Asian ships, but the hull is a hybrid, and the bulkheads coexist with a keel and the genuine stem and stern post (Needham 1971: 439).

The idea of hybridization, which more specifically highlights not rigs and ship's configurations but integration of hull components, has been forwarded by Pierre-Yves Manguin and has come to be a known theory in interpreting shipbuilding tradition in Southeast Asian and East Asia (Manguin 1984; Manguin 1993). Manguin (1993) introduced a term "South China Sea tradition" for ships that shared distinctively the different features developed in the two different regions including Southeast Asia and southern China (but not northern China). Southeast Asian ships, historically known as the sixteenth century's Malay and Javanese jongs, could be built without using iron materials. Instead, wooden dowels were extensively used for the joining of their planks and frames (Manguin 1993: 267). This has been practised as a result of the consequences of the advancement of sewn-plank and lashed-lug techniques that had evolved in many places of Southeast Asia before the tenth century (Manguin 1993: 255-264). The sewn-plank, lashed-lug and the wooden dowels correlate with the edge joint of plank's seams forming carvel built. Comparably, using iron nails and clamps is one of the main characteristics of the Chinese tradition. The excavated ships originating from southern China after the Tang Dynasty (618-907 A.D.) onward show that the seams of the hull planking were fastened by square iron nails. Bulkhead structure is mentioned as another important key feature representing the southern Chinese shipbuilding tradition.

According to Manguin (Manguin 1993: 271), however, quite a few ship remains dating after the thirteenth century that have been archaeologically excavated in the regions of the South China Sea had been constructed according to a different principle from the above mentioned two distinctive shipbuilding traditions. These ship remains reveal the features of hybrid ships:

> *[T]heir planks are always fastened by iron nails to the frames, but they may also be dowelled together by wooden pegs; some have single, axial rudder while others have quarter rudders; their holds are separated by bulkheads, but these are not structurally essential and kept watertight as in the Chinese tradition (all have waterways with limber holes hollowed out of the bulkheads); all their hulls are V-shaped and have a keel that plays an essential structural role, a striking difference with the traditional flat-bottomed, keel-less (Northern) Chinese build.*

For archaeological evidence of a typical hybrid ship, the early-mid fifteenth century Bukit Jakas site found at Bintan Island in the Riau archipelagos of Indonesia is presented in Manguin's studies (Manguin 1993; Manguin 2010); the main structure of the hull consists of a keel and bulkheads with planks that are edged-joined with wooden dowels, but the hull planking is fastened to sturdy frames by square iron nails.

An underwater archaeological excavation project by French scholars at the wreck site identified in the Brunei waters has brought forward the idea of a hybrid ship to assess the details of the ship that had carried a number of ceramic cargos, although the hull has not been identified (L'Hour 2003). The Lena Shoal shipwreck of the Ming Dynasty (1368-1644 A.D.) found off the island of Busuanga in the Philippines may be an interesting example as follows. A large number of Chinese ceramics were found at the site, indicative of the ship’s involvement in maritime trade between China and Southeast Asia in the 1500s. The hull planking adopts double layered planks that are edged-joined with wooden dowels (Goddio, Crick et al. 2002: 22-25). The hull is said to have been constructed based on bulkheads instead of frames (Goddio, Crick et al. 2002: 26). Although neither actual bulkheads nor frames have been identified, the use of bulkheads is said to be evidenced by observing the distribution of cargo showing a rectangularly margined space (Goddio, Crick et al. 2002: 26). The outcome of the commercial salvage work on the Lena Shoal shipwreck focuses on the cargo of the shipwreck instead of the hull, and it does not provide sufficient explanation of further structural details, nor technical ideas to assess the hull structure and construction methods.

Figure 3-1 Historical scroll paint depicting a red seal ship known as Araki bune, sailing to Vietnam. *Courtesy of Museum of Maritime Science*

A hybrid ship in Southeast Asia is recognised as an integration of the portions of the ship and hull components among people from outside of the region. The idea of hybridisation of shipbuilding technologies has been enunciated by modern scholars based initially on ethnological boat studies, and later developed by using historical and archaeological resources. Manguin (1984) suggests that it could have occurred around the tenth century in the South China Sea in his early study of the hybrid ship. Around the time, the Chinese in the southern coast that had been contacted by people from Southeast Asia, and after some time Persia and Arabia made inroads into the maritime trade. It seems that the South China Sea has been a focal place for different shipbuilding traditions to interact and integrate. From this point of view, a hybrid ship could develop in the area, yet it co-existed with ships constructed under indigenous traditions in southern China and insular Southeast Asia. The fact that the Europeans colonised the region and used the term "mestizo" construction ships indicates that the technological integration had substantially been developed by the time. Coincidently, it appears that the advantage of the integration has been conceived outside of the South China Sea. In fact, in the first half of the seventeenth century, a ship known as the Red Seal Vessel (Shuinsen) was used for long distance maritime trade between Japan and Southeast Asia (Figure 3-1) (Nagazumi 2001). The ship was defined as a historical Japanese merchant ship authorized to conduct foreign trade by the Tokugawa Shogunate with a licence having a red seal. Ships used in this trade were initially large vessels built in China, yet later ships which form a hybrid feature started to be used, although the places where those ships were built is disputable, possibly being in Japan but also in Southeast Asia, such as Thailand. The representative configuration of the Red Seal Vessels has been fully perceived, which is evidenced in many Japanese iconographical resources depicting this type of ship.

Based on the presumption that hybridization occupies an important part of shipbuilding technological development, its initial importance in East Asia can be traced back to around the tenth century. While this phenomenon is apparent, evidence of the late thirteenth and early fourteenth century shipwrecks analysed in this research is given to illustrate the hybridization of technologies in the region.

III-2 Environmental conditions of seafaring in the East Asian ocean

This section focuses on the conditions occurring in East Asia and its adjacent waters relating to historical maritime interactions. The significance of geographical space has been highlighted, from a broad perspective. This is to allow for a better appreciation of the historical events and dynamism when locating archaeological objects in the broad scale of spatial and chronological background. Thus, geographical conditions need to be considered as a factor determining the development of East Asian shipbuilding technology.

Geographical context of the East Asia and adjacent waters

The geographic term “East Asia” is generally used for a specific topographic area of Asian regions and normally indicates those nations that are located at the edge of the Eurasian continent and facing the Pacific Ocean. A current United Nation’s classification of the geographical region and composition of each region includes China, the Democratic People's Republic of Korea, Japan, Mongolia and the Republic of Korea under “Eastern Asia”. Using “East Asia” in this research, geographically covers the core areas of China, the Korean Peninsula, and Japan. Looking at the historical background of this region, the cultural exchanges and interferences between these countries have been active for over two thousand years. For centuries they have shared cultural analogies in language, religion, political systems, social and economic customs.

From north to south, the Sea of Japan, the Yellow Sea, the East China Sea and the northern portion of the South China Sea are focal sea areas comprising the East Asian waters (Figure 3-2). The Sea of Japan is a marginal sea partially enclosed by the Eurasian Continent and the coast of Japan. It is known that cultural interaction took place across the sea at least around the eighth century, such as the direct maritime trade route between Japan and the Balhae kingdom (698–926 A.D.) that governed the southern parts of Manchuria. However, as almost no archaeological ship remains relating with this maritime routes are available, the Sea of Japan is out of scope of this research. The Korea Strait, which connects the Sea of Japan to the East China Sea, historically served as the most significant access route between Japan and Eurasia. Passing through this strait, to the Korean Peninsula and through to the Yellow Sea was perceived as a secure route among Japanese envoys, and this route was coincidently used by other East Asian merchants to reach Japan, in particular, during the ninth century (Yamauchi 2008). The Shandong Peninsula projecting into the Yellow Sea could have been a major destination among Japanese sailors aiming at landing on the Chinese Continent and sailing further down to the south along the Chinese coasts (Reischauer 1940). The Yellow Sea has relatively shallow waters and its average depth is less than 50 metres. The stable environment of the sea provided access to the northern part of China that had been politically occupied by the centralized government of imperial dynasties of the Han-Chinese. The Yellow Sea opens to the East China Sea, which is bounded in the south by Taiwan, and in the east it is margined by the Ryukyu Islands. Although the northern sea route passing the Korean Peninsula and into the Yellow Sea was common in the early stage of historical seafaring between the Chinese Continent and Japan, in the later period a sailing route by way of the Ryukyu Islands increased the direct trade between the two regions (Reischauer 1940). The developments of the multi sailing routes also stimulated trading patterns in East Asia. For example, the Ryukyu Islands rose to prominence in the later period as a powerful maritime figure of one of the entrepots covering not only the direct linkage with East Asian waters but also the direct linkage with Southeast Asian waters (Uezato 2008: 26-27; Wade 2010). Mercantile shipping existed in Asian waters for a long time, and by alternating vessels to sail the entire length of a long trading route, they could sell commodities to the entrepots.

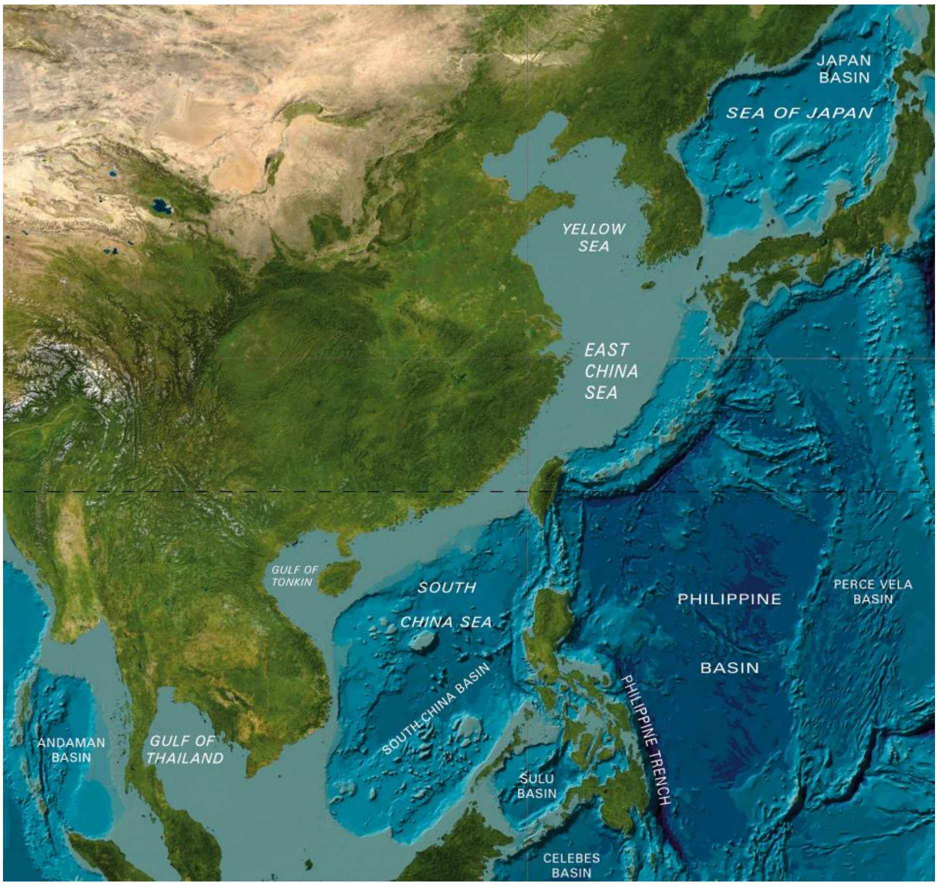

Figure 3-2 Geographical features of East Asian waters. *From ASTER GDEM*

By this system the merchant maritime activity of the East China Sea could connect into that of the South China Sea. The southern coast of the Chinese continent opens to the South China Sea which is a marginal sea largely occupying Southeast Asian waters. This sea has complex topographical features where its maximum depth reaches more than 5,000 metres, while the central deep basin is divided by two broad shelves shallower than 200 metres. The South China Sea connects the far east waters and far west waters, such as the Indian Ocean.

Those who sailed the East China Sea and the South China Sea must have appreciated the seasonal monsoon winds and the tidal currents. Generally, the southeasterly winds prevail around Japan during the summer season from May to

September. The prevailing winds on the Chinese coast during summer are generally from the southern sector. It should be noted that in the East China Sea, June to August is the typhoon season. During winter, the northwesterly winds prevail around Japan. In the Yellow Sea, the seasonal monsoon winds prevail from a northerly direction, while the north-east trade prevails in the East China Sea (McGrail 2001: 346). With regard to the South China Sea, the northeasterly winds prevail over the entire region, whilst there are weaker southwesterly winds which change direction to more southerly in the northern South China Sea during summer. The seasonal monsoon winds affect the tidal currents of the above waters. The Kuroshio Current (Black Tide) is one of the main currents originating from the North Equatorial Current which forms a powerful current to the east of the Philippines archipelago. The current flows to the South China Sea through the Luzon Strait and impacts on the circulation pattern of the area. It flows northward to reach the East China Sea by passing between Taiwan and the southern end of the Ryukyu Island. It reaches the southern coast of Japan and the Korean Strait where it becomes known as the Tsushima Current. The seasonal patterns of the monsoon winds and the intrusion of the Kuroshio Current in summer and in winter must have been understood among local sailors based on their experience.

The knowledge of geographical features must have been shared and expanded among those who made journeys overseas such as in diplomatic missions and by foreign merchants. Either diplomatic missions or foreign merchants were motivated by commercial benefits from their overseas activities and were characterized as international traders. Except for the tributary between nations and kingdoms, Silla merchants who were involved in the private trade between Japan and the Korean Peninsula during the eighth and ninth centuries, for example, represent the early international trades appearing in the historical records (Matsunami 2006; Enomoto 2008). Moreover, Persian and Arabic merchants advancing into the South China Sea around the seventh to the eighth century, and the prominence of Chinese merchants in the tenth century became apparent. In China, as Arabic merchants progressed and made advancements, settlements known as the “Fanfang” (蕃坊) and the “Shibosi” (市舶司) functioned as a government authority responsible for foreign activities (Reischauer 1940). They were established since the Tang Dynasty (Kuwabara 1989). Those ports defined as international must have had these facilities and offices dealing with external affairs where they were not only venues for trading commodities and materials but also venues for exchanging knowledge and information. They must have included ships from many areas and the various ways of how they could sail in the different waters. The appreciation of the different geographical conditions could have contributed to the development and modification of the shipbuilding tradition depending on the areas.

Standardization of ship configurations depending on topographical features

The premise that topographical factors have impacted on the designs and structures of East Asian oceangoing vessels has been previously suggested. This is preconceived more in the Chinese shipbuilding tradition (Worcester 1966: 16-17; McGrail 2001: 347-348; Tilburg 2007: 62). A well known theory is that very different waters of the northern and southern regions of the Chinese cultural area have led to the development of two distinctive types of vessels along the Chinese coast. This has been mentioned by referring to Chinese historical records such as the *Chou Hai Tu Bian* (Illustrated Seaboard Strategy 籌海図編) written in 1562 and the *Wu Bei Zhi* (Treatise of Armament Technology 武備志) written in 1621. Needham (1971: 429) introduced the passage in the *Ri zhi lu* (Daily Additions to Knowledge 日知録) originally written by "Guyanwu" (顧炎武) in 1672:

> *The sea-going vessels of Chiang-nan are named 'Sha-chuan (sand-ship)' for as their bottoms are flat and broad they can sail over shoals and moor near sandbanks, frequenting sandy (or muddy) creeks and havens without getting stuck…Chekiang ships… (are built in the same way) and can also sail among sandbanks, but they avoid shallow waters as they are heavier than the sand-ships. But the sea-going vessels of Fukien and Kuangtung have round bottoms and high decks. At the base of their hulls there are large beams of wood in three sections called 'dragon-spines' (lung ku). If (these ships) should encounter shallow sandy (water) the dragon-spine may get stuck in the sand, and if wind and tide are not favourable there may be danger in pulling it out. But in sailing to the South Seas (Nang-Yang) where there are many islands and rocks in the water, ships with dragon-spines can turn more easily to avoid them* (*Jih Chih Lu*, *vol. 29,* annotated by Ku Yen-Wu).
>
> 江南海船．名曰沙船．以其船底平闊．沙面可行可泊．稍擱無凝．…浙江海船…亦能過沙．然不敢貼近淺處．以船身重於沙船故也．惟閩・廣海船．底圓面高．下有大木三段．貼於船底．名曰龍骨．一遇淺沙．龍骨陷於沙中．風潮不順．便有疏虞．蓋其行走南洋．山礁叢雜．船有龍骨．則轉灣趨避 (日知録集釋，卷二十九，謝占壬注).

The seventeenth century text evidences the perception of distinctive local shipbuilding traditions existing along the Chinese coasts. The northern part of China preferred to specialize in the construction of a flat bottom ship named after its capability to navigate sandbars. In contrast, another type of ship was constructed in the Fujian and Guangdong regions, using the keel that was manoeuvrable in the rocky and reefy-strewn waters.

The *Wu Bei Zhi* is one of the most cited historical Chinese texts among naval historians. This text mentions the people called, “Sha-min” (沙民), who settled along the coast of China, excelled in naval battles with their ships, the “Sha-chuan” (Literally sand ship 沙船), which are compared with the “Fu-chuan” (Fu ship, indicative of the Fuazhou ship 福船), the “Cang-chuan” (Literally blue ship 蒼船), and the “Naiowei-chuan” (Literally bird tail ship 鳥尾船). The text describes that the “Sha-chuan” was able to tack against a head wind and it was convenient in the north sea, but it was hard to sail in the south sea. The north sea has shallow waters and the south has deep seas. The bottom of the sand ship was flat, which did not allow it to plow through the big waves of the deep seas. There are swells in the north sea. The Fu ship and the Blue ship had an acute angle in their bottoms because of the swells, but the sand ship could preferably sail against these swells. In the north sea, iron anchors could be used for mooring, but in the south sea, the deep-water allowed only the dropping of wooden anchors.

Needham (1971: 429) states that the Hangzhou Bay around Latitude 30 degrees is the boundary between two different types of ships. North of the Hangzhou Bay the coastal and oceangoing craft are flat bottom and their suspended rudder can be lowered well below the bottom of the ship or can be lifted up, which can function in the estuarine, shallow harbours and even in inland waters. The flat bottom ships are suitable for dual use in both sea and inland waters. It should be noted that the impact of historical development of riverine infrastructures in north on the flat bottom ships may need to be considered as important as that of northern sea conditions. Intensive study on ports related issues and possibly inland waterway navigation is probably useful, while to address the details of these matters is beyond the scope of this research.

Northern type ship

The unquestioning interpretation that geographical differences are inseparably linked to the vessels’ flat bottom, round-bottomed or V-shape, on the other hand, may lead to a generalization of the typological approach. A limited view of the diversities is likely to suggest that the Sha-chuan (sand ship) was a dominant type of flat bottom ship, which has been defined in comparison with the round bottomed and V-shaped-hull. The flat bottom ship is also likely to be characterized with no-keel construction, and its intuitive image has been used as a typical Chinese “Junk” of the north. Despite the perception that there were diversities of the flat bottom ships in the north sea of the Chinese cultural areas, most of the flat bottom ships were vaguely identified since the sand-ship was equated with the flat bottomed ship.

- Sha-chuan (sand ship) interpreted as the Jiangsu Trader:

The image of Sha-chuan is likely to have been from a drawing on the seventeenth century historical text's *We Bei Zhi* (Figure 3-3). Needham (1971: 429) captions the ship depicted on this historical image as the sand ship of the Chiangsu (Jiangsu) style. Worcester (1971) also regards the Jiangsu (Kiangsu) Trader as the Sha-chuan (sand ship) in his study. The Jiangsu Trader was developed by the Shanghai ship yards. It was an oceangoing ship that can be recognized by two distinctive features that included five masts and a false stern and a projecting gallery of 3 metres or more in length. The Jiangsu Trader is possibly classified together "with the Antung trader as one of two fundamental types of seagoing craft of the north from which have evolved various other crafts" (Worcester 1971: 162).

Figure 3-3 Image of Sha-chuan depicted in *Wu Bei Zhi*. *From Xi et al.*

- Sha-chuan (sand ship) and a Hangzhou Bay Trader:

The Sha-chuan may be more identical to the Nanjing ship drawn in an iconographical resource and the Hangzhou Bay Trader recorded in boat-ethnological study. Oba (1974; 1980) introduces an accurate image of the "flat bottom" ship titled the Nanjing ship as the Sha-chuan ship, by referring to the historical picture scroll *Tosen no Zu* (Images of Chinese ships 唐船ノ図) (Figure 3-4 and 3-5). The Nanjing ship depicted on the *Ka-i Tsusho-Ko* of 1708 by Nishikawa Joken is also a useful resource to help identify the sand ship (Oba 1980). Importantly, the Nanjing ship in the iconographical resources show similarities with ships defined as the Shaohing Chuan or the Hangzhou Bay Trader in the study about Chinese ships in the pre-modern period (Donnelly 1930: 62-65; Worcester 1966 28-32; Worcester 1971: 184-186; Sokoloff 1982: 19) (Figure 3-6). Worcester gives a detailed explanation about this type of ship. The Hangzhou Bay Trader was flat bottom with no keel construction, which was modified to work in the shallow waters of the bay and the shifting mudbanks of the Yangtze Estuary. It was specifically designed for riding the Bore known as the world’s largest tidal bore.

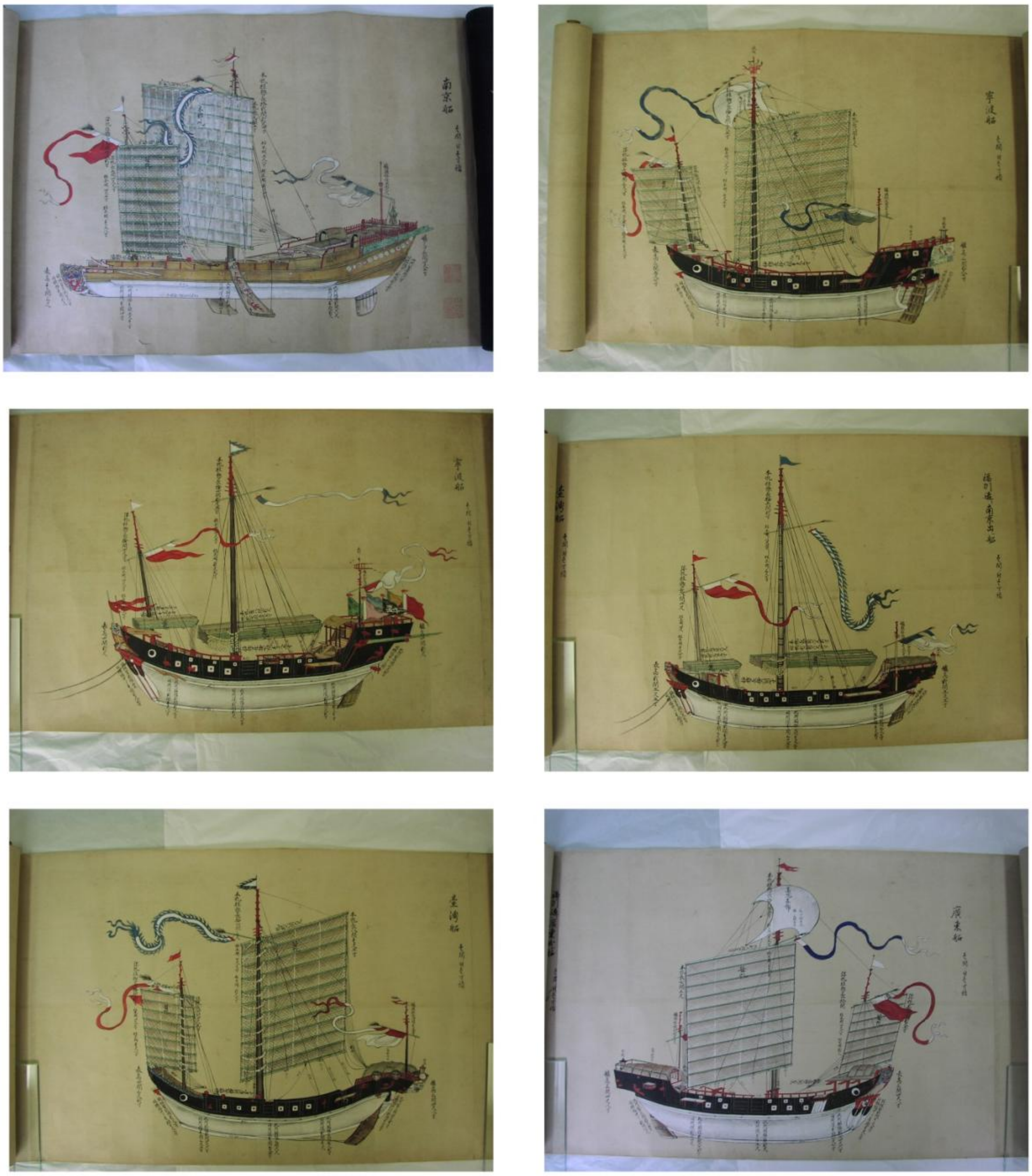

Figure 3-4 Scroll paint, *Tosen no Zu* depicting merchant chips including Nanjing ship known as Sha-chuan (top left), Ningbo ship (top right), Ningbo ship anchoring (middle left), Fuzhou ship built in Fuzhou, departed from Nanjing (middle right), Taiwan ship (bottom left), Guangdong (bottom right). *Photo by author, Courtesy of Matsura Historical Museum*

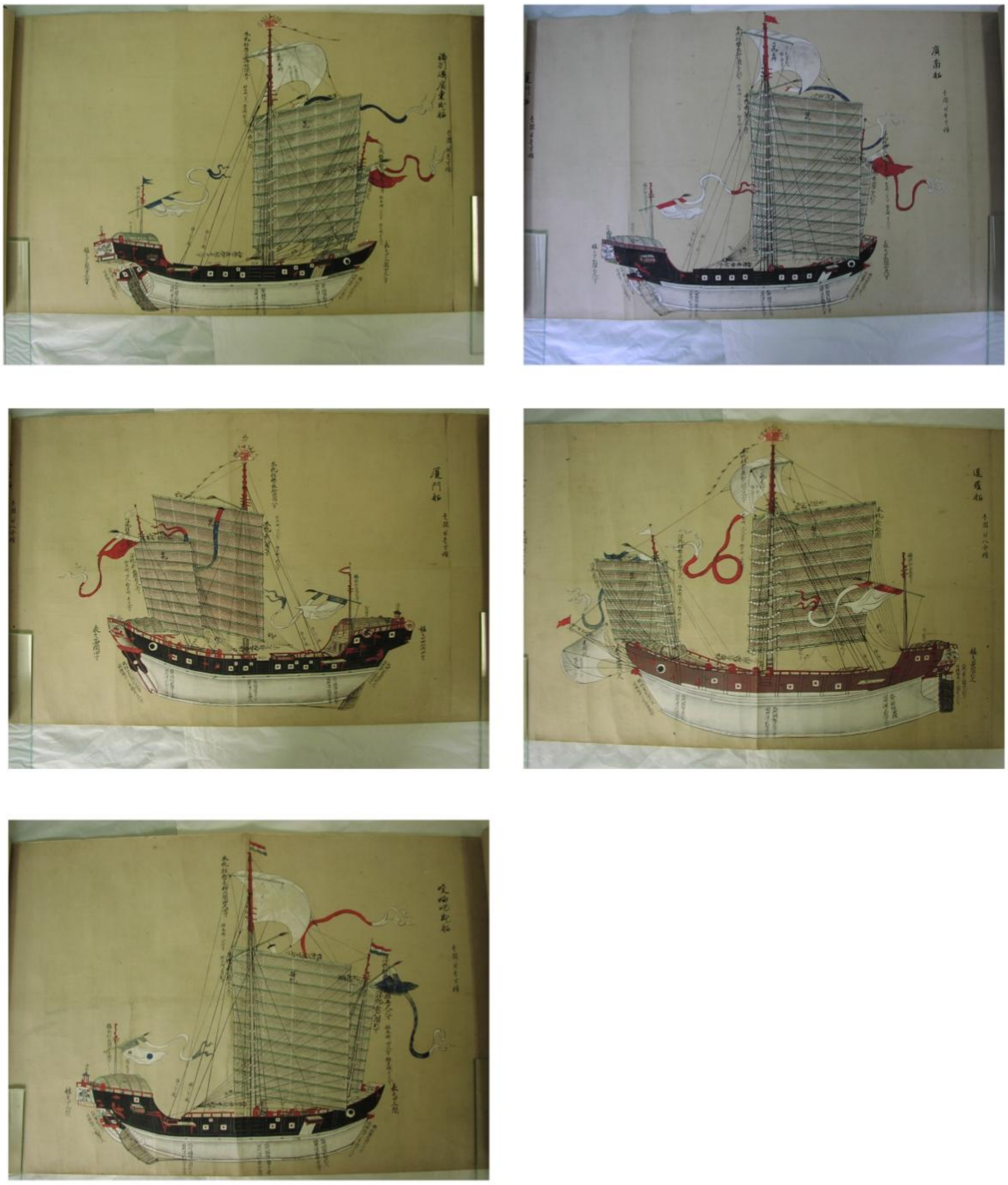

Figure 3-5 Fuzhou ship built in Fuzhou departed from Guangdong (top left), Guangnan ship (top right), Amoi (Xiamen) ship (middle left), Siam ship (middle right), Calapa (Batavia) ship (bottom left) in the *Tosen no Zu*. *Photo by author, Courtesy of Matsuura Historical Museum*

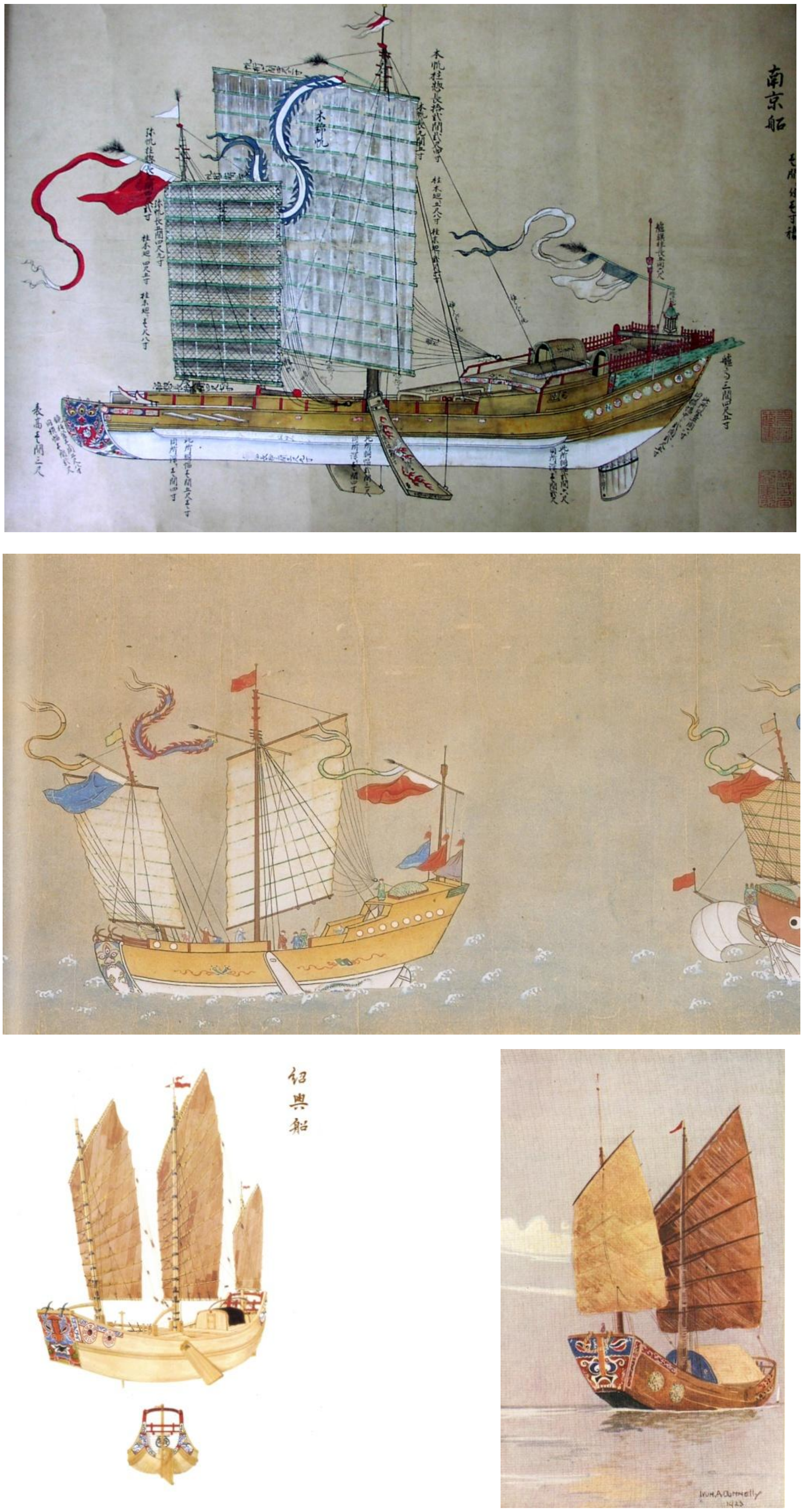

Figure 3-6 Nanjing ships depicted in *Tosen no Zu* (top *photo by author*) and Kiyo Tojin yashiki Zukei (middle *from Oba (ed.) 2003*), and drawings of Hangzhou Bay Traders. *From Sokoloff 1982* (left), *Donnelly 1930* (right)

The Hangzhou Bay Trader is characterized by a vivid painting of a stylized tiger on the bow and the adoption of leeboards consisting of two or more solid planks. These characteristics can also be observed on the Nanjing Ship introduced by Oba (Oba 1974). Leeboards are the most definitive characteristic of the Sha-chuan appearing on the iconographical resources mentioned above.

It is still disputable whether the Shaohing chuan or Hangzhou Bay Trader had a direct link with the Sha-chuan (sand ship) described in the historical records. Worcester (1971) introduces some other ships known as Sha-chuan. These ships are also flat bottom ships, and they have been widely used further up the northern coasts including many estuaries and upper inland rivers.

- Sha-chuan in archaeological evidence

The shipbuilding industry in the northern part around Hangzhou Bay had been undergoing development until the early fifteenth century. This can be supported by the fact that some of the ships used for the Chinese maritime expeditions during the Ming Dynasty period were constructed on the shipyards at a latitude of 31.58.01 N, to the north west of Nanjing, close to the Jia River, a small tributary of the Yangzi. This shipyard called the Baochuanchang (Treasure Shipyard) could have been a significant place where some ships consisting of the expedition fleet were built, possibly including Zheng He's flagship. The location of the shipyard is geographically in the sphere of the northern shipbuilding tradition. However, there is a disputable issue whether the ships built at the Treasure Shipyard were of the northern type of the Sha-chuan (sand ship) or the southern type known as Fuzhou or Guangdong ship, which had round bottoms. This matter has been argued for a long time, similar to the matter regarding the size of Zheng He's ship (Needham 1971: 480-481; Church 2005; Church 2008). Xi *et al*. (2004: 208) concluded that the presence of the flagship of the fleets for the expeditions on the high seas in Southeast Asian waters supports the idea that the southern type of ship was employed. Nevertheless, the long term establishment of the Nanjing shipyards in the northern sphere that were more specialized in constructing flat bottom ships should not be overlooked.

	[m]	Nanjing ship	Ningbo ship	Ningbo ship (anchor-ing)	Fuzhou ship built in Fuzhou, departed from Nanjing	Taiwan ship	Guang-dong ship	Fuzhou ship built in Fuzhou departed from Guangdong	Guang-nan ship	Amoi (Xiamen) ship	Siam ship	Calapa (Batavia) ship
Hull	length	34.09	29.48	31.36	29.30	29.72	29.70	29.70	30.00	32.06	42.36	29.45
	height of bow	2.73	7.18	7.88	5.30	8.24	6.90	6.76	6.60	7.39	9.09	5.45
	height of stern	6.82	7.18	7.88	5.30	6.90	6.90	6.76	6.60	7.39	9.09	5.45
Lower part of hull	forward width	3.36	4.63	4.33	4.06	5.03	5.03	?	4.70	4.15	6.06	4.24
	forward depth	1.93	2.36	4.18	2.79	2.88	3.24	3.03	3.12	3.00	5.15	2.88
	width of midship	3.72	6.12	6.58	5.85	7.27	6.06	5.85	6.73	7.30	8.64	5.90
	depth of midship	1.93	2.42	4.24	2.88	2.88	3.33	3.03	3.12	3.03	5.21	2.88
	aft width	5.45	5.24	6.09	4.64	6.12	5.52	4.90	5.81	6.42	7.27	6.06
	aft depth	2.42	2.45	5.51	4.00	3.94	4.85	4.09	4.18	4.09	6.87	3.97
Bow transo	height?	3.57	3.72	3.72	3.73	4.06	4.09	3.76	4.24	4.33	5.45	4.06
	width	2.42	2.48	2.48	1.97	2.21	2.21	2.06	2.27	2.30	3.30	4.03
Stern transo	width	4.39	4.39	5.45	4.48	4.09	4.85	4.24	4.51	5.15	5.97	3.94
	height?	9.27	6.90	8.24	3.73	6.09	6.21	6.06	6.15	7.88	7.03	4.85
Main mast	length	22.54	24.70	26.21	23.33	26.36	29.24	31.06	31.97	25.70	36.45	30.42
	circumference	1.76	2.60	2.27	2.58	2.15	2.70	2.12	2.03	2.18	2.88	2.63
	circumference of tip	0.78	1.06	0.87	1.12	0.87	1.09	0.88	0.81	84.85	1.06	0.97
Fore mast	length	16.64	17.52	19.51	15.76	18.24	18.20	17.12	18.58	?	22.72	19.88
	circumference	1.36	1.27	1.33	1.21	1.30	1.39	1.12	1.15	1.21	1.81	1.39
	circumference of tip	0.54	0.54	0.51	0.51	0.54	0.60	0.48	0.48	0.45	0.75	0.54
Ensign	length	10.90	9.55	8.79	7.67	7.72	7.58	7.73	7.73	9.85	18.45	7.73
Main sail	length	16.52	14.85	15.15	14.60	15.00	13.64	14.55	16.45	14.76	18.18	14.39
	width	12.21	13.18	14.39	12.85	12.72	12.58	12.97	13.33	12.58	16.51	12.27
Fore sail	length	10.58	8.42	7.73	9.09	8.76	8.03	8.18	8.24	10.76	11.06	10.97
	width	6.36	6.67	5.90	5.60	5.85	6.06	5.90	6.39	6.52	6.21	7.27
Keel	length	24.64	23.12	N/A	22.21	20.06	21.15	21.45	21.72	21.55	37.72	
Top sail	length	N/A	7.06	N/A	N/A	N/A	7.58	9.15	7.88	N/A	9.33	
	width	N/A	4.21	N/A	N/A	N/A	5.60	6.00	5.85	N/A	5.90	
Sprit sail	length	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.06	

Table 3-1 Dimensions of Chinese ships recorded on the *Tosen no Zu*.

Comparable dimensional information about the early seventeenth century oceangoing ships from different regions of China including Nanjing, Ningbo, Fuzhou, Taiwan, Guangdong, Guangnan, and Xiamen is available on the *Tosen no Zu* (Figure 3-4 and 3-5). Table 3-1 shows the dimensions of these ships recorded in the picture scroll with a Japanese unit, calibrated into the metric system. The flat bottom ship from the Nanjing could have been built in a relatively large size (Oba 1974: 357). The data demonstrates an interest in the size of the Nanjing ship, which is a few metres longer than other Chinese ships of southern origin. The length of the Nanjing ship is approximately 34 metres long. The dimensional data of the ships on the *Tosen no Zu* is not evidenced sufficiently to prove the standard size of the ships used as oceangoing traders. This is an indication that flat bottom ships that were constructed in the ship industry of the northern parts of China could be sufficiently large to satisfy the dimension of the ship used as a flagship.

The northern tradition distinguished by geographical sphere is characterized as flat bottom ships. This is illustrated in historical and iconographical resources, and reviewed in boat-ethnological studies. The northern type ships were constructed according to the traditional Chinese shipbuilding method not using a keel (Needham 1971: 390-391). The development of shipbuilding technologies is still unclear in terms of how the structure and construction methods historically evolved as a tradition and formed the flat bottom as one of dominant type of oceangoing ships in Chinese coasts. Perhaps, archaeological approach would be best suited to the identification of the past existence of the tradition, which probably leads better understanding of the chronological and spatial dominance of the flat bottom ship in northern East Asia.

Southern part, connecting to the South China Sea and the Nan Hai Trade

Compared with the northern coast, the southern coast of the Chinese Continent had shown a distinctive shipbuilding tradition, since this area has been historically independent as a buffer zone characterized under the lesser influence of sinicisation. A time period, when this area was densely integrated into the Chinese centralized system, dates back to the Song Dynasty (960-1279 A.D.). By this period, the southern regions had successfully established networks of maritime activities in the South China Sea, which functioned as a link with the Southeast Asian nations. Wang (1958) defines the area of the South China Sea during the period of the first millennia, by referring to maritime activities between cities located on the Southern Chinese coast and Southeast Asian nations. This South China Sea’s trade is described as the Nan Hai (South Sea) Trade, and the sphere of the first millennium’s Nan Hai Trade is defined thus:

> *It extends in the west from the port of Foochou to that of Palembang and in the east from the island of Formosa to the west coast of Borneo. The area is roughly equivalent to that of Nanhai or Southern Sea mentioned in ancient Chinese Records* (Wang 1958: 5).

Fuzhou, located in Fujian Province in modern China, is in the southern end part on the Chinese coast of the East China Sea. It has also been a focal place for the northern end of the southern coastal cities to flourish as maritime ports, which include Quanzhou after the tenth century, and in the later period Mingzhou and Wenzhou established their presence. The role and development of these maritime cities in terms of the connection with both East Asia and Southeast Asia have been mentioned in previous studies (Reischauer 1940; Wang 1958). With regard to the maritime activities of the South China Sea, Wang (1958) attempts to explain the flourishing of the first millennium's Nan Hai Trade by clarifying the intermediary role of the southern coast's cities in the chronological transition of the tribute system as follows. The cities have played significant roles in the tribute system as a portion of sinocentrism that was practised by the delegation of people to the successive Chinese Dynasties from various Asian states in order to demonstrate respect, submission, or allegiance. The tribute system benefitted the Chinese rulers and allowed them to obtain regional products produced in Southeast Asia. Alternatively, the tribute countries were allowed access to the regional specialities of China, such as metal products, silk articles, and porcelains. The commercial aspect as a governmental trade has been aligned to the development of the southern coastal cities in terms of their commercial role. Under occasional trade they could strengthen their significance as a mediator of valuable goods from the southern nations to the imperial court. Politically, the southern coast cities have been under the influence of the northern rulers, and the Nan Hai Trade depended heavily on the demand from the courts and palaces of the central government in the north. This has restricted the continuous flourish of the trade and there were less movements to grow the trade itself for local consumers. The Nan Hai trade has been dependent on the demand of the court and royal households in the capital until the establishment of wider consumer markets in other greater cities (Wang 1958: 61). In general, the socio-economy grew substantially by the period of the Song Dynasty (Shiba 1968).

By the time of the tenth century, the Nan Hai Trade allowed cities in southern China to keep a sort of cultural and economical independence supported by maritime trade. Although the southern cities have kept political relationships with the central government, not all dynasties had successfully unified the entire Chinese

Continent, which meant that the volume and amount of the Nan Hai Trade occasionally declined depending on the political situation. The benefits of the Nan Hai Trade helped local officers to accumulate considerable wealth, but again the market could only exist through the demand of the central rulers. The local consumer societies had not been sufficiently matured to demand valuable materials throughout most of the first millennium. Under such a circumstance, the Chinese merchants would probably not see the benefits of being involved in maritime trade by themselves, possessing their own ocean trading ships and organizing their own sailors. They instead transported goods to the north. The southern idiosyncrasy in maritime activities can be characterized by taking into consideration the role of the people who have been outside of the process of sinicisation and specialized seafaring. There are descriptions about people specialized in seafaring who have settled along the Chinese coasts and the Southeast Asian nations' surrounding waters in the Chinese texts.

The voyagers of the South China Sea ahead of Chinese advancement

Different groups of people have been involved in the development of shipbuilding technology and complex maritime activities at different stages. The people who contributed to the development of ship structure and construction cannot be determined by only highlighting those sailors and ship carpenters who directly worked on shipbuilding industries. Attention should be given to those people who demanded oceangoing ships as a form of transportation for commodities and people. Historical texts may not provide evidence about these people. They are likely to appear in fragmentary bits of information associated with records of immigrant processes, militarily activities, and trading activities.

It has been claimed that "Chinese ships were reported at Penang on the west coast of the Malay Peninsula by 350 A.D. and at Ceylon by the end of the 4th century" (Guy 1980: 11). On the other hand, the settlement of the sinicised Chinese around the South China Sea before the tenth century has not been clearly documented in the historical texts (Wang 1958: 93). The *Ta Thang Chiu Fa Kao Seng Chuan* (Account of Buddhism sent from the South Seas and Buddhist Monks' Pilgrimage of Tang Dynasty 大唐西域求法高僧傳), a travel record of the Tang Dynasty Buddhist monk "Iching" (義浄) is the only relevant resource that mentions the Chinese merchant settlement before the Song Dynasty (Wang 1958: 93). Before the ninth century the cultural exchange in East Asia and South East Asia had been more diplomatic between states and state trades, including the tribute traders who were dominant (Momoki 2008: 15). It is presumed that the majority of historical texts could remain only as governmental records of trades. Here, the discussion necessarily focuses on outlining those who were employed by the state traders as practitioners of seafaring or on voyagers that made inroads in the South China Sea's trade. It is said that the activities of the Chinese merchants in the maritime trades in the South China Sea can be traced up to mid-tenth century in historical texts (Enomoto 2008). So, who were engaged in the Nan Hai Trade before this time? Wang (1958: 113) has identified a few different groups of people involved in maritime activities during the period from the first century B.C. to the founding of the Song Dynasty in the tenth century. The stages of the activities are divided into: 1) the first period during the first five centuries and the end of the Jin Dynasty (265-420 A.D.) when Indian merchants and the Yueh people were the predominant providers of the precise southern goods to northern rulers. 2) the second period from the two centuries of the Southern Dynasties (439-589 A.D.) when there was a need for "holy things" such as jewels, perfumes and religious items, carried by Bosi (Po-sse) and Kunlun traders and sailors from the Southeast Asian coasts and archipelagos through contact with Java-Sumatra and Ceylon. 3) the third period from the Tang Dynasty to the rise of Song Dynasty when massive quantities of medicines and spices were demanded. Coincidently, the commercial power of Srivijaya and the embarkation of Persian and Arab merchants and sailors occurred in the early stage of this period. This, finally, stimulated the advance of the Chinese people on maritime activities in the South China Sea.

The fragmentary understanding of the voyagers and their ships

Little is known about the details of those people who have been involved in developing maritime networks before the tenth century, while it is presumed that they were seafarers who could conduct long distance voyages as sailors into the deep southern ocean. Although the idea as to how these seafaring groups could be involved in the trade with the Chinese courts is open to question. To some degree, there was a possibility that rulers of the Dynasties based in the northern part of China could contact them somehow. Chinese rulers have been trying to intervene in the southern part of the Chinese Continent, and the resultant intervention in the South China Sea was an attempt to establish connections within the Chinese continent. It was initially achieved by the First Emperor of China during his reign (246–210 BC) and he founded the Three Commandries including "Guilin" (桂林), "Xiang" (象), "Nanhai" (南海) of South China around current Guangdong and Guangxi (Kuwata 1954). It was then extended to the Nine Commandries by Emperor Wu of the Western Han Dynasty (206 B.C.-8 A.D.), after defeating the Kingdom of "Nanyueh" (南越) which had occupied most of the southern parts of China and Northern Vietnam (Kuwata 1954: 5-6). With the expedition of Emperor Wu to the south, notably, it has been cited that there existed a record regarding the ship called “Lou-chuan” (Castle ship 楼船) which was used in the battle with “Tongyue” (東越) or Nanyueh (Kuwata 1954: 5-6; Needham 1971: 424-426; Xi, Yang et al. 2004: 51-53). The intervention toward the south by two Han Dynasties allowed them access further west. According to Wang (1958: 21), “…, it may be claimed that there was trade between Han China and the countries of the Nanhai in the years following the fall of Na Yüeh at the beginning of the first century B.C. and that this trade had been gradually extended to include the areas to the west India”.

In the early days, a counterpart for the cultural exchange of the Chinese Continent was the Indian subcontinent via Southeast Asian waters which was also under the influence of two prevailing cultures, but the direct connection between central Han China and India must be carefully considered. The name of “Huangchi” (黄支) appears in the historical texts as an initial record of the tribute trade in the second century (Wang 1958: 20). Whereas there is a hypothesis to locate Huangchi with the kingdom placed in south India, possibly Kanchipuram (Conjeevaram), its exact location is still disputable (Kuwata 1954: 9). According to Kuwabara (1954: 10), the Huangchih was another form to represent “Chiaochih” (交阯) in northern Vietnam. Although the places that appeared in the early historical records of the first millennium are hardly identifiable, the Chiaochih is a definitive area replacing the Nanyueh as land under the direct control of the Han China consisting of the Nine Commandries. Of the Commandries one was known as Chiaochih district (also described as Giao Chi), and “Longbian” (龍編), which is one of the units under this district, had flourished as an international port. A book written by the ninth century’s Persian geographer Ibn Khordadbeh listed this port as Loukin (al Wakin) which was the most southern port of China at the time (Kuwabara 1989). In 226, there was a record of a merchant from the Roman Empire that had visited this port who was sent to the Emperor of Wu, Sun Quan (182-252 A.D.). While the port was the southern frontier for Chinese Empires, it could have been the entranceway to the South China Sea. The Han Dynasty could sent imperial envoys to the southern seas with assistance from the people originating from Nanyueh who were skilled in sailing (Guy 1980: 11). Later, it flourished by the arrival of foreign ships.

During the third and fourth centuries, the early international trade route to reach the Malay Peninsula ran along the Gulf of Siam and the Funan coast. An ancient Cambodian kingdom, Funan (68-550 A.D.) had occupied the area around the Mekong Delta and rose to prominence in the maritime trade between China and India (Hall 1985). Hall (1985: 48-49) has pointed out the significance of an archaeological site Oc Eo (or Oc-eo) identified as an ancient historical port of

Funan. The site proves the significance of this port for connecting China to the Indian region and even further west, by identifying archaeological remains of trading materials including ancient Roman coins, Indian Buddha statues, and Han style copper mirrors (Hall 1985: 8). Historical Chinese records, such as *Funan Yiwu Zhi* (Record of Rarities of Funan 扶南異物志) and *Wu Shi Wai Guo Zhuan* (Foreign Countries in the Period of the Kingdom of Wu 呉時外國傳), show that the two commanders "Zhu Ying" (朱應) and "Kang Tai" (康秦) from Wu during the Three Kingdoms Period (222-280) were delegated to Funan (Watanabe 1985). The record of their journey dating to around the early or middle third century is said to have covered many countries in Southeast Asia, while their original texts are now lost and only fragments may be found in historical texts written in later periods (Watanabe 1985: 7). One of Kang Tai's record's *Wu Shi Wai Guo Zhuan* mentions the configuration of Funan ships:

> *In Funan cut down timbers to construct ships, were twelve hsin (about 23 metres) long and six shaku broad (about three metres), with iron sheets, and they formed their bows and sterns like fishes. The large ones carried a hundred men, each man carrying a long or short oar, or a boat-pole, from bow to stern, fifty men sitting on the side, or forty-two men, depending on the size of the ships, using the long oars when standing, using the short oars when sitting down, in sailing on the shallow waters using the long boat-pole,…* (author's trans. Thai-Phing Yu Lan, vol, 769, Li Fang).
>
> 扶南国伐木爲舡，長者十二尋，廣肘六尺，頭尾似魚，皆以鐵鑷露裝，大者載百人，人有長短橈及篙各一，從頭至尾，面有百五十人，作或四十二人，随舡大小，立則用長撓，坐則用矩橈，水淺及用篙… (太平御覧，卷 769，李昉).

This description partly tells the configuration of the long boat commonly used in Southeast Asian waters. Although in the above text there is no mention regarding the usage of sails, there is an indication of using seasonal winds in the Kang Tai's record. Another third century historical passage *Nan Chou I Wu Chi* (Record of Rarities of Southern regions 南州異物志) indicates that foreigners (people outside of Chinese cultural sphere) used a sail on their ships. These ships were called *Po*, measuring 60 metres long and about 6 metres in breadth and carrying 600 to 700 men. The numbers appearing in the text could be exaggerated. The text emphasizes that the sails used by those foreign ships allowed them to sail under strong gales and violent waves when the sails were made of woven fronds. Multiple sails rigged from bow to stern were manoeuvrable, according to the direction of the winds.

The rise of Funan impacted on the development of its local shipbuilding technology (Hall 1985). While Funan occupied an important position in the maritime network of the South China Sea, in the fourth century, the political situation of Funan became unstable (Hall 1985: 68-77). The network between Han China and further maintained by Funan west was still important, but the other sea routes between the two regions probably developed. The disorder in Funan resulted in shifting the sailing routes toward further south where a few other countries of the South China Sea, such as Java-Sumatra, gained power as an entrepot between China and India around the fifth century (Wang 1958). "The transhipment of across the Malay Peninsula was abandoned in preference for sea travel through the Straits of Malacca to the western edge of the Java Sea and then north to China" (Guy 1980: 12).

The development of knowledge regarding the monsoons and ocean currents of the South China Seas in early seafaring is suspicious. There was still substantially high risk on long distance voyages. There is a historical text known as *Fu Kuo Chi* (佛國記) or *Fa hsien Zhuan* (法顯傳) that recorded "Fa hsien" (法顯)'s pilgrimage to India and Ceylon in 411 (Wang 1958: 42-43). On his return journey from Ceylon to China between 413-414, he appears to have taken passage into Southeast Asian merchant vessels (Hall 1985). The voyage was nearly in distress but finally reached "Yeh-p'o-t'i" (possibly Java 耶婆堤), or west coast of Borneo, according to Hall (1985: 40).

> *After receiving the Sanskrit verses (in Ceylon), I got on board a large ship carrying about two hundred people. ... yet being caught in a gale throughout thirteen days and nights, we managed to get to the shore of an island. At low tide, we repaired the leaking and sailed back to the waters. There were a number of pirates around this area. None of us would have survived if we had encountered them. The ocean was so vast that by determining the direction of east and west only from the position of sun and stars, we could barely sail.… Thus, after ninety days we finally reached a country. It was called Yeh-p'o-t'i* (author's trans. Fa hsien Zhuan).
>
> 得此梵本已即載商人大舶上可有二百餘人…如是大風晝夜十三日到一島邊. 潮退之後見船漏處即補塞之. 於是復前. 海中多有抄賊. 遇輒無全. 大海彌漫無邊不識. 東西唯望日月星宿而進….如是九十許日. 乃到一國. 名耶婆提 (法顯傳).

The historical text shows, without mentioning specific navigational tools, that the sailors of the Fa hsien’s voyage had no landmarks to follow. They steered by the position of the stars and the sun. The ship that was used to across the Indian Ocean appeared to be a large Indian ship (Wang 1958: 43). Although the details of Indian shipbuilding are unclear, their role in the long distance voyages by taking a direct route from the Indian Ocean to the South China Sea is implicative from the content of the text. After the journey of ninety days to get to Yeh-p’o-t’i, Fa hsien had to spend five months there. When departing Yeh-p’o-t’I, he was transferred to another ship to reach Guangzhou. This ship could also carry over two hundred people. It seems that a group of Brahmans embarked together, yet there is no details if the second ship that Fa hsien took passage on was an Indian ship or not. This ship also lost its way. The journey took seventy days longer, twenty days more than the anticipated fifty days that they would take to cross northward to the South China Sea around the time. The techniques around this time were characteristic of primitive navigation, followed by quantitative navigation and mathematical navigation in the later period (Needham 1971: 562-563). Fa hsien seems to have not seen the Chinese during his stay in Ceylon. Apart from some official Chinese pilgrim monks represented by the Fa hsien’s journey, around the fifth century it was still unlikely for the Chinese to be actively involved in voyaging further west off the Malay Peninsula and Indian oceans.

Another Chinese Buddhist monk “Shiyun Wujie” (釋曇無竭), whose name appeared on the *Gao Seng Zhuang* (Biographies of Eminent Monks 高僧傳), travelled to India through a land route in 420 A.D. and retraced Fa hsien’s route. On the way back to China, he could have embarked on ships that departed from southern India via the South Sea and reach Guangzhou (Watanabe 1985: 9). The appreciation of seasonal monsoons and tidal currents contributed to the voyages of two Chinese monks, which could rely on the usage of sail that had developed by the time. However, from the two monks’ voyages it is difficult to confirm the development of the navigation techniques and hull structure. An annotated text regarding a Buddhist Scripture, known as *Huilin Yinyi* (Literary, Phonetic and semantic dictionary of Huilin 慧琳音義) which was written between 783 and 807, is barely descriptive of the hull of a Southeast Asian ship called the Kunlun ship. The ship in the text appears to be a locally built ship, not having originated from India. The Kunlun ship is a general term for ships from the Malay Peninsula or the Indochinese Peninsula, as the term Kunlun was used in the Tang and Song Dynasties’ records for collectively calling those regions. Therefore, except for the premise that the ships must have been built and used by the Kunlun, there is no clear definition regarding their ships, which could have included various types and sizes of ships operating along the coasts of the Peninsulas. The description of the text firstly provides an impression of the substantial size of the ship, but the more notable information is about the fastening of the hull planking that had probably been constructed using wooden dowels. Vegetable fibres appear to have been used to caulk the seams of the planks. The text does not clearly depict if the vegetable fibres were also extensively used for the other parts of the hull planking, such as a lashed-lug technique for planking. The planking of the Kunlun ship gave an unusual impression to the person who recorded it as unique techniques. This suggests that the usage of iron nails for shipbuilding was more ordinary somewhere in China where the person came from, likely to be identified to further north. In contrast, in some southern regions of China, such as the area of Guangzhou, during the early Song Dynasty the hull could still be constructed by lashed-lug techniques using rattan.

> *Large ships in the sea were called "Bo", and according to Guang ya, all these ships were for oceangoing purposes. The size of the ship was as large as 14 metres, managing to carry over a thousand people excluding the cargo. It was also called "Kunlun bo", because Kunlun people were employed as sailors to sail it. Rigs were made from the bark of palm trees, and the woven fibre of kudzu was used for caulking, so there was no leaking of cold water. Iron nails or clamps were not used due to the risk of fire from friction of the iron; alternatively, wooden dowels fastened the hull planking. Passengers were anxious about using such thin planks for the hull. The hull would look as long as a mile, having the three members. Propulsion fully relied on sailing by wind, rather than manpower* (author's trans. Huilin Yinyi, vol.61).
>
> 海中大船曰舶廣雅舶海舟也人水六十尺使運載千餘人除貨物亦曰崑崙舶運動此船多骨論為水匠用椰子皮為索連縛葛覽糖灌塞令水不入不用釘鍱恐鐵熱火生櫐木枋而作之板薄恐破長數里前後三節張帆使風亦非人力能動也(慧琳音義 卷六十一).

Southern China may be regarded as a culturally independent region and has occupied a natural position under the influence of both China and Southeast Asia before the tenth century. In the completion of the successful voyage crossing the South China Sea, the Chinese monks aimed at safely getting back to ports in Guangzhou, China. The destination of the South China Sea trade on the Chinese Continent around this time was Guangzhou. The city was the most southern gateway in China and a hub port linked to Southeast Asia and further west. There were local voyagers skilled in shipping in the region, although they might not have been regarded as truly Han Chinese people. Yueh people could have been a representative of those who had been out of sincinization as voyagers. Although their details are less definitive, Yueh people have occupied the Guangdong and Fujian areas until the Tang Dynasty. Coincidently, Indian people started to appear in the southern ports of China during this time.

Guangzhou could have been the most important international ports in south China by the tenth century, which resulted in the establishment of Shibosi to administrate merchants and ships from those overseas (Kuwabara 1989). Kuwabara (1989) listed names of foreign ships that appeared in several Chinese historical texts that included "Nanhai bo" (南海舶), "Fanbo" (番舶), "Xinanyi bo" (西南夷舶), "Bosi bo" (波斯舶), "Kunlun bo" (崑崙舶), "Kunluncheng bo" (崑崙乘舶), "Xiyu bo (西域舶), "Ban bo (蠻舶)", "Hai bo" (海舶), "Nanfanhai bo" (南蕃海舶), "Bolumen bo" (波羅門舶), "Shiziguo bo (師子國舶)", "Wai guo (外國舶)". A few of these names simply represent a general term for foreign ships. Ships associated with specific groups of people or countries include Bosi (possibly from Persia), Kunlun, Bolumen (possibly from India), and Shiziguo (from Ceylon), although further details of these ships are unclear. Recent discoveries of shipwrecks in Indonesian waters including the Belitang shipwreck, the Intan shipwreck, and the Cirebon shipwreck suggest the active role of the origin of non-Chinese ships in the South China Sea during the ninth and tenth centuries (Guy 2006). Arabic merchants, representative of foreign merchants, appeared in Guangzhou during the Tang Dynasty and extended their trade to Quanzhou in Fujian and Yangzhou in Jiangnan. How the influence of Southeast Asian indigenous shipbuilding and foreign merchants ships south of China had been growing is an important matter to be considered. They probably impacted to form a basis of shipbuilding technologies of southern China, what came to be called the South China Sea shipbuilding tradition in the later period.

Archaeological evidence

The long term development of Southeast Asian indigenous shipbuilding is being clarified through archaeological discoveries. The earliest archaeological discovery of Southeast Asian indigenous boats is from the Philippines. The excavated boats known as Butuan Boats have been assessed by Australian researchers in terms of nautical archaeological perspectives (Clark, Green et al. 1993). Of the five boats found in 1986 two boats have been fully excavated. One of the boats identified as Butuan No. 2 has been dated to 1250 (?), according to the result of radiocarbon dating. The hull planking of this boat uses wooden dowels and lashed-lug for fastening. The technique has been comparatively reviewed in the preliminary report of a ship that was more recently discovered at Punjulharjo, near Rembang in Java

Tengah (Central Java), Indonesia (Manguin 2009). The hull remains of the Punjulharjo ship measure 15.6 metres in length and 4.5 metres in width at amidships (Figure 3-7). The remaining part of the hull consists of a well-preserved bottom structure including a keel and five strakes in portside and four strakes in starboard. A part of the bow and stern structure also remains. A rudder post was discovered next to the hull. According to Pierre-Yves Manguin, the ship is classified under a “lashed-lug and stitched-plank” type boat identified as an example of ancient Southeast Asian construction methods. The method of planking identified is the fastening of the planks by both dowels and disconnected stitch. After joining the strakes, frames and thwarts are consequently lashed to the lugs. The similarity in the stem and stern structure of the Punjulharjo ship with the other ship remains from Southeast Asia including the Butuan Boats has been pointed out (Clark, Green et al. 1993; Manguin 2009). The “lashed-lug and stitched-plank” technique has been identified on those ship remains from Southeast Asia dating between the second to the thirteen centuries, though some changes in the technique are observed among them. In the preliminary report, the planking technique is presumably dated to the time period between the last quarter of the first millennium and the early second millennium. However, the exact date of the ship has not been determined until the result of the radiocarbon dating analysis is available. In Thailand, the use of the dowels and lashed-lug construction method has been identified, indicating the widespread use of the technique in the Indochinese Peninsula during ancient times. Before the tenth century, the growth of the Southeast Asia indigenous shipbuilding tradition forms a sphere of the technology, evident in archaeologically identified ship remains north of the Philippines and south of Indonesia. This seems to cover vastly the South China Sea. As southern China openly faced the South China Sea, the shipbuilding in the region could have been impacted by the tradition.

Perspectives obtained from this chapter

This chapter has attempted to clarify a meaning of technology in the context of the regional development of shipbuilding. A cycle of technological innovation and hybridization is a key factor to interpret it. Some regional factors are considered to be behind the circle. For example, geographical background of the region demonstrates the historical difference in the shipbuilding traditions between the north and the south within East Asia, and this has been reviewed by using iconographical and historical resources. This chapter reviews shipbuilding traditions in the north where flat bottom ships were dominantly used. Compared to the southern part of China where the shipbuilding tradition is distinctive from the major part of East Asia, there were connections with Southeast Asian and further west. Based on an understanding of the diversity within East Asia, the next chapter will focus on archaeological ship remains and their interpretation.

Figure 3-7 The Punjulharjo ship discovered in Java Province. *From Manguin 2009, Courtesy of Ministry of Maritime Affairs and Fisheries*

Chapter IV – Shipwrecks and ship remains in East Asia

The analysis of the development of ship construction and naval architecture in East Asia takes into account approaches that include the categorisation of hull planking methods and the origins of watercraft (Greenhill 1976: 60-95). In East Asia, the use of primitive types of watercraft including rafts and dugout canoes has been a focal issue. The section of this chapter introduces Japanese researchers' approaches to explain the ships' chronological development, which have relied on a linear development theory that elucidates how traditional types of watercraft have descended from dugout canoes. Such linear development theory, however, may need to be reviewed by looking at the evidence from the increased number of excavated ships in the region from the late twentieth century onwards. This chapter presents an inclusive inventory of archaeological ship remains dating to the period throughout the second millennium from China, Japan, and Korea. The inventory chronologically presents excavated ships with their structural information. A number of data of the ships are from the "Shipwreck ASIA" project and are integrated into the inventory. The project has recently been conducted for the purpose of establishment of a regional database about shipwrecks and ship remains in East Asia and Southeast Asia.

IV-1 Technologies and materials of East Asian watercraft before the tenth century

In East Asia, a wide range of materials has been available for shipbuilding and facilitated generating various types of watercraft and diverse construction techniques. The availability of materials determined the types of native watercraft. All major types of primitive watercraft including bark boats, skin boats, rafts and dugout canoes, according to Basil Greenhill's criteria, appeared in East Asia (Needham 1971: 383-387; Greenhill 1976: 91). Several boat ethnological studies reported simple floating devices made of plants and animal skins, and some of them have been used until the early twentieth century in China and Korea (Donnelly 1936; Ito 1975; Peng 1988; Deguchi 1995; Xi 2000; Xi, Yang et al. 2004). Deguchi (1995: 121-124) introduces the sea-going watercraft used by the Ainu people in northern Japan who had constructed the hull until modern times by using sewn techniques with baleen or the tendon of whales, while the use of plant fibres from bark of native trees of *Cerasus* sp. and *Tilia* sp. were common in their shipbuilding tradition. Further south in East Asia, an indigenous group in Taiwan known as the Tao people constructed seagoing boats by traditional methods developed through lengthy periods, similar to the Austronesian shipbuilding tradition (Deguchi 1995: 141-148). This perspective is important in considering the influence of the

Austronesian tradition on the evolvement of East Asian shipbuilding traditions in the past. However, the impact of the Austronesian tradition is not appreciated in the history and archaeology of East Asian shipbuilding, as there is no clear evidence regarding the influence of the tradition in the region. Apart from the raft and dugout canoe, previous boat ethnological studies have not suggested the relevance of the technologies of the other primitive watercraft to the construction of oceangoing ships.

Re-evaluation of rafts in terms of the fastening methods

Of primitive watercraft, it is worthwhile pursuing the regional significance of rafts in terms of its construction methods linked with the structure of later period's ships. Throughout the long term in China, it seems to be common that rafts made from timber logs were used for river cargo transportation and bamboo rafts were used as people's residential place and for transport, as depicted by a Chinese poet, Lu Yu (陸游) living in the Southern Song Dynasty (1127-1279 A.D.). Log and bamboo rafts were widely used in East Asia over centuries. Even during the modern period in China, using rafts was recognized as a dominant form of water transportation (Donnelly 1936; Worcester 1971). Seagoing bamboo rafts could sail to Taiwan with the use of a centreboard and leeboards (Ikuta 1975).

Hornell (1934) presented the idea that the bamboo raft could have been an ancestral watercraft of the sampan and junk with a construction method used for the double dugout canoe possibly influencing the appearance of carvel-built junks. Needham appears to be supportive of Hornell's evolutionary theory (Needham 1971: 381-385). These perspectives have been reviewed by Greenhill by stating, "…that the raft played a larger part in the evolution of boats in China than perhaps elsewhere in the world" (Greenhill 1976). What Hornell and Needham agree on is the importance of using bamboo as construction material for the raft.

Study on East Asian rafts has been conducted based on ethnological and archaeological data (Deguchi 1995). Deguchi (1995: 52-53) referred to Sean McGrail's perspective that there is less usage of seagoing rafts in areas of high latitude and identified the distribution of seagoing rafts in East Asia ranging from South China and Taiwan up to the latitude of 40 degrees north around Korea and Japan. Moreover, her research suggested raft materials used for rafts are different around 33 degrees north latitude within the East Asian regions in that further north rafts tended to be constructed from logs, such as cedar, pine, and paulownias wood, compared to further south where bamboo is a common raft construction material. Furthermore, Deguchi (1995: 54-55) has clarified the different fastening methods existing in the rafts from different materials; about log rafts from Japan and Korea, two holes transversally penetrate the timbers of the rafts in the forward and aft parts through which wooden bars pass; the bars are fixed by wooden nails perpendicularly driven from the top surface of the timbers, for the bamboo raft; transversal bars are surmounted on the aligned bamboos and are tightened by fibre ropes, although some of the bamboo rafts in China adopt the penetrating transversal bars. Deguchi's perspective focusing on fastening methods used for the Korean rafts and their structure is important. Moreover, Deguchi (1995: 85-87) pointed out that there is a similarity in fastening methods observed on the modern log rafts from Japan and Korea with the techniques observed on the eleventh century coastal trader, known as Wando ship, archaeologically discovered in the Korean waters (Details of the Wando ship below in this chapter). This research locates technologies used for the construction of the rafts that have been examined through boat ethnological evidence as significant technologies, following recent archaeological discoveries of the traditional Korean traders of the Goryeo Dynasty (918-1392 A.D.). Therefore, there is historical relevance between technologies to build the raft and the construction methods of Goryeo coastal traders. The latter will be reviewed in detail in this chapter.

Evolutionary theory and fastening methods in the dugout canoe from Japan

Of the primitive watercraft, as Hornell (1934) has insisted early in his work, a dugout canoe has been regarded as an ancestral watercraft evolving into more seaworthy vessels. In China, three ancient boats have been assessed with a focus on their fastenings. They include: boat remains dated to around the Western Han (206 B.C.-9 A.D.) found in Wujin, Jiangsu Province in 1975, a double canoe dated to the period of the Sui Dynasty (581-618 A.D.) discovered in Pingdu in Shandong Province in 1975, a boat composed of a solid bottom timber and strakes discovered in the vicinity of the Chuan Yang river (川杨河) in Chuansha, Shanghai, dated to the Tang Dynasty (618-907 A.D.) (Dai 1985; Xu 1985; Deguchi 1995; Xi 2000; Xi, Yang et al. 2004). Types of fastenings observed on these remains include wooden pegs (or dowels) and iron nails to fix wash strakes to the hollowed dugout or baulks of the bottom structure.

In Japan, dugout canoes appear to have been widely and predominantly used, and under the circumstance a linear process from dugout canoes to indigenous coastal traders has been discussed as a focal theory of ships' structural development (Ishii 1957; Ishii 1995a). With regard to the number of excavated dugouts, Ishii (1957: 6) pointed out that over seventy dugout canoes' remains had been discovered by the 1950s in Japan. According to a recent report, the number of discovered dugout canoe remains dating to the prehistoric period is 117 all over Japan (Shiga Prefectural Association for Cultural Heritage 2006). This number increases to 243 by adding dugout remains dating to later than prehistoric periods (Miyashita 2006). Typological study on the discovered dugout remains had initially been conducted by Shinji Nishimura and has been developed through comparison with discovered dugout canoes in Europe (Ishii 1957; Shimizu 1975). Ishii (1957: 15) in his typological approach defines that, whatever the fastening methods used, if a vessel's bottom hull consists of a dugout base and built up planks it can be called "Jun-Kozosen", that is, a planked up dugout (Figure 4-1). The planked up dugouts have been interpreted as any type of boats or ships at the transitional stage between the dugout canoe and seaworthy ships. Later, Deguchi (1991; 1995; 2001) suggested different types of planked up dugouts and different patterns to expand planks or wash strakes to demonstrate the evolution from dugout canoes to planked up dugouts in Japan.

Figure 4-1 Reconstructed planked-up dugout canoe at the Osaka Maritime Museum (bottom part consists of a hollowed log). *Photo by author.*

To locate such planked up dugouts in the history of the structural development of the ships is supportive, considering it as an existent theory (Greenhill 1976). Moreover, some dugout remains archaeologically found in Japan have been introduced as evidence of the planked up dugouts (Ishii 1957; Shimizu 1975; Adachi 1998). Yet, the development of the planked up dugouts has not been explained beyond the framework of the planked up dugouts presented by Ishii that focuses on structural configuration. Apart from an extensive study on the dugout canoes by Deguchi, some important aspects as to how transition of the construction methods developed associated to the structural development have not been addressed, including the sequence of construction, enhancement of longitudinal and transversal strength, and associated fastening methods (Deguchi 1995). The study of the structure of later Japanese coastal ships have been studied in detail (Ishii 1995a). The history of the structural development of these ships is yet to be clarified. It is believed that the origin and development of the construction methods are still open for discussion in the history of Japanese ships.

The planked up dugouts have been appreciated as part of the linear development from primitive watercraft to seagoing ships, such as in Japan where its shipbuilding tradition has been addressed as descendent technologies only from locally developed techniques. The endogenous growth of technology is considerable in shipbuilding. However, as this research pursues shipbuilding traditions associated with the historical development of oceangoing ships from a regional perspective, the linear development is not regarded as a dominant theory to explain all aspects of the shipbuilding evolution. Exogenous factors are deduced in this research. In Japanese shipbuilding tradition, the possible impact from the Korean Peninsula on its development will be addressed below in this chapter.

Fastening methods using iron

One of the earliest examples of iron used for ship construction is among the ship remains discovered in the Sui Dynasty's tomb of Zhongshanwang (中山王), in Pingshan, Hebei Province (Xi, Yang et al. 2004). The tomb has a funeral chamber inside, in which a well constructed ship was found used as a coffin. The size of the ship is 13.10 metres in length and 2.30 metres in width and the depth of the ship is 0.76 metres (Figure 4-2). Its basic structure is composed of several planks having a 400-600 millimetres width and a 100–150 millimetres thickness. The planks are fastened together with iron strips. The iron strips are threaded through square 20 millimetres square ligature holes that are located 40-50 millimetres from the seam of the planks to tie the planks together with three or four turns. These iron strips are at 0.80-1.00 metre intervals. The ligature holes appear to be sealed with small wooden pegs. The small pegs on the ligature holes are probably for securing the iron strips and perhaps make the hole watertight. The iron strip functions as stitches to fasten the planks together and also resist shearing forces between planks. In the case of the Zhongshanwang's tomb ship, a sealing in the ligature holes by fused lead has been found. The techniques of sealing and caulking seem to have been well developed by the Sui Dynasty. The fact that two techniques are observed on the Zhongshanwang's tomb ship indicates that it might have been in service on the water for a certain period before its use as a coffin.

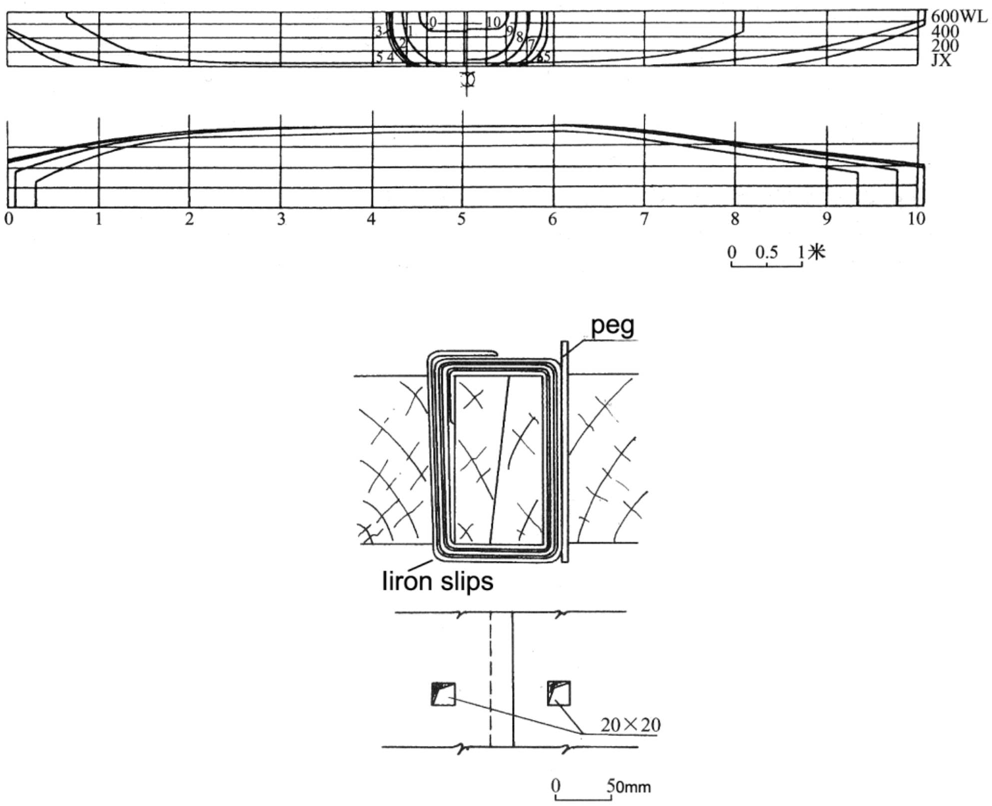

Figure 4-2 Metal fastenings evidenced in the ship remains used as a coffin discovered in the Sui Dynasty's tomb of Zhongshanwang, and the reconstructed ship lines of the ship. *From Xi 2000*

There seems to be good evidence of the use of iron in shipbuilding in the Sui Dynasty period of China. Around the seventh century and eighth century, many ships regularly made ocean voyages between China and Japan. Before this, the interaction by delegating diplomats and monks from Japan to China occurred during the Southern and Northern Dynasties (420-589 A.D.) and Sui Dynasty. The details of the ships are unknown. The route that the Japanese representatives took did not entail long distance voyage, and ships departing from current Osaka (Nanba at the time) got to Kyusyu and the tip of Korean Peninsula, and then voyaged upward north along the Peninsula and crossed the Yellow Sea to reach Yantai in China. The long distance voyages recorded in the historical texts refer to the delegation of envoys from Japan to China in the later periods. The voyages of “Kentoushi” (Envoys to Tang 遣唐使) from Japan to the Tang Dynasty of China were undertaken eighteen times between 630 and 894. At the last stage of the envoy’s voyage around the 830s – 840s, a Japanese monk “Ennin” (円仁 or 圓仁) recorded his journey over nine years as one of the pilgrim members to China, including a voyage from Japan to China. His diary is known as *Nitto Guho Junrei Gyok*i (Record of Pilgrimage to China in Search 入唐求法巡礼行記). An early record of the voyage has been reviewed not only by Japanese researchers but also by a foreigner (Reischauer 1955). According to the record, Ennin’s envoy ships confronted difficulties, and his diary depicts his hazardous voyage to China. This might have resulted from the paucity of navigation techniques and partly from embarking such a fragile ship, as it is described, that “[I]ron strips came off by wave smashing (平鐵（鎹？）為波所衝悉脱落)”. The manuscript indicates that the ship Ennin embarked on might have partly used iron for fastening, though details of the fastening is not recorded. “Iron strips” in the text might mean iron strips like those used on Zhongshanwang ship.

Advancing seagoing technology

Some Chinese researchers give emphasis to the introduction of iron nails, caulking systems, propulsion by square sails, and watertight bulkheads, resulting from continuous improvements since the Han Dynasty (206 B.C.- 220 A.D.) (Tang 1991; Xin and Yuan 1991). It is probably true that such technological development facilitated early maritime interaction between Japan and China and it was continuous within the Sinocentrism embodying as a tribute system throughout the second half of the first millennium. Chinese merchants’ ships, however, slowly occupied an important position in maritime trades from the late ninth century. Korean seafarers may have had a high profile in East Asian waters ahead of the Chinese merchants’ rise. Those Korean people, for example, played a significant role in ship transportation for the Japanese and in maritime trade (Matsunami 2006). In the ninth century’s maritime activities, two different trading patterns between Japan and other East Asian countries can be chronologically pursued. First, ships from Silla (57 B.C.–935 A.D.), which was one of the Three Kingdoms of Korea, initially occupied an important role in trade with Japan before the early ninth century. It seems that during the late eighth century private merchants from Silla voyaged and visited diplomat facilities known as Dazaifu in the Southern part of Japan. Jang Bogo who is known as a prominent maritime figure from Silla visited Dazaifu in 824. The details of the Silla ships used by the traders have not been depicted in historical documents. The seaworthiness of the ship, however, is partly illustrated by the fact that the central government at the time in Japan gave orders to construct the Silla type ships to Dazaifu in 837. In 840, a local bureaucrat of Tsushima Island, located between the Southern parts of Japan and the Korean Peninsula, requested Dazaifu to provide one of the better constructed Silla ships due to the high frequency of wrecking of their native ships. Some of those envoys to China appeared to have preferably used the Silla ships. Despite the fact that the development of the Silla seagoing ships has not been clarified, a presumption that they probably used flat-bottomed ships adopting several beams for transverse strength can be derive from the discovery of indigenous Korean coastal ships (See the next section). All the discovered ships so far are dated after the tenth century. The long-term continuity of the structural design through the Goryeo Dynasty and much later periods allows one to propose that the same construction methods might have been used for earlier ships. The non-use of bulkheads and fastening methods relying on wooden fastenings could be ancient features of Korean shipbuilding.

Chinese shipbuilding in riverine tradition

In China, technologies preceding the advancement of seafaring have been accumulated in shipbuilding tradition for riverine use by the Tang Dynasty period. This can be assessed by looking at a few remains of river ships dated to this period. They have been barely studied and the limited available information is summarized as follows.

Rugao 如皋 ship (Figure 4-3):

According to Chinese sources (Wang 2000; Xi 2000; Xi, Yang et al. 2004), the Rugao ship was found at Puxi in Ruguo city, Jiangsu Province during reclamation in 1973. The well-preserved hull measures 17.32 metres in length and 2.58 metres in width. The remaining part consists of bottom planks, bulkheads, and some strakes from the sides of the hull. The bottom is a flat shape suitable for river transportation. Its bluff bow and aft parts are slightly narrower than the midship. The Chinese researchers' reports indicate that the basic joinery of the bottom timbers appears to be a mortise and tenon, yet the details are unclear. Mortises and tenons are also said to be used for the bulkheads and hull planking. The hull profile shows that the bulkheads divide the hull into eleven holds. The fifth, sixth and seventh bulkheads are very close together and create two very small holds. The beam of the vessel is approximately 2.80 metres and measures approximately 0.95 metres athwartship in the bow and stern. Chinese researchers have mentioned that there are doorways through the sixth to the eighth holds, yet these bulkheads produce watertight compartments. The Chinese researchers' reports states that these holds could have been used as a living space covered over by bamboo sheets in the absence of decks. The hull planking is clinker-built. The thickness of the planks is 40–70 millimetres and its bottom planks are 80-120 millimetres thickness. The length of iron nails is 165 millimetres, and the section of the nail head measures 15 millimetres. Iron nails are used for the fastening of hull planking and the driven pattern at 60 millimetres interval. The seams are sealed by putty. Associated artefacts, mainly ceramics from the Yue kiln, allow the Rugao ship to be dated to the Tang Dynasty. Chinese researchers conclude that the ship was used around the reign of Gaozong (649-683 A.D.) who was the third Emperor of the Dynasty.

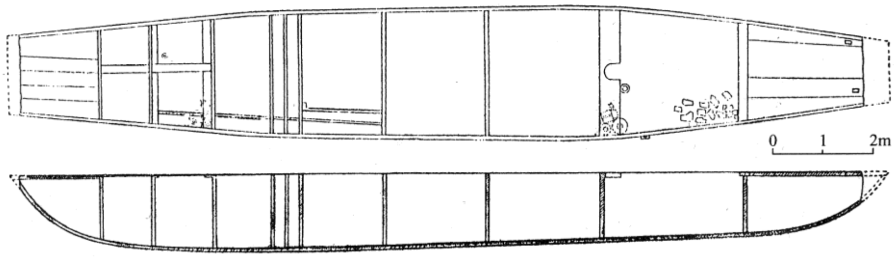

Figure 4-3 Plan of the Rugao ship. *From Wang 2000*

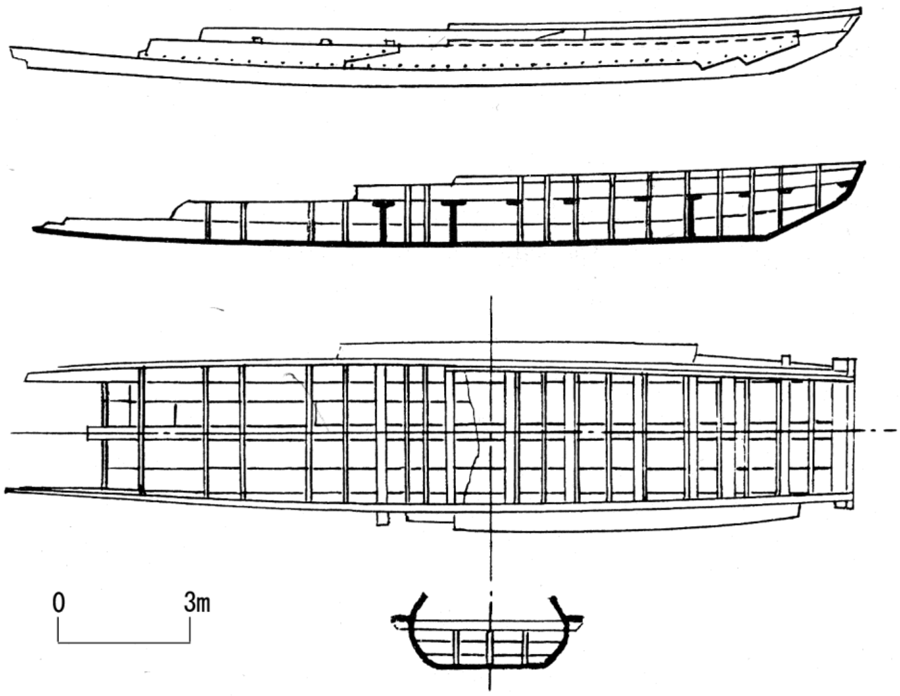

Figure 4-4 Plan and cross section of the Shiqiao ship. *From Xi 2000*

Shiqiao 施桥 ship (Figure 4-4):

During river development at Shiqiao in Yangchan, Jiangsu Province in 1960, one wooden ship was found with a few dugout canoes. According to Xi (2000), the ship shows a sturdy structure. Although its stern part was missing, the remaining part of the hull measures 18.40 metres in length, 2.40 metres in width, and 1.30 metres in depth. The transverse structure consists of the combination of beams and bulkheads (the exact number of the holds divided by the bulkheads is unclear). Mortise and tenon and iron nails appear to have been used for hull planking. The dimension of the nails used is 170 millimetres in length, and its head is 20 millimetres. These nails are driven into hull planks with an interval of approximately 250 millimetres. The nails are used for the construction of the bottom as well as the sides. The exact date of the ship is disputable. Initially, the date was given to the Song Dynasty based on artefact analysis, but later the majority of researchers reassessed that it dates back to the Tang Dynasty. The depth of the ship is not high and the structure indicates that the ship was originally used for river transportation.

All identified ship remains before the tenth century seem to be for riverine use, not specifically designed for coastal or ocean seafaring. They are dated to the late periods of the Tang Dynasty. The state of development of riverine infrastructure during the Tang Dynasty continued from the previous dynastical period, and presumably propelled Chinese shipbuilding industries to construct inland watercraft for transportation in rivers as well as canals.

These river craft outline techniques of ship construction that developed before the tenth century. Fastening methods using iron that had appeared earlier had become standard by the Tang Dynasty. Iron, compared with other metals, has been predominant in China for a long time. The use of putty for sealing and luting has probably spread out widely during the Tang Dynasty; the use of some kind of putty probably dates back to earlier periods than the Tang Dynasty. It was also used with some caulking materials that are vegetable fibre pushed into the seam after construction. The putty can be used to seal over the caulking as paying. With the development of planked hulls, the transverse structure of the ship also evolved. The use of bulkheads in constructing riverine ships is evidenced in the archaeological discoveries. It seems that bulkhead structure and construction methods were well established by the ninth century before bringing it into the structure of seagoing ships. This had been developed, distinct from other areas of East Asia, by the time the Chinese commenced seagoing. Little information is available on what types of ships were used in the early stage of seafaring. Whether they used riverine ships or there were some changes in the structure and shape before seagoing was tried remains an open question. In China, internal conflicts and disorder of political state from the end of the Tang Dynasty to the Five Dynasties and Ten Kingdoms Period (907-960) occurred, and historical records contribute little to any discussion of the type of ships used during these periods. Seagoing Chinese ships developed in a historically short period of time. Diffusion of the use of bulkheads in shipbuilding was limited within the East Asian region. Each nation within East Asia started to show separate shipbuilding traditions by the tenth century.

Less activity in constructing coastal and oceangoing craft may lead to stagnation or ceasing of technological innovations, implying less stimulation from the low volume of seaborne trade. After the fall of the Tang Dynasty, China met war time periods, which brought stagnation of social activities. This could have impacted on seaborne trade into which Chinese merchants made greater inroads in later periods. Raising their presence presumably came up within a few hundred years or even less presumably around the period of the Northern Song Dynasty (960-1127 A.D.).

IV-2 Inventory of the shipwrecks and ship remains in East Asia

Comprehensive inventory of on ship remains in East Asia has not been offered since Jeremy Green's and Sean McGrail's studies (Green 1986; Green 1997; McGrail 2001). This section provides an overview of historic shipwrecks and archaeological ship remains dating to after the tenth century discovered in East Asia, based on updated data through the "Shipwreck ASIA" project. The section intends to provide an inclusive dataset of the excavated hulls which have been less examined, compared to the studies of cargoes and trading commodities from those sites. In thematic studies in maritime archaeology in Asia, the hulls of the shipwrecks and ship remains have been largely overlooked. It is only recently that access to the remaining part of the hull raised from the waters has been permitted after long term conservation in Asian countries. Considering the past achievements in each state, at present it becomes more relevant to conduct an inclusive analysis about archaeological remains of Asian ships. As an initial approach, an inventory of shipwreck sites and ship remains in the region needs to be developed and such an inventory is typically designed as an archaeological site database for the sake of academic research and site management.

The database in the Shipwreck ASIA project is developed as an instrument not only to collect data but also to store and share the information and to contribute to develop a regional cooperation in both archaeological research and cultural heritage management. The database is the most accessible resource about ships that have been used in riverine, coastal and ocean waters archaeologically identified not only underwater but also on land. Data about identified ship remains from East Asia is available on the project web-site (www.shipwreckasia.org) and in the published resource (Kimura 2010a). Based on the data from the project, ship remains from China, Japan, and Korea in this section will be described focusing on dimensions of the remaining of ships, characteristics of hull components, and fastening methods. The section will also present development, structure and construction methods after the tenth century through the second millennia in East Asia.

China

Data on the hulls of the 22 excavated ships from China are presented here. These ship remains are introduced chronologically following their Dynastical periods from the Song Dynasty to the Qing Dynasty (1644-1912 A.D.). This is the most extensive dataset of excavated Chinese ships, which covers approximately a thousand year time span, ever presented in archaeological hull study. This provides a comparative perspective to this research and a basis to this research that attempts to identify transition of innovations in hull structure and construction methods within a chronological framework. The blanket data is also of use to address comparatively endemic features of shipbuilding in the country in terms of archaeological view. Some historical backgrounds about the dynasties are introductorily presented to provide insights regarding factors that might have impacted on shipbuilding in each period. Many of them have been dated by artefact assemblages and the study of an absolute date regarding the built date of the ship has been examined on only a few sites. Data shown here does not include those archaeological watercraft remains which have a dugout as the hull main component i.e. dugout canoes and planked-up dugout canoes. Ships constructed without a dugout canoe base have appeared before the tenth century, and they are introduced in the previous section.

- Song Dynasty ships – riverine and coastal

  Dazhi boat (大治舟):

  According to a short archaeological report (Ji 1987), ship remains were discovered in 1978 during the dredging of the Dazhi River, Nanhui district in Shanghai city. The Cultural Properties Administration Board in Shanghai city conducted the excavation at the site (Figure 4-5). Although the upper part of the hull is missing, the bottom was well preserved when discovered. The remaining part measures 16.20 metres in length and 3.86 metres in width. The cross section of the hull bottom is flat. The bottom consists of seven strakes. The strakes comprise three planks, each joined by lap joints. Three internal runs of planks double the bottom planking, though they only partly remain. Eight bulkheads divide the hull into nine holds. The spacing of the bulkheads varies: 2.90 metres, 1.26 metres, 1.90 metres, 1.70 metres, 1.84 metres, 1.42 metres, 0.78 metres, 1.30 metres, and 1.61 metres. There is no report of limber holes. Iron nails are used to fasten the hull planking to the bulkheads and putty made from lime and oil was used to seal the iron nail heads. A notable feature is a hole with a diameter of 200 millimetres through the median plank in the bow (if the bow is correctly identified on the basis of the position of a mast step). This is what is called "Mao chayan" (Hole to drive anchor through 錨揷眼) (Ji 1987: 177). This would be a type of anchor that has been reported as "stick-in-the-mud" anchor in Worcester's study; it is a pole used by Chinese river boats as an anchor, driven through the bottom of the hull into the bed of the river. (Worcester 1971: 89). There is one mast step attached to the third bulkhead having one recess to hold a mast. From a hole located at the first hold, 24 copper coins with the inscription of Taibin Tongbao (太平通寶), which represents the reign of the second emperor of the Northern Song Dynasty, were discovered. In the hole, a silver hairpin was also discovered. Based on the discovered coins and one ceramic glazed bowl, the date of the ship has been determined as having originated during the Song Dynasty. It is said that the use of this ship probably was for short distance coastal transportation and, for some reason, it had been abandoned (Ji 1987: 177).

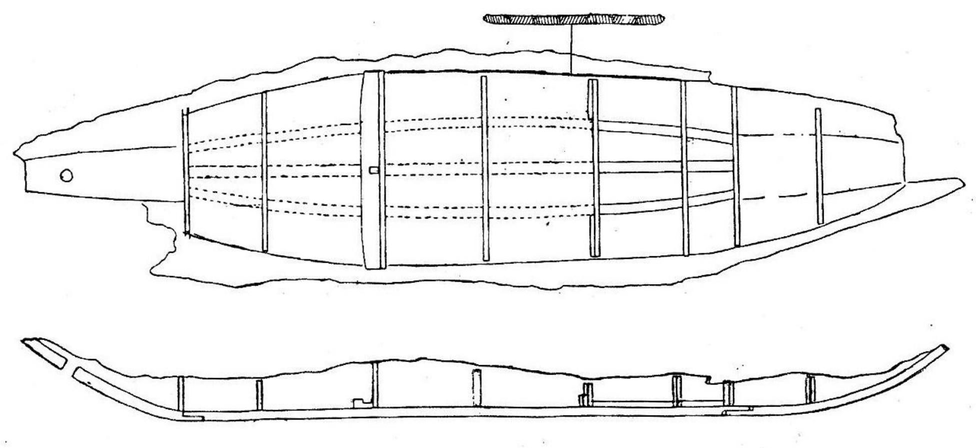

Figure 4-5 Plan of the Dazhi boat. *From Ji 1987*

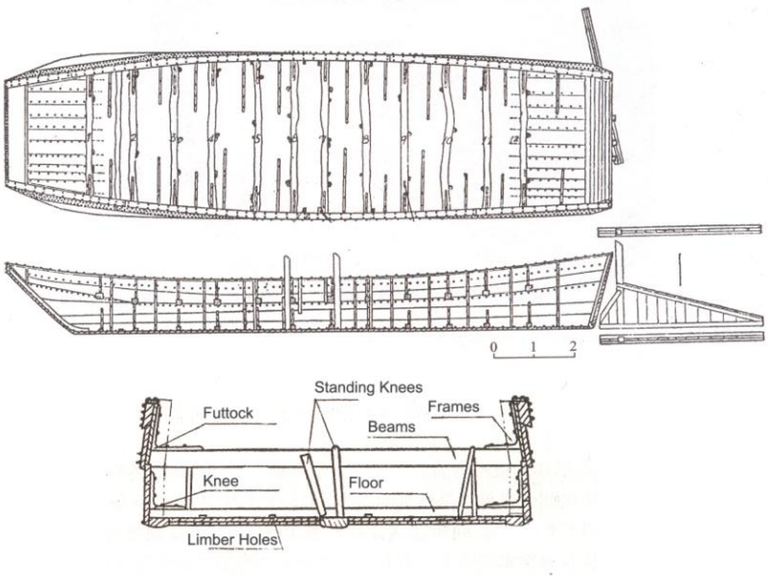

Figure 4-6 Plan and cross-section of the Yuanmengkou ship. *From Xi 2000*

Yuanmengkou ship (元蒙口船):

According to Xi Longfei (2000: 152-157; 2008: 66-67), Song Dynasty ship remains were discovered at Yuanmengkou, at Dongtantou of Jinghai district in Tianjing Province in 1978. The remains of the ship are 14.62 metres in length, 4.05 metres in width, and 1.23 metres in depth. Except for the upper part of its port side, the hull is relatively well preserved. The displacement of the original ship has been estimated to be approximately 38 tons (Xi, Yang et al. 2004: 112). The shipwreck shows a flat bottom and a rectangular section shape throughout its length (Figure 4-6). It is effectively a box with a scow-bow. The structure of the bottom hull has not been clearly reported, but it seems that a large piece of flat timber was longitudinally placed in the centre of the hull, and there were large chine planks as well. Between these large planks, planks were longitudinally placed. The cross section drawing indicates a flush edge joint in both the bottom and topside planking. However, the topside planking shows a double layer. The drawing shows floors (bottom frames), futtocks or knees at the chines, beams, and standing knees supporting the plank above the beams. There are limber holes in the floors or bottom frames. There are pillars between the beams and the floors. In addition, there are twenty half frames between the beams. The strength of the hull is further enhanced by top timbers on the fifth beam to the eighth beam around the midship. Chinese researches have pointed out that the most significant discovery is a wooden rudder regarded as the oldest example of a balanced rudder (Xi, Yang et al. 2004: 114). The rudder blade forms a scalene triangle measuring 3.90 metres along the bottom. The height of the rudder post is 2.19 metres. The ship could be dated to the Northern Song period. The date has been initially determined by identifying a copper coin Zhenghe Tongbo (政和通寶) recovered from the site which gives an idea of an absolute date of 1111, and sedimentation analysis suggests that the ship may have been abandoned before the flood prevention works were conducted in 1117. With regard to the date, however, the uniqueness of the structure using half frames with an absence of bulkheads makes the hull appear more modern than the twelfth century.

Fengbinyang Bay ship (封滨杨湾沉船):
In 1978, a local commune of Fengbinyang discovered ship remains among the sediments of Fengbinyang Bay adjacent to the Jiading district in Shanghai city. The remaining part of the hull measures 6.23 metres in length. Although the forward part of the ship is mostly missing, it is in relatively good condition (Figure 4-7). The hull is slightly tapered from the midship toward the bow, yet it forms a square transom bow that has a platform at the deck level. There are seven bulkheads comprising eight compartments, and a mast step is placed on the forward side of the fourth bulkhead. Iron brackets, known as Guaju, are used to fasten hull planking to the bulkheads (Wang 2000: 120-121). Some butts of hull planks show a half-lap joint. The cross-section shape shows a flat bottom made of two strakes, double chines, and some tumblehome of the topsides above the second chine. One of the notable features of the ship is two longitudinals beneath the bottom planks. The two longitudinals have a semicircle section and they run along the hull as small bilge keels or bilge runners. It has been pointed out that these are more likely to provide further longitudinal strength to the hull, and they appear to be small runners to protect the bottom planking during launching and beaching (Wang 2000: 120-121). From the inside of the hull, bricks and yellow glazed ceramics, which are probably from the Jizhou kiln in the Jiangxi region, were discovered. These artefacts have been used to determine the date of the ship to the late thirteenth century. Furthermore, the discovery of an iron pan and sword also indicates a link to this period.

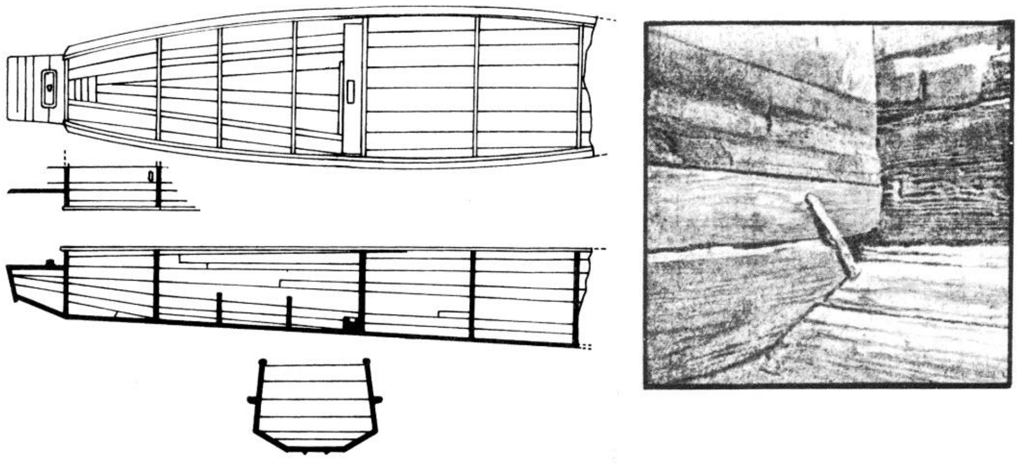

Figure 4-7 Plan and cross-section of the Fengbinyang Bay ship and its photograph showing the use of a bracket fastening the hull planks and bulkhead planks together. *From Wang 2000*.

Fashi ship (法石船):

A shipwreck was found at Fashi vicinity of Quanzhou Bay in 1982. A portion of the hull was located under a building, so only a partial excavation was implemented (Green 1997: 19; Xi, Yang et al. 2004: 124-125). An exposed part of the hull was reburied for in situ preservation. A portion around midship toward the stern was revealed during the excavation. The hull had a keel, and three bulkheads were also identified. The exposed keel consists of a part of the main (midship's) keel and the aft keel. Bilge water could run along the bilge through limbers in the bulkheads. The Fashi ship shows evidence of the use of wooden brackets (or pegs) to fasten bulkheads to hull planking. The length of one wooden bracket measures 720 millimetres and its cross-section is 60x60 millimetres at the hull planking and tapers to 20x30 millimetres at the inboard end. They are driven from outer surfaces of some of the hull planks and attached onto the forward sides of the bulkheads. This is a similar fastening method to that noted above in the Fengbinyang Bay ship, also observed on the Quanzhou ship, and it is more or less identical to the use of wooden brackets in the Shinan shipwreck. Iron nails are used to fasten the bulkheads' planks. A portion of the recovered hull including a bulkhead plank is under chemical treatment in the Quanzhou Ancient Ship Gallery of the Museum of Overseas Communications History) (Figure 4-8).

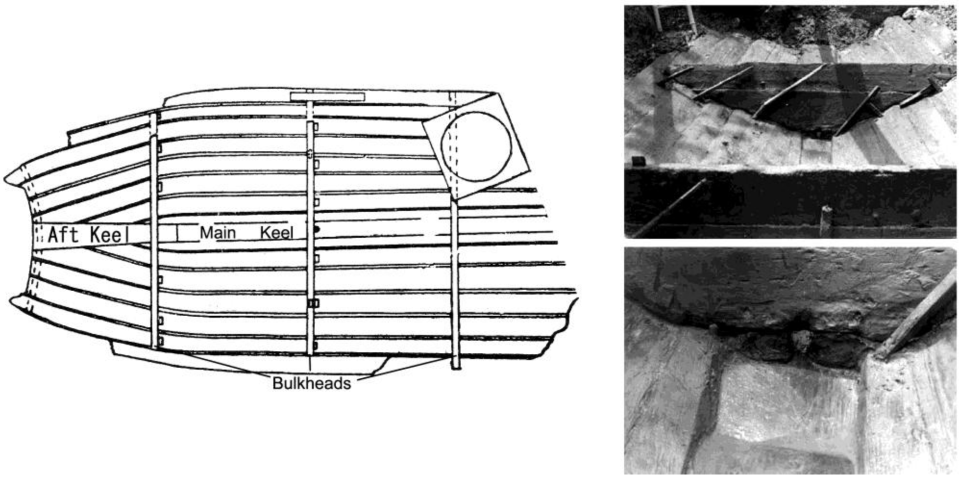

Figure 4-8 Plan of the Fashi ship and its photographs showing the limber and the brackets fixed onto the bulkhead planks. *From Xi, Yang, et al. 2004*

Heyilu ship (和义路船):

In 2003, during a rescue excavation conducted by the Cultural Relic Preservation Administration Center of Ningbo and Archaeological Research Institute of Ningbo at the south side of the site of Heyimen Wengcheng (Turret of Heyi gate), the remains of a watercraft were found. (Gong, Ding et al. 2008). Although the stern of the hull is missing, the remaining part is relatively well-preserved and measures 9.20 metres in length and 2.80 metres in width (Figure 4-9). The bow of the ship is fairly sharp and the cross-section of the lower hull is a fairly sharp V-shape. The forward keel and main keel remain, and the cross section of the main keel around midship is rectangular and measures 300x100 millimetres; yet toward the bow it changes to a triangular shape to fit to the forward keel. Nine bulkheads remain and sturdy frames are attached to them. The bulkheads appear to be irregularly distributed. Each bulkhead remain consists of three to four planks fastened by iron clamps. There are limber holes in the bottom planks of the bulkheads. Seven strakes remain at the portside and starboard side in the mid part of the hull. Hull planks measuring 400-600 millimetres are edge-joined by skewed iron nails. A mast step has not been found, and according to a figure of the reconstructed ship in the report, its propulsion appears to have relied on a yuhlo (Gong, Ding et al. 2008: 187). Based on ceramics recovered from the inside of the hull, the ship has been dated to the Southern Song Dynasty (1127-1279 A.D.) and it could have been used for short distance transportation in the harbour or coastal areas.

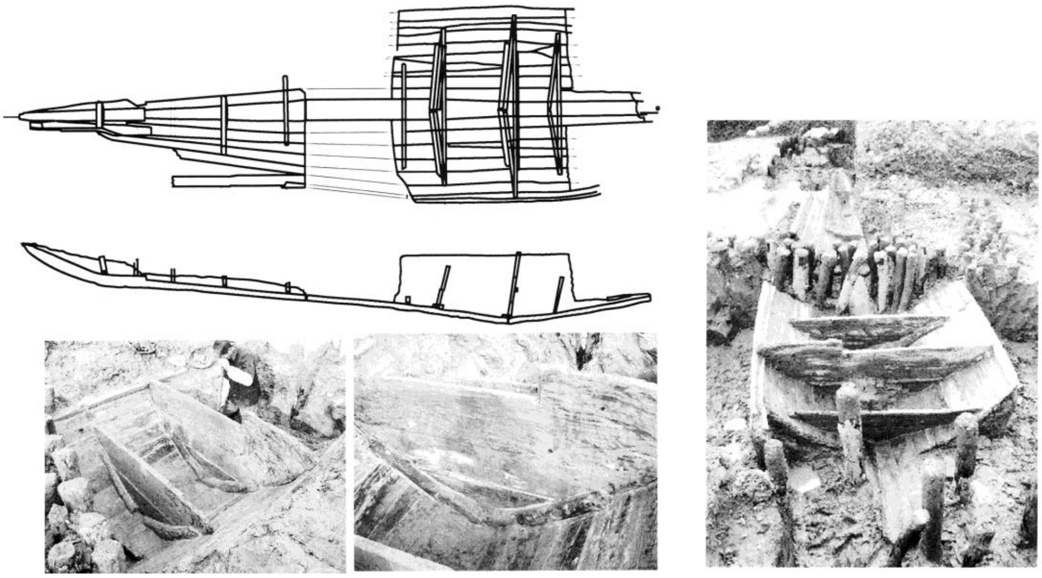

Figure 4-9 Plan and photographs of the Heyilu ship. *From Gong, C., Ding, Y., et al. 2008*

A relatively number of excavated ships dating back to the Song Dynasty have excavated on land, and they were used as riverine ships. Short archaeological reports published in Chinese are primary resources for detail about those ship remains. Some ship remains seem to show ship-types that could have been widely used, not only riverine but also estuarine areas or they might have been used for lighterage in ports, including the Dazhi boat, Yuanmengkou ship, the Fengbinyang Bay shipwreck. They were discovered in the late 1970s when only limited preservation was able to be conducted. The locations of these ship remains are around Shanghai on the estuary of the Yangtze River flowing to Hangzhou Bay and Tianjing in the further northern part of China. The cross-section of these ships present flat or flat-round bottom, correspond with the generic idea that ships from northern parts used in the either inland waters or open waters typically observed north of Hangzhou Bay. The frames and bulkheads are used as transversal components. The use of the axial rudder and mast steps are suggested to date back to the earlier than the Song Dynasty periods. Besides fastening relying on iron nails, the use of the brackets to fasten hull planking to bulkheads which is seen on the Fengbinyang boat is noted. Fastening using iron characterises Chinese shipbuilding tradition. Iron fastenings include nails, brackets, and clamps, and each type can be further sub-classified into different shapes. These have been reviewed by Chinese scholars (Xu 1985; Xi, Yang et al. 2004: 123-125; Zhang, You et al. 2004: 288-291). In these studies, iron brackets have been defined as a more advanced form of technology evolved from wooden brackets. The Fengbinyang Bay shipwreck is the earliest archaeological evidence of the use of metal brackets. As there is no evidence of wooden brackets pre-dating Fengbinyang, the evolution mentioned above is speculative. The continuing use of wooden brackets can be observed over centuries. Their use in the fastening of hull planking to bulkheads is the same for wooden brackets and iron brackets. The Fashi ship discovered in the vicinity of Quanzhou city in Fujian Province in the 1980s uses brackets made from wood. The cross-section of the hull shows that the bottom of the ship is not flat, regarded as a feature suitable for use in shallow and tidal waters. The Heyilu ship excavated in Ningbo city in 2003 has probably been used for transportation in the inshore and for lighterage in ports. It has a sharp bottom with considerable deadrise. Diversities in the types of the hull used for inland water and inshore are recognized. The configuration of riverine ships dating to the Song Dynasty period can be seen in the picture the scroll by Zhang Zeduan (1085–1145 A.D.) entitled *Qing Ming Shang Ho Tu* (Along the River During the Qingming Festival 清明上河圖) , which has been used in some previous studies (Needham 1971; Green 1997). The scroll graphically depicts a few different types of river ships. In particular, of some features depicted in this scroll including rigs, sails, shipboard items, and super structure, the stern structure of the depicted ships is useful to assess the excavated ships. The historical and archaeological resources appear to correspond with each other.

- Song Dynasty – coastal and oceangoing trade
  Ningbo ship (寧波船):
  The Ningbo ship's archaeological remains were discovered at the vicinity of the Fenghua River (奉化江) at Dongmenkou in Ningbo city (Lin, Du et al. 1991). After revealing the hull, deterioration occurred quickly and, unfortunately, the hull was not properly preserved. The remains of the hull measure 9.30 metres in length and 4.40 metres in width, consisting of the forward section of the hull bottom including the forward keel, the main keel, bulkheads, and hull planking (Figure 4-10). The length of the remaining main keel is 7.34 metres long, 0.26 metres wide, and 0.18 metres deep. The middle member of the main keel shows the greatest length measuring 5.10 metres and both ends are stepped for the scarfs. On its aft scarf, a piece of the timber regarded as a part of the aft member of the main keel or an aft keel remains. Since this is hardly determined, the number of the original members that consists of the main keel is not ascertained. The forward member of the main keel is approximately 2.00 metres long and its forward end is scarfed to join the forward keel. The forward keel angles upwards at 35 degrees. The remaining part of the forward keel measures 1.55 metres long and has a triangular cross section with the widest part measuring 180 millimetres with a depth of 200 millimetres. There are twelve coins and associated small holes in the scarf joint between the main keel and the forward

keel, associated to shipwrights' tradition (Green 1997: 20). Seven bulkheads remain on the main keel. The thickness of the bulkhead planks is 70-100 millimetres on average. The bulkheads are nailed to the frames that are, in turn, nailed to the hull (Green 1997: 20). A supporting timber or stiffener is vertically installed against the aft side of the fifth bulkhead, and this timber is fixed into a recess on the keel. As this arrangement only appears to be on the fifth bulkhead which is the position of a mast step, the timber is presumably for reinforcing the bulkhead against the loads imposed by the mast. The spacing of the bulkheads varies, and the smallest hold is the second hold measuring 620 millimetres, and this is compared to the space of the fifth hold measuring 2.05 metres, which is the largest space. A forward mast step is placed on the forward side of the first bulkhead and it measures 840 millimetres athwartships, 210 millimetres wide and 140 millimetres thick. A main mast step is placed in the forward side of the fifth bulkhead and measures 1.04 metres athwartships, 250 millimetres wide and 180 millimetres thick. Both mast steps have recesses to receive tabernacle cheeks. The cross section drawings show a gentle turn to the bilge starting at the garboards with a moderate deadrise. In the bow the cross-section shows sharp V-shape. The hull planking is carvel-built, and according to the drawing, it is single layered. The length of the remaining plank measures 3.00 to 8.00 metres with a width of 210-420 millimetres and a thickness of 60-80 millimetres. Iron nails having a rectangular section with a side of 10-15 millimetres are used for the hull planking and these nails have been skew driven with an interval of 100-250 millimetres. The seams of the strakes are filled with putty. On the outer surface around the seventh and eighth strakes in the starboard side, a longitudinal timber having a semi-circular profile is fixed by iron nails. It is 7.10 metres long and runs along the hull. This has been explained to function as a bilge strake to contribute to stability and strength (Wang 2000: 144). It seems that a part of the rudder stock has remained.

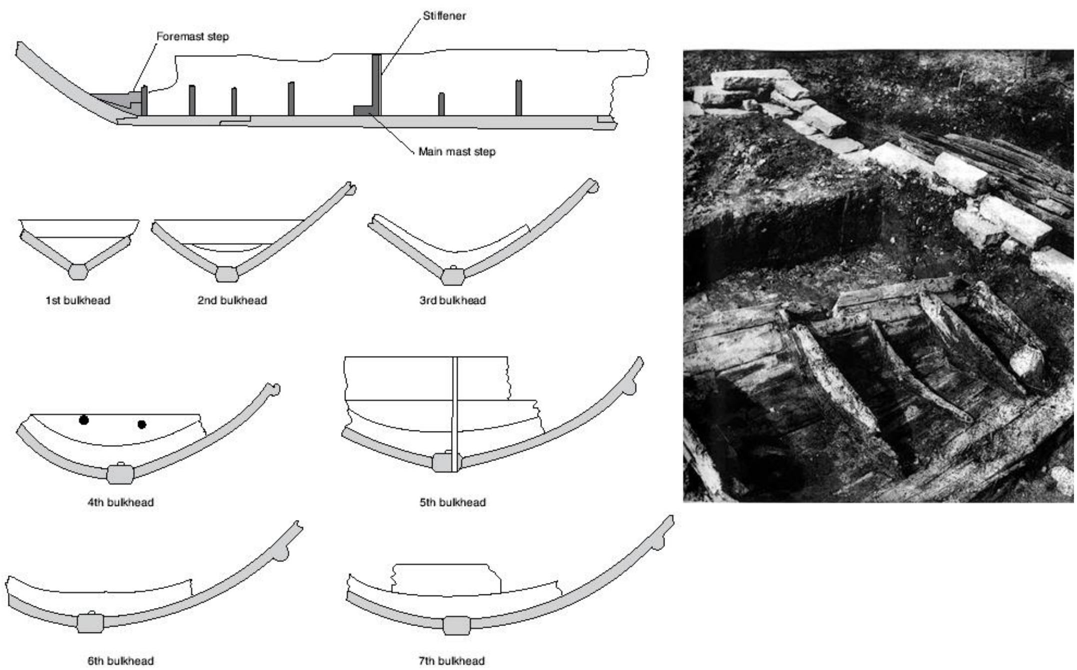

Figure 4-10 Plan and cross-section of the Ningbo ship and cross sections, and a photograph of the exposed hull. *From Green 1997*

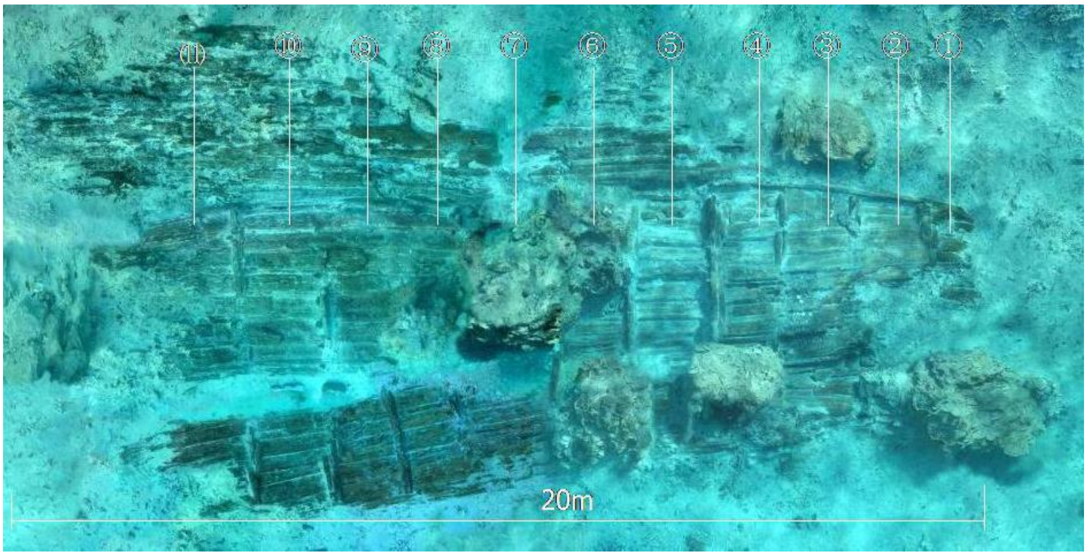

Figure 4-11 Underwater photograph from the top view of the Huaguang Reef No.1 shipwreck. *Courtesy of the Research Centre for Underwater Archaeology, in China*

Bai Jiao Shipwreck No. 1 wreck site (定海 I 号沉船):

The site is known as the Dinghai wreck site or the Bai Jiao 1 wreck site (Kenderdine 1995; Kenderdine 1997). The site is located at 3.5 kilometres northeast of Dinghai village on the south of Huangqi Peninsula and north of the Min and Ao rivers' mouths in Fujian Province. It was well known by the locals that from the waters around the Dinghai, a large number of various types of ceramics including bowls, jars, pots, and dishes had been recovered. These ceramics have been dated to different periods ranging from the Tang to Qing Dynasties, and the artefacts probably originate from different sources such as river sedimentation, abandoned cargos, and wreck events. The wreck site was found during shell dredging operations and was inspected in 1989 to assess whether potentially it was suitable as a training site for the China-Australian cooperative programme. In 1990, provisional surveys and test excavations were conducted on the concentration of ceramics in the site. The majority of the recovered ceramics are black glazed bowls, so-called ten moku or tainmu tea bowls. In 1995, a full excavation was implemented in the extended area adjacent to the 1990 excavation area. During the 1995 excavation, two large metal concretions regarded as originally comprising of iron billets or bars, the concentration of bowls, and some large timbers were identified. The timber lies beneath the concretions and its exposed part measures 1.40 metres with a section of 280x300 millimetres, and iron nails and metal concretions were observed on its surface. This timber baulk was not removed during the excavation. However, a small sample of the timber with a tree nail and nail hole was recovered, and some bamboo ropes as well. Due to the evidence of the use of iron nails and tree nails, the sample is regarded as part of the hull of the shipwreck. The species has been identified to pitch pine or yew by Australian researchers. The use of the treenails and wood used for the hull raises suspicions as to whether the ship originated from China. The date of the ship is estimated by a number of black glazed bowls that could have comprised the main cargo of the ship.

Nanhai No.1 shipwreck (南海 I 号沉船):

The Nanhai (South China Sea) No.1 shipwreck is the most well-known shipwreck attracting people’s interest, not only because of its historical significance but also because of its state of preservation of the hull and cargo. The details of this shipwreck, however, is barely available only in limited resources (Zhang 2006a). The shipwreck was accidently discovered in 1987 by the Guangzhou Salvage Bureau under the Ministry of Communications and a British salvage company, while they were searching for Dutch East India Company’s shipwrecks offshore near the Shangchuan and Xiachuan islands. The significance of the site was recognized after some precious artefacts were recovered, and immediately after that the site was protected. In 1989, the shipwreck site was initially inspected by an international team consisting of the National Museum of Chinese History and an avocational organization for underwater archaeological survey from Japan. Since 2001, a Chinese team from the Underwater Archaeology Research Center of the National Museum commenced a series of surveys and partial excavations. As a result of the exploration that continued until 2004, a challenging approach was adopted in a way that would raise the ship remains with surrounding sediment for the sake of presenting underwater archaeological excavation work on the shipwreck within a caisson inside a museum. In 2007, a large caisson was placed onto the Nanhai No.1 shipwreck and was recovered containing the shipwreck and its physical seabed context. It was moved to the newly built museum in Hailing Island in Yangjiang city, Guangdong. Almost two decades after the discovery, the entire shipwreck still remaining in the sediments was placed on land. Chinese researchers continue removing the sediment and exposing the hull in the following years in the museum. According to the result of the partial excavation and remote sensing survey that was previously conducted, the estimated size of the burial shipwreck in the caisson measures 30 metres long, 7 metres wide and 4 metres deep. At this stage, information about the shipwreck's hull is not available. A number of recovered ceramics originating from Jingdezhen, Jiangxi, Longquan, Zhejiang, Dehua, and Cizao, indicates that the ship was a trader. Many copper coins were also recovered and mainly dated to the Northern Song Dynasty. Among them, two coins inscribed as Jianyan Tongbao (建炎通寶) and Shaoxing Yuanbao (紹興元寶) date the wreck to the Southern Song Dynasty. Relevant academic reports have not yet been published, and only partial information about the recovered artefacts is available at this stage.

Huaguang Reef No.1 shipwreck (華光礁 I 号沉船):

A Chinese underwater archaeology team has conducted underwater archaeological surveys and excavations in the Paracel Islands (Xisha Islands) through the late 1990s. During the seasonal work, thirteen sites dating between the Five Dynasties (907-960 A.D.) and the 20th century were identified (Zhang 2006b). They include one well-preserved shipwreck site. The remaining part of the hull was found at the southern-central reef known as a Discovery Reef or Huaguang Reef among the Islands. The shipwreck is named the Huaguang Reef Shipwreck No.1. The date of the discovery was 1996, and immediately after locating the hull, the site was disturbed by looters. Through 1998 and 1999, the Chinese team conducted surveys and test excavations. During the operation a total of over 850 pieces of ceramics, ship timbers, and other artefacts was recovered. In 2007, a full excavation commenced, and the preservation status of the hull and the area of the site were assessed. The number of artefacts recovered from this operation is more than 6,000 items, which were more mostly ceramics, including some intact artefacts. During the second season's excavation of the year, a total of 511 ship timbers were recovered. The recovered ship timbers were brought into a museum in the Hainan Island in Hainan Province for preservation and analysis. Although the detailed information about this shipwreck is not available for researchers outside of the country at this stage, the brief explanation of the site was provided in international conferences in 2009 by a Chinese government officer. (Yang 2009). According to Yang Zelin from the Institute of Cultural Relics and Archaeology of Fujiang Museum, the remaining hull measures approximately 17.00 metres in length and 7.54 metres in width (Figure 4-11). The preservation state of the hull is very good. Three members of the keel remain. Hull planking shows five layers in some parts. The first and second inner planks were thicker than the other outer planks. Iron nails were used for the hull planking, while the details have not been reported yet. There are ten bulkheads. The seams of the bulkheads' planks show rabbeted joints. There were limber holes in the bulkheads. It has been pointed out that the manner of joining the bulkheads to the hull planks was similar to that of the Shinan shipwreck in the use of the wooden brackets and frames (Yang 2009). The shipwreck was dated to the Song Dynasty. Some blue and white porcelain pieces were found in the hull, and some ceramics were discovered beneath the shipwreck. A large metal concretion was in the middle of the hull. This shipwreck is as significant as the Quanzhou ship and the Nanhai No.1 shipwreck in terms of comparative analysis of the hull. The official site report is expected to be available in the near future.

The early second millennium, hulls discovered in China include ships thought to have been devised for coastal and open sea use. The Quanzhou ship found in 1974 and the Ningbo ship found in 1979 are the early archaeological discoveries of the Song Dynasty's oceangoing ships. The hull of the Quanzhou was secured for exhibition and study, and it is the only accessible archaeological resource to examine the hull dated to the period of this ship will be presented in Chapter V. On the other hand, the fate of the Ningbo ship was not as favourable as that of the Quanzhou ship. Though the remaining part of the hull has been documented and the description can be referred to in both Chinese and English, the hull does not remain extant (Lin, Du et al. 1991; Green 1997: 19-21). Aside from the Quanzhou ship, of the Song Dynasty's oceangoing ships, the sites containing hull remains are the Bai Jiao shipwreck 1 wreck site, the Nanhai No.1 shipwreck, and the Huaguang Reef No.1 shipwreck. The majority of the ship remains identified as oceangoing ships in East Asia are thought to be from the late thirteenth century. The construction dates of the Nanhai No.1 and Huaguang Reef No.1 shipwrecks, raised in the 2000s, have not been securely ascertained so far.

Through the Song Dynasty period, the water transportation system of China's inland waters and open waters was continuously growing. Shiba's research regarding commercial activities of the Song Dynasty locates the meaning of shipping in this period as follows:

> *Progress of water transportation showed itself in general in the construction, propulsion and control of ships (both on the ocean and in the inland waterways) as well as in the growing specialization of ships according to their purpose, their region of operation and the like*" (Shiba 1968: 7).

Such a specialization occurring in water transportation industries was coincident with the growth of ship industries where a large number of shipyards for inland watercraft had been developed in Wenzhou and Mingzhou.

Around the period when the Quanzhou ship was built, the Song Dynasty has already lost many parts of the territory by invasion by a group of the Tunguses from the north. As the Southern Song Dynasty, the Dynasty had relocated its capital from Beijing to the southern city known as Linan (current Hangzhou city) and managed to reign in the southern China. The Southern Song Dynasty could still maintain inland waters, but there might be some movement considering the establishment and maintenance of a naval power. Comparing to the Northern Song Dynasty, there seems to be less demands to build ships for river transportation during the periods of the Southern Song Dynasty (Merwin 1977: 73-74). In the Northern Song Dynasty, for example, there was a record that a large number of the river transportation ships counting 2,916 ships were constructed by governmental shipyards (Merwin 1977: 73-74). However, it disputes whether the similar demands for constructing riverine ships occurred in the Southern Song Dynasty located at the south where there are more significant ports opened to the South China Sea.

In the Song Dynasty, the private and governmental sectors were widely involved in water transportation and shipbuilding industries relevant to the background that the hierarchy of groups of shipowners was diverse at the time, including rich farmers, lords, merchants, Buddhist clergy, regional and central bureaucrats (Shiba 1968). Industrialization of the shipyards was, in particular, under government control. Interference of governmental control with private shipyards that have existed in south is presumed after relocation of the capital to the south. The consequences of the interferences might have been related to the change of the shipbuilding tradition in the middle- and southern part of China. Another factor which may stimulate local shipbuilding is the number of non-East Asian ships including the ones from the Arab world that visited southern ports more than the previous periods. Shipbuilding industries in the south might have adopted some innovations from technologies outside of China. Thus, discussing the increase of the archaeological discovery of coastal or oceangoing ships dating to the thirteenth century in south of Hangzhou considers these factors.

Technological innovation, such as the combination of bulkheads and keel produced a type of hull better suited to seafaring, occurred in some parts located the area of Zhejian and southwards. Bulkheads were main transversal components for the coastal or oceangoing traders. Other developed features in the hull structure of its sturdiness for oceangoing voyage included assemblage of the frames and brackets attached to each side of the bulkheads for their fixing with hull planking. The hull planking of the coastal or oceangoing ships was often some sort of clinker structure. The adoption of sacrificial planks also became a common feature.

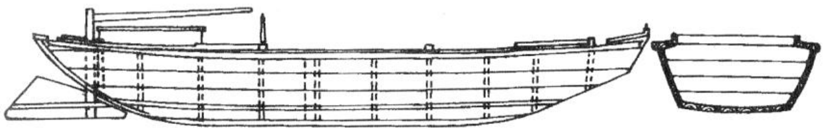

Figure 4-12 Plan of the Nankai River ship. *From Wang 2000*.

- Yuan Dynasty

  Nankai River ship (南开河船):

  In 1975, six river boats were discovered at the ancient channel of Zhang River vicinity of Nankai village in Ci district, Hebei Province. It has been reported that of the six remains, the No.5 ship shows the most well-preserved state, measuring 16.60 metres in length and about 3.00 metres in width (Figure 4-12) (Wang 2000: 121). The hull is nearly flat-bottomed with a slight curve in the cross-section of the bottom, hard chine, flared topsides, and it has eleven bulkheads. The hull planking is edged-joined, and the cross section of the hull has side decks and a low coaming. It appears that iron nails are the main fastening method. An axial balanced rudder was found on the hull. The date of the ship was determined to the Yuan Dynasty (1271-1368 A.D.) period based on an inscription on the stern of the No.4 ship remain among the six boats, implying the reign period of Toghun Temur of the Yuan Dynasty. The inscription includes the term Liang chuan (粮船), indicative of its use as a cargo ship, and for riverine transportation from the structure. The date of the ship is arguable since the hull remains look modern.

Sandaogang Yuan Dynasty wreck site (三道岗元代沉船):

A shipwreck was found by a local fisherman in the place called Shandaogang in the Bohai Sea, southwest of Suizhong district in Liaoning Province. From 1991 to 1997, members of the Underwater Archaeological Research Centre of the National Museum conducted remote sensing surveys and underwater archaeological excavation. Although the ship's cargo has been identified, little information about the hull of the shipwreck is available. According to an official site report, there are no remains of the wooden hulls because of the action of marine borers (Zhang 2001: 133-134). The area of the distributed artefacts suggests that the dimension of the original ship could have been 20.00-22.00 metres long and 8.50-9.00 metres wide. Despite the loss of most parts of the hull, radiocarbon dating managed to have been conducted on a sample of the ship's timber. Its result shows 740 ± 80 BP (Zhang 2006a: 431). The report focuses on the ship's cargo including a large number of porcelain remains mostly from the Cizhou kiln. They are white and black glazed porcelains with various motifs and their types vary, such as jars, basins, bowls, dishes, lids, and vases.

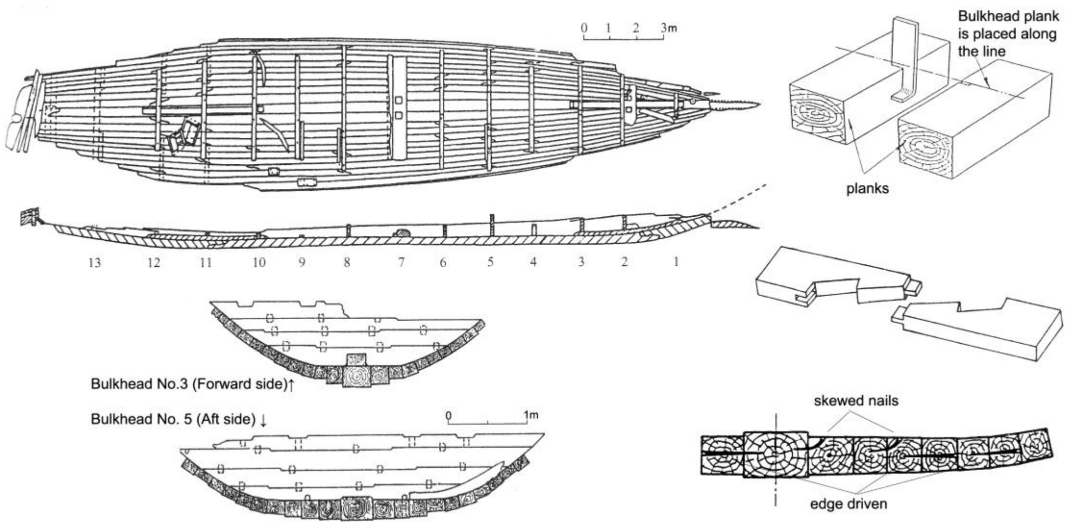

Figure 4-13 Plan of the Penglai ship No.1 and diagrams showing the use of metal brackets to secure hull planks and a bulkhead plank, a hook scarf of the hull planks, and two different nails (the skewed and edge driven nails) fastening the hull planks. *From Xi 1989 and Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum, et al. 2006*

Penglai ship No.1 (蓬莱古船 I 号):

The Penglai ship No.1 is the earliest discovered ship of the four ship remains known as Penglai ancient ships. They were found outside of the Penglai Castle at Yantai city in Shandon Province. In 1984, during dredging at Dengzhou harbour, one ship remain was discovered. The shipwreck has been documented in various resources (Xi 1989; Xi and Xin 1991; McGrail 2001: 371-373; Blot 2006). The remaining part of the hull measures 28.6 metres long and 5.6 metres wide. There is a narrow flat bottom and then a gentle turn to the bilge (Figure 4-13). It appears that the cross-section shape above that turn of the bilge is very flared. The well-preserved lower hull includes a keel and thirteen bulkheads. The keel consists of three members that are joined by hooked scarf joints. The lengths of the keel members are: 3.60 metres (forward keel), 17.06 metres (main keel), and 5.58 metres (the aft keel). The main keel shows slight hogging. There are recesses for placing mirrors or coins in the keel joints. The keel scarfs are reinforced by hog pieces fitted on the top of the keel. The most well-preserved bulkheads No.3 and No.5 consist of four planks and are 160 millimetres thick on the average. A part of the upper surface of the three lower planks is rabbeted to form a tongue and groove joint, and the uppermost bulkhead planks have four holes that could be used to place longitudinal timbers through the hull. Each bulkhead plank is joined by four sets of mortises and tenons, and iron clamps appear to fasten the lower and upper bulkhead planks. There are two limber holes in each bulkhead, about half a metre from the keel on either side. The bulkheads located forward show that half-frames are attached to their aft side and iron brackets are used to fix; bulkheads hull planking is also attached to their forward side. The reverse arrangement is practised on the bulkheads located aft of midships: they have half-frames on the forward side and L-shaped iron brackets on the aft side. Ten strakes remain on the port side and eleven strakes remain in the starboard side. The dimension of the hull planks is from 3.70 to 18.50 metres in length, 200 to 440 millimetres in width, and 120 to 280 millimetres in thickness. Garboard strakes show the greatest thickness; they are baulks rather than planks. The hull planking is edge-joined by two different types of square iron nails including large edge driven nails and bent skewed nails. The hull planks are joined to make up strakes with hooked scarf joints having mortise and tenon ends. Propulsion of the ship is evidenced by two mast steps remaining on the hull. A forward mast step having two recesses with a size of 200x200 millimetres to receive tabernacle cheeks is located on the forward side of Bulkhead No.2, measuring 1.6 long athwartships. A main mast step having two recesses with a size of 260x260 millimetres is located on the forward side of Bulkhead No.7, measuring 2.88 metres athwartships. A transom consisting of three timbers has a rudder stock hole (rudder trunk) with a diameter of 300 millimetres. Discovered artefacts from the ship include five iron grapnels, a wooden anchor, three stone anchors, ropes, 489 Chinese ceramics, a few Korean ceramics, and Japanese coins. From the discovered ceramics and the study of sedimentation where the hull was discovered, it has been concluded that the ship was built around the end of the Yuan Dynasty and was used into the early Ming Dynasty (Yang 1989: 61-62). Considering the historical background of the Penglai Castle and a few weaponry artefacts discovered inside the hull, Chinese researchers speculate that the ship could have been used as a battle ship, referring to a ship mentioned as “Daoyu Zhanzhao” (Sword-fish battle ship 刀鱼战棹), and in the Qing Dynasty’s historical text, “Penglai Xianzhi” (History of Penglai) (Zou and Yuan 1989: 76).

The rise of the Yuan Dynasty, which followed the Mongolian Empire, substantially impacted on relationships between nations and changed maritime networks between China and the other East Asian countries including the destruction of the tribute systems. Instead of the seaborne tribute trading between the nations, the restricted relationships between countries allowed private traders to make more inroads into overseas trading. The Yuan Dynasty fully appreciated the significance of water transportation and maritime trade more than the previous dynasties (Matsuura 1995: 39). Based on the understanding, their policy strictly controlled piracy yet conciliated those illegal traders. Chinese ships were employed as a means of overseas transportation. The Shinan shipwreck which originated from China but was discovered in the Korean waters implies that seaborn trade could still have been active, following the previous periods. A large number of ceramics recovered from the Sandaogang wreck site offshore of Suizhong in Huludao city, Liaoning Province, which has been surveyed by a Chinese underwater archaeological team, is indicative of the significance of shipping ceramic trades in the northern part of China. A few ship remains dating to the Yuan Dynasty and the following Ming Dynasty (1368-1644 A.D.) show defensive features by carrying fire weapons, and some of them were initially designed as battleships and patrol boats. One of the best preserved Chinese ships from Penglai city in the Shandong Province has also been recognized as a battleship or patrol boat. The advent of armed ships or ships carrying fire arms came to be more apparent probably during the late Yuan Dynasty period. The reason why the ships were armed is probably addressed from different aspects. One factor relates to the necessity of self-defence among private trades from piracy that occurred and could extend to the increase of smuggling. This became more serious issues with declining of the Yuan Dynasty.

- Ming Dynasty

  Liangshan Ming Dynasty ship (梁山明代船):

  In 1958, a well-preserved ship was discovered near a channel of Songjin River at Heihumiao district in Liangshan, Shandong Province. The ship has been reviewed in a few resources (He 1991; McGrail 2001: 373-374). The ship remain is said to be the most intact condition among ship remains ever discovered in China (Xi, Yang et al. 2004: 192). The intact condition allowed scholars to reconstruct the original configuration of the hull. It is 21.90 metres long, 3.49 metres wide at deck level, 1.24 metres deep with a draught of 0.75 metres, and with a displacement of 31.96 tonnages. The hull has a flat bottom and bulkheads. Nine planks compose the bottom of the hull. Three planks at the centre have a thickness of 165 millimetres while the other planks have a thickness of 80 millimetres. Twelve bulkheads divide the hull. Bulkhead No.8 is the largest and consists of five planks. The bulkheads have two limber holes each located next to either side of the three centre bottom planks. The use of half frames has been indicated, yet they have not been confirmed in the original position (Xi, Yang et al. 2004: 192). Hull planking is comprised of eight strakes and an extra wale (or fender) is attached. The planking up to the deck level is flush constructed (Figure 4-14). There are side decks surmounted by a coaming which is supported by the bulkheads; the bulkheads are built right up the height of the top of the coaming. Butts of the hull planks appear to be of a hooked scarf joint: the same technique as the Penglai ship. Iron skewed nails are used for hull planking and the joints of bulkhead planks. A forward mast step is located at the front of the Bulkhead No.3 and a main step is located at the front of the Bulkhead No.7. When the ship was discovered, a number of artefacts were also recovered, including weapons, harnesses, metal wares, ceramics and an iron grapnel. The time period of this ship was determined from some artefacts, such as copper coins, and the date inscribed on the bronze gun and the anchor associated the ship with the reign of Hongwu (1368-1398). It has been pointed out that the appearance of armed river crafts occurred in the early Ming Dynasty (Xi, Yang et al. 2004: 192). The overall configuration and structure of this ship bear remarkable similarities with watercraft for riverine use during the twentieth century China.

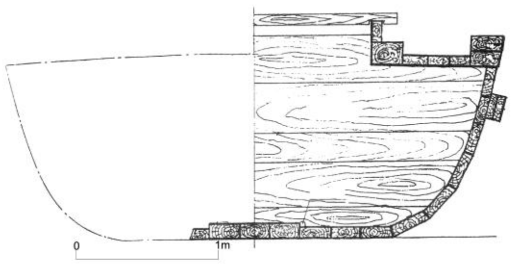

Figure 4-14 Cross-section of the Liangshan Ming Dynasty ship. *From Xi, Yang, et al. 2004*

Xiangshan Ming Dynasty shipwreck (象山明代沉船):

In 1994, a Ming Dynasty ship remains were found in the silt of the area of an ancient harbour around Qibu village in Xiangshan, Zhejiang Province. From 1995, the Archaeological Research Institute of Ningbo conducted an excavation of the ship (Figure 4-15). The remaining part of the hull measures 23.70 metres in length and 4.90 metres in width and includes a keel and bulkheads (Xi, Yang et al. 2004: 195-198). The cross section shows a rounded bottom with sharper sections in the bow. The details of the keel have not been reported, yet it seems that the keel consists of three timbers. On each posited joint in the keel, there is a hog piece like those observed on the Penglai ship. Twelve bulkheads divide the hull and two or three broad bulkhead planks remain in each bulkhead. Some of the second bulkhead planks have two square holes with a size of 18-20x14-20 millimetres to place two timbers longitudinally running through the hull. The bulkhead planks in the bottom have two limber holes. There are frames attached to the bulkheads. The distribution of the frames has not been clearly explained but it seems from the drawings that most bulkheads have frames on both the forward side and the aft side. The frames attached to the bulkheads seem to have been fastened to the hull planking by iron nails. A large number of hull planks remain, numbering a total of 17 strakes per side through the mid-body of the hull. The dimension of the planks is 140-160 millimetres in thickness and 80-200 millimetres in width. They are baulks rather than planks. The hull planking is edge-joined and fastened by iron nails, though the details of iron nails and the pattern of fastening are unclear. The seams of the hull planking were caulked with hemp and secured by a putty of tang oil and lime. The hull planking extends beyond the aft transom where a part of the rudder remains. A forward mast step remains on the forward side of Bulkhead No.2 and a main mast step remains on the forward side of Bulkhead No.7. From the bottom of the hull, besides bricks and roofing and ridge tiles, a few ballast stones were found. The date of the ship was determined from discovered ceramics including a porcelain bottle with a small mouth dating to the Yuan Dynasty period and a few celadon from the Longquan kiln dating to the early Ming Dynasty. The purpose of the use of the ship has not been identified. It was either a local cargo ship used by private merchants or a battle ship employed by the government. It is said that the ship is in most respects similar to Penglai ship No.1 (Xi, Yang et al. 2004: 199-200).

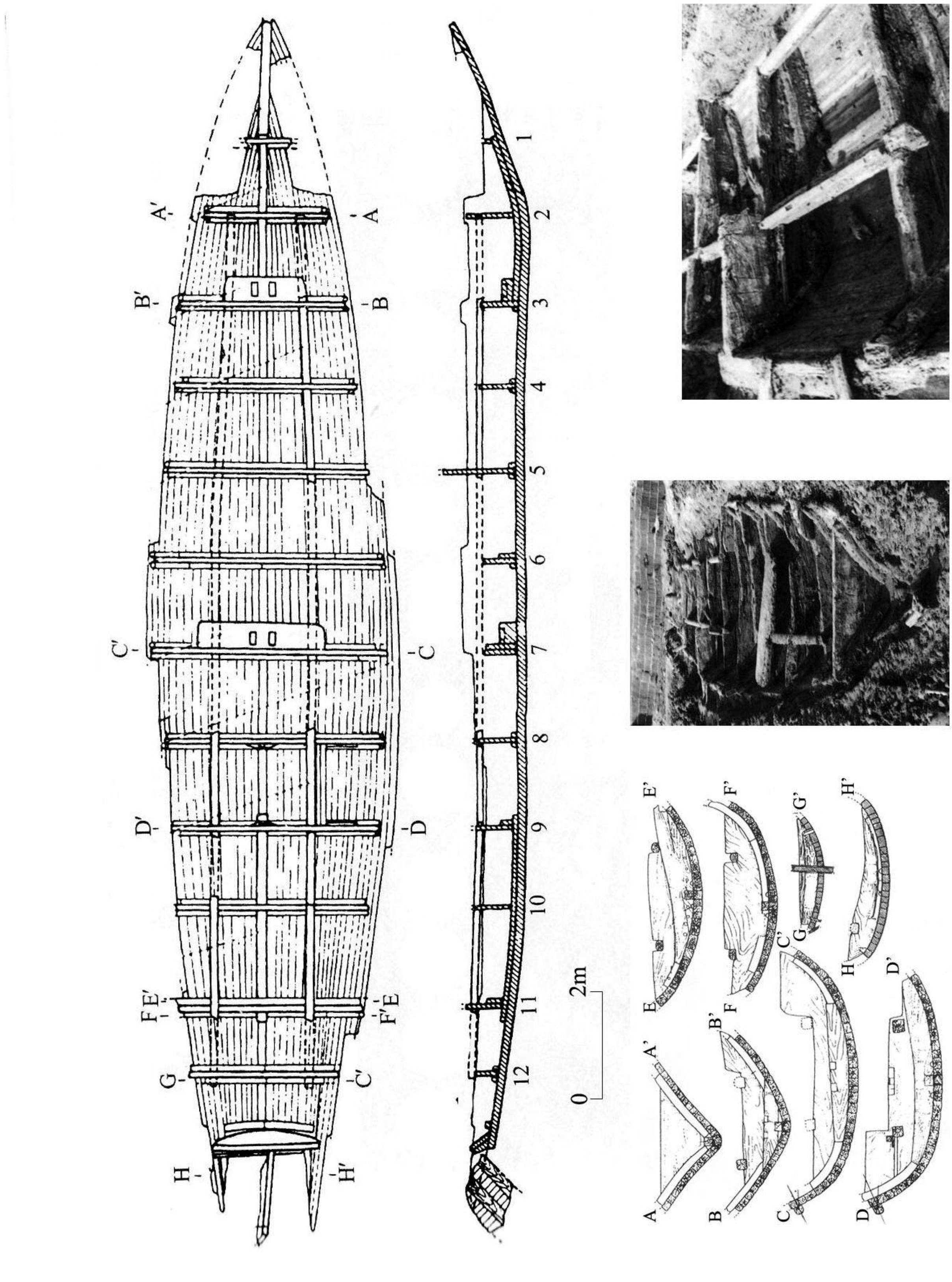

Figure 4-15 Plan and cross section of the Xiangshan Ming Dynasty shipwreck. *From Xi, Yang, et al. 2004*

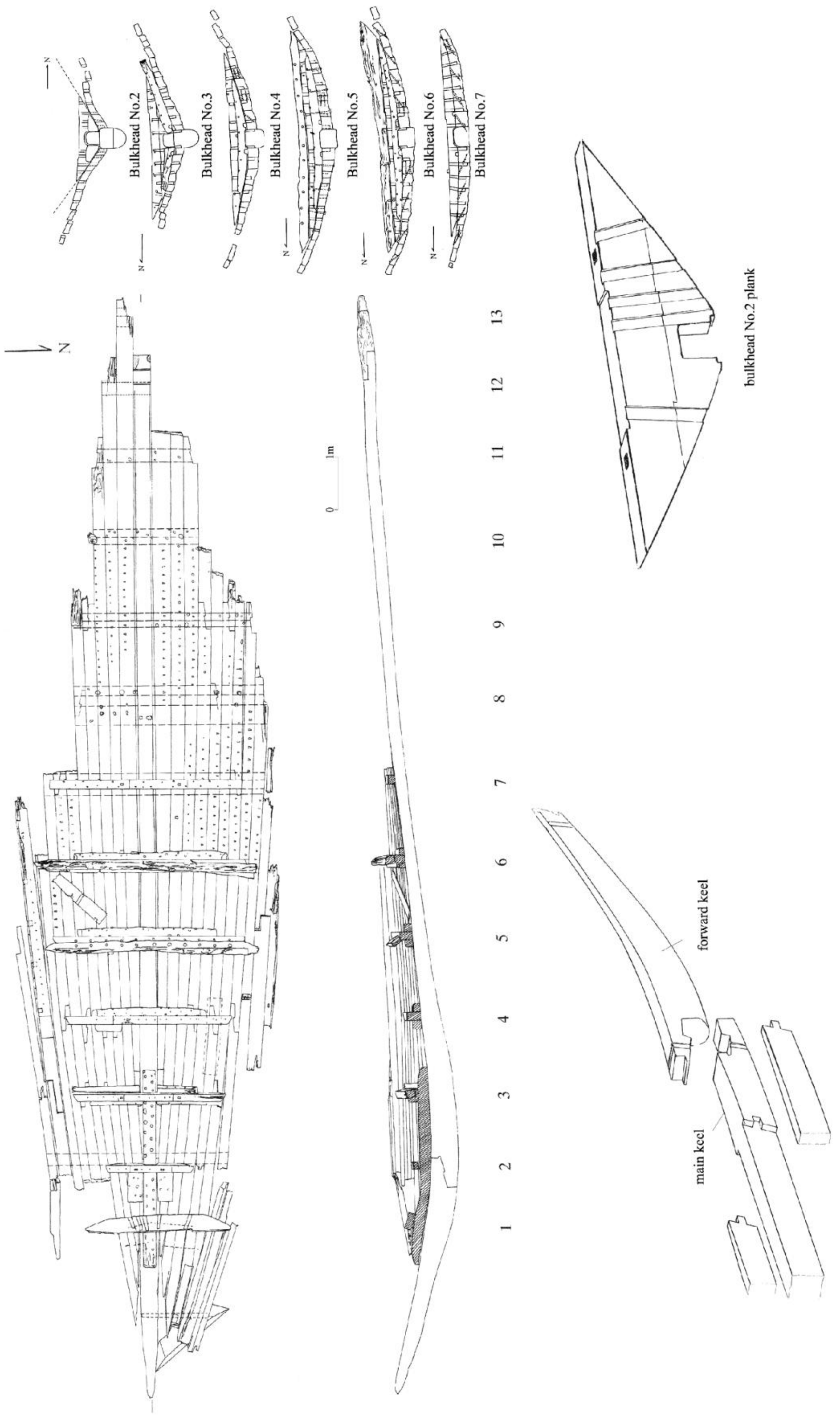

Figure 4-16 Plan of the Penglai ship No.2 *From Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum., et al. 2006*

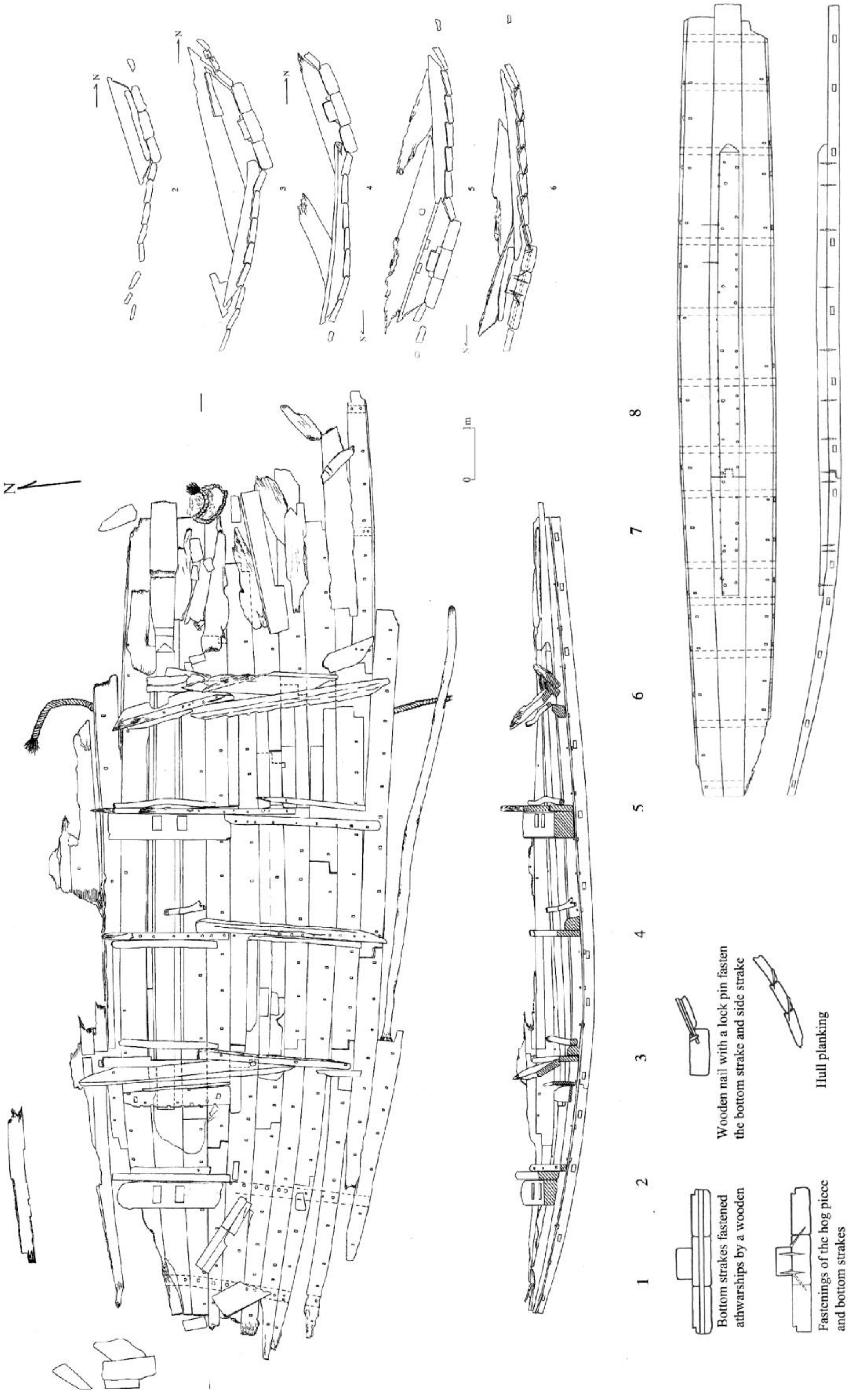

Figure 4-17 Plan of the Penglai ship No.3 *From Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum., et al. 2006*

Penglai ship No.2 (蓬莱古船 II 号):

The remaining part of the hull of the Penglai ship No.2 measures 21.5 (or 22.5) metres long and 5.20 metres wide. Although the stern is missing, the bottom of the hull is relatively well-preserved and the remaining includes a keel, some bulkheads and eleven strakes in each side (Figure 4-16). Details of the hull including the dimensions of the remaining planks are available in the archaeological report with other detailed information about the hull (Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum et al. 2006: 25-34). The cross section of the bottom hull shows some hollow around the bow, and this changes to a rounded shape through the mid-body. The keel shows slight hogging. The keel is comprised of three members: 4.78 metres (forward keel), 16.22 metres (main and aft keel). These are joined by hooked scarf joints with the mortise and tenon. In the joints, there seems to be a hole for the placement of a mirror or coins evidencing the practice of the shipwright's belief. Iron straps and iron nails are used to fasten the forward and main keel. A hog piece is fitted on top of each joint and large iron nails are driven from them down through the keel. The sides of the main keel are rabbeted and thick planks (garboard planks) are fitted using a mortise and tenon joints. Although the ship originally had thirteen bulkheads, only six bulkheads remain. There are limber holes from the Bulkhead No.3 to No.7, yet Bulkhead No. 2 and No.8 do not have limber holes due to mast steps located at their forward faces. The lower and upper parts of each bulkhead planks are fashioned for a tongued and grooved joint and they are joined with mortises and tenons (loose tenons). Skewed iron nails are also driven into the seams of the bulkhead planks. Frames are used to fix the bulkheads and hull planking together, fastened by iron nails. Using iron brackets to fasten the hull planking to bulkheads is evidenced on the Bulkheads No.2, No.3 and No.7, although these brackets are mostly degraded. Only corroded iron remains in the recesses of the surface of the bulkhead planks into which the brackets have been slotted. The joint pattern of the hull planking shows the same method with the Penglai ship No.1 and uses large edge driven nails and bent skewed nails. The mast steps are fixed to the hull planking by iron nails. The length thwartships of the forward mast step is 1.90 metres with two square recesses measuring 160x225 millimetres. The main mast step is missing. The Penglai ships No.1 and No.2 were evaluated as the same type of ships.

Penglai ship No.3 (蓬莱古船 III 号):

Ship remains were identified just next to the Penglai ship No.2. However, the two ships are distinguishable in their structure. The remaining of the hull measures 17.10 metres long and 6.20 metres wide and includes bottom planks, bulkheads, and hull planks, though the stern is missing (Figure 4-17). Details of the hull including the dimensions of the remaining planks are available in the archaeological report with other detailed information about the hull (Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum et al. 2006: 35-44). The structure of the bottom hull and hull planking shows remarkable similarity with indigenous Korean shipwrecks discovered in Korean waters (see the section below). The hull has a flat bottom consisting of three strakes. The planks of the strakes are joined together by transverse wooden bars or dowels. Thirteen bars are used in the extant portion of the ship's bottom. Wooden nails seem to be driven from the centre bottom planks to the sided planks in a few places. The structure of the bottom planks and their fastening methods are similar to those observed on the Korean origin shipwrecks. However, an extra plank placed on top of the centre bottom plank and its fastening method using edge driven iron nails have not been found on the Goryeo Period's Korean ships. Three strakes remain in the portside and nine strakes remain in the starboard side. The first strakes are fitted into rabbets on the upper edge of the side bottom planks and appear to be fastened with mortises and tenons (or dowels). The hull planking is a form of clinker-built with rabbeted seams. Skewed wooden nails are driven from the outer surface of the upper planks into the lower plank through the rabbeted seams. Butts of the hull planking are held together by lap-joints. Also, iron nails are used for fastening of the hull planking. Bulkheads, which are not used in the Korean shipbuilding tradition, are the main structures for the transversal strength of this ship. Five bulkheads remain and they are regarded as the second to sixth bulkheads. One to five remain. More than eight bulkheads have been originally used. The bulkheads' bottom planks have a recess in their bottom that fits to the extra plank onto the centre bottom plank and they also creates limbers. Bent skewed iron nails are used to fasten bulkhead planks as well as to fix the hull planking and bulkheads together. Frames are attached onto some of the bulkheads and bent skewed iron nails are used to fasten the hull planking to the frames. Intensive use of iron nails is unusual in the traditional Korean shipbuilding. The use of different types of wooden bars, mortises and tenons, nails and iron nails is emphasized in a comparable study on the Penglai Ship No.2 and No.3 (Yuan 2006: 500-501). The forward and main mast steps that have two recesses are identified at the second and fifth bulkheads. The ship was discovered in almost same elevation as the Penglai Ship No.2, indicative of the contemporary use of the two ships.

Penglai ship No.4 (蓬莱古船 IV 号):

A few ship timbers were discovered about twelve metres away from the No.2 and No.3 ships. Only four timbers remain, yet they clearly show identical features with the Penglai ship No.3. According to an archaeological report, (Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum et al. 2006: 44-46), of the four timbers, three are the bottom planks forming a flat bottom (Figure 4-18). The dimension of the remains of the centre bottom plank is 3.46 metres long, 200-440 millimetres wide, and 160-200 millimetres thick. It has two recesses that could receive tabernacle heels directly, instead of using a mast step. This arrangement is well-evidenced on the discovered shipwrecks of the traditional Korean coastal ships as discussed below. Two bottom planks are positioned, one on each side of the centre bottom plank. The dimension of the remaining part of the two planks measures 4.8 metres in length, 260-520 millimetres in width, and 100-220 millimetres in thickness. The upper edges of their outer parts appear to be recessed to place strakes. The three bottom planks are fixed by two wooden bars. One timber regarded as a part of the hull planking was found and another large timber measuring 9.24 metres long was found away from the four timbers and also regarded as a hull plank. It is disputable if the Penglai ship No.4 had hybrid features like the Penglai ship No.3's bulkhead structure, and the use of both iron and wooden fastenings. Besides many distinctive structural features between the ship remains adopting elements of Chinese traditions (Penglai ship No.1 and No.2) and the ship remains adopting elements of Korean traditions (Penglai ships No.3 and No.4), assemblage of woods used for each tradition shows differences. The Penglai ship No.1 and No.2 use more different types of wood in the hull structure. In contrast, woods used for the main structure of the Penglai ships No.3 show less diversity, and most parts of the hull use pine.

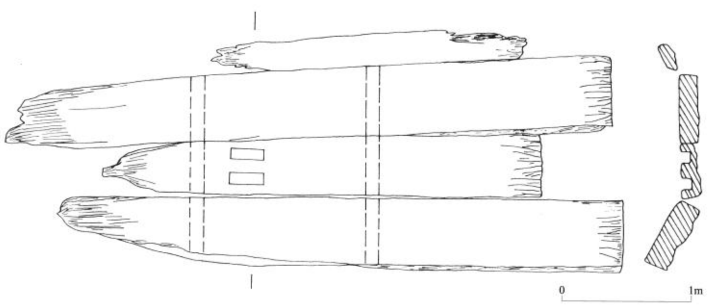

Figure 4-18 Plan of the Penglai ship No.4 *From Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum., et al. 2006*

The Ming Dynasty that ruled China over two hundred and seventy years. It is said that during the Ming Dynasty period, substantial political and socio-economical changes emerged in both East Asia and Southeast Asia (Reid 1988-1993; Wade 2010). The changes partly formed from dynamism of maritime activities across over the two regions during the period. The Ming Dynasty made more effort to control piracy and repossession of the maritime trading (Danjo 2005). Restriction of private maritime trading enforced by a legal policy known as Hai Ban or the Ming Ban were from the motivation of securing control of maritime power. Also, a first ruler of the Ming empire attempted to reinvolve the other East and Southeast Asian nations into the tribute system. The presence of recovering the sea hegemony was embodied diplomatically by delegating Zheng He's fleets to the Southeast Asian regions and further west. The purpose of Zheng He's voyage is implicitly or explicitly to demonstrate the retrieval of a Han-Chinese empire to those nations (Needham 1971: 487-488; Zheng 1991). It has been interpreted as a sort of armed diplomacy (Matsuura 1995: 46; Danjo 2005: 160). More recently, an impact of the voyage has been addressed in terms of developing Chinese Muslim networks in China and Southeast Asia, considering the background of Zheng He as a eunuch Muslim admiral (Wade 2010 13-16). Miksic (2010) has archaeologically assessed the issue whether the voyage affected on Southeast Asian trading patterns.

Despotic government policy probably affected shipbuilding industries, and some shipyards operated under government control. As mentioned in the previous chapter, a shipyard found in Nanjing is regarded as the one that constructed the Zheng He's ships, and one large rudder stock has been found. The rudder stock appear to have been used as an axial rudder that could be hung on the stern and its remaining length measures 11.07 metres. The nineteenth picture scroll *Tousen-no Zu* indicates that a traditional Nanjing ship with a length of 34.00 metres could carry a rudder consisting of stock about 6.4 m long. The rudder stock from the Nanjing Shipyard could be used for larger ship but not substantial size.

All the excavated ships dating to this period show very different structure from the Song Dynasty's excavated ships. The cross-section of the hull does not show steep deadrise as much as that of the Song Dynasty's oceangoing ships. The presence of the keel is not clear in the hull structure. Their discovered located is more northern parts of China than those Song Dynasty's oceangoing ships where the use of the keel is identified as more common feature. The other differences include: the form of the hull that does not show greater width than the Song Dynasty's ships, distinctive fastening methods of the hull planking, and none use of the sheathing planks (the hull planking shows a single layer). These will be reviewed in Chapter

IX after presenting the structure of Song Dynasty’s oceangoing ships in detail.

A significant discovery of ship remains dating to the Ming Dynasty is from Penglai again. In 2005, another three ship remains were found during the development work at the area adjacent to Penglai Castle. The significance of the discovery lies in the fact that one of them shows evidence of Chinese shipbuilding tradition and the other two indicates evidence of Korean shipbuilding tradition in their structure and construction methods. One of the ships shows the structure based on the Korean shipbuilding technology, but adopts bulkhead structure. Cooperative research by Chinese and Korean scholars has been implemented and reviewed (Yuan 2006). Although the idea of hybridization has not been introduced and appreciated among the scholars so far, this research considers Penglai as evidence that the hull represents technological integration in north East Asia.

- Qing Dynasty

  Baolian Harbour shipwreck (or known as Hainan Wenchang Shipwreck) (宝陵港沉船):

  The Agency for Cultural Affairs in Hainan Province discovered one old shipwreck in the waters of Baoling Harbour in Wenchang in 1987. The Underwater Archaeology Team from the National Museum that was conducting a survey on the shipwreck in 1990 identified a remain of the shipwreck that had been substantially covered by sediment. Large concretions were found on the sites and contained some metal remains consisting of iron pans and copper drums. Also, miscellaneous artefacts, such as some ceramics, a copper candle stick, silver ingots, and copper coins were found inside the concretions. It is said that remnants of hull planking were identified under the concretions, yet the details have not been made available.

  Shantou Guangao shipwreck (or known as Nangao No.1 Shipwreck) (汕头广澳沉船):

  In 1995, members of the National Museum of Chinese History conducted an underwater survey in Guangao Harbour in Shangtou city, Guangdong Province and found one shipwreck. On the seabed, its keel and frames were exposed, yet most parts of the hull were still covered by sediments. During the inspection, copper alloy seals were found and their inscriptions indicate that the ship probably dates back to the seventeenth century.

  DongguMingzheng wreck site (冬古明郑沉船):

  The site was identified by a local museum in Dongshan district in Fujian

Province in 2000. As result of underwater surveys, four bronze guns, two iron muskets, a set of bullets and gun powders, and ten pieces of ceramics and some ship timbers were recovered. The discovered ceramics are blue and white porcelains from the Zhangzhou kiln, likely being back to the end of the Ming Dynasty or the early Qing Dynasty.

Jinjing Shenhu Bay wreck site (晋江深沪湾沉船):
A municipal museum in Jinjiang in Fujian Province inspected the shallow waters of Shenfu Bay and found the wreck site. Discovered artefacts include a large bronze cannon that has been casted in Wenzhou, an iron gun, fragments of copper alloy drums, and a few other metal objects, such as a spoon, a sword handle, and ingots. From the inscription on the discovered white porcelain, the date of the site was determined to have been at the end of the Ming Dynasty or the Qing Dynasty.

Wanjiao No.1 wreck site (碗礁 I 号沉船):
The site was discovered at the Wanjiaoreef which is a part of the Wuzhou reefs offshore of Yutou at Pingtan district in Fuzhou city in 2005. Immediately after the discovery the site was looted, such that an underwater archaeological excavation was conducted and directed by the Underwater Archaeology Research Center of the National Museum cooperative with regional government agencies. As a result of the excavation, 17,000 ceramics, which mostly consist of the blue and white porcelains from the Jingdezhen kiln dating to the mid-period of the reign of Kangxi Emperor (1661-1722 A.D.) were recovered. Also an ink stone and copper coins were also found. Despite the discovery of this great number of artefacts, the site has been substantially destroyed by looters since it was shallowly buried in the seabed in a depth of 13.00-15.00 metres. Many artefacts as well as the hull went missing. An archaeological report lists the major types of ceramics from the site, yet no hull is available (Zhang 2006c).

In general, ships and their activities during the seventeenth to nineteenth century, in the early to the late Qing Dynasty, are known from iconography and historical records. Where Chinese ships were built and where they were used, were used to classify types of Chinese ships in this period. The abovementioned picture scroll, *Tousen-no Zu* demonstrates this classification system. An eighteenth century painter assorted and depicted Chinese ships from different places that sailed to Japan (Oba 1974). Chinese ships in later ethnographical studies are classified based mainly on where they were built (Donnelly 1930; Worcester 1966; Matsuura 2008a: 150).

Apart from this classification system, four representative types of Chinese ships including *Sha-chuan* (Sand ship 沙船), *Niao-chuan* (Bird ships 鳥船), *Fu-chuan* (Fuzhou ships 福船), and *Guang-chuan* (Guangzhou ships 広船) are found through the Ming to the Qing Dynasty records, though Xi and Yang *et al* (2004: 186-191) have pointed out the Bird ship is a descendent type of the Fuzhou ships (Matsuura 2008a: 150). Matsuura's study demonstrates that the heyday of coastal trades by these Chinese ships dates between the mid-seventeenth century and nineteenth centuries based on historical records with focus on types of the Chinese ships and their commodities (Matsuura 2008a; 2008b). Matsuura (2008a: 150-151) has pointed out that even after the late nineteenth century when the steamship commenced usage, those Chinese ships were still dominantly being in domestic voyages between northern waters around Bohai Bay and southern waters including the South China Sea. A record regarding the number of flat bottom ships identified as Sachuan sailing to Shanghai in 1825, for example, shows more than three thousand. Only forty to fifty southern types of Chinese ships known as Bird ships visited Shanghai in the same year, yet they were much more used in the trade with Japan since the late eighteenth century. Fuzhou ships conducted voyages from south to north as far as Tianjin. Guangzhou ships also sailed competitively to the north. They played a significant role in domestic transportation for products including grain, livestock, food stuffs, spices, timbers, bamboo materials, and ceramics.

Nautical archaeological study with focus on the hull of Chinese ships dating to the Qing Dynasty is limited, yet some underwater sites have been identified. The early discovery appears to be the one found in 1987 offshore of Baoling Harbour at Chengdong in Wenchang district, Hainan Province. Throughout the 1990s to the 2000s, a few ship remains in the same time periods have been discovered, and on some of these sites including the Shantou Guangao Shipwreck, with hull intact. On the other sites from Fujian Province including the Donggu Mingzheng wreck site and the Jinjing wreck site, the hulls are mostly missing.

Korea

Korean shipbuilding shows a long-term tradition, generated from technologies to construct ships used for sailing along the coast of the Korean Peninsula and for seagoing in the Yellow Sea. This specialization has formed a sort of idiosyncratic features in the hull of those ships that show a number of similarities between the late eleventh century coastal trader and the hull of the early twentieth century coastal fishing ship (Figure 4-19). In general, the traditional Korean ships show a flat bottom with the transom bow and stern forming a box shaped-hull. The planks are edge-fastened with rabbeted seams making the hull planking appear a clinker-built. The use of wooden fastenings is a common feature. Beams are used as transverse components. An early archaeological discovery of a Korean coastal trader dating back to the early Goryeo Dynasty (918-1392 A.D.) has been initially reported in an English resource by Jeremy Green (Green 1983b). Since the 1980s Korean experts have continuously excavated several Goryeo Dynasty ships, including the Wando ship, the Sibidongpado ship, the Taean ship, the Daebudo ship, the Talido ship, and the Anjwa ship. The information about the hull of these ships have been more recently reviewed in the Shipwreck ASIA project’s report (Sasaki and Lee 2010). These Goryeo Dynasty ships will be reviewed and compared here in order to review critically the chronological evolution of the hull structure and construction methods.

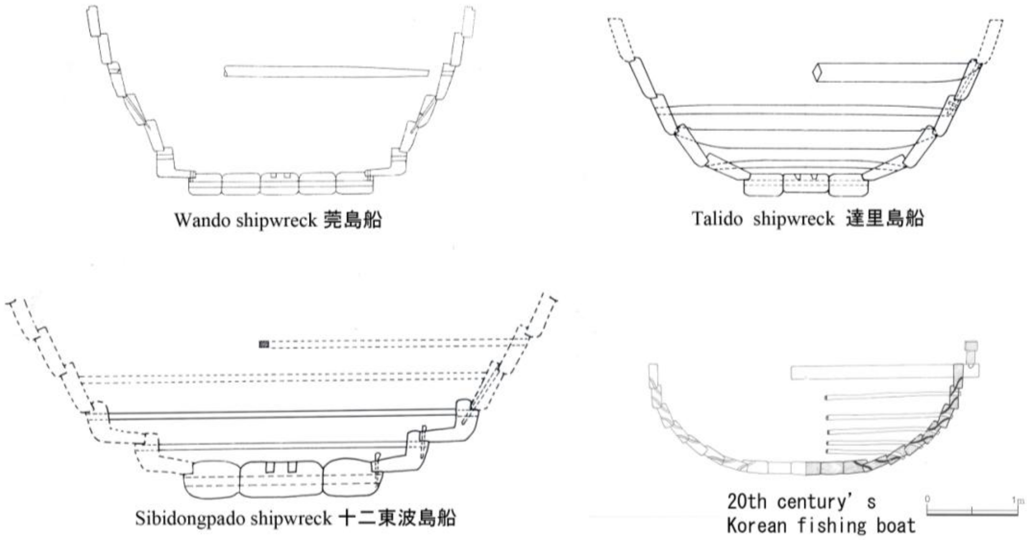

Figure 4-19 Cross-sections of the Wando ship (the end 11th - early 12th century), Sibidongpado ship (the end 11th - the early 12th century), and Talido ship (13-14th century).

Wando ship (莞島船):

The shipwreck was discovered offshore of Wando inland in Jeolla Province, South Korea and excavated in 1983-84. This is the first discovered Korean origin shipwreck, and more importantly it is one of the earliest dated shipwrecks recovered from the East Asian waters. A few brief reports are available in non-Korean resources (Green and Kim 1989; Kim 1991; McGrail 2001: 361-363). Goryeo celadon, over 30,000 pieces, determines that the date of the ship to possibly be the second half of the eleventh century (National Maritime Museum of Korea 2005a). The result of the wood species identification is indicative of Korean origin and the structure and construction represent Korean tradition (See Chapter VIII). The remaining part of the hull measures 6.50 metres in length and the widest part of the hull bottom is 1.60 metres. The hull has a flat-bottom structure consisting of five strakes (Figure 4-20). Two or three planks are joined to make these strakes. Butts of the median strake show a protruding-tongue scarf, and the butts of the other four bottom strakes are joined with a stepped scarf. Around the mid part of the median bottom strake, there are two square recesses that could be associated with mast tabernacle. Six long wooden bars penetrate athwartship the three centre strakes of the five bottom strakes, fastening them together. The bars are neatly slotted through the apertures cut in each strake to join them tightly. The other two strakes, individually joined onto each side of the centre three strakes, are fixed by six mortise and tenons. There are L-shaped planks fitted on both sides of the bottom, defined as chine strakes (See Glossary). Mortises and tenons fasten the L-shaped chine planks onto the rabbeted edges of the bottom strakes. Five side strakes above the chines remain on one side and four side strakes remain on the other side of the hull. A rabbet is cut on the outer part of the upper edge of each side plank of the strakes. The planks are fastened together by wooden tenons which pass right through the mortises plank and down into the mortise of the lower plank. These tenons are secured by wooden locking pins. Transverse strength is provided by multiple beams. Apertures in the planking show where the ends of the beams protruded through the chine strake and the strakes of the hull's sides. The original length of the ship has been estimated to be approximately 9.00–10.00 metres.

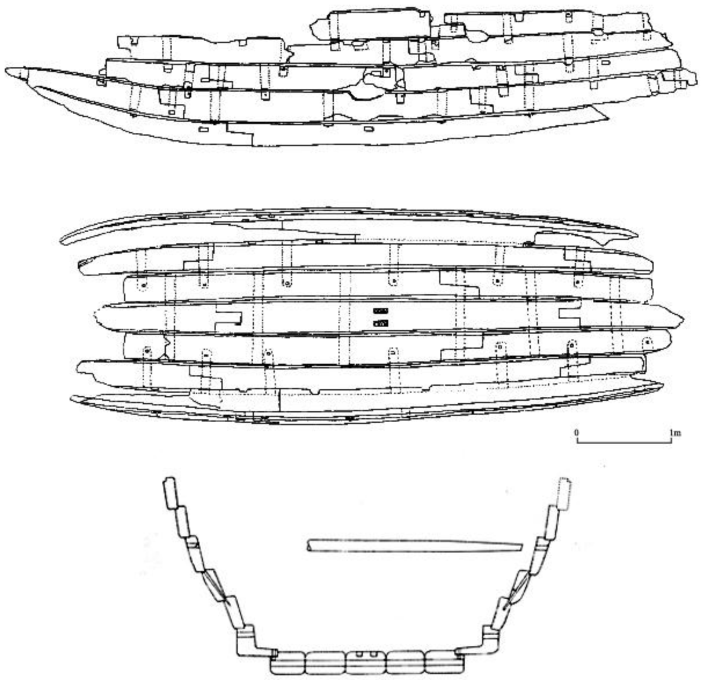

Figure 4-20 Plan and cross section of the Wando ship. *From Green 1989*

Sibidongpado ship (十二東波島船):

The shipwreck was discovered offshore of the Sibidongpado, Okdo-myeon in Gunsan city in Jeonbuk Province and was excavated in 2003-04. It dated from the end of the eleventh century to the early twelfth century, according to analysis of artefacts, mainly of approximately 8,000 pieces of ceramics. It is noted that a report published more recently has dated the ceramic assemblage of this ship to the earlier period than that of the Wando ship (National Research Institute of Maritime Cultural Heritage 2009). The details of the remaining of the hull and associated artefacts have been presented in the excavation report (National Maritime Museum of Korea 2005b). The remaining hull measures approximately 7.00 metres in length and the widest remaining part of the bottom hull is 1.80 metres (Figure 4-21). Although the preservation state of the hull is not as intact as the Wando ship, the overall configuration and structure of the remaining part of the hull show considerable similarity with the Wando ship. The remaining part of the Sibidongpado ship includes three bottom strakes, and two L-shaped chine strakes sitting on one side of the bottom structure. Each of the three longitudinal joined strakes comprises two timbers remaining. The longitudinal joint of the median strake shows a protruding-tongue scarf and step joints are in the other two, the same pattern as the bottom strakes of the Wando ship. Five wooden long bars or tenons run athwartships through rectangular mortises that have been cut through the three bottom strakes. The upper edges of the planks of the outer strakes are rabbeted to receive L-shaped chine planks. The most distinctive feature of the Sibidongpado ship from the Wando ship is the double L-shaped chine strakes; the lower chine strake is placed on the bottom strakes and the upper chine strake sits on the rabbeted edge of the lower one. The presence of two beams is inferred from the square mortises in the lower chine strake into which they were fitted. Several timbers detached from the ship were scattered around the remaining part of the hull and include a part of the square bow transom. Although the bow remains are substantially degraded, three planks show evidence of wooden tenons used to edge-join them. Of the three planks the most well-preserved plank measures 1.60 metres in length. The edges of the bow transom are recessed and form steps where the clinker arranged hull planking could meet. The other detached timbers include a piece of a hull plank and timbers possible associated with an anchor windlass. The original length of the ship has been estimated to be approximately 14.00 metres.

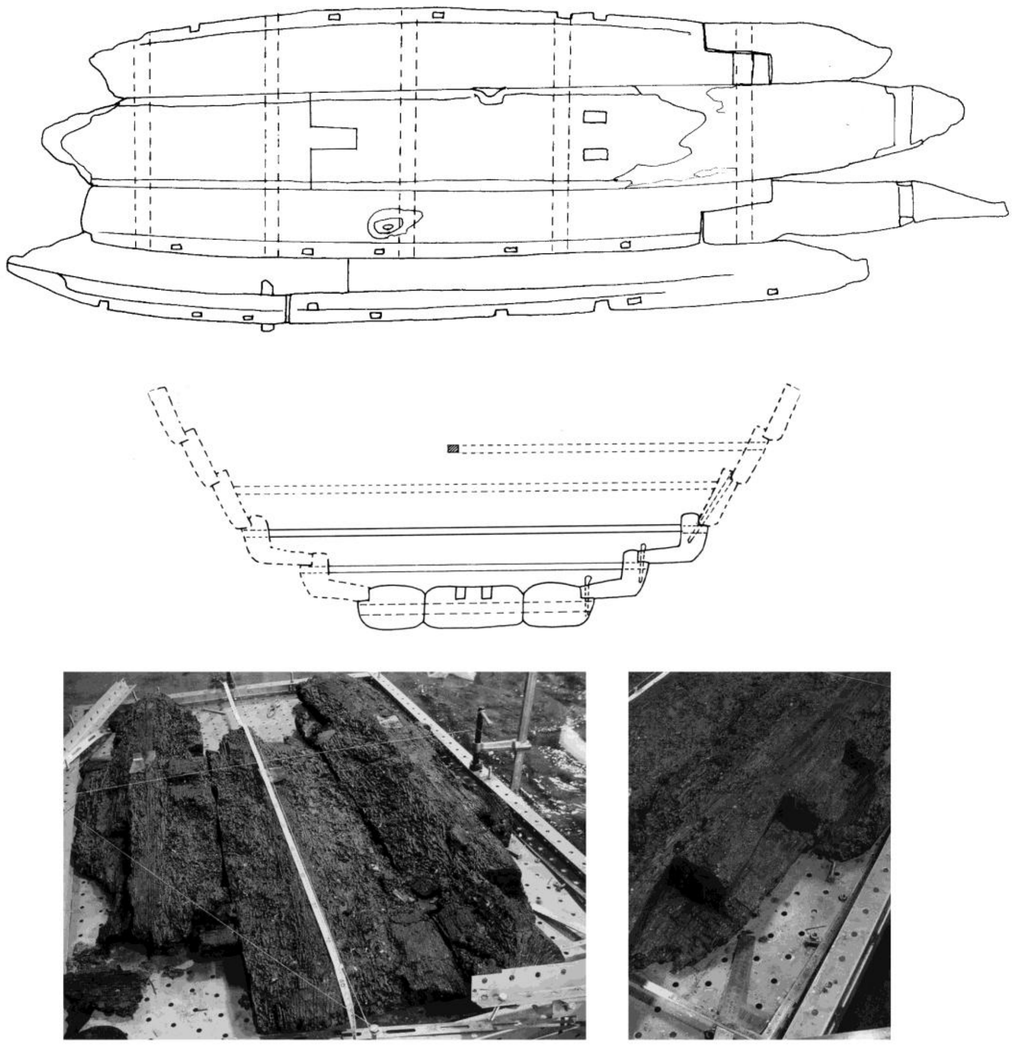

Figure 4-21 Plan and cross section of the Sibidongpado ship and photographs of the bow planks' remains. *From National Maritime Museum of Korea 2005b*

Taean ship (泰安船):

The shipwreck was identified in 2007 offshore of Daeseom Island in Taean located at the tip of the peninsula in Chungcheongnam Province through the discovery of a celadon bowl found by a local fisherman. During the excavation in 2007 and 2008 by the National Maritime Museum, over 23,000 artefacts were recovered, including six ship timbers, two large stone anchor stocks (or anchors' weights), pieces of a windlass, wooden strips, metal and earthen wares, stone bricks, bones, and 20,000 pieces of celadon. The significance of this shipwreck has been recognized because of the quantity and quality of celadons, some probably for the royal court, from which the shipwreck is known as the Goryeo Celadon Treasure Ship. The details of the recovered artefacts and hull are well documented (National Research Institute of Maritime Cultural Heritage 2009).

It has been presumed that the ship sank during the voyage from Gangjin in the tip of Korean Peninsula to Kaesong (known as the ancient capital of the Goryeo Dynasty) in the twelfth century. All of the six identified ship timbers are associated with hull planking, comprising parts of four side strakes measuring 8.50 metres long and 1.50 metres (Figure 4-22). The method of the plank fastening of the Taean Ship shows the difference from that of the abovementioned ships. The wooden fastenings directly fasten the seams of the planks; they are driven diagonally from the lower part of the upper plank to the upper part of the lower plank like the nailing of Chinese ships. There appears to be locking pins to secure these wooden fastenings. The fastening method is still used in conjunction with rabbeted seams forming clinker steps. The lower and upper strakes, identified from the pattern of the fastening and clinker joint are thicker than the other two (Figure 4-22). The remains of these thicker strakes or wales consist of two timbers that have been joined with a stepped scarf. The two stepped scarfs are vertically aligned in the presumed configuration of the planking. All these side strakes have square holes probably associated with the use of beams. Two large stones (one is 115kg and another is 70.5kg in their weight) that have been a part of anchor or used as anchor weights are identified. Grooves or recesses on their sides are believed to have been for the anchor ropes. The estimation of the original hull length is over 20.00 metres. Around the Taean's waters, a few sites have been identified and underwater survey and excavation are ongoing.

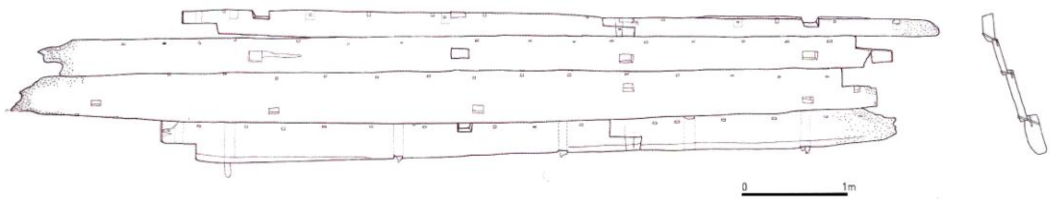

Figure 4-22 Drawing of the remains of the Taean ship. *From National Maritime Museum of Korea 2009*

Daebudo ship (大阜島):

The ship remains were discovered in the intertidal zone of Daebu Island, Ansan City in Gyeonggi Province and was excavated in 2006. The results of the excavation are documented (National Maritime Museum of Korea 2008a). Discovered ceramics date the shipwreck from the late twelfth century to the early thirteenth century. Most of the hull is missing, only three bottom strakes and a chine strake remain. The remaining part of the hull measures 6.60 metres in length and 1.4 m in the widest remaining part (Figure 4-23). The bottom of the hull was originally formed by five bottom strakes, yet only the three sets of the bottom planks remain. Three long wooden bars penetrate through athwartships the bottom strakes and there are also several square mortises where shorter tenons or bars have been fitted. The remaining of the centre bottom strake consists of only one timber with two recesses possibly for a mast structure on the top, the same feature as the Wando and Sibidongpado ships. Each of the other two bottom strakes consists of two longitudinally jointed planks. The joint of the one next to the centre bottom strake appears to be a butt joint, and this is compared to the other bottom strake which holds the chine stake that has a scarf joint. All of these bottom strakes have slight curvature upward toward the bow and stern (the same configuration has been identified to the Wando ship and the Sibidongpado ship). The chine strake consists of two planks. It is said that the planks of the chine strake was originally cut to L-shape in its cross section, yet due to the degradation of the timber, the main part of the plank to clarify the original configuration of the cross-section, is missing. The chine strake is joined into the bottom plank by mortises and tenons.

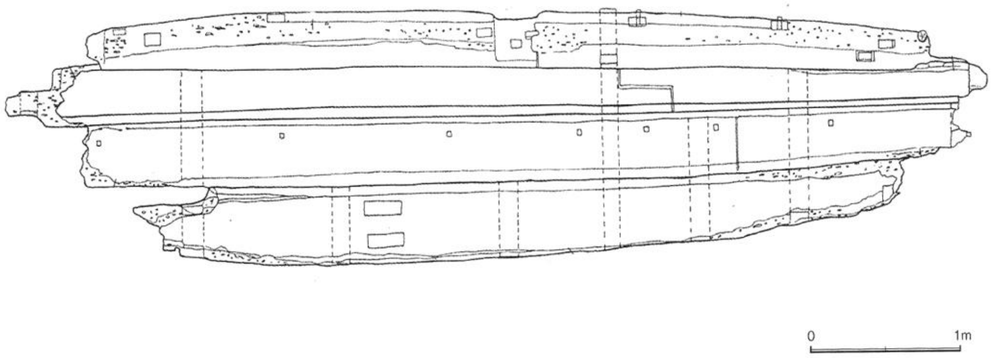

Figure 4-23 Drawing of the remains of the Daebudo ship. *From National Maritime Museum of Korea 2008a*

Talido ship (or Dalido) (達里島船):

The ship remains were found in 1995 in the intertidal part of the shore of Talido (or Dalido) island in Mokpo-city, Jeonranam Province. The ship is dated to the thirteenth or fourteenth century based on radiocarbon dating on the ship timber (BP 730±57). There are no artefacts associated to the hull. The remaining part of the hull includes three bottom strakes and four side strakes on both sides. The remains measure approximately 10.50 metres in length and 2.72 metres at their widest. The median bottom strake plank consists of two planks joined by a tongue scarf. It has two square recesses presumably associated to mast structure. As the cross-section shows, the median bottom strake is thinner than the other bottom strakes (Figure 4-24). The other bottom strakes, either side of the median bottom strake, consist of three planks each and they are lap-joined. These bottom strakes are slightly rockered and tapered toward the bow and stern the same as the other ships. The bottom strakes are joined by long wooden bars or tenons athwartships through mortises. Twelve of these mortises are observable. The absence of L-shaped-chine planks is remarked as the most important feature of this ship, replaced by thick strakes at the chine. Three strakes above these chine strakes consist of three planks longitudinally joined by step joints, which are secured with tenons. For edge-fastening the hull planking, tenons are driven through rabbets cut in the upper edge of the upper plank to the lower plank, and pegs are used to lock the tenons. This fastening is used for the connection of the chine strake and the bottom planking as well. Six beams are identified, and there are distinctive features in fixing them into the hull planking; the thinner beams are slotted into square apertures cut in the hull planks; the thicker beams are fixed into recesses in the inner surface of the hull planks. Four timbers of the stern transom remain. Although they are degraded, the third plank appears to have tenons on the side for the joint with the hull planking. It appears the lowest side planks at one end of the hull have recesses and they might have been cut for the transom stern (or bow) structure.

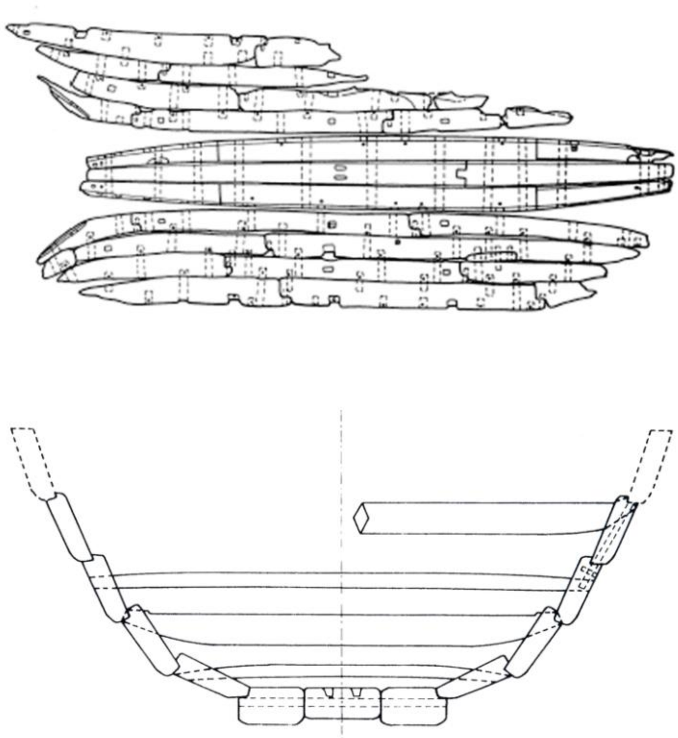

Figure 4-24 Drawing of the remains of the Talido ship. *Courtesy of the National Maritime Museum of Korea*

Anjwa ship (安佐船):

The ship remains were discovered at Guemsan, Anjwa-myeon in Shinan district in 2005 and in the same year the excavation was implemented. The results of the excavation at the site is available in an archaeological report (National Maritime Museum of Korea 2006c). Although the upper structure of the hull is missing, the remaining parts are preserved well, including three bottom strakes, two side strakes on the portside, seven side strakes on the starboard, and a part of the stern structure, a few beams, and a portion of possibly sculling oar. A few celadons were discovered beneath the hull. They provide an approximate date of the ship determined to the late fourteenth century. The remaining part of the hull measures 14.50 metres long and 6.10 metres wide. The median bottom strake consists of two large timbers joined by a tongued half-lap scarf, distinctive from the joinery of the centre plank of the other ships (Figure 4-25). Fourteen mortises are cut through to receive long wooden bars to join all three bottom strakes. The bars appear to be secured by locking pegs. The median bottom strake has two square recesses for mast structure around the middle surface. The two other bottom strakes consist of two planks, joined with lap joints. All the bottom strakes have a slight rocker and are tapered toward the bow and stern. All the bottom strakes have a recess near their end at the bow, forming a groove into which a bow transom has been slotted. Planks of the first strakes building the sides up from the chines are thicker than the other hull planks and comprise four planks with step joints. The planks of this first side-strake in the bow are distinctive in that they have a triangular cross-section shape (Figure 4-25). The aft planks of this strake have grooves or recesses to secure a plank of the stern transom. Four planks are used for each of the intact strakes with step joints fastened by dowels (Figure 4-25). The edge-fastening of the hull planking is the same method as that of the previously mentioned ship remains including the Wando ship, the Talido ship, and Sibidongpado ship (Figure 4-25). Five beams are identified. A thicker beam has been fixed athwartships into the second strake. It has two square recesses cut through its middle parts, which presumably allowed longitudinally timbers to run through from the bow to stern. Thin beams are sub-classified into the two types based on the different ways to fix them into the hull planking. The end of the first type penetrates through the hull planks and is secured by wedges; the end of the second type is hooked on recesses cut into the inner surface of hull planks. Evidence of using putty for caulking and sealing the hull planking is identified in this ship.

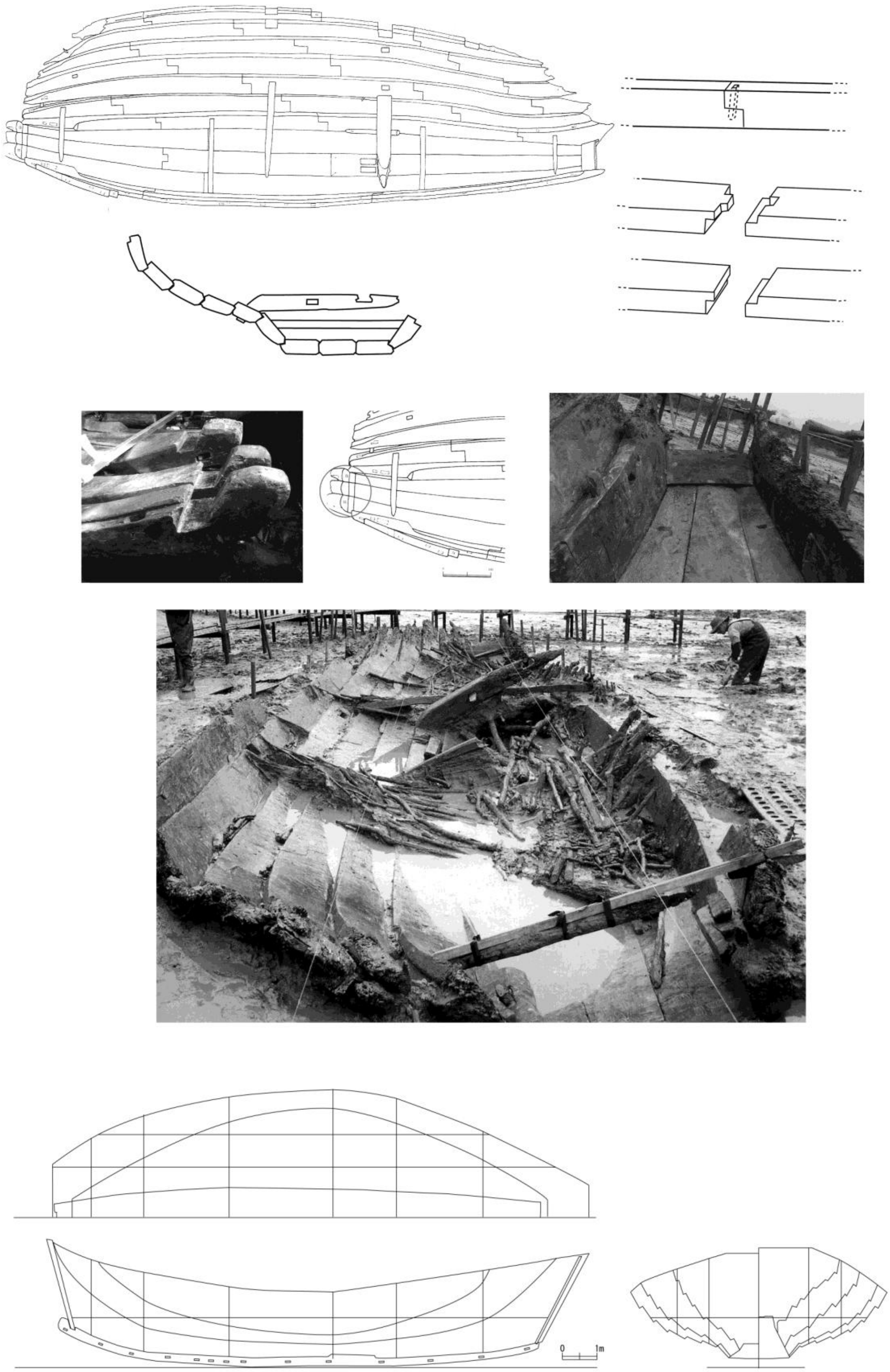

Figure 4-25 Plan and the cross section of the Anjwa ship, diagrams showing the butts of the bottom and side strakes, and photographs showing bow and stern structure. *From National Maritime Museum of Korea 2006, Shiplines drawn by author*

Green highlighted the distinctive construction of the Goryeo Dynasty, comparative with the features of the early twenty Korean fishing boats reported by precursors (Green 1986). Underwood (1979) has identified hull planking of the early twentieth century coastal ships that relies on a bent skewed wooden nails (Figure 4-26). According to Underwood (1979: 25), the holes are chiselled for the wooden nails in those modern fishing boats. In the similar way, the wooden tenons identified in the Goryeo ships must have passed through the holes that had previously cut. Further details of the driving method are described, "[t]he trenails are driven diagonally down from the outside of the upper plank and project on the inside of the lower planks. These ends are later sawed off, and the outer end counter sunk" (Underwood 1979: 25).

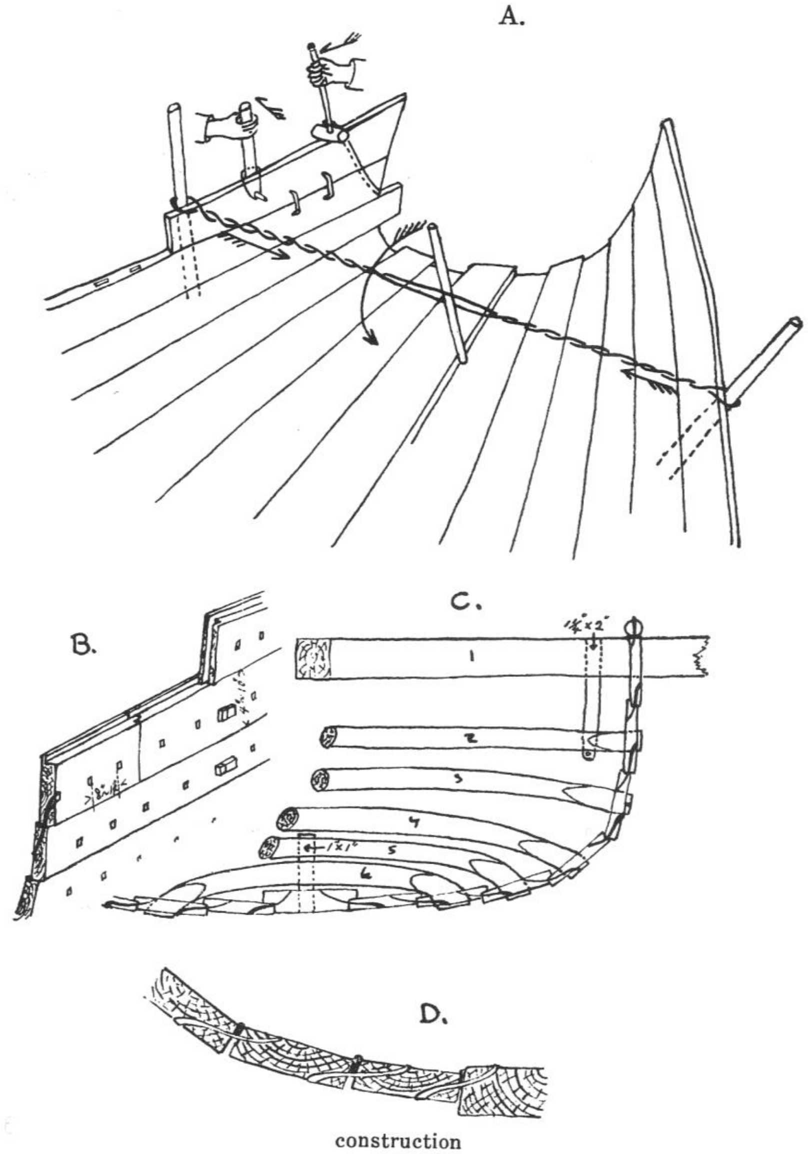

Figure 4-26 Structure and construction methods of the 20th century Korean fishing ship recorded by Horace H. Underwood. *From Underwood 1979*

With regard to the type of the wood, Underwood has explained follows:

> *Trenails are used almost exclusively in Korean boats even today and these are almost invariably of oak, as are the anchor chocks, the pegs for the sweeps and other fittings where a hardwood is required. The wood is not usually allowed to season thoroughly as it thereby becomes too stiff to bend easily* (Underwood 1979: 24).

For the material of the other components of the hull, Underwood has explained that Korean shipwrights preferred to use pine. A Korean researcher presented the type of the woods used for the different part of the Korean ships (Choi 2006: 28) (The details of the wooden species identification on the excavated ships will be discussed in Chapter VIII). Underwood (1979: 25-27) provides further description about the hull construction methods of the fishing boats by a plank-fast technique and the explains structural details with Korean shipbuilding terms used for each hull components. There is an issue of the identification of traditional naval terms (with a matter of English spelling) although naval terms could have been used under shipwrights' own unique practices. "Ship-building in Korea has never been reduced to a science and apparently has always been done by rules of thumb rather than to exact specifications, plans or lines" (Underwood 1979: 22). Nevertheless, archaeologically identified ship remains dating from the end of eleventh century to the end of the fourteenth century demonstrates the scheme of consistent development of Korean coastal ships. There are obvious structural changes between the Goryeo Dynasty ships and modern Korean ships. L-shaped chine strakes represent the historical transition of the hull structure and construction methods. The strakes were originally innovative structure, but to produce the chine strakes having such complex shape probably required a lot of work. Their use ceased in the later periods. The long term Korean shipbuilding provides a perspective on the difference between structural improvements and changes that would make shipbuilding easier. The innovation may be interpreted in different ways: all changes are not in the direction of improvement. Even sometimes economic changes force shipbuilders to produce cheaper ships rather than better ships.

Japan

As previously mentioned, except for a number of dugout canoes mainly dating to the prehistoric periods, Archaeological discovery of watercraft is limited in Japan. The development of watercraft in Japan has been raised and reviewed in the recognition of dugout canoes with their evolution to planked-up dugout canoes. Further developing the planked-up dugout canoes linked to the advent of the

Japanese native watercraft has been coherently presented through the simple development theory fundamentally comprising the extension of the hull planks and the change of the use of a dugout by either splitting it or replacing it into the bottom planks. Evolution of watercraft is likely to be simplified and diagrammed within the use or non-use of the dugout components for the hull construction and the way of their use (Adachi 1998; Farris 2009: 274). However, the date of the transition of the disappearance of the dugout component from the hull of oceangoing ships has not been clarified. Ishii (1957: 16-17) indicates that the development of flat bottomed inland watercraft by the ninth century and the use of large ships to conduct oceangoing voyages to China occurred by the fourteenth century. Through these studies, iconographies, ethnographical-boats, and historical texts have been recognized as the most available clues to study the evolution. Written and drawn information restricts the detailed examination of the hull structure and construction techniques. Previous studies based on the simplified seriation and typological evolution does not consider structural development with external influence and internal technological innovations.

Against the lesser expectation of the archaeological discovery of watercraft, there is some feasibility regarding the identification of the late thirteenth century's Japanese watercraft in the Takashima underwater site. The site is the historical battle field Japanese native watercraft resisted the Yuan Dynasty's fleet, thought so far the discovered ship timbers from the site appears to originate from the raider. Apart from the evidence of ships dating back to such older periods, it seems that there are more chances to review a component of the hull of the Japanese native ships dating to the post-medieval period defined as the Edo Period (1603-1868 A.D.) in Japanese history. Two large rudder posts, probably associated with Japanese native coastal ships, are identified. Only two examples of the large rudder posts are limited to providing inclusive examination of the representative Japanese coastal ships. Interestingly, they were independently identified, as they were buried in the sediments of the adjacent historical harbours. There are no relevant archaeological survey records to examine the associated context, such as the existence of shipyards, and clues to assess whether the rudder had been deliberately abandoned or buried, or perhaps accidentally broken up as wreckage. In terms of a thematic study of rudders, they are not enough to deduce if their structural innovations followed the previous periods. In general, depending on a large rudder post or rudder stock with a tiller is perceivable in the tradition of East Asian shipbuilding technology. Diffusion and interaction in developing an axial rudder within the regions are presumed. However, an axial rudder from the Japanese coastal ships is a hanged rudder fixed by ropes in the stern, distinguished from a transom-mounted rudder slotted into the transom like some Chinese ships.

- Archaeological evidence of indigenous ships around the Edo Period
  Rudder post from a Japanese ship Sekibune:
  According to an online database of underwater sites in Japan produced by the Asia Research Institute of Underwater Archaeology, a large wooden rudder stock was discovered in the riverbed of the Kushi Imamura River in Bouzu town. It is now exhibited in the Bouzu Historical Resource Centre in Minamisatsuma city. Bouzu is known as a historically significant harbour developed before the tenth century until the Edo Period for both domestic and international trading. The data on the website briefly defines the features and origin of the rudder post. Its remaining part measures 8.20 metres in length and the largest cross-section is 490x230 millimetres, although both ends are damaged. Chemical preservation has been conducted on the timber. The timber has been identified as *Quercus acuta* widely growing in the East Asian regions. The rudder was presumed to have been originated from a coastal ship called a Sekibune and dated to the Edo Period. The Sekibune is generally classified as a middle size coastal ship developed as a battle ship during the Japanese medieval period, and in some cases of the post-medieval periods it was used to carry peerage (Figure 4-27). However, according to the database, the age of the rudder post is indicative of its origin from the Sekibune used as transportation ship, though the method how it was dated is not clear. Another problem is that the configuration of the Sekibune has not been archaeologically clarified. In general definition, it is presumed that it adopted Japanese representative construction methods using multiple bottom planks rather than keel with thwart beams penetrating hull planking and fastened by iron nails and brackets. One type of the Sekibune constructed as a battle ship appear to have had substantial size of bulwarks and a castle-like super structure running from the bow to the stern, and its multiple oars enhanced not only propulsion but also maneuvability.

Figure 4-27 Scale model of the Sekibune that was made based on historical and iconographical resources. *Photo by author, Courtesy of Matsuura Historical Museum*

Rudder post from a Japanese coastal ship Bezaisen:

Another example of a rudder post from a Japanese ship remains in Okitsu town in Chiba prefecture (Kimura 2009). A large timber is believed to have been a part of the rudder from a traditional Japanese coastal ship known as a Bezaisen used mostly during the Edo Period. The timber was discovered in the estuary of a small river flowing into Okitsu Beach during the development of an extension of the harbor (Figure 4-28). The rudder post is 6.02 metres in length and appears to be made of oak (*Quercus* sp.). When discovered it showed a well-preserved state, but due to a lack of proper conservation treatment, it is now unfortunately deteriorating and splitting finely, with cracking and shrinking appearing on the surface. Two holes in the middle are damaged from the harbor construction work. The top part of the rudder post has a square shape and a square hole allows a tiller to be inserted. From the top to the bottom part, the section of the rudder gradually changes to a flat shape. This part could have had a rudder blade attached, though it is now missing. In the bottom part of the rudder, there are a few corroded iron pins, probably to fasten the rudder blade to the rudder post. A maritime historian Ishii Kenji briefly inspected this timber and concluded that it is a rudder post of a Bezaisen. The Bezaisen was a coastal trader mainly used from the middle seventeenth century to the late nineteenth century. Although the definition of the Bezaisen is vague, they developed as a cargo ship of approximately 150 tons. The overall design and structure of these vessels became standardized through the seventeenth century and eighteenth century, and by the nineteenth century the representative features of the Bezaisen showed more uniformity. It has been said that the spine of the Bezaisen is distinguished from a western ship’s keel (Adachi 1998). However, structurally it functions the same way as a keel. The hull planking was assembled using edge joints with iron nails. The transverse strength of the hull was secured by several beams distributed along the length of the hull. Propulsion was highly dependent on one large square sail, initially made from bamboo fibres, but in later periods cotton fabric. Like most square sails, Bezaisen sails were made with the panels of cloth arranged vertically, parallel to the leaches of the sail. The Bezaisen used a large suspended rudder. The section of the stern gallery is the typical feature of this vessel that has an open poop deck, allowing an axial rudder to be suspended and to be lifted up

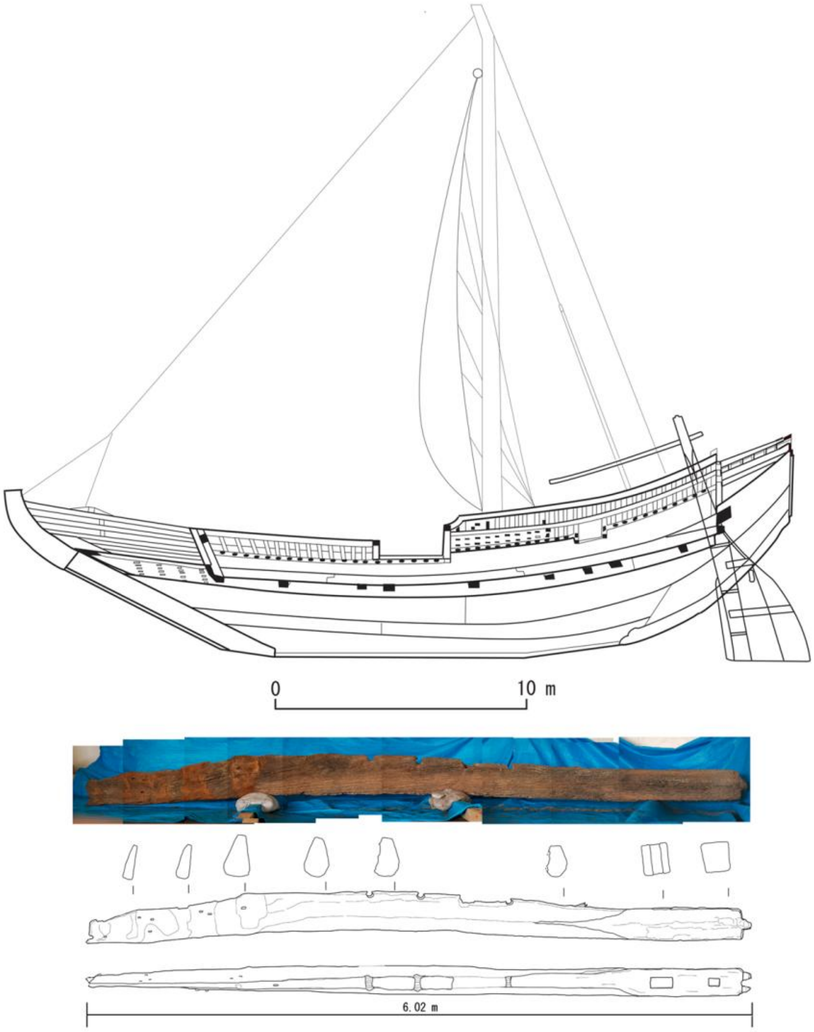

Figure 4-28 Image of the early 19th century Bezaisen and drawing and photograph of the remains of the rudder post. *Produced by author*

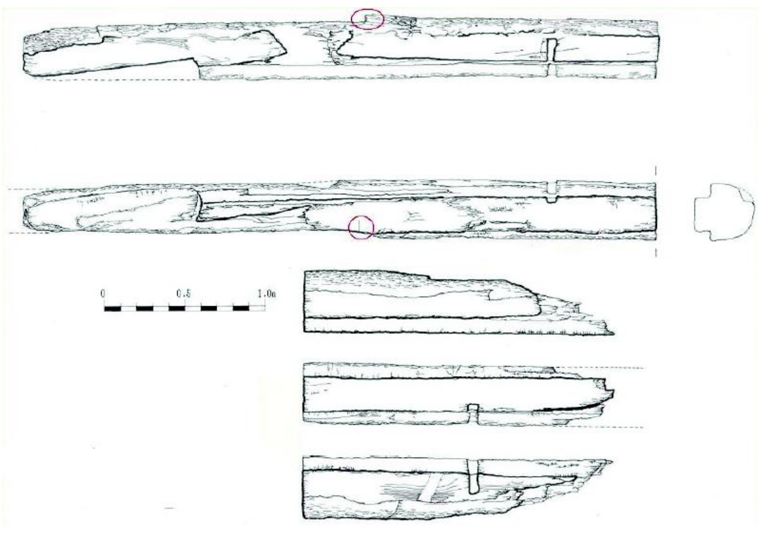

Figure 4-29 Drawing of the remains of the timber discovered from Nishihama in Ngasaki city. *Produced by Kashiwagi Kazuma from Kimura 2010c*

- Archaeological evidence of foreign ships in Japan

  Keel from the Nagasaki Prefecture:

  A large timber was discovered in Nishihama in Nagasaki city in 1966 during development work (Figure 4-29). Nagasaki is a historical port and a part of the city was the only place where foreigner merchants were allowed to land known as Dejima (literally exit island), while Japan had the national isolation policy in the seventeenth and eighteenth centuries. From the discovered place and its general configuration, cultural heritage management officers of the city have presumed the timber a ship timber from a foreign trader. However, no detailed examination has been implemented since its discovery. The timber was cut into two pieces during the development work. The total length of the two timbers is 5.9 metres. The timber is degraded and has many cracks. Some of the original features are obscured or lost, but the timber is clearly grooved or rabbeted along its edges. The size of these rebates suggests the rabbets of a ship's keel. It shows what appears to be the scarf to join it to either the forward or aft keel. There are a few corroded metal remains in the rebates, but their details are not elucidated. The radiocarbon date of the timber shows 325±15 (yrBP). By calibrating this date, the estimated date of the build may date back to the period between the early sixteenth century and the middle seventeenth century. The wood of the timber has been identified as *Pinus* sp., not the species from Japan. The port of the Nagasaki was initially opened for the Portuguese until around the middle seventeenth century and after the ban of trading with the Portuguese, the Dutch were the only Europeans with access to Dejima. The number of Chinese merchants visited Dejiman were greater than the European merchants. The images of Chinese merchants, their activities and ships (including a ship from Southeast Asia) are depicted in the ichnographic resources (Oba 2003). The timber of the keel is inferred to Asian origin, yet the details have not been identified. It might have been a part of an abandoned ship or have been taken from a broken-up ship for the reuse.

The main transverse structure in Japanese ships was massive beams. Although Chinese ships with bulkheads were chartered for long-distance and foreign trade, bulkheads were not adopted in either naval vessels, such as the Sekibune, or merchant vessels such as the Bezaisen. A query arises about some similarities in shipbuilding tradition, such as the use of beams as main transversal components similarly in the Korean shipbuilding. A perspective that the Japanese shipbuilding could adopt some technologies from outside has not been seriously addressed in the existing theories by the Japanese researchers. On the other hand, a few people outside of Japan have pointed as brief notions, for instance, mentioning "Japanese ships seem to follow a similar style to Korean ships" (Green 1986: 4). Also, a remark by Underwood is considered, recognised through communicating with a Japanese researcher regarding the historical fact that many shipwrights were sent from Silla to Japan in order to transfer the skills of shipbuilding before the tenth century (Underwood 1979: 23). A verification regarding the two countries' interactions that impacted on the development of the Japanese shipbuilding is expected to occur through archaeological discovery. It will be testimony to raise an argument whether a linear development theory is valid to explain the advent of Japanese shipbuilding tradition. The necessity of reconsideration on the theory that the development of the use of dugout canoe directly linked the formation of the hull structure of Japanese coastal traders has never been pointed out.

The idea that the Japanese ships adopted innovations from foreign shipbuilding technologies is also applicable for the ships developed in the later periods. It has been speculated that some of the large, Japanese-built Red seal ships authorised for foreign trade in the sixteenth and seventeenth centuries could have been built with bulkheads, but there is no firm evidence for this. Chinese trade to the historical ports of the Kyushu region, including Nagasaki and Hakata, might have resulted in some influence on the Japanese shipbuilding technology of the region. The discovery in Nagasaki City of a large timber, thought to be the keel of a foreign ship, is an interesting hint of such interaction.

Perspectives from this chapter

This chapter has reviewed the remnants of ships found in China, Japan, and Korea. The primitive watercraft have been addressed, considering the origin of construction methods for East Asian oceangoing. This is also significant relevant to understanding of endogenous growth as well as exogenous factors in the development of regional shipbuilding tradition. Of the primitive watercraft in East Asia rafts and dugout canoes are important to understand the structure and construction methods which later oceangoing ships inherited. Many Japanese researchers have explained the advent of tradition Japanese ships as evolution emerged from structural development of dugout canoes. However, this research insists the significance of re-evaluation of some other technologies, including construction methods that originated from rafts. It is also considered that technological integrations played an important role as an innovative factor on forming shipbuilding traditions in early East Asia.

The second section of this chapter has developed datasets of excavated ships and ship remains dating to the tenth century onward in China, Korea, and Japan based on available archaeological reports and literatures. This approach identifies twenty-two excavated ships in China throughout the Tang and Qing Dynasties. This is the most inclusive inventory of excavated Chinese ships that have been ever summarised with a focus on the structural information of the hulls. The dataset include the remnants of six ships of the Goryeo Period which were found offshore of west coast of the Korean Peninsula. The Goryeo ships' configuration demonstrates the Yellow Sea shipbuilding tradition in north, as their bottom structures are flat. However, the details of structure and construction methods are substantially distinctive from the northern Chinese shipbuilding tradition. The identification of the Goryeo ships extends the importance of the flat bottom in northern East Asia. It might have been influential outside of the Korean Peninsula. With regard to archaeological evidence of Japanese ships, despite the limitation of the identification of the hull, the contents of the data indicate the use of different types of ships through maritime history, which requires careful discussion in the formation of the shipbuilding tradition in the light of both endogenous growth and exogenous factors.

Chapter V – Quanzhou ship

The remains of the hull known as the Quanzhou ship or "Quanzhou Guchuan" (Quanzhou ancient ship 泉州古船) has been studied over three decades as one of the most important and intact archaeological shipwrecks ever discovered in East Asia. The Quanzhou ship is a trader dating to the late thirteenth century. A comprehensive report, the collaboration of many Chinese researchers, was published by the Museum of Overseas Communications History which is the custodian of the ship remains (Museum of Overseas Communication History 1987). The Quanzhou ship has been reviewed and assessed in a few English resources (Merwin 1977; Keith and Buys 1981; Green 1983a; Steffy 1994; Burningham and Green 1997; Green, Burningham et al. 1998; McGrail 2001; Xi and Chalmers 2004). The ship is currently displayed at the Quanzhou Ancient Ship Gallery in "Kaiyuan-shi" (Kaiyuan temple 開元寺) at Quanzhou city in Fujian province. The condition of the ship remains is deteriorating and its current configuration is somewhat different from that of the ship at the time of the discovery due to the preservation problems. This chapter initially attempts to review the *in situ* status of the hull while it was being excavated, based on original reports and photographs produced from the excavation work. Achievements of previous research conducted by members from Western Australian Maritime Museum will be reviewed to provide further details, in particular, regarding the structure of the hull. The contents of this section include the results of the most recent archaeological surveys at the Quanzhou ship in 2008 and 2009. By reviewing previous work and giving a new perspective, this section demonstrates the structural significance of the hull of the Quanzhou ship and principles of the construction method that were the conceptual basis of the work of the shipwrights during the construction of the ship.

V-1 Site background

The discovery of the Quanzhou ship

The Quanzhou ship is the earliest archaeologically excavated vessel in China and the East Asian region, dating back to the second half of the thirteenth century. Its discovery raised markedly a public concern regarding history and evoked the heyday of past maritime trading of the Chinese. Since its discovery, a series of articles on the excavation and research have been published in the authorized Chinese archaeological journal *Wen-wu* (文物). Afterwards, English translations of these articles were produced, resulting in the first resource (Merwin 1977)available for non-Chinese-reading scholars .

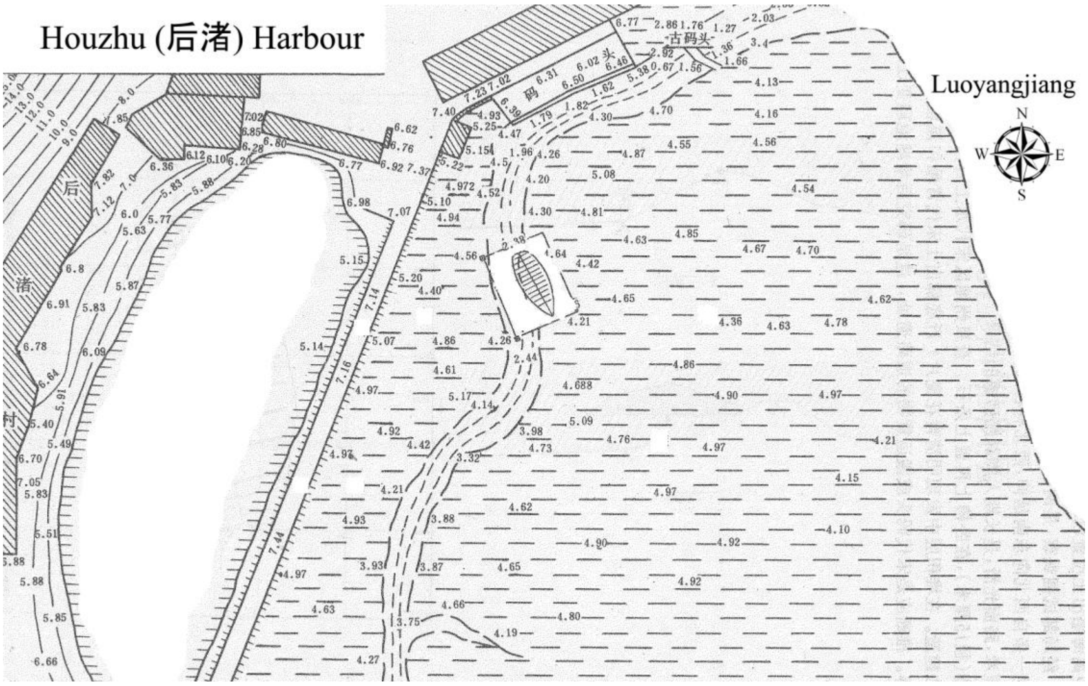

Figure 5-1 Discovered location of the Quanzhou ship at the Houzhu Harbour. *From Museum of Overseas Communication History 1987*

The Quanzhou ship was found in the tidal mud flats of the modern Houzhu Harbour along the river Luoyangjiang flowing into Quanzhou Bay (Figure 5-1). Quanzhou Bay, which contains two large estuaries of two major rivers including Luoyangjiang and Jinjian, has been known as a mooring place throughout history. The bay extensively encompassed a few ports including Houzhu and Fashi. These harbours had started to rise in prominence during the tenth to thirteen century as major ports of the city of Quanzhou, which were also called Zaiton at the time. The area of the port, which is approximately 10 kilometres away from the city of Quanzhou, was known as Linjiangli in the Song Dynasty (960-1279 A.D.), and in the thirteenth century during the Yuan Dynasty (1271-1368 A.D.) it was renamed to Houzhpu. It appears that throughout the Song and Yuan Dynasty periods the area was settled by foreign merchants. The growth of international trade is evidenced by various multi-cultural and religious monuments remaining in the Quanzhou region (Pearson, Li et al. 2002). Despite flourishing as an international port, environmental factors including the accumulation of silt gradually decreased the significance of the harbours of Quanzhou Bay during the later periods. After the fourteenth century, other historical cities such as Amoy began to take over the dominance of international seaborn trades, although Houzhu harbour still functions as a major port of Quanzhou Bay in modern times.

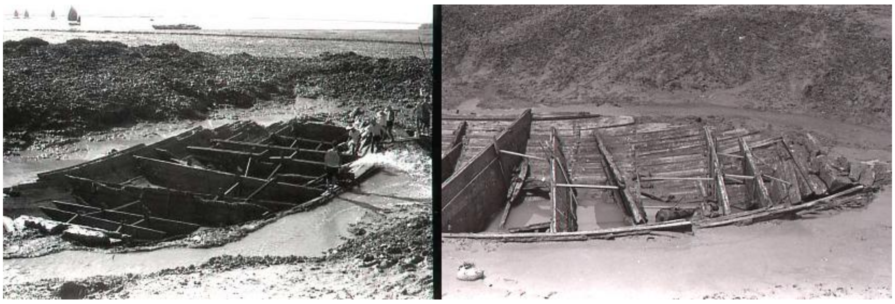

Figure 5-2 Exposed hull of the Quanzhou ship during excavation. *Courtesy of Museum of Overseas Communication History*

The Quanzhou ship was found in 1973 during dredging at the southwest part of Houzhu Harbour, below sea level covered by sediments with a thickness of 2.10-2.30 metres (Figure 5-2). “When the vessel was discovered, only a portion of its side was exposed (Merwin 1977: 10)”. It appears that a portion of the starboard side of the hull was revealed, according to the site plan (Museum of Overseas Communication History 1987: 7). In the year of the discovery, test excavation was implemented. It is said that as a result of the test excavation in the vicinity where the Quanzhou ship was found, stone pilings and wooden platforms presumably associated to an ancient slip or a part of the harbour structure were also discovered, though detail of the relationship between this maritime infrastructure and the Quanzhou Ship was not clearly explained (Merwin 1977: 10). The full excavation started in 1974 and continued for one-and-a-half months. The local authorities including the Chin-chiang District Revolutionary Committee, the district Association of Cultural Organizations, the History Department of Amoy University and the Museum of Overseas Communications History. The excavation initially removed the thick sediments covering the hull. During the excavation the strata were recorded and classified into three layers; the first layer (400-600 millimetres thick) is coarse greyish yellow silt with a bit of sand and containing modern artefacts such as roof tiles and ceramic shards; the second layer (600–700 millimetres thick) is light grey blue-coloured fine silt and contains ceramics dating from the Song to Qing Dynasties’ period; Between the second and third layers there is a thin sand layer; the third layer is dark grey fine and dense silt and contains the Song and Yuan Dynasties’ ceramic (Museum of Overseas Communication History 1987: 8-9). After the accumulated sediments were cleared, the hull was exposed. The quality of sediments observed inside of the hull was the same as that of the third layer that has been previously identified (Museum of Overseas Communication History 1987: 14). A small trench was opened under the hull in order to confirm the quality of the sediment on which the hull has been laid. Dense fine silt was observed just under the hull and there was soft grey fine silt. In these sediments beneath, ceramics dating to the earlier period of the Song Dynasty were identified. From the dense grey fine silt, large pieces of oyster shells were found, and some oyster shells were also discovered on the outer surface of the bottom of the hull. Thus, in the previous reports, the study of sedimentation focues on determining the relative date of the Quanzhou ship. Burial conditions of the ship in the sediments, however, has not been fully explained from the view-point of the site formation processes. With regard to *in situ* status of the discovered hull, it is only said that the hull was on a level plane when it was discovered (Merwin 1977: 11). According to Merwin (1977: 18), "Inspection of the present condition of the vessel's hull reveals virtually no signs of it having been repaired. It was a seagoing vessel that had been built and in service not long before." These descriptions are not sufficient to determine whether the ship was accidentally wrecked or deliberately abandoned.

V-2 Overall hull dimension and hull form and basic structure

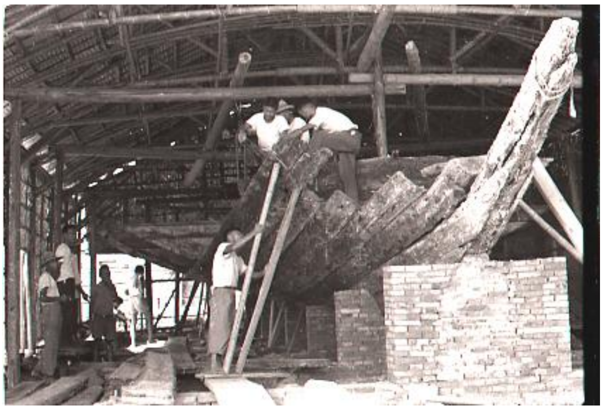

Figure 5-3 Reconstruction of the dismantled hull of the Quanzhou ship at the Kaiyuan temple. *Courtesy of Museum of Overseas Communication History*

The following section provides dimensional information about the Quanzhou ship. During the full excavation in 1974, the well-preserved lower hull was revealed, and it was dismantled to be carried away from the site. The dismantled components were reconstructed at the Kaiyuan-shi (Figure 5-3). The overall length of the hull remains is 24.20 metres and 9.15 metres breadth (Merwin 1977: 11; Museum of Overseas Communication History 1987: 16). The main structure of the hull is composed of a keel, twelve bulkheads, and sturdy planking. The hull planking forms clinker-like steps and consists of multiple layers, double changing double to triple layers around the turn of the bilge. A forward part of the hull narrows to a sharp shape (perhaps a narrow transom), compared to the broad stern (Figure 5-4). The cross-section of the hull shows considerable deadrise in the bow; however, toward the stern the sections are flatter and broader. Chinese researchers have estimated that the cargo capacity of the Quanzhou ship could be over 200 tonnes and another study demonstrates that the laden displacement of the Quanzhou vessel is approximately 370 tonnes (Merwin 1977: 81: 94). It has been suggested that the Quanzhou ship could carry fifty people on board and some livestock (Merwin 1977: 96). However, since the upper part of the hull is missing the precise reconstruction cannot be certain. In fact, the cargo carrying capacity of the Quanzhou ship may be less than 200 tonnes. This perspective is comparative based on another study of the hull of the Shinan ship (See Chapter VI).

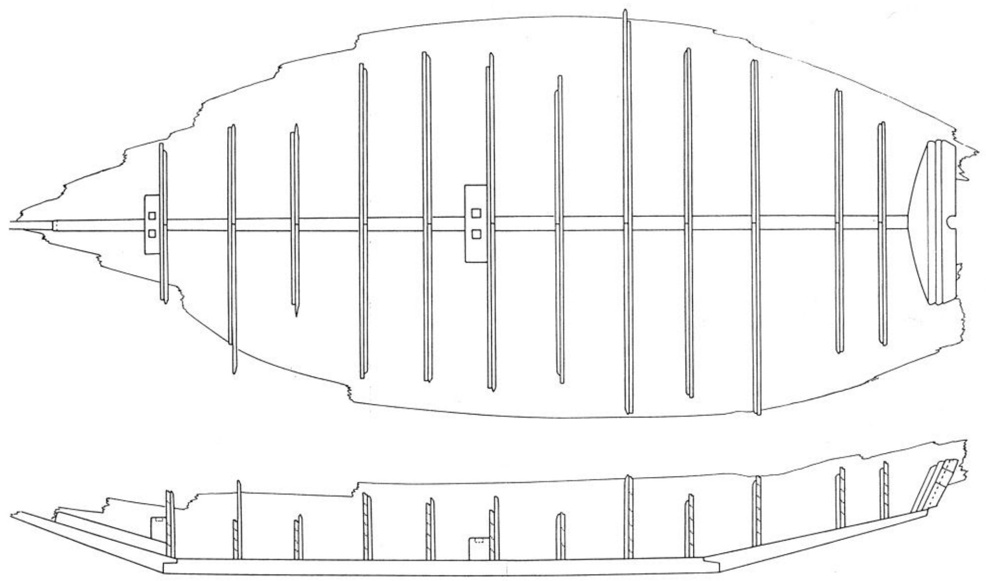

Figure 5-4 Plan of the Quanzhou ship. *Courtesy of Museum of Overseas Communication History*

V-3 Cargo stowage

Information about artefacts discovered inside of the hull is briefly presented. The inventory of these items is available in a few reports with the information about their distribution in the holds of the hull (Merwin 1977; Museum of Overseas Communication History 1987). The quality and quantity of the original cargo are not ascertained, as the loss or the salvage of most of the cargo probably occurred after the wreck event. However, the recovered artefacts include several seaborne trading materials and their assemblages, indicating the use of the Quanzhou ship as a trader (Appendix I). Some of the recovered artefacts include various fragrant woods and spices, such as pepper, common commodities in Asian maritime trade. Chinese ceramics are also typical seaborne commodities, likely identified in Asian merchant shipwrecks. However, the discovered amount of Chinese ceramics from the hull is relatively small. Most of these artefacts can be regarded as the items that were originally laden as cargo. Several inked wooden strips are found and these seem to be labels or tags associated with the trade items loaded onto the ship. Distribution of the cargo is used to interpret the utility of the holds and the cargo loading patterns of the thirteenth century's East Asian oceangoing ships. In the case of the Quanzhou ship, however, very limited information about its cargo distribution is available and it seems that during the excavation detailed site plans were not produced. Apart from the trade goods, artefacts from the hull include possible personal belongings. These appear to be from the aft holds including the twelfth and thirteenth holds such as carpenter tools, chopsticks, ivory chess pieces and a tortoise shell. The wider distribution of the pieces of fragrant woods, from almost all holds apart from the thirteenth hold (the aftermost hold), indicates that they might have been a part of the main cargo. These fragrant woods, however, show relatively small dimensions measuring 30-100 millimetres on average (the largest fragrant wood is 1.68 metre length). In the case of the Shinan shipwreck, the type of fragrant wood is of only one species (sandal wood) and the size is of greater length. In the Quanzhou ship, each space of the holds of is smaller than that of the Shinan ship. Therefore, the design of the stowage space of the Quanzhou ship might be more suitable for smaller size cargo.

V-4 Details of the hull structure

Intensive survey highlighting structural and construction aspects of the Quanzhou ship was conducted by a research team between 1983 and 1994 (Burningham and Green 1997; Green, Burningham et al. 1998). The result of the four surveys cooperating with local researchers included a detailed lines plan and a plan of the hull structure drawn from offset measurements, careful visual observation and the use of an Electronic Distance Measuring System in 1994. In 2008 and 2009, the site was further inspected for this research project. These most recent surveys aimed at recording further details of the hull structure.

Since the excavation in 1974, the hull of the Quanzhou ship has deteriorated so that physical contact must be minimized and access to the hull was limited during the latest survey. With regard to a cause of the deterioration, it is assumed that only limited conservation methods were available after the hull was recovered from the estuarial site. According to Li (2004), they intended to season the waterlogged timbers by slow drying as much as possible, and they have spent four years on completing the drying processes with a few treatments including covering the ship remains with plastic sheets to retain moisture, antisepsis of the timbers by spraying water with 5% alcohol , and control of humidity of the storage room. Also, to prevent exfoliation of the timber surface, coatings of sesame oil, tong oil, acetone mixed with 7% tong oil were attempted. For the preservation of the timber, a substance made from resin and paraffin wax was used. Despite these efforts, it appears that the deterioration continues. Structural distortion of the hull is recognisable, including the shrinkage and cracking of the planks. Giving an example of the status change of the hull, the stern transom that is comprised of a vertical set of three layers of solid timbers was originally well-preserved and a round shaped rudder socket was visible in photographs (Figure 5-5). This can be compared with the current condition of the stern (Figure 5-6). The information regarding the original dimensions of the rudder socket, for example, appears to be lost. The photographic record suggests that there could have been more accurate data recording immediately after the hull was revealed. Even from the presence of the current remaining stern, however, it is still obvious that the rudder is raked at the same angle as the transom, and that the rudder socket could slide up and down in the socket.

Figure 5-5 Stern of the current hull. *Photo by author*

Figure 5-6 Stern of the Quanzhou ship recorded in an old photograph taken during the excavation. *Photo by author.*

It is pointed out that many iron nails have been initially used for the modern hull reassembly, and later their corrosion became the cause of secondary damage resulting in more recent deterioration of the timbers, so that attempting to find a fastening system with less impact on the hull was conducted by replacing the iron nails into bamboo nails (Li 2004). However, this work seems to have been uncompleted, and many corroded iron nails as well as bamboo nails are unfavourably exposed at the lower part of the hull (Figure 5-7). In addition to the degradation of the nails themselves, a number of cracks are focal around those iron nails and their holes in the hull planks. More serious consideration is the position of these modern nails. It is said that these modern nails were driven into the original nail holes. By observing the outer structure of the hull, it seems that Portland cement was used to seal the heads of these modern nails or perhaps to fill original and non-original nail holes. Nails were driven from surface of the outermost planking to the inner planks, yet the nail driven patterns are likely to be more or less random. Whether these modern nails have been located exactly in original nail position or not could not be examined due to lack of response to contact the people involved in the reconstruction work. The structural distortion of the hull and imprecise reconstruction has been taken into consideration here to allow an acceptable error range in recovering the data from the ship. Furthermore, in order to minimise misinterpretations only relying on the information from the current ship remains, assessing the structural characteristics of the Quanzhou ship in the following section will be partly from the original resources including reports and photographs produced in the 1970s and 1980s and the results of the sequence of more recent surveys.

Figure 5-7 Modern iron nail seen at the bottom of the hull. *Courtesy of Museum of Overseas Communication History*

Keel

The keel of the Quanzhou ship is composed of three parts: a forward keel, a main keel, and an aft keel. These are joined by stopped scarfs with tenons (Figure 5-8). In the Chinese shipbuilding tradition, a keel is called longwu, meaning a dragon spine (See Glossary). Accurate dimensions and configuration of the keel is difficult to examine at the current hull due to the difficulty of access to the inner hull. However, the dimensions and details are well provided by the existing literature. The overall length of the keel consisting of the main keel and aft keel is 17.65 metres, and 0.45 metres its width (Merwin 1977: 11-14; Museum of Overseas Communication History 1987). The depth of the keel is about 400 millimetres (the depth of the keel below the garboard which sits down in a rabbet is 270 millimetres). The length of the main keel measures 12.40 metres, the length of the aft keel is 5.25 metres. The aft end of the aft keel is tapered. While the forward keel measures 4.50 metres, it is suspected that the end of the forward keel may be partly lost. The forward end of the forward keel is tapered and measures a width of 180 millimetres and a height of 200 millimetres.

Figure 5-8 Scarf of the keel showing circular holes to place coins and a mirror. *Courtesy of Museum of Overseas Communication History*

The forward and aft keels are scarfed to the main keel. The forward and aft keels are angled upwards; the former slopes upwards 20 degrees and the latter slopes upwards 15 degrees. In the joints or scarfs, the upper member of the forward and aft keel overlap the lower member of the centre keel by fitting an end joint with added mortise and tenon. Remarkably, it is said that there is no evidence of using nails on these scarfs (Museum of Overseas Communication History 1987). A tradition to place seven coins or coin holes with a bronze mirror, known as Bao shou kong, was confirmed in the scarf between the forward keel and main keel (See Glossary).

Structure of the bow and stern

Upper structures of the bow and stern of the Quanzhou ship are missing, yet their characteristics can be partly inferred from the remains of the lower hull and general characteristics of Chinese watercraft. Modern reconstruction at the bow prevents one from examining directly the original configuration (Figure 5-9). It seems that a large timber is placed forward of the keel scarf of the forward and main keel, according to the plan of the ship (Figure 5-4). It is regarded as a hog piece. A forward mast step sits on the aft end of the hog piece. The first bulkhead is placed immediately abaft the aft of the hog piece and the mast step. The fastening methods of these components were not able to be examined, as their joins are not visible in the reconstructed hull. With regard to the missing part of the forward keel and bow structure, it is open to question whether the Quanzhou ship had a trapezoid shaped bow transom. In the case of the Shinan shipwreck, a transom bow surmounted the end of the forward keel (See Chapter VIII). A similar structure may have been used on the Quanzhou ship.

Figure 5-9 Bow from the front view of the Quanzhou ship. *Photo by author*

Figure 5-10 Stern from the aft side of the Quanzhou ship. *Photo by author*

Three layers of heavy timber baulks appear to compose a stern transom and this is barely identified in the current state of the hull. It is, however, remarked that the layers are not evident on an old photograph, which was presumably taken immediately after the exposure of the hull (Figure 5-6). A layer of thin sheathing on the outside of the current stern transom can be also seen, and this is identified on the old photograph (Figure 5-10). Based on the published information, the remaining part of the stern transom measures 1.37 metres. (Museum of Overseas Communication History 1987: 21). The breadth across the top of the remaining transom is 3.44 metres and the width of the two or three baulks measures 0.44 metres. The stern transom is raked aft 20 degrees. A large slot for a rudder stock passes through the centre of the aft face of the transom. The diameter of the slot is 380 millimetres. This is slightly less than the width of the baulk. The current dimension of the slot might not precisely reflect the original dimension, considering the deterioration of the timbers around the hole. There is no clear evidence how the rudder stock was secured to the transom stern. The rudder post could have been simply slid into the slot. The rudder was probably similar to the hoisting type of rudder which has been recorded in Worcester's study on Chinese junks, (Worcester 1971: 98). A structure to retain rudders of the Quanzhou ship is designed as a transom-mounted rudder. Yet in the same way as those junks use wooden gudgeons (or sockets), the rudder of the Quanzhou ship could have been slung probably from windlass and raised or lowered as circumstances required. Hull planking in the stern is extended beyond the stern transom to form a sort of false counter stern. This indicates that a superstructure including a stern gallery could have partly shielded the stern transom as well as the rudder.

Hull Planking

Hull planking of the Quanzhou ship consists of double- and in parts triple-layered planking. The strakes are edge-joined by skew nailing through rabbets which produce clinker-like steps in some strakes while most are flush or carvel. This skew-nailed and rabbeted construction is important to the strength of the hull. Thirteen strakes remain on the starboard side and fifteen strakes remain on the port side. During the survey in 1994, a sixteenth strake was recorded on the port side (Figure 5-11). However, in the 2009 survey it was noted that the uppermost strake (the sixteenth) was missing, and the uppermost sheathing plank associated with the fourteenth and fifteenth strake had also disappeared. Each strake consists of two or three planks per side, whose butts show two different joint methods; a short lap joint and long scarf joint (Figure 5-12). However the long scarf is an exception, appearing in only one join. The lengths of the planks range from 9.21 to 13.50 metres. Their widths are 280 to 380 millimetres. The thickness of the planks shows difference between the layers. The first inner layer is about 82-85 millimetres thickness, compared with the two outer layer planks consisting of the second layer plank with the thickness of 50 millimetres and the third layer plank (the outermost planking) with the 30-50 millimetres of thickness.

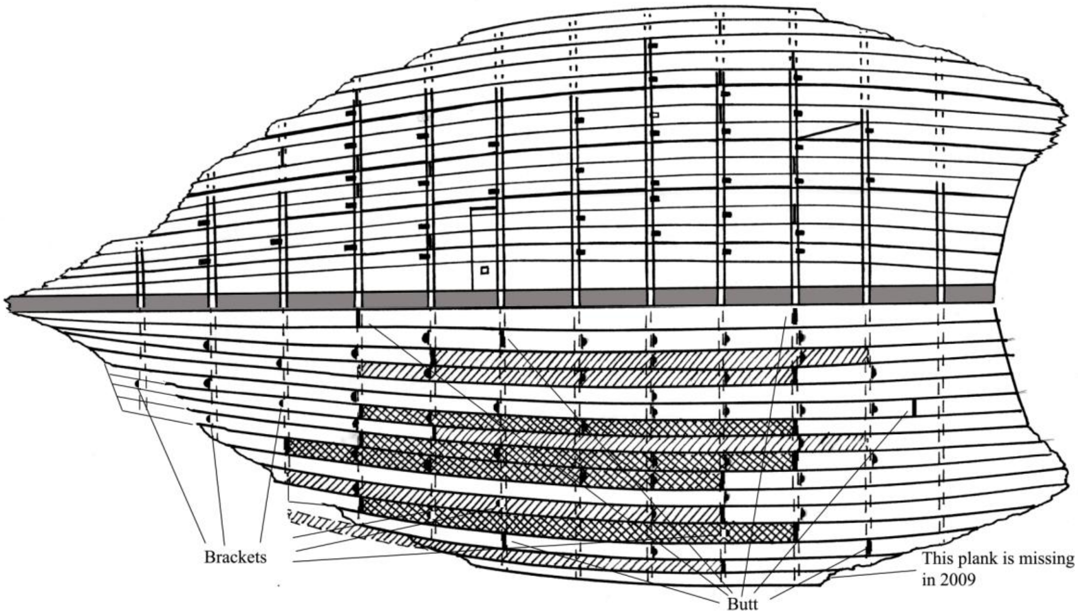

Figure 5-11 Plan of the planking arrangement showing the positions of the iron brackets and butt. *After Burningham, N. and J. Green 1997*

Figure 5-12 Long scarf joint that only appears in the ninth strake between Bulkhead No. 10 and No.11 at the starboard side. *Photo by author*

The hull planking of the Quanzhou ship shows complex structure. Green, Burningham et al (1998) highlighted the complexity of the planking system. In the hull planking of this ship one to two outer layers function as sheathing to protect the main planking from teredo. The outer layers also contribute to the strength of the plank-shell. The planking is two layers up to around the beginning of the turn of the bilge, and above that there are three layers (Figure 5-13). To assemble and key the multiple layers, the planking forms a combination of carvel and clinker construction. The terms "rabbeted carvel seam" and "rabbeted clinker seam" were newly defined to explain the complex planking (Green, Burningham et al 1989: 284) (See Glossary). The layers of planking on the cross-section shows that the assemblage of the inner planks consists of a set of rabbeted carvel seams and rabbeted clinker seams (Figure 5-14). The outer layers are fitted to the clinker steps but have no rabbet where they repeat the step; these outer layers form the clinker-like steps but they are not functionally of clinker construction. The significance of the hull planking focuses on the arrangement of the inner layer as follows. The rabbeted clinker seams appear on the seam of the second and third strake, the fifth and sixth strake, the eighth and ninth strake, and the eleventh and twelfth strake, which amounts to four clinker steps in the inner planking of the portion of the ship that remains available to us. The rabbeted carvel seams appear between those clinker steps. The pattern of the set of the rabbeted carvel seams and rabbeted clinker seams continues up to the twelfth strake. It is noted that all grooves on the rabbeted clinker seams and the rabbeted carvel seams show consistency, cut into the inside on the upper strakes.

Figure 5-13 Three layered hull planks showing rabbeted seams in the innermost planks.
Courtesy of Museum of Overseas Communication History

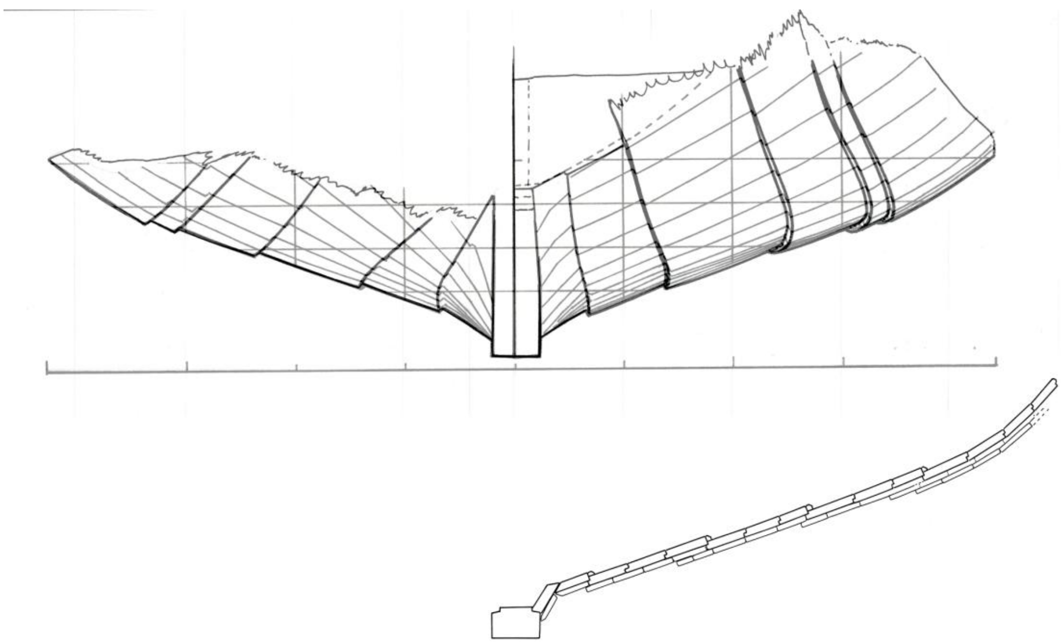

Figure 5-14 Clinker steps of the plank-shell from the combination of the rabbeted carvel seams and rabbeted clinker. *After Burningham, N. and J. Green 1997*

Iron nails are used for the fastening of the planking. Burningham and Green (1997) confirmed that these nails have been diagonally driven down from the upper plank to the lower, so the fastening can be termed skew nailing. The nails used in this skew nailing have been described as Ding ting in Chinese reports (Museum of Overseas Communication History 1987) (See Glossary). It is said that the nails used for the planking were estimated to be 200 millimetres in length through the communication of a Chinese scholar (Burningham and Green 1997: 42). The existent broken pieces of the corroded iron nails, which have been recovered from the hull, will be addressed in Chapter VIII. With regard to the original nails, even their corroded remains as well as their driven patterns are hardly identified in the current visible part of the hull planking, because they appear to have been replaced by modern iron and bamboo nails. Nevertheless, during the survey in 2008, some attempts to identify original nails or nail holes were implemented. This was based on an assumption that the upper strakes, which are away from the keel, showed a condition less impacted by modern reconstruction. The replacement with modern nails might not have been carried out in some parts. Strake No.13 of the inner planking on the starboard side, remaining of the uppermost strake, exposes nail holes and remains of corroded iron nails on its seam to the adjacent missing upper strake. The inner strake is overlapped by two outer planks, but only this inner strake shows the nail holes on the seam; the seams of the outer strakes are not edge-fastened by the skewed nails. The nail holes and degraded iron nails are spaced 150-200 millimetres apart. The nailing of the garboard to keel and second strake to garboard is approximately 125 to 150 millimetres apart. The original iron nails were driven around 90 millimetres above the plank seam from the upper strake to the lower strake from the outside of the hull (Green, Burningham et al. 1998). According to Li (1989), after nail heads were fully driven through the surface of the plank, they were further hammered using a nail punch to recess the nails into the plank. Or more likely, the nails were recessed into notches that had been made with a chisel. The recessed nail heads could have been sealed by putty (a possible substance known as chunam) in order to protect the iron nails from corrosion (See Glossary). It seems that a nail punch was found on the hold No.13 of the bottom of the Quanzhou ship. The remains of this tool, however, seem to no longer exist. There is a black and white photograph of it, but details based only on the photograph are incomplete (Figure 5-15).

Figure 5-15 Degraded metal object found from the hull, said to be a nail punch. *Courtesy of Museum of Overseas Communication History*

Bulkheads

The Quanzhou ship uses bulkheads as a transverse component of the hull. Twelve bulkheads produce thirteen holds on the hull. Upper planks of most bulkheads are missing, and the remains of the planks vary in each bulkhead; for example, the Bulkhead No. 8 has the six planks which is the largest number remaining and measures 1.86 metres in height, on the other hand on Bulkhead No. 6 only three planks remain and measure 0.80 metres in height (Figure 5-16). The pattern of the distribution of these bulkheads was reported and it was stated that they were irregularly spaced (Merwin 1977). The largest spacing appears on the eleventh hold between Bulkheads No. 10 and No. 11 and measures 1.80 metres, compared to the twelfth hold where the narrowest spacing measures 0.80 metres. It is also obvious that the first two bulkheads and last two bulkheads are narrowly spaced. The 2009 survey re-examined the bulkhead spacing. The result shows more regularity in spacing from Bulkhead No. 2 to Bulkhead No. 10. than has been thought previously. These bulkheads are now spaced approximately 1.50 metres with variation from 1.42 to 1.55 metres. During the survey, there was a consideration that some bulkheads were not correctly located in the original positions. The measured spacing was corrected for observed misalignments. For example, the upper part of the Bulkhead No.1 is not as far forward as it should have been and does not rake forward enough. This prevents it from properly meeting the upper planking.

The thickness of the bulkhead planks is approximately 80 to 120 millimetres. The width of the planks ranges from 250 to 530 millimetres. The topmost extant plank tier of Bulkhead No. 4 consists of two planks, which are joined together by stopped scarfs. Similar scarfs also appear in the two top planks in Bulkhead No. 8 and in the topmost extant plank tier of Bulkhead No. 9. According to an old photograph, metal clamps could be used to fasten these scarfs, yet this can hardly be identified in the current hull (Figure 5-17). It appears that the same fastening method by clamps could be used to tighten the bulkhead plank tiers (Figure 5-18). These clamps have not been mentioned in previous study. A query arose if these clamps were introduced to hold the planks together during excavations. They may be a modern installation, taking into consideration if they were iron they would have been substantially corroded. Despite this issue, it is noted that the use of iron clamps or dogs to tight planks' tiers was common technique in Chinese shipbuilding traditions (Worcester 1966). Due to this, whether such iron fastenings were used in Quanzhou ship or not is still open to question.

Upper and lower edges of the bulkhead planks are rabbeted to join the planks tightly. The groove of the rabbet cut on the forward side up to the Bulkhead No. 9 and from the Bulkhead No. 10 the groove appears on the aft side. Iron nails are also used for the fastening of the bulkhead planks. These nails are driven downwards from both forward and aft faces of the bulkheads. Yet they appear to be rather randomly spaced. The use of wooden fastenings for bulkheads such as wooden tenons has not been identified in the Quanzhou ship. As the exposed seam of the bulkhead planks is obscured, this is not ascertained. The use of wooden bulkhead stiffeners, which appear to have been vertically attached to the bulkhead surface, is barely evident in the old photographs (Figure 5-19). These are missing in the current hull, though in some bulkheads the modern wooden strips are reconstructed to look like the originals (Figure 5-20).

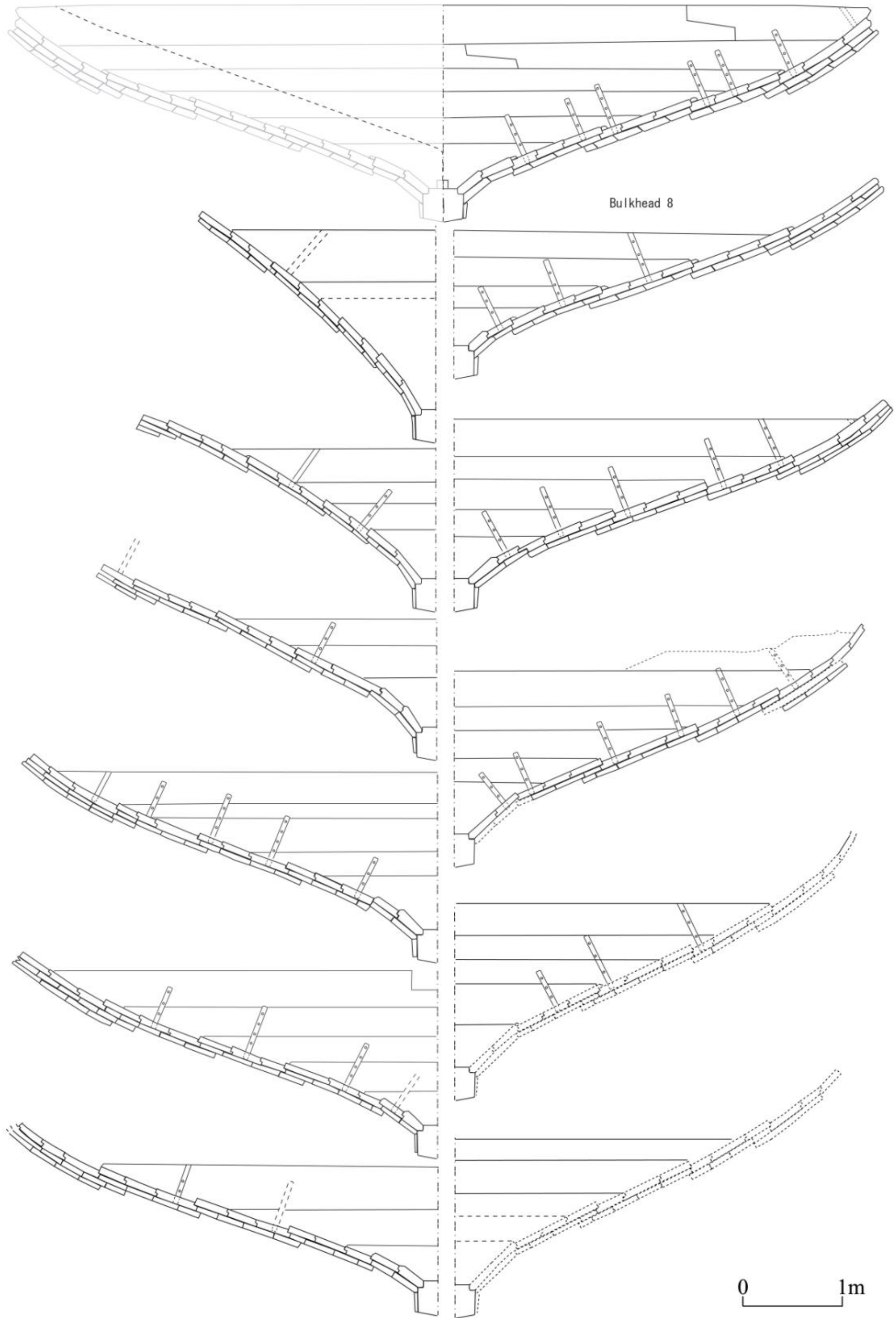

Figure 5-16 Cross-sections showing the remains of the bulkhead planks and brackets. Bulkhead No.8 (*Top image*) presents the use of the large frame in the forward side and the brackets in the aft side, and the same arrangement appears from the Bulkhead No.7 to No.12 (*Right side images*). Bulkhead No.1-6 (*Left side images*) have the brackets in forward side and large frames in aft side.

Figure 5-17 Stopped scarf joint of the bulkhead plank fastened by an iron clamp *Courtesy of Museum of Overseas Communication History*

Figure 5-18 Iron clamps fastening bulkheads planks together. *Courtesy of Museum of Overseas Communication History*

Figure 5-19 Bulkhead stiffener partially remains in the bottom of the hull. *Courtesy of Museum of Overseas Communication History*

The sides of the bulkheads have been carefully shaped. They are cut to fit neatly to both the carvel and clinker profile of the inside of the hull. In places some bulkhead planks are notched or hooked to fit over clinker seams, but this is seldom the case since the seams of the bulkhead planks often align with the clinker seams of the hull planking in a way which obviates the bulkhead planks being hooked over the clinker steps (See Figure 5-14 or 5-16). There are fairing laths on the inside at each clinker step (Figure 5-21). The fairing laths prevent water and grunge from lying in the clinker steps. Some fairing laths run under the bulkheads; while others are cut to fit between the bulkheads.

Figure 5-20 Wooden strips standing in the Bulkhead No. 10 and No.11 representing the reconstruction of the original bulkhead stiffeners. *Photo by author*

Figure 5-21 Fairing laths sitting on the inside at each clinker step. *Photo by author*

The limber holes for drainage of bilgewater are cut to bulkheads. Figure 5-22 is an early record of the bottom plank of a bulkhead. As it is shown on the photograph, the bottom plank is substantially degraded, compared with the upper bulkhead planks. The degradation appears on most of the lowest bulkhead planks from the bow to stern. It is likely that these bottom planks were kept wet by bilgewater much of the time and became waterlogged. According to a Chinese report, limber holes have been measured 120x120 millimetres (Museum of Overseas Communication History 1987: 19). Unimpeded by the bulkheads (and frames), the bilgewater could flow along the channel formed by the garboards which stand at a fairly steep angle of deadrise from the keel. Bilge boards or bottom ceiling planks sit on the seam between the bottom plank and second plank. These planks or boards would keep cargo and other things from falling into the bilge (Figure 5-23).

Figure 5-22 Photograph showing the degraded bottom bulkhead plank. *Courtesy of Museum of Overseas Communication History*

Figure 5-23 Bilge boards (or bottom ceiling planks). *Photo by author*

Figure 5-24 Bulkhead plank has the recess for a metal bracket to be attached where corrosion and a nail hole can be seen. The nail might have been driven diagonally upward. *Photo by author*

- Fastenings of the transverse components with the hull planking

The details of fastening methods to fix the bulkheads to the hull planking are examined here. The bulkheads are also fastened to the hull planking by metal brackets called, Gua ju (See Glossary). The details of the brackets from the Quanzhou ship have been given in the previous studies (Xu 1985; Museum of Overseas Communication History 1987: 19-20; Li 1989; Burningham and Green 1997: 44; Green 1998: 288-289; Zhang, You et al. 2004: 288-290). They were made of iron. Most of the brackets are completely lost through corrosion and probably past salvage, but a few corroded fragments remain. The shapes and positions of the brackets are shown by iron corrosion deposits on the faces of the bulkheads. In some cases, the slight recess in the bulkhead that the brackets were let in to is of use to consider the original configuration. The brackets are L-shaped, and their length ranges approximately 300–550 millimetres, width approximately 50–60 millimetres and they are about 6–7 millimetres in thickness on the evidence of the slits in the hull planking which they passed through. The L-shaped portion of the brackets is fastened on the outer face of the inner planking, and the brackets passing through slits in the planking are recessed into the surface of the bulkheads. The depth of this recess varies and in some cases the recess is slight or absent. The brackets are fixed on the planks and bulkheads by four or five short iron nails. These iron nails are hardly identified in the current hull. At one place, the nail seems to have been driven diagonally into the bulkhead not perpendicularly (Figure 5-24). This is an inconvenient way to fix the brackets and as a single example cannot be relied on as indicative of the normal arrangement. With regard to an issue how the brackets have been fitted, hull planks and bulkhead planks were chiselled to make slits and recesses ahead of the installation of the brackets. In the uppermost plank of Bulkheads No.8 on the port side (possibly starboard side as well), there is a very slight recess (Figure 5-25). This might be evidence that the bracket was wrongly positioned, or somehow the shipwright stopped the chiselling.

Figure 5-25 A part of the bulkhead plank, indicated by a circle, barely shows the evidence of recessing but not completed. *Photo by author*

The distribution of the brackets on the hull planking shows a logical pattern and some regularity (Burningham and Green 1997: 44; Green, Burningham et al. 1998: 289-291). As mentioned before, two or three planks comprise each strake of the hull, and the brackets are never positioned at the butts of the planking, but almost all adjacent to the butts (See Figure 5-11). The position of the brackets is symmetric on the port side and starboard side except for one extra bracket in the tenth strake that is positioned at the Bulkhead No. 8 only on the port side. Not all strakes are fastened to each bulkhead with brackets. There are no brackets fastening the garboard strakes, as they would not fit, but all other substantially intact strakes have at least one. A total of 46 brackets' positions on the strakes in port side were recorded in the 2009 survey. On the fifth and eleventh strakes, only one bracket was confirmed. The seventh strake shows the greatest number of the brackets and has six brackets. The number of brackets on the other strakes ranges from four to five brackets. The number of brackets remaining on each bulkhead in the port side (some are only indicated by the recesses) is: Bulkhead No.1 (1); No.2 (3); No.3 (2); No.4 (5); No.5 (5); No. 6 (3); No.7 (5); No.8 (7); No. 9 (6); No.10 (6); No.11 (3); No. 12 (0). The number of the brackets for each bulkhead varies, yet a certain pattern of the use of the brackets is definitive as at least one bracket must be used for each set of the three planks with carvel seams. On the bulkhead profile, either one bracket or two brackets appear on the strake(s) that comprise the four carvel sets. To sum up, the brackets can be seen as fastenings for joining a set of strakes to the bulkheads rather than just fastening for individual planks. The brackets are recessed into at least two bulkhead planks (in some cases three bulkhead planks). Their lengths vary. Either shorter or longer brackets are attached over the lower and upper bulkheads in a way that each bulkhead plank from the bottom to the top can be fixed by either one of the brackets. Thus, the brackets can be also seen as a method to fasten a set of the bulkhead planks.

Figure 5-26 Square nail hole identified in the inner hull plank. *Photo by author*

The brackets can sustain tension in only one direction and do little to secure the bulkheads and the planking in any other direction. The brackets, however, are used together with nails. The nails through the inner planking to the transverse components (bulkheads and frames) are not as strong as the brackets, but strongly resist distortion in the other directions. The use of the two different types of fastenings together creates a strong system to secure a plank-shell and transverse component. It is still arguable whether iron nails were driven from the innermost planking into the bulkheads when these components were assembled together. The outer planking for sheathing obscures the identification of the use of iron nails in the inner planking. A part of the topmost plank remains at the Bulkhead No.7 exposes the surface of the innermost plank where iron nails appear to have been originally driven from outside of the inner planking to the bulkheads (Figure 5-26). They are identified as corrosion remains and original nail holes are positioned where the bulkhead plank was originally placed. Although the original bulkhead plank is missing, its position can be ascertained by the location of an opening from the iron bracket. Figure 5-26 also indicates the use of Portland cement that seals a modern nail. This nail is located where it can fasten the planking and frames together. A fastening method used in the Shinan ship demonstrates two transverse components. Both frames and bulkheads are fastened to the hull planking by iron nails. The use of the same method of fastening is also taken into consideration in the Quanzhou ship.

Frames

Figure 5-27 Top view of the Bulkhead No.1 that has original half-frames. *Photo by author*

Frames are fitted against the bulkheads on the side towards midships: in other words the frames on the six bulkheads forward of midships are on the aft face of the bulkheads, aft of midships the frames are on the forward faces. There is no frame associated with bulkhead 12. Most of the frames observed in the current hull remains are not original, according to communication with staff of the Museum of Overseas Communication History during the 2009 investigation. Only the frames associated with Bulkhead No. 1 are likely to be original, and these frames are significantly deteriorated (Figure 5-27). The only evidence regarding the dimensions of the original frames remains on the surface of the bulkheads where the outline of the upper edge of the original frames can be faintly seen and on the planking where the edge away from the bulkhead can be discerned in places. The faint line indicates that a moulded dimension of the frame can be shown to be approximately 280 millimetres and a sided dimension is indicated by a line on the planking is approximately 200 millimetres. These are fairly large dimensions for frames which can be seen as auxiliary to the bulkheads. They are presumably intended to secure the bulkheads against deformation and against sliding forward and aft with the brackets. An old photograph shows the structure of the frames consisting of two pieces of timber per side (Figure 5-28). The timbers of the frames meet at the keel where limbers are cut in the frames.

Figure 5-28 Large half-frames attached into the bulkheads. *Courtesy of Museum of Overseas Communication History*

Other hull components

Two mast steps remain in the hull. Their dimensional information is available in the published resource (Museum of Overseas Communication History 1987: 22). A forward mast step is positioned on the forward side of the first bulkhead (Figure 5-29). It measures 1.76 metres athwartships, 0.50 metres fore and aft and 0.36 metres in depth in the middle. Mortices which measure 240x210 millimetres about 400 millimetres apart presumably indicate the position of two tabernacle cheeks. A main mast step is located on the forward side of Bulkhead No. 6 (Figure 5-30). It is shaped to fit directly on the keel and hull planking out to the fifth strake. It measures 2.74 metres athwartships, 0.56 metres fore and aft and 0.48 metres in depth in the middle. Two tabernacle mortices are about 375 millimetres apart, and measure 240x210 millimetres. The mast steps are not now accessible to examine their details, and how they are fastened to the hull has not been determined. Photographs taken during excavation show that there were substantial timbers running forward from the mainmast step to the frame on Bulkhead No. 5 to secure the step against moving forward. The diagram in the report shows that the bottom of the forward mast step has a somewhat rounded shape where it fits into the bilge, but the bottom of the main step, in contrast, has a flat shape fitted to the keel (Museum of Overseas Communication History 1987). With regard to the mast, a large notch on the Bulkhead No.5 is thought to be related to the mast, which could possibly be lowered aft in its tabernacle with the heel of the mast swinging forward through the gap in Bulkhead No.5 (Burningham and Green 1997; Green, Burningham et al. 1998).

Figure 5-29 Old photograph of the forward mast step after excavated. *Courtesy of Museum of Overseas Communication History*

Figure 5-30 Old photograph of the main mast step after excavated. *Courtesy of Museum of Overseas Communication History*

There is an unidentified timber placed on the current hull and an old photograph records this timber (Figure 5-31). It is rectangularly shaped with the length of 3.00 metres and measures 0.32x0.20 metres in cross-section. It has a square hole (110x120 millimetres) at one end and the other end is tenoned. According to the original report, this timber was discovered outside of the stern and it is not related to the hull structure, yet this has not been ascertained.

A capstan or perhaps a windlass mentioned in the report is not able to be seen in the current hull displayed at the Shipwreck Gallery. They found a cylinder shape timber with a length of 1.40 metres and diameter 0.35 metres. It has four notches in the middle part and on one side there are holes 130 millimetres in diameter. This is probably a windlass barrel and the holes are for the pins or hand-spikes. Because of the loss of the actual object, only a photograph is available as a resource to access what is apparently a capstan or windlass (Figure 5-32). One photograph indicates that the discovered position of this possible windlass might be the stern (See Figure 5-2**)**. The report further describes the discovery of the wooden post with the length of 3.00 metres and rectangular cross-section of 0.32x0.20 metres. Besides this solid timber, another four pieces of timber, an oar, and long bamboo poles were identified, however, it is not possible to identify where these were located in the hull. The above information was summarised from the Chinese reports and resources including photographs and videos in the Quanzhou Maritime Museum's custody.

Figure 5-31 Timber discovered around the stern. Its purpose of use has not been determined.
Courtesy of Museum of Overseas Communication History

Figure 5-32 A cylinder shape timber, which might have been a part of the windlass.
Courtesy of Museum of Overseas Communication History

V-5 Perspectives on hull construction

Hull construction date by radiocarbon dating

Attempts in collecting new data include radiocarbon dating of the timber of the Quanzhou ship. The determination of the date of the Quanzhou ship was based on the study of its cargo. Despite the fact that the amount of the discovered cargo presents about 1% of the original, the assembly of the cargo remains indicates that the ship probably dates to the last quarter of the thirteenth century. The era 1265-1274 of the minting of the coins, in particular, was determined as the latest date after which the ship was sunk or abandoned. The radiocarbon dating in this research has been implemented to obtain a perspective regarding the date of the ship's construction. This has been achieved by analysing specimens of the timbers from the hull that were provided by the Museum of Overseas Communications History during the inspection of the hull. Of the provided specimens, celluloses of two samples (ID: Sample.1 and Frame) were extracted and analysed by the Paleo Labo Co., Ltd in Japan for the analysis using Accelerator mass spectrometry (AMS). Table 5-1 shows the result of AMS analysis. It is remarked that the 14 C dates of the two specimens show approximately a hundred year's difference. Considering the matter of which hull components the two samples are derived from, may offer an insight into the difference. The origin of neither of the specimens has been identified in detail, but based on what is featured in Sample. 1, it might be a portion of timber used for planking, perhaps from the outermost planks (See Chapter VIII). The wood species of these specimens do not conflict with the presumption that Sample. 1 is a part of the plank and Frame is a part of the frames. With regard to the construction date of the Quanzhou ship, the results of the analysis on Sample.1 and Frame are compared in the calibrated dates showing a high probability; Sample. 1 dated to 1275AD (70.1%) 1305AD, Frame dated to 1186AD (95.4%) 1269AD. The results consider the uncertainty related to an issue of non-identification of the outermost annual ring of the timber specimens that prevent the determination of cut age of the timber and a chronological gap between timber cutting period and construction period (Figure 5-33 & Figure 5-34). Another consideration is the possible relevance of the date variance between the two specimens with the order of the hull construction. The outer planks of the Quanzhou ship are likely to have been assembled later than the frame. The calibrated date of Sample. 1 that corresponds to that of Frame may help determine when the construction of the Quanzhou ship was completed, which is presumed to have been around the 1260-1270s; however, the period of the construction is more controversial.

ID	14 C (yrBP±1σ)	14 C date corrected to calibrated dates	
		1σ calibration date range	2σcaribration date range
Sample. 1	685±20	1280AD (61.5%) 1298AD 1373AD (6.7%) 1377AD	1275AD (70.1%) 1305AD 1363AD (25.3%) 1385AD
Frame	810±20	1220AD(68.2%)1254AD	1186AD(95.4%)1269AD

Table 5-1 Radiocarbon dates of the ship timber samples from the Quanzhou ship.

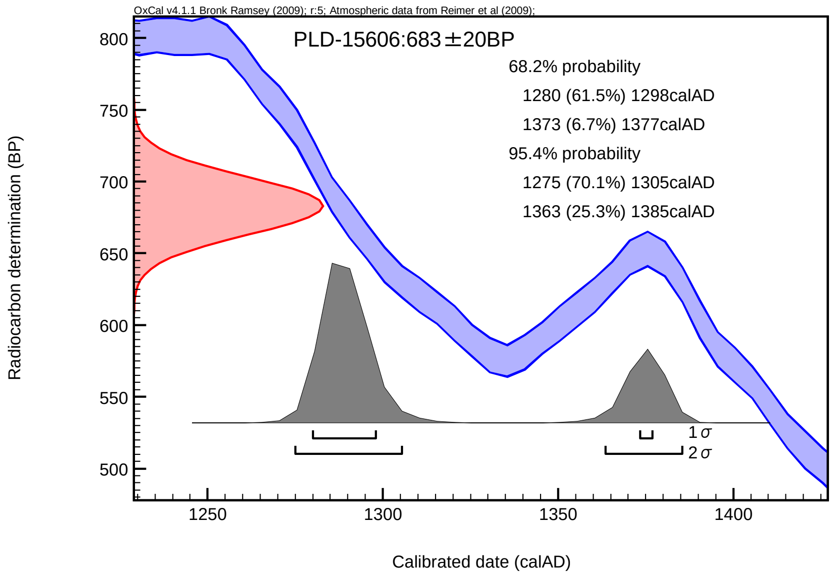

Figure 3-33 Radiocarbon date’s probability on the specimen, “Sample. 1”.

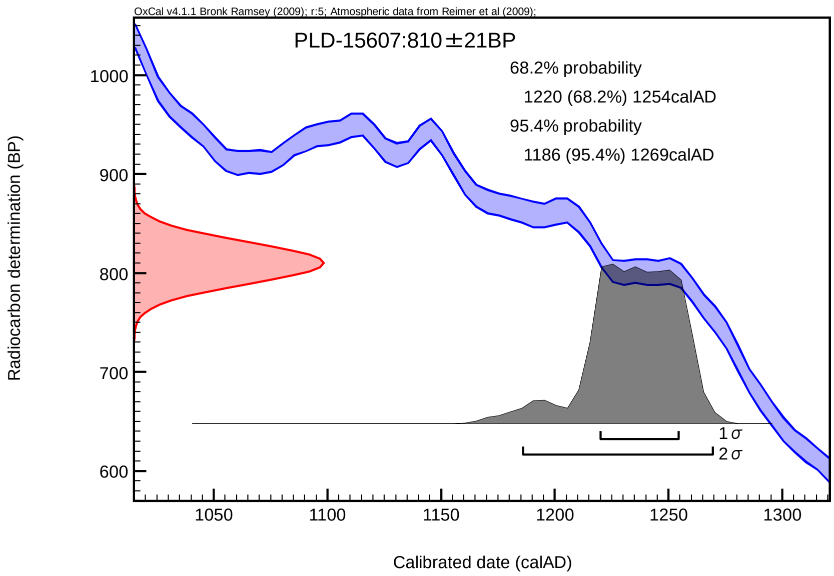

Figure 3-34 Radiocarbon date’s probability on the specimen, “Frame”.

Two standard deviations of the calibrated dates are overlapped.

Construction of the plank-shell

It was not until the 1990s that a series of surveys were conducted that involved the detailed analysis of the construction method of the hull by teams from Western Australia. The result of these surveys suggests that that the Quanzhou ship is likely to have had plank-first construction. In bulkhead first construction (in the way which bulkheads should be seen as solid frames), principally, the bulkheads must be strongly fastened to the keel by large nails (or bolts). The use of the nails was not confirmed during the inspection of the Quanzhou ship, as direct access to the hull was limited. However, it seems that there are no nails to fasten the bulkhead planks to the keel. It is unlikely that such large nails could have been driven into the thin bulkhead planks of the Quanzhou ship. The plank-fast construction is inferred by looking at some innovations in the construction of the plank-shell of the ship. The rabbets of the planking that are arranged the same way, for example, could make the job of shipwrights assembling the inner plank-shell easier. The projecting lips of the lower part of the upper plank that appear on the outside are helpful for the plank-first construction. Through this method, shipwrights could join the upper strake into the lower strake along the curvature more easily, probably by fixing the rabbeted seam of the strakes in the mid-part first, and then by pushing and fastening the upper strake from there gradually toward either forward or aft. Another innovation is the construction of the plank-shells by fastening a set of strakes. Each set is formed by strakes that are edge-jointed by carvel seams and the strake sets are fastened into the bulkheads by using iron brackets. The distribution pattern of the brackets is concentrated in positions adjacent to butts of the strakes. As the butts are weak points of the plank-shell, the way of positioning the brackets around butts to secure them is according to a logical and deliberate construction principle. Furthermore, it is remarked that there are many brackets in strakes above clinker seams, but fewest in strakes below clinker seams. The clicker seams as a joint of the carvel-built strakes' sets needed to be secured as important joint parts. The structural principle results from the shipwrights' understanding that the plank-shell is the most fundamental structure for constructing the sturdy hull of the Quanzhou ship.

Chapter VI - Shinan shipwreck

The Shinan shipwreck is a shipwreck that originated from China and was discovered in Korean waters. The ship is dated to the first quarter of the fourteenth century. The importance of the Shinan shipwreck has been recognized since its discovery. It has been introduced in some English sources (Keith 1980; Keith and Buys 1981; Green 1983b; Green and Kim 1989; Lee 1991; National Maritime Museum of Korea 2006a). The National Research Institute of Marine Cultural Heritage (National Maritime Museum) located at Mokpo city in South Jeolla Province in Korea has analysed its structure, hydrodynamic and hydrostatic performance. Some official resources including excavation reports and post-analysis of the hull are available in the Korean language (Choi 2004; Kim 2004; Lee 2004; National Maritime Museum of Korea 2006a). The hull of the Shinan shipwreck was inspected by the author during this research in 2007 and 2009 with support from researchers in the National Research Institute. The following sections will review the structure of the hull based on the previous research and some non-structural elements including historical background and cargo. The hull construction method will be addressed with new perspectives.

VI-1 Site background

The Shinan ship is an East Asian trader sunk around the early fourteenth century. The discovered hull is as large as the Quanzhou ship. The background of this shipwreck represents maritime trade between Korea, China, and Japan during the Yuan Dynasty (1271-1368 A.D.). With regard to a port of departure and intended destination, one of the bronze plumb-weights recovered from the cargo shows an inscription “Qingyuan lu” (慶元路 present Ningbo), which suggests that the ship sailed from this historical Chinese port. Also, a narrow strip of wood, shows the name of a Japanese temple “Tofukuji” (東福寺) located in Kyoto, which suggests that the destination was Japan. This wooden strip provides a date of 1322, described as “Zhizhi San Nian” (至治三年) dating to the Yuan Dynasty, and the date range of bronze coins from the ship also supports the idea that the ship was engaged in trade in the early fourteenth century. The Yuan Dynasty, considered as descended from the Mongolian Empire and also regarded as an imperial dynasty of China, took over maritime hegemony from the Southern Song Dynasty (1127-1279 A.D.) in 1279. The Yuan rulers adopted a strict policy to control overseas trade. In addition, the Mongol invasion produced a temporary decline in overseas diplomatic exchange, including the communication between Japan and China. Under these circumstances maritime trade persisted sporadically due to overseas demand for commodities and continued to benefit Japanese society contributing much to Japan's material culture.

Historical study and cargo analysis suggest that the Shinan shipwreck can be classified as an East China Sea trader of the category entitled "temple-shrine chartered ship" (Murai 2005). Temples and shrines in Japan authorised by the Japanese feudal rulers were allowed to invest in maritime trade to finance their building expenses. Chartered ships carried cargoes partly or entirely owned by a temple or shrine. They sailed overseas as authorized merchant ships and were particularly active from the thirteenth to fifteenth centuries. The Japanese temples and shrines were involved in delegating ships, but the owners of the chartered ship and the sailors were mainly Chinese.

Discovery of the Shinan shipwreck

Figure 6-1 Discovered location of the Shinan shipwreck in the waters of the Shinan archipelago. *From National Maritime Museum of Korea 2006b*

The Shinan shipwreck was located about 4 kilometres offshore from Imjado Island, which is one of the islands of the Shinan-gun, Jeollanam-do archipelago (Figure 6-1). The site is in a strait between two islands. The depth of the water is 20 metres, the area has been known as a narrows, difficult to navigate, where a tide race flows at average of 2.5 knots. The strong tide and sediments of the seabed consisting of fine sands and gravels cause turbid water which restricts underwater visibility to

150-200 millimetres. Seasonal excavations from mid-July to mid-November, the most favourable season, were conducted for nine years to bring to completion the recovery of artefacts and hull.

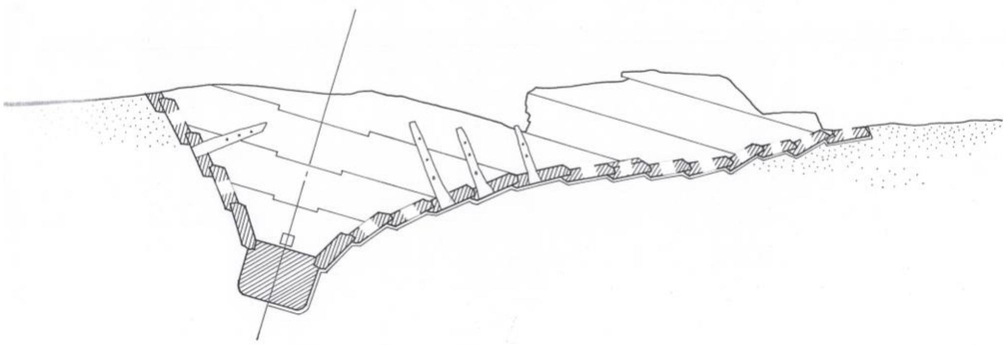

Figure 6-2 Cross-section showing the buried state of the Shinan shipwreck. *Courtesy of National Maritime Museum of Korea*

According to a site report, the site was initially discovered by a local fisherman in 1975 who recovered a number of ceramics, and immediately after this discovery the site started to be disturbed by locals, which resulted in concern among government officials (National Maritime Museum of Korea 2006b). Archaeological survey and excavation with collaboration of the Korean Navy Support Force were conducted from 1976 to 1984. In 1976, the Ministry of Cultural Properties conducted a site assessment survey to determine the significance of the site. Eleven full excavations were implemented during the following periods. In the fifth and sixth underwater excavations in 1979 and 1980, Korean survey teams identified the main structure of the hull including the keel and well preserved planking to the fourteenth strake on the starboard and four strakes on the port sides. These surveys found that the ship remains lay on the seabed inclining about 15 degrees to starboard (Figure 6-2). The hull components were raised from the seabed in 1981 and 1983 by cooperating navy divers. Due to the difficult environmental conditions, the hull was dismantled by cutting it into convenient sized pieces underwater. By this approach approximately 720 pieces were recovered by the end of the work. The recovered parts consist of 479 portions of the hull's structural timbers and 223 portions of thin wood planks that were sacrificial sheathing planks.

The Conservation Laboratory (current National Research Institute of Marine Cultural Heritage) established in Mokpo conducted PEG conservation on the recovered hull remains from 1982 to 1999. In the same period, to interpret the structure of the ship, a scale model of the ship was constructed at 1:5 scale. The model was completed in 1986. After the completion of conservation treatment, the physical reconstruction of the Shinan shipwreck commenced based on the scale model in 1994 and it was completed in 2002 (Figure 6-3)

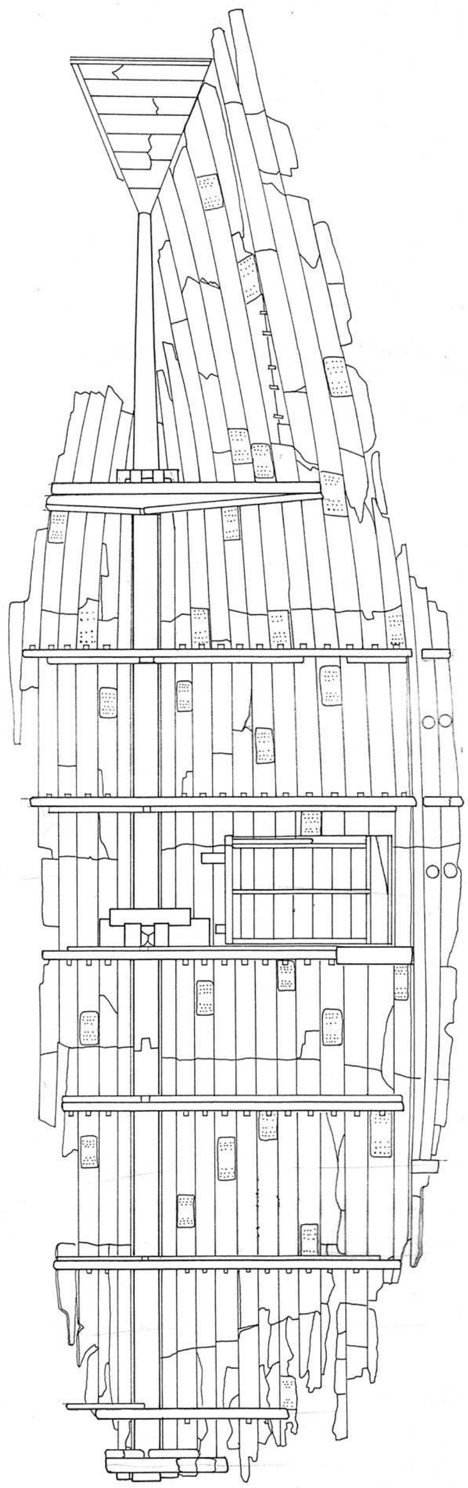

Figure 6-3 Plan of the hull. *Courtesy of National Maritime Museum of Korea*

VI-2 Overall hull dimension and volume of the ship

The hull measure 28.40 metres in length and 6.60 metres in breadth. The extant starboard side includes a portion of the deck structure, which allowed Korean scholars to reconstruct the hull's original breadth and depth to the level of the deck with some confidence. According to a previous study, the reconstructed length of the original Shinan ship hull is 33.50 metres, its beam is 10.20 metres, and the vessel's depth is 3.60 metres with a likely laden draft of about 2.60 metres (Choi 2004). This reconstruction posited that the freeboard of the Shinan ship was approximately 1.00 metre. Based on the reconstruction and posited freeboard, the displacement of the Shinan ship has been calculated at 260.5 tonnes in the previous study. The light displacement of the ship, which compromised of all its permanent equipment and hull weight, has been calculated at 120 tonnes. Deadweight has been also calculated (the total weight of cargo, crew, and other necessary properties associated with the persons on board) as 140 tonnes. The deadweight is slightly greater than the ship's light displacement. Another study has reconstructed the depth of the Shinan ship as approximately 3.75 metres and posited a laden draft of 3.1 metres allowing only 0.65 metres freeboard (Kim 2004). These figures are largely based on hypothetical load-line and freeboard. From these perspectives, an estimated cargo carrying capacity of the Shinan ship would be significantly less than that of the Quanzhou ship that had been calculated for approximately 200 tonnes, despite the fact that the two ships show similar size hulls. This casts doubt on the previous estimation of the cargo carrying capacity of the Quanzhou ship. Chinese scholars might have assumed too much depth in the hold of the Quanzhou ship.

VI-3 Cargo stowage

The assemblage of the cargo characterises the Shinan ship as a trader. The distribution of the artefacts in the remains of the hull recorded during the excavations provides important information about loading pattern of the cargo. The number of artefacts raised during the 1977 to 1984 excavations includes a total of 20,661 pieces of ceramics. Major items consist of approximately 28, 018 kilograms of coins, and 1,017 pieces of woods, and 729 metal objects. The details of these artefacts are available in the official reports (National Maritime Museum of Korea 2006b). According to the site report, those artefacts that have been identified as highly valuable merchandise appear to be in the midbody of the hull. The cargo assemblage is a range of commodities similar to that found on the Quanzhou ship. However, the quantity of the discovered cargo of the Shinan ship is greater. The diversity of product quality reflects some specific market demands from both institutions and individuals. The site plan of the Shinan shipwreck (produced from a grid recording system) shows the distribution of the excavated cargo (Figure 6-4). Some elements of the cargo of the Shinan shipwreck were discovered in wooden containers when the hull was excavated. Although most of these containers were identified as broken pieces, remains of 10 containers show the intact configuration with the ceramics packed inside. The ship carried a large amount of woods (Figure 6-5). The species of the woods has been identified as *Dalbergia Latifolia* (known as rosewood). The woods that have been discovered from the hull were cut in approximately 2.00 metres in length, which were stowed at the bottom of the hull. The vertical cargo loading pattern was discussed with a Korean researcher (C. Lee, pers. comm. 2010). Many copper coins were at the bottommost of the hull and placed on the keel. In terms of the stowage that loads heavy stuff at the bottom the holds that contributes to stability (acts as ballast), this is a normal arrangement. According to Lee, the way of the stowage of the copper coins, on the other hand, appears to have blocked the bilgewater way. The woods were laid as the second tier, likely as dunnage. The packed ceramics were placed on the top of the wood commodities. As copper coins, rose woods were common seaborne commodities at the time. This loading pattern can be standardized.

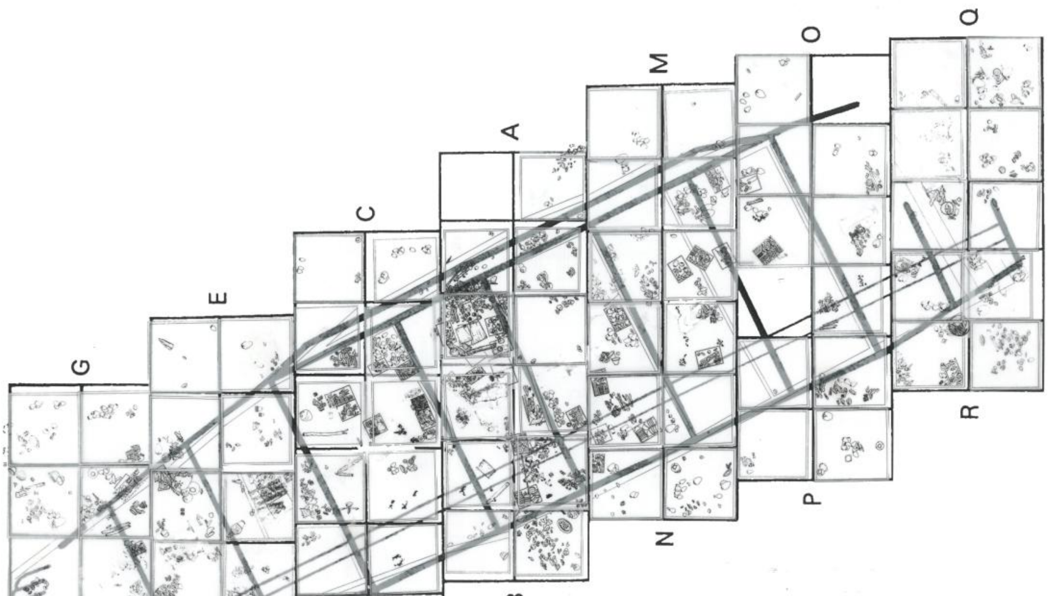

Figure 6-4 Diagram of the excavation using a grid system to record the cargo location. *After National Maritime Museum of Korea 2006b*

Figure 6-5 Woods, one of the major cargo of the ship, could be stored in the hull to function as dunnage. *Photo by author*

VI-4 Details of the hull structure

Keel

The hull of the Shinan shipwreck is built up from a keel. The keel consists of three parts; the forward keel with a length of 6.79 metres, the main keel with a length of 11.27 metres, and the aft keel with a length of 8.44 metres (Figure 6-6). The forward keel is connected to the main keel at approximately 10 degrees, but it curves to rise at a greater angle (Figure 6-7). The cross section of the forward keel forms a trapezoid effective against wave action. In contrast, the cross-sections of the main keel and aft keel show rectangular shape with a width of 710 millimetres and a height of 500 millimetres. Originally the keel was sheathed with thin sheathing planks.

The assembly of the keel consisting of three members is the same as the keel of the Quanzhou ship. However, the structure of the keel of the Shinan shipwreck is sturdier than the Quanzhou ship in that it uses hooked scarfs in connecting the members (Figure 6-8). There is an opening in the centre of the scarfs where a pin was driven through to tighten the scarfs. Iron staples were attached on the sides of the scarfs to secure them. Large iron nails were driven down through the scarf from top surface of the scarf of the forward keel into the main keel. The scarf of the aft and main keel is also secured by a mortise and tenon on the end of the scarf, which could prevent the scarf from opening horizontally.

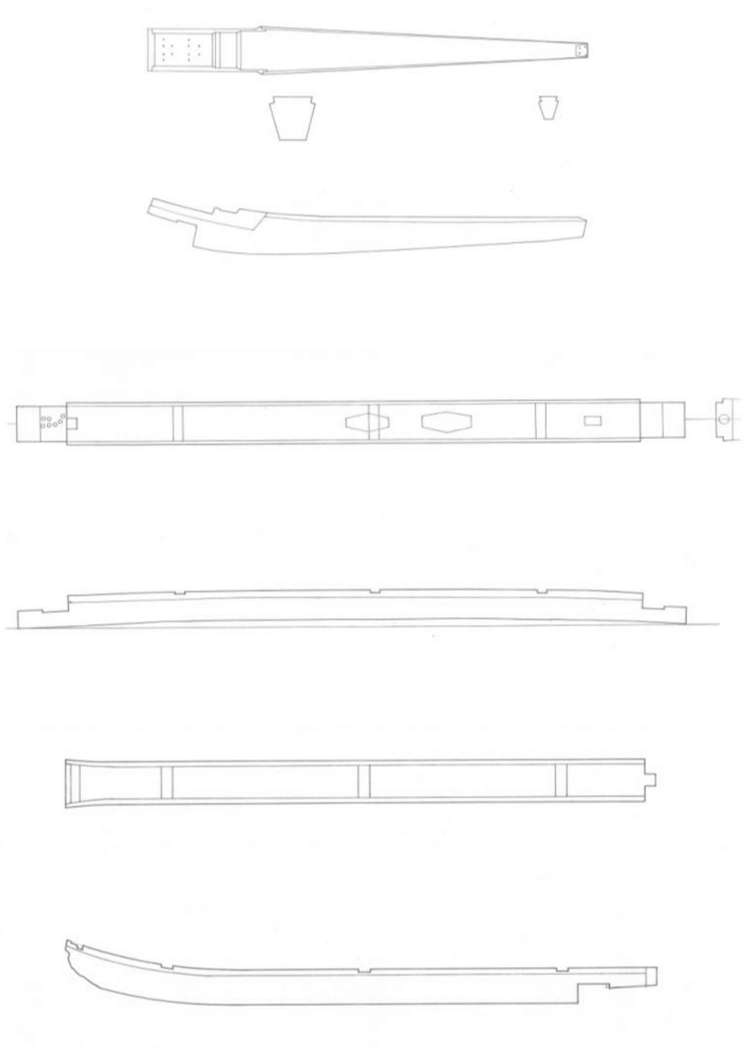

Figure 6-6 Keel members. *Courtesy of National Maritime Museum of Korea*

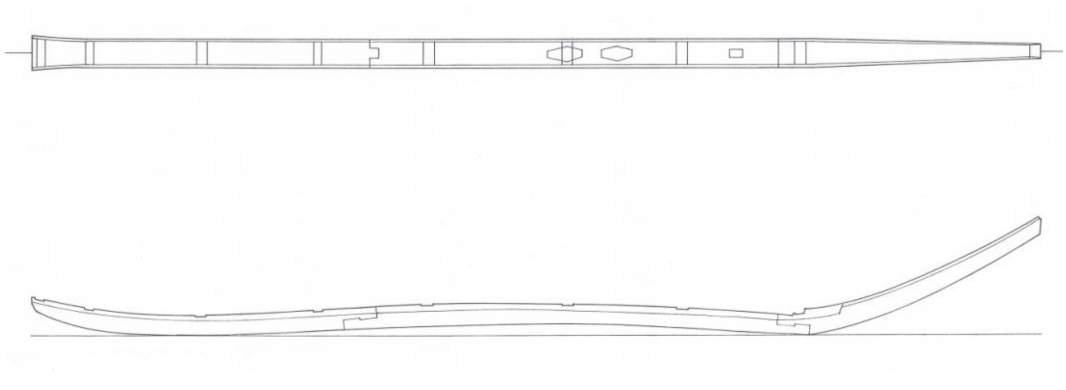

Figure 6-7 Joined keel members, showing a hog. *Courtesy of National Maritime Museum of Korea*

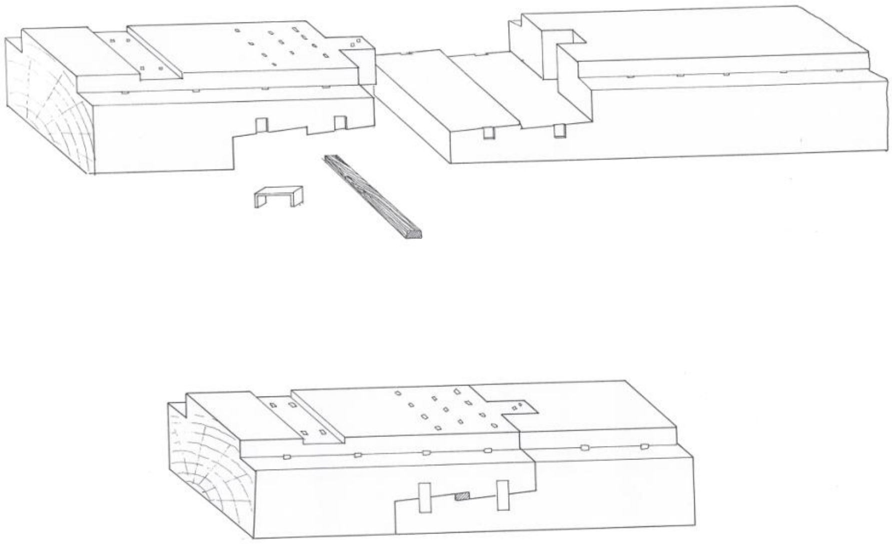

Figure 6-8 Hooked scarfs of the keel join, secured by a wooden pin and iron clamps.
Courtesy of National Maritime Museum of Korea

The Chinese shipbuilding custom of placing coins and mirror known as Bao shou kong was identified on the keel scarf; one mirror hole was recessed on the vertical face of the scarf of the main keel's forward scarf and an associated bronze mirror was identified (National Maritime Museum of Korea 2004). There are nine coin holes, for which seven copper coins "Tai ping Tongbao" (太平通寶), manufactured during a reign period (976-983 A.D.) of the second emperor of the Northern Song Dynasty (960-1179 A.D.), were found. These coins were placed on the horizontal face of the scarf of the main keel to the aft keel. As there are iron nails down through the aft scarf, the horizontal distribution of the coins on the scarf might have partially restricted the possibility to drive those nails on this scarf, a deficit partly compensated by the mortise and tenon. Lozenge-shaped timbers were inlaid on the main keel's upper surface to seal holes in which were placed seeds; this could also be a custom to bring good fortune to the ship.

As Figure 6-7 shows, the keel is hogged; the centre of the main keel is 200 millimetres higher than the fore and aft ends of it. It has been disputed whether this feature had been deliberately incorporated in the construction of the ship or is distortion resulting from forces, particularly gravity operating on the shipwreck (Green and Kim 1989; Lee 1991; Lee 2004). Most recently, in a final report, Korean researchers mention that this hogging could be deliberate design aimed at shifting the hull's buoyancy and weight-carrying aft (National Maritime Museum of Korea 2004). The issue whether the hogging was deliberately designed or not will be discussed in Chapter VIII. With regard to the unusual characteristics of the main keel, it is also noted that according to the site report despite the main keel being waterlogged, when it was recovered it still showed strong buoyancy, unlike other waterlogged timbers including the forward and aft keels.

The keel is shaped to fit bulkheads and garboards. There are eight transverse recesses on the keel to slot the bulkheads and a stern transom (one recess on the forward keel, three recesses on the main keel, four recesses on aft keel). Both sides of the keel have rabbets for the garboards. The garboard strakes consist of two planks on each side. The total length of each of the garboard strakes is approximately 20.00 metres. The planks of the garboard measure approximately 400 millimetres in width, and the thickness is approximately 180 millimetres, which is almost twice as thick as other planks. The garboards are cut to fit to the keel rabbet, and the bottom bulkhead timbers. The garboard stakes are fastened to the keel by large square-sectioned iron nails at an interval of approximately 200 millimetres, and fastened to bulkheads by a few square iron nails driven. Of interest is the pattern of those nails used to fasten the bottom planks of the bulkheads to the garboard planks. They are diagonally driven from the surface of the bulkheads to the insides of the garboards, whereas the nails are driven from the outer surface of the garboards into the keel (Figure 6-9).

Figure 6-9 Diagram showing driven nails into the keel, garboards, and Photograph of the bottom bulkhead plank showing the driven nails. *Courtesy of National Maritime Museum of Korea, photo by author*

Structure of the bow and stern

The bow of the ship has a trapezoid shape transom on the forward end of the forward keel. The reconstructed angle of its rake appears to be approximately 60 degrees, but the original angle is open to question. The remains of the bow transom consist of two layers of planks including six outer planks and six inner planks (Figure 6-10). The inner planks are attached into the thicker outer planks and are assembled to overlap the seams of the outer planks. The inner planks measure approximately 110 millimetres in thickness on average. They are joined by rabbeted carvel seams, compared to the joint of the outer planks without rabbets (Figure 6-10). The edge of the outer planks is recessed where the strakes could join into the bow transom. The details how the strake ends fitted to the transom have not been clearly explained in the previous study. The upper part and bottom part of the bow transom are missing, but the size of the original bow was estimated to have been built up to 7.00 metres in height in the previous study. A large baulk of timber is placed at the interior of the bow on the starboard side and perpendicularly cross over eight strakes (Figure 6-11). This timber appears to have been part of a frame and it is presumed that a similar timber must have been symmetrically fitted on the port side. Although this timber is seriously deteriorated, it has been cut with steps to fit neatly the inner surface of the rabbeted clinker strakes. The timber has four rectangular holes which were probably used to install beams. The interior of the bow forward of Bulkhead No.1 has a space that seems to need framing or some other reinforcing structure. A few beams might have been used at different levels in the bow to provided transverse strength.

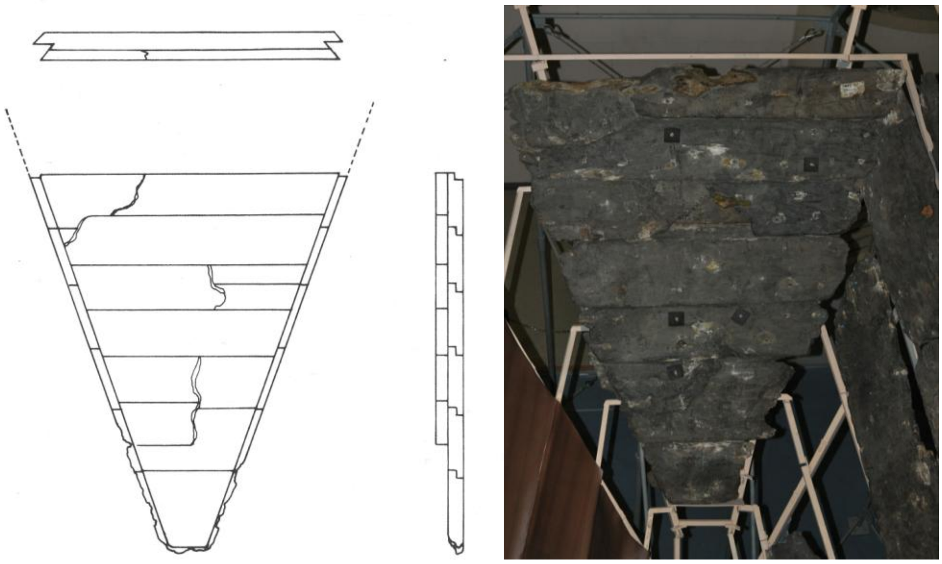

Figure 6-10 Drawing and photograph of the bow transom. *From National Maritime Museum of Korea 2004, Photo by author*

Three solid baulks remain in the stern and form the bottom of a stern transom placed on the aft end of the aft keel. The transom baulks with a thickness of 220 millimetres consistently from the bottom to top are thicker than bulkhead planks. The transom rakes aft at an angle of 15 degrees. A frame consisting of two timbers is placed on the forward side of the transom. The upper part of the transom does not remain, but it could possibly extend up to the deck level and support superstructure including a stern gallery. The evidence of a transom-mounted rudder is vague. The transom stern and the end of the aft keel barely show evidence of the usage of nails. These were possibly used to fix some sort of gudgeons or sockets. The rudder could be also fixed at a stern gallery, which possibly extended aft of the transom. However, most of the strakes around the stern are missing, so it is impossible to examine how far the strakes were extended and how the end of the hull planking fitted to the transom. The ends of the third and fifth strake inconclusively indicate that these strakes could have possibly extended beyond the transom.

Figure 6-11 Baulk on the inside at the starboard in the bow. *Photo by author*

Hull planking

Hull planking in the fourteen strakes on the starboard and four strakes on the port sides is edge-fastened by skew nailing in rabbeted clinker construction. All seams are rabbeted clinker. The planking in the bow, forward of the first bulkhead, however, shows gradual changes from clinker to carvel (Figure 6-12). This is produced by gradual change of the rabbeted seams; the rabbets are cut on only the lower inside of the plank from around Bulkhead No.1 to the stern, this arrangement changes in the bow where gradually a rabbet also develops on the upper outside of the planks. Initially this still forms clinker steps, but as the rabbet on the lower plank becomes deeper it changes to a rabbeted carvel seam. The benefit of this arrangement has been explained for allowing the planks' alignment to meet the transom bow smoothly (Green and Kim 1989; National Maritime Museum of Korea 2004). Each strake is comprised of three or four planks, and the remains of the planks measure 450-500 millimetres in width (except for a bulwark plank measuring 600 millimetres) and 110-120 millimetres in thickness. During the underwater excavation, most of the planks were cut into several pieces to make it possible to lift them (See Figure 6-3).

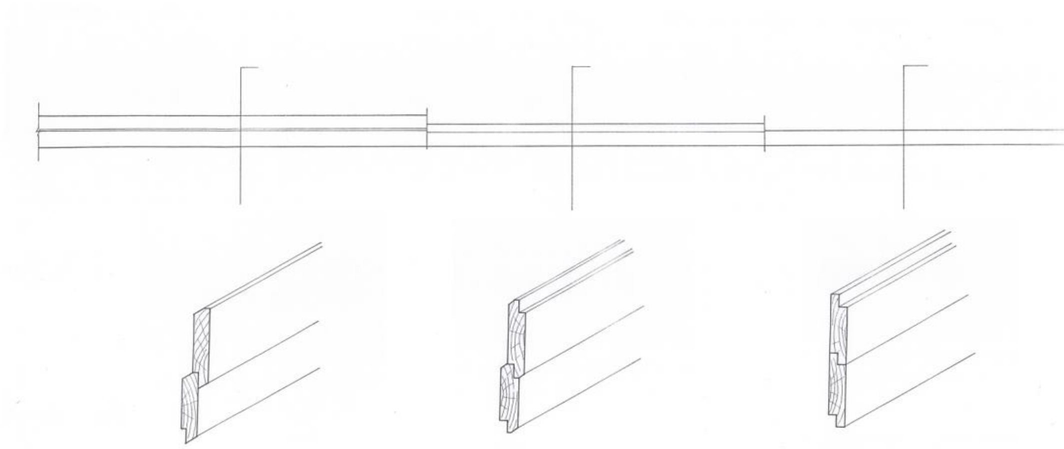

Figure 6-12 Hull planking arrangement in fore part of the hull: rabbeted clincker changing to rabbeted carvel. *Courtesy of National Maritime Museum of Korea*

- Butt joints and butt plates

The butts of the planking show simple lap joints, but in some places including the garboards there are a tongue and groove joints (Figure 6-13). The longitudinal assembly of the strakes shows that the location of the butts is carefully distributed to avoid alignment of the joints of adjacent strakes. The rule about the shift of butts, however, shows irregularity in the strake 6 and 7 in the bow where the butts are aligned in adjacent strakes. To further secure the butts, short lengths of plank are fastened on the inside to make what are usually called, “butt straps” (Figure 6-13). No butts are placed beneath the bulkheads. The butt straps are visible on the interior of the hull. The distribution of the butt straps is approximately symmetrical on the starboard and port sides to the extent that the port side remains only four strakes. However there is asymmetrical arrangement of butts and straps between the fifth and sixth bulkheads. On the third strake, port side, there are two butt straps close together, which suggest a repair. The butt straps are rectangular or trapezoid in shape. Their width is designed to fit to the width of the plank, and they measures 0.8-1.0 metres long and 0.07-0.10 metres thick. They are fastened to the planks by using 20 to 22 nails, and these nails are in three rows each side of the rectangular butts. A few butt straps have one end beneath large frames associated with bulkheads and one is positioned so that a wooden bracket associated with a bulkhead penetrates its end (Figure 6-14). Considering the sequence of construction, they are likely to have been placed on the butts prior to the fitting of the frames, and probably the brackets as well.

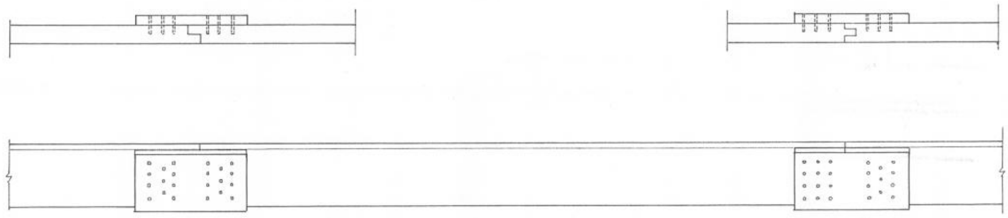

Figure 6-13 Butt joints (lap joint and tongue and groove joint) tighten by butt straps. *Courtesy of National Maritime Museum of Korea*

Figure 6-14 Butt strap attached into the bulkhead plank. *Photo by author*

- Bulwark planks

Of the remains of the fourteen strakes on the starboard side, the two uppermost strakes are bulwarks. That is, the thirteenth strake is regarded as a first bulwark plank; and obviously the fourteenth strake is regarded as the second bulwark plank. The details of the bulwarks have been disputed since the reassembly of the hull components. Four complete bulwark ports are visible on the remains of the bulwark planks. These bulwark ports are aligned in each bulwark strake to allow water to run away from sides of the deck as scuppers (See Glossary). The bulwarks are supported by bulwark stanchions. The remains of the stanchions extend from the second and third bulkheads, and a portion of a stanchion also remains between the fifth and sixth bulkheads. The stanchions sit on a longitudinal plank attached on the lower bottom of the first bulwark plank. This longitudinal plank is in effect a deck plank or may be a part of a coaming (Figure 6-15).

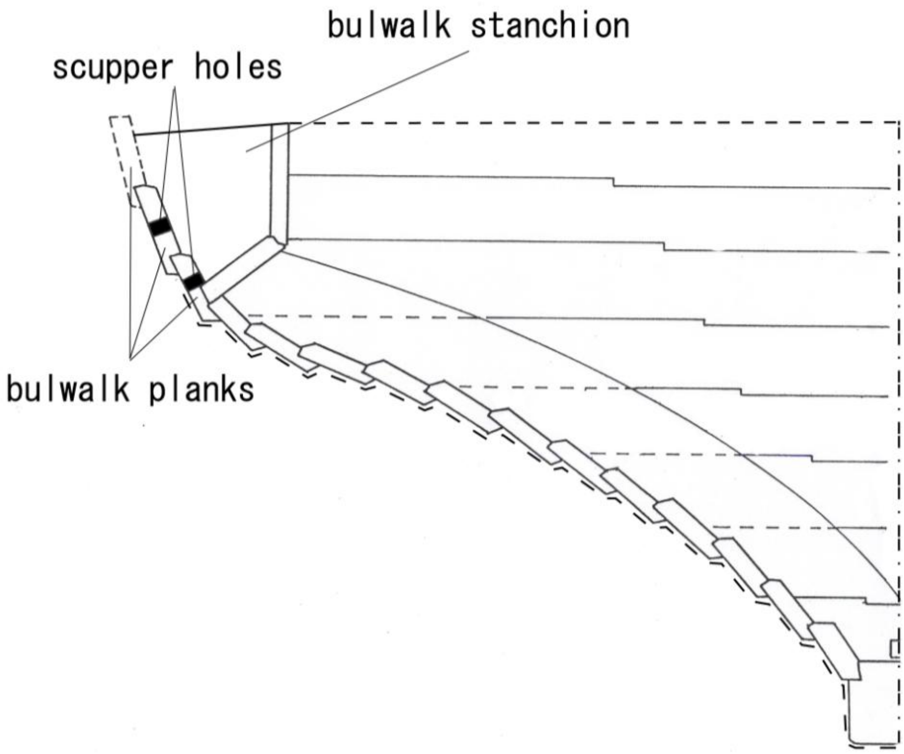

Figure 6-15 Reconstructed image of the coaming structure. *Courtesy of National Maritime Museum of Korea*

- Sacrificial planks (Sheathing planks)

Hull planking of the Shinan shipwreck is a single layer, but all planks used to be sheathed by sacrificial planks. The thin wooden planks covered the outer surface of most of the hull planking and the keel against the attack of marine borer. The sacrificial planks comprise approximately 30% of the recovered wooden remains associated with the hull of the Shinan shipwreck. When the hull was discovered, these sacrificial planks were still tightly fixed onto the outer surface of the planks. The sacrificial planks were preserved with polyethylene glycol after recovering. They were not restored in the reconstructed hull and are still stored at the conservation centre of the National Research Institute of Marine Cultural Heritage (Figure 6-16). The exhibited hull exposes the outer surface of the inner planks on which there is evidence of adhesive putty used to affix the sacrificial planks along with small iron nails. The thickness of the sacrificial planks is 10-20 millimetres, but their width particularly varies to fit to clinker step and to seal the seams of the hull planking.

Figure 6-16 Sheathing plank that has been covering the hull. *Photo by author*

- Fastening of the hull planking

Square-sectioned and round-sectioned iron nails were used for hull planking (National Maritime Museum of Korea 2004: 54). They were diagonally driven through the seams from the upper planks to the lower planks. This is usually described as skew nailing. The interval of the nails ranges from 150 millimetres to 200 millimetres (National Maritime Museum of Korea 2004). The planks are fastened to the bulkheads and their associated frames by iron nails. Most of these iron nails are considerably degraded, and they were replaced by modern metal nails when the hull was reassembled. These modern nails are said to be driven into the original nail positions. Although the corrosion of the original nails was considerable, magnetite remnants of the original nails have remained in the planks. Yellow substances surrounding the nail holes and modern nails, which are probably sulphur compounds and other substances, are now visible in many places on the hull. The other corrosion observed on the outer surface of the planks is the remnants of square metal clamps. The square clamps measuring around 150 millimetres in length were used to secure the scarf joint of the planks in the eighth strake on the starboard bow (Figure 6-17). This is the only scarf in the hull planking; all other plank joins are butts with lap-joints or tongue and groove joints. The use of similar metal clamps is observed elsewhere on the outer surfaces of the planking; one square recess with little metal remaining is visible near Bulkhead No.2 on the port side, one square recess with a little corroded metal remaining is visible around Bulkhead No.3 on the portside, and two recesses are visible around the Bulkhead No. 5 on the starboard side. These recesses measure 145 to 185x40 millimetres with a depth of 180 millimetres, which indicates the original configuration of the metal clamps. The metal clamps are placed adjacent to the square holes through which penetrate the wooden brackets associated with the bulkheads. The use of the clamps is presumed to be from one place where it seems that the clamp was used to prevent the planks from splitting caused by cutting the wooden bracket hole (Figure 6-17).

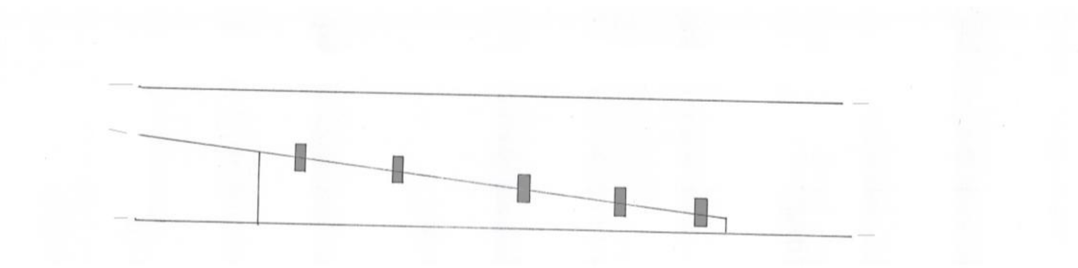

Figure 6-17 Diagram of the scarf joint of the hull planks fastened by iron clamps. *Produced by author*

Bulkheads

Bulkheads of the Shinan shipwreck are well preserved. Seven bulkheads divide the hull into eight holds. The remains of the bulkhead planks are summarized in Table 6-1. According to the site report, the bulkheads were not regularly spaced (Figure 6-18). Table 6-1 also shows the spacing of the bulkheads, calculated based on the recesses indented on the keel to take the bottom bulkhead planks presented on the site report (National Maritime Museum of Korea 2004: 45).

Bulkhead	Remains of plank tires	**Hold**	Space
BulkheadNo.1 (Foremost)	6	**1st hold (Bow transom-BK No.1)**	5.01m
Bulkhead No.2	9	**2nd hold (BK No.1-2)**	2.70m
Bulkhead No.3	7	**3rd hold (BK No.2-3)**	2.58m
Bulkhead No.4	7	**4th hold (BK No.3-4)**	3.07m
Bulkhead No.5	7	**5th hold (BK No.4-5)**	2.54m
Bulkhead No.6	6	**6th hold (BK No.5-6)**	2.47m
Bulkhead No.7 (Aftmost)	4	**7th hold (BK No.6-7)**	2.62m
Transom	3	**8th hold (BK No.7-Transom)**	1.10m

Table 6-1 Planks tires and the space of the holds.

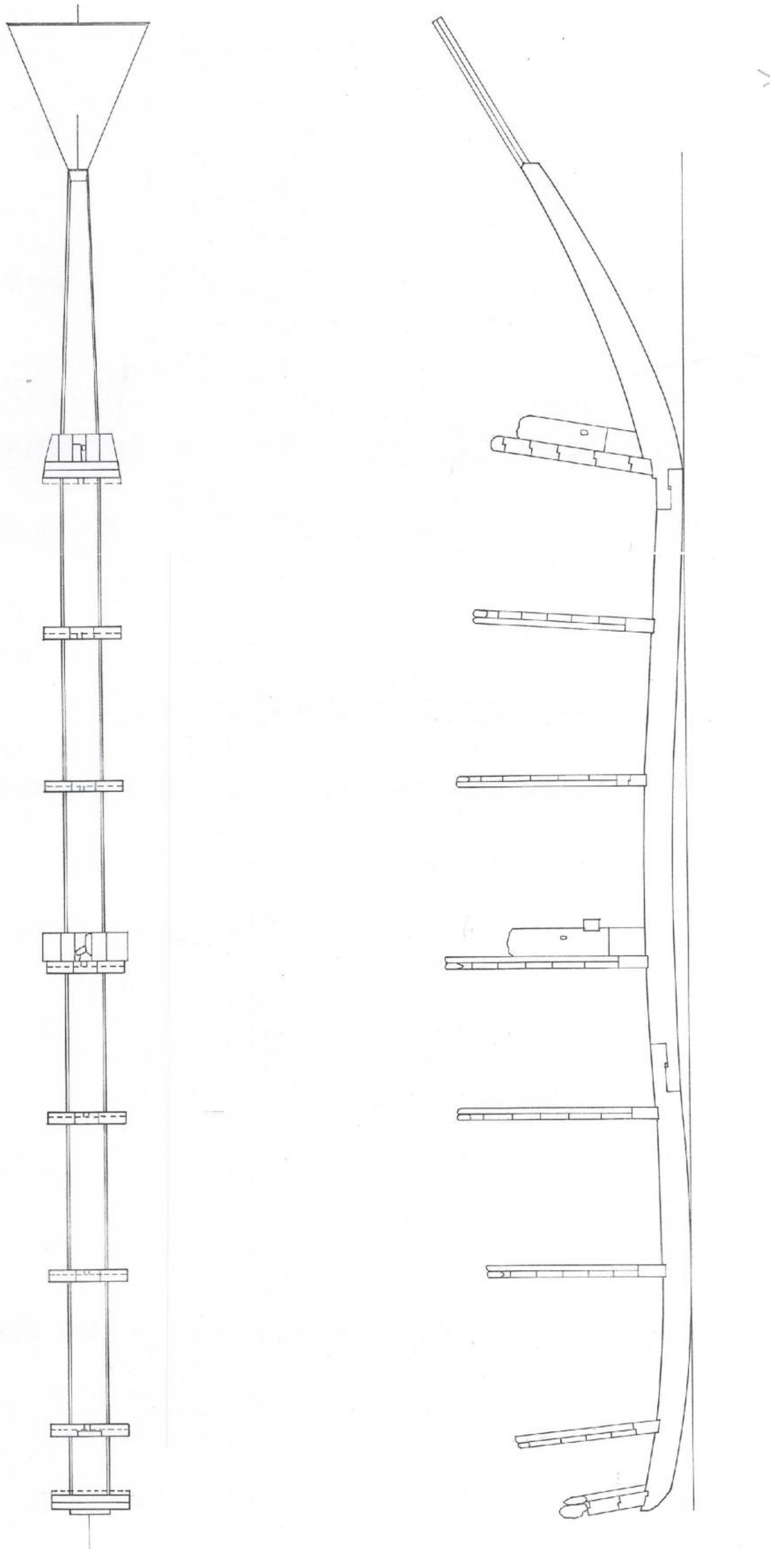

Figure 6-18 Profile showing the position of the bulkheads. *Courtesy of National Maritime Museum of Korea*

Bulkhead No.1 consists of thicker planks than other the other bulkheads and their thickness is consistent from the lower to the upper planks. Bulkhead No.2 to No.7, however, show different structure. The lowest planks of these bulkheads have greater thickness than the upper planks. These thick bulkhead blanks have been described as "bulkhead floors" (Green and Kim 1989; National Maritime Museum of Korea 2004). The thickness of the bulkhead floors is 180–200 millimetres, compared with the other upper planks measuring 110-120 millimetres in thickness. The thickness of the bulkhead floors are designed enough to place thinner upper planks as well as the associated frames (approximately 100 millimetres thick), so the thickness of the floors is equal to the total thickness of the upper planks and the frames. These floors are a base to hold the upper planks and associated frames; the middle part of the upper surface of the floors is partly recessed to slot the bottom edge of the next upper plank and the frame (Figure 6-19). The thick floors are fastened onto the keel by two large iron nails on each side. There is a limber hole on the bottom of each bulkhead floor. The square limber holes measure 100 to 110x120 to 130 millimetres. The holes allow the flow of bilge water along the bottom of the hull.

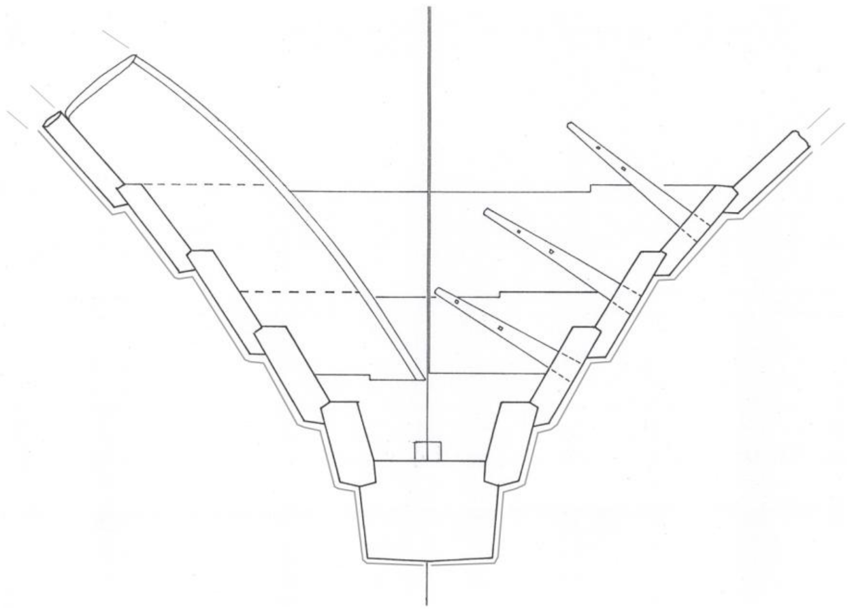

Figure 6-19 Cross-section showing floors into which the end of the large half-frame slot.
Courtesy of National Maritime Museum of Korea

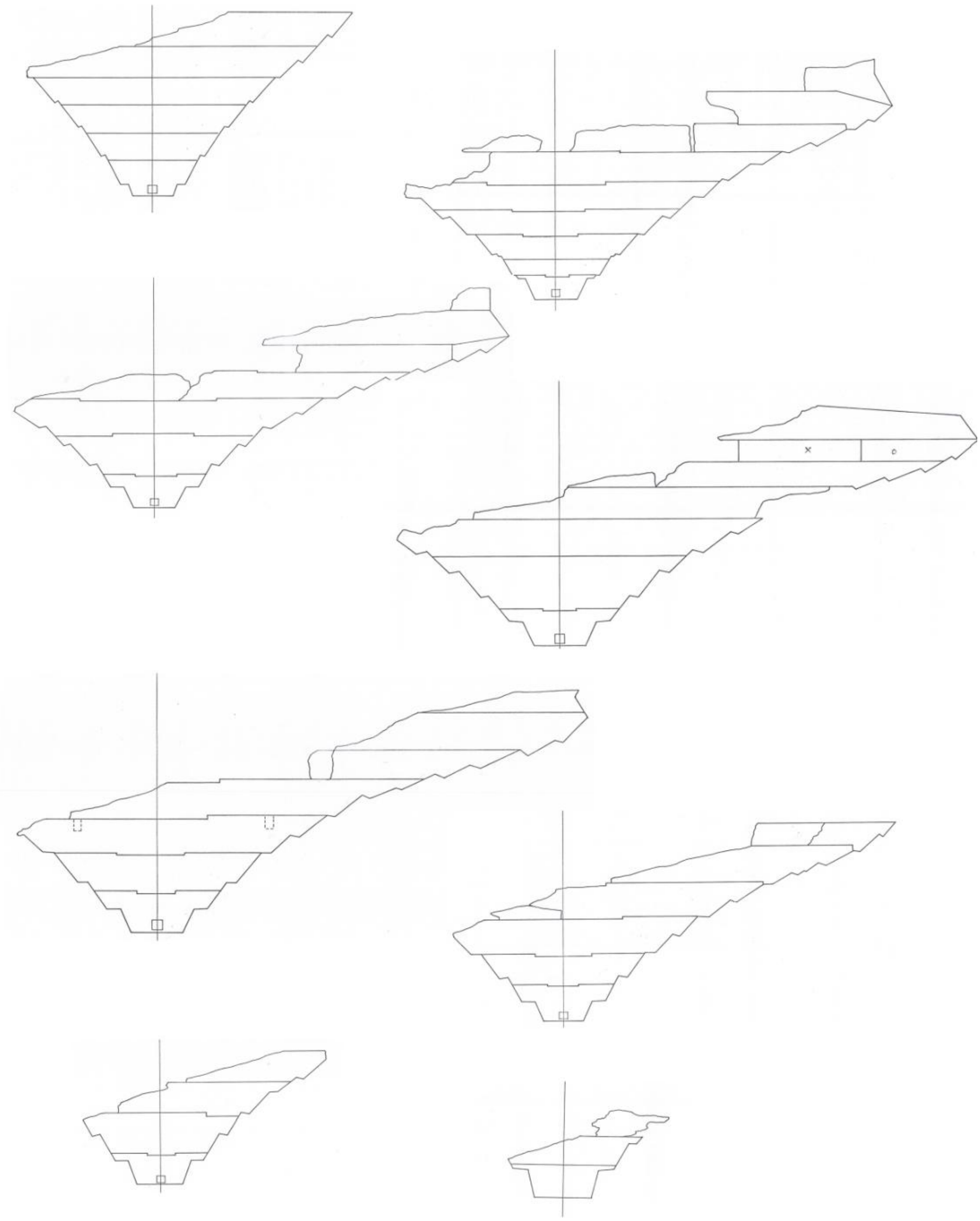

Figure 6-20 Drawing of bulkhead planks from the Bulkhead No.1 (*Top left image*) to the stern transom (*Bottom right image*). *Courtesy of National Maritime Museum of Korea*

The bulkhead planks up to deck level are edge-joined (Figure 6-20). Bulkhead No.1 consistently uses a half-lap joint. As previously mentioned, Bulkhead No. 1 consists of a series of thicker planks different from the other bulkhead planks, and moreover the joint method is also distinctive from the joint used for the other bulkheads' planks. The planks of Bulkhead No. 1 (and the transom stern) are rabbeted at the lower part forward and at the upper part toward the stern, which forms a half-lap joint (See Figure 6-18 and Figure 6-20). In contrast, the seams of the upper planks of Bulkhead No.2 to No.7 are different. The upper planks, which have the half size of the thickness of the floors, form ridges or recesses either at the middle of the lower part of the plank or at the middle of the upper part of the plank; the tongue is sometimes in the upper plank and sometimes in the lower plank (Figure 6-20). Although the groove is shallow and the wide tongue shaped to fit, this joint method is effective to prevent the horizontal slide disintegration of the bulkheads. In some seams, there are grooves in both the upper and lower plank edge. Multiple tenons or splines are inserted in these grooves to produce a strong join. These tenons or splines have been mostly identified on the seams of the bottom planks. The tenons are 100 millimetres in length, 60 millimetres in width, and 20 millimetres in thickness (Figure 6-21). In order to fasten the bulkhead planks together, a few iron nails are skew driven from the upper to the lower plank on both sides of the bulkheads. These iron nails are regularly spaced. The nail heads are recessed into notches chiselled in the planks before the nails were driven. Two iron nails are used at each side of the floor, and the regular pattern, such as four nail for the second plank, six nails for the third plank, and eight nails for the fourth, is observed at each side of the plank. The bulkhead seams are caulked with vegetable fibre and paid with a putty of tung oil and lime (Figure 6-22).

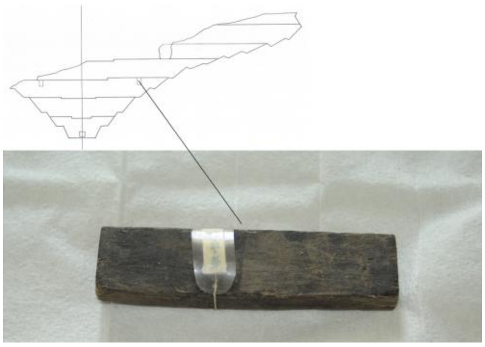

Figure 6-21 Tenon used for the joint of the bulkhead planks. *Photo by author*

Figure 6-22 Vegetable fibre identified in the seam of the bulkhead planks. *Photo by author*

Frames

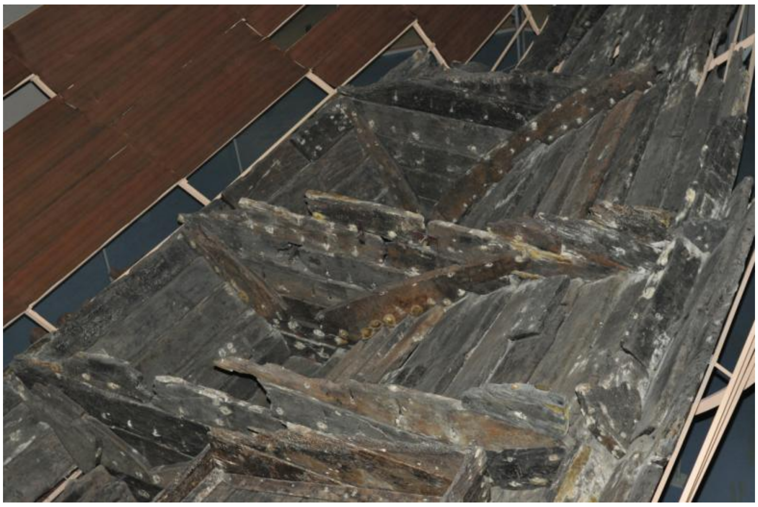

Figure 6-23 Half-frames of the aft side of the Bulkhead No.1-3. *Photo by author*

Figure 6-24 Limber cut in the bottom end of the frame. *Photo by author*

The bulkheads are reinforced by frames. The frame timbers are cut from solid pieces of large timbers and reach from floor to deck level (Figure 6-23). Two timbers (one timber each port side and starboard side) compose a set of the frames and meet on the top of the bottom bulkhead plank. The frames attached to the aft side of Bulkhead No.1, however, show an exceptional arrangement. They meet on the top of the forward keel and their bottom ends are cut to produce a limber hole (Figure 6-24). The outline of the upper edge of the frames is smoothly curved. The edges of the frames that face the hull planking are shaped to fit to the clinker. The dimensions of the frames are approximately 100 millimetres in thickness (siding) and approximately 300-500 millimetres in width (moulding). The frames are fastened to bulkheads by a number of iron nails (Figure 6-25). The nails seem to be randomly driven and one of the large frames on one aide has over thirty nails fastening it to the bulkhead.

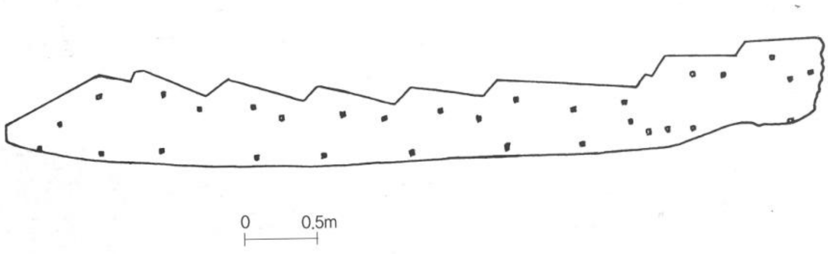

Figure 6-25 Drawing of the half-frame showing irregular distribution of the nails. *From National Maritime Museum of Korea 2004*

Wooden brackets

The method used to fasten hull planking and bulkheads together on the Shinan shipwreck is similar to that used in the construction of the Quanzhou ship. The combination of using fames and brackets on the bulkheads seems to have been a common technique. In the case of the Shinan ship, instead of iron brackets observed on the Quanzhou Ship, tapered wooden brackets (which have been called "stiffeners") were used (Green and Kim 1989; National Maritime Museum of Korea 2004).

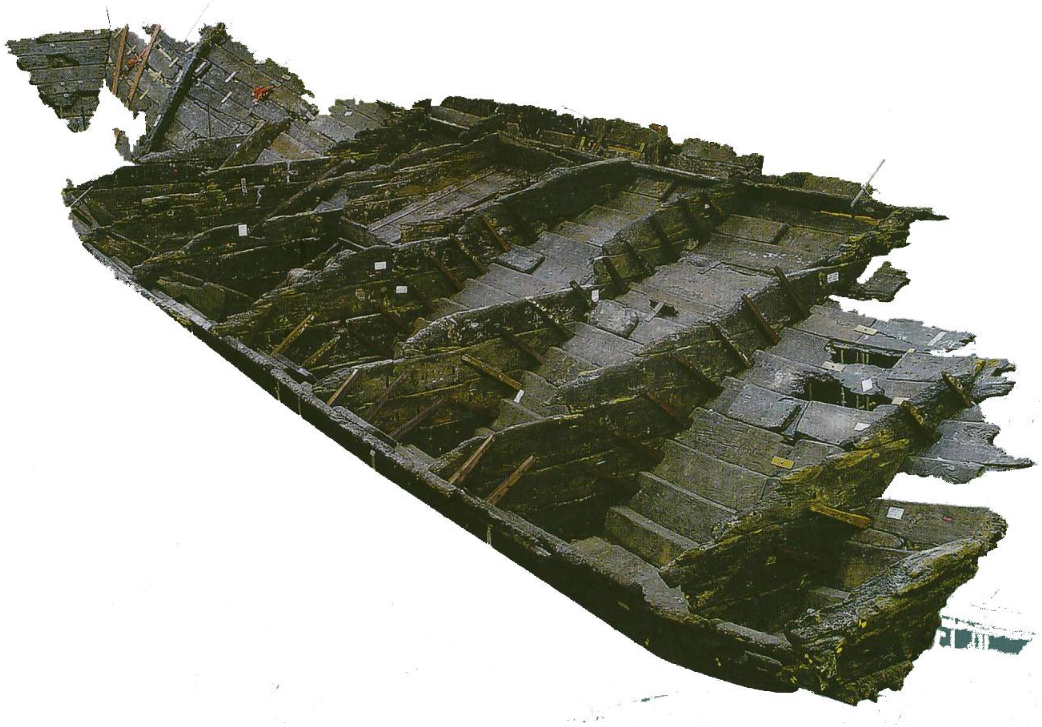

Figure 6-26 Bird's eye view from the aft side of the hull showing arrangement of the frames and brackets. *From National Maritime Museum of Korea 2004*

On the bulkheads forward of midships, which includes Bulkheads No.2 and No.3, brackets are used on the forward side and then frames on the aft side. Bulkhead No.1 has the frames on the aft side, but the fore side where the mast step is located does not have any brackets. The reverse pattern is observed aft of midships where Bulkheads No. 4 to No. 7 have the frames on the forward side and brackets on the aft side (Figure 6-26). These components effectively lock the bulkheads to prevent them moving fore and aft. The brackets also tie the strakes to the bulkheads.

Figure 6-27 Wooden brackets fastened into the surface of the bulkhead planks. *Photo by author*

Figure 6-28 Wooden brackets. *Photo by author*

The wooden brackets are square at the bottom (outer) end and tapered to the other end (Figure 6-27). The length of the wooden brackets varies, but a number of brackets average 800 millimetres in length, and approximately a square of 100 millimetres on the bottom. Two examples that were measured during this research show: one measures 950 millimetres in length square 114 millimetres at the bottom; another measures 824 millimetres square 105 millimetres at the bottom (Figure

6-28). Square holes in the strakes having the same dimensions as the bottom of the brackets allow the brackets to penetrate from the outside of the hull planking. Presumably the holes were made slightly smaller than the brackets so that the brackets would not pull right through the planking. The brackets are fastened to the bulkheads by iron nails. The number of the iron nails depends on the length of the brackets, ranging from three to five nails.

Other hull components

- Mast Steps

Mast steps and the heel of the mast of the ship remain on the hull of the Shinan shipwreck. A foremast step is identified forward of Bulkhead No.1 on the forward keel (Figure 6-29). A mainmast step is placed on the forward side of Bulkhead No.4 (Figure 6-30). Both mast steps have flat bottoms which sat on the keel and their sides are shaped to fit to the clinker steps of the hull planking. A few iron nails are driven skewed from the side of the mast step down to the keel and garboards for fastening. There are limber holes on the bottoms of the mast steps for bilge water to flow. There are two tabernacle holes measuring 250x160 millimetres with a depth of 150 millimetres on each mast step to place tabernacle cheeks. The main mast tabernacle cheeks remain and are distanced about 500 millimetres apart, which shows the diameter of the heel of the main mast. Three irregularly shaped timbers remain between the tabernacle cheeks on the main mast step. These appear to be the heel of the main mast. The timbers are fixed to the tabernacle cheeks by a locking pin which penetrates across the three timbers (might have originally used four timbers) and the tabernacle cheeks. A square shaped-timber is horizontally fixed to the forward side of the tabernacle cheeks tying them together. Except for this transversal lock, the structural remains of the foremast tabernacle and mast heel is the same as the main mast. The foremast step use the same system, though only two timbers of the mast heel remain between the tabernacle cheeks. The assembly of the mast heel indicates that the masts of the Shinan ship originally consisted of multiple timbers assembled to make one mast pole. On later Chinese ships this arrangement was used with iron bands to hold the timbers together. The two mast steps show that the Shinan ship had at least two masts, and Korean researchers have suggested that a mizzen mast might have been located on the upper part of the stern (National Maritime Museum of Korea 2004).

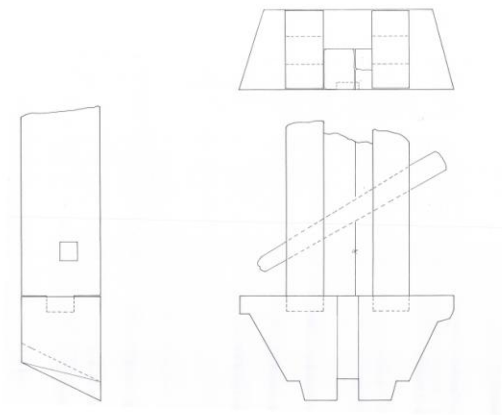

Figure 6-29 Drawing of the foremast step. *Courtesy of National Maritime Museum of Korea*

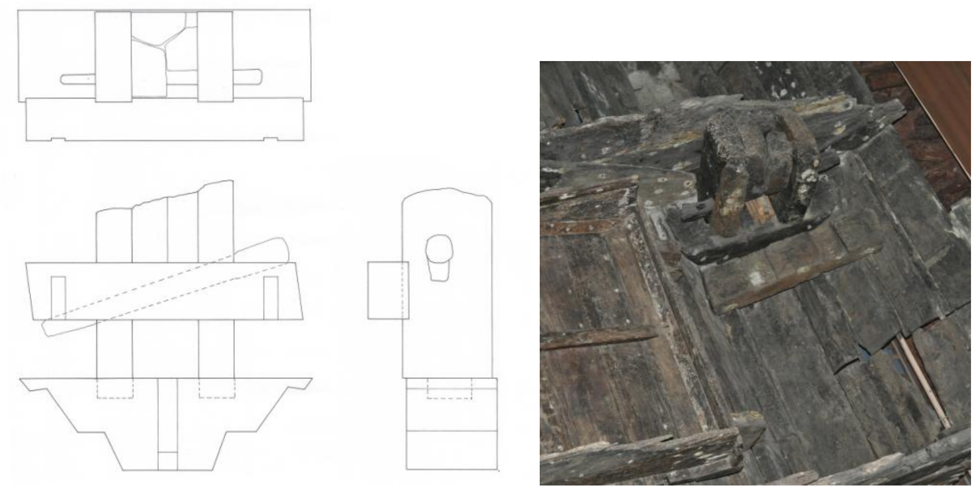

Figure 6-30 Drawing of the mainmast step and photograph of the mainmast step from top view. *Courtesy of National Maritime Museum of Korea, Photo by author*

- Tank

Remains of a tank are identified on the starboard side of the Shinan shipwreck. The wooden tank is placed in the fourth hold between Bulkheads No.3 and No.4. According to a site report, the structure shows evidence of having been caulked and paid to achieve watertightness which is seen as indicative of use to carry water (National Maritime Museum of Korea 2004: 58). A drainage hole is observed on the bottom of the tank (Figure 6-31). The upper part of the tank does not remain, but the well-preserved bottom of the tank measures 5.5 square metres (Figure 6-32). Apart from the bottom planks, the lateral planks of the tank partly remain. There are wooden brackets which fasten the sides of the tank to the bottom (Figure 6-33). These brackets function the same as those brackets which are used to fasten the bulkheads. The brackets are smaller than the bulkhead brackets and their bottoms are dovetailed to fit to the tank bottom planks. Six brackets inserted into the ends of the six bottom planks and are attached on the forward and aft faces of the tank. The tank is supported by two frames that sit on the third strakes up to the tenth strake on the starboard side of the hull. The frames are formed to fit to the clinker steps. It is thought that on the port side another tank was probably placed. In the case that they were used as water tanks, two tanks would provide enough drinking water for the Shinan ship to be engaged in long distance trade. There is an interesting issue with the interpretation that they are water tanks. The dimensions of the tank appear to be more than 2.5 x 2m. If the tank were about two-thirds full, and the ship was rolling heavily, there would be about 5 tonnes of water crashing back and forth inside the tank. Such big tanks would be problematic. Paradoxically, the tank might have been used as cargo stowage for materials keeping them from wetting. In such a case, the hole in bottom could still function for draining water that accidently came into.

Figure 6-31 Photograph showing a drainage hole in the tank. *Photo by author*

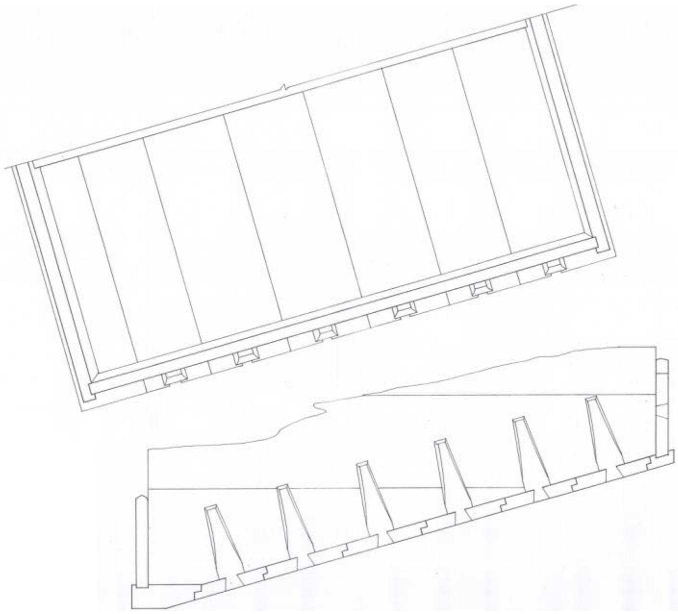

Figure 6-32 Drawing of the tank. *Courtesy of National Maritime Museum of Korea*

Figure 6-33 Wooden bracket to fix the tank *Photo by author*

VI-5 Perspectives on hull construction

The discovery of the Shinan shipwreck is as significant as that of the Quanzhou ship, and these two ship remains are valuable resources for comparative and complementary study of East Asian shipbuilding traditions. The similarity in the background of the two ships that were used as traders from the East China Sea is evident from their cargo assemblages. A standardization for the construction of a merchant ship represented in remains of the two ships, fundamentally composed by the keel consisting of three members, fastening methods of edge-joint hull planking and bulkheads as transverse components. Some idiosyncratic features are, on the other hand, identified in the hull of the Shinan shipwreck. The hog of the keel, for example, has raised dispute as uniqueness. In general, the hogging of a keel is regarded as a distortion. During the reconstruction of the Shinan shipwreck, the hull distortion has been already recognized (C. Lee, pers. comm. 2010). However, the current state of the hull distortion was not reasonably discussed in relation to the issue of the hogging of the keel. The issue of the hog of the keel will be examined in Chapter VIII through the reconstruction of the original shiplines. Meanwhile it is suggested that it is not deliberately designed. If the ship was designed with the hogged keel, it would drag its aft transom deep in the water which would result in poor sailing performance.

The bulkheads are less in number than that of the Quanzhou ship, and the adequacy of the transverse strength needs to be carefully argued. On the other hand, the structure of the bulkheads shows an innovation to resist lateral distortion by forces imparted by mast and rigging, by identifying structural integrity of the bulkhead planks. The nail driven pattern in the bulkhead planks show regularity, and mortises and tenons are used for the seams of the planks. The way of joining the bulkhead planks by forming ridges or recesses in their middle, could provide the integrity against such forces. The use of the bulkhead floors, thicker than the upper bulkhead planks, is remarked as a characteristic of the Shinan shipwreck's bulkheads, though some shipwrecks from Southeast Asia dating to the later periods use a similar structure. The size of the bulkhead floors provide space on side of the limber holes for nails to be driven into the keel. In general, a large limber hole in the centre of the bulkhead is likely to be an obstacle to nailing bulkhead planks to the keel. For this reason a limber hole does not often appear on the centreline, usually there are two small limbers, either side of the centre line. Compared to the thin bulkhead planks of the Quanzhou ship, the large and thick floors are regarded as facilitating to fasten the bulkheads into the keel by nails. Iron nails are also used for fastening the floor to the garboards. The garboards are fastened into the keel by large nails driven from outside, but for the fastening of the floors the nails are skewed from inside. The fastenings show that the garboards probably came before the bottom of the bulkheads. If the bulkheads were fitted first, the fastening would be through the garboard from the outside into the bulkhead floor.

The hull planks of the Shinan shipwreck shows layered planking. They function as sheathing planks rather than any other purposes, such as contribution to the longitudinal strength. For example, the arrangement of the outer planks of the Shinan shipwreck are not designed to cover the seam of inner planks, likewise those of the Quanzhou ship. Furthermore, each strake of the Shinan shipwreck is individually fastened into the bulkhead by wooden brackets; they appear on every strake except the garboards. This is compared to the use of the iron brackets in the Quanzhou ship that appear in the set of strakes. It is remarked that the technique using the brackets for individual strake might result in considerable weakening of the hull as all the square holes that cut in the individual strakes align.

An underlying idea of using brackets that fasten the planking to the bulkheads is the similarity between the Quanzhou ship and the Shinan ship, while the configuration and material of the brackets is different from those used on the Quanzhou ship. From these points, the structural efficiency is also considered to be different. The L-shaped iron brackets, firmly fastened into both the plank-shell and bulkheads, would have good tensile strength, but it is possible that the wooden brackets could pull through the planking under tensile load. On the other hand, the wooden brackets would probably be better for preventing fore and aft movement of the bulkheads. The iron brackets seem to have been too thin to be strong against that kind of distortion.

Chapter VII - Ship remains from the Takashima underwater site

The Takashima underwater site is a historical site associated with the thirteenth century Mongolian attempted invasions of Japan. A large fleet of the Yuan Dynasty (1271-1368 A.D.), which was established in China by the fifth Mongolian emperor, was sent to Japan. However, the invasions, which occurred twice in 1274 and 1281, failed, and in particular during the second invasion many ships were lost. The loss of the fleet that transported an enormous number of Mongolian, Chinese, and Korean troops is evidenced by the discovery of diverse artefacts including ceramics, weaponry, personal items, and portions of hull at the site. The site is located offshore from a small island, Takashima in Nagasaki Prefecture (Figure 7-1). Since the 1980s, several underwater archaeological surveys and excavations have been intermittently conducted on the site. In particular, a series of the rescue excavations that commenced at the site offshore of Kozaki harbour on the southeast coast of the island since the 2000s revealed the remains of ships. However, most of these remains were fragments, and only a few of them can be confidently identified as ship construction components. Despite their poor condition, the hull remains recovered from the site are significant and considered as comparable archaeological resources of the late thirteenth and fourteenth centuries' East Asian vessels. Remains of bulkhead timbers identified in 2002 are the particular study objects in this research. Clarifying their details will be a main focus in this section, and some other ship timbers from the site will also be examined.

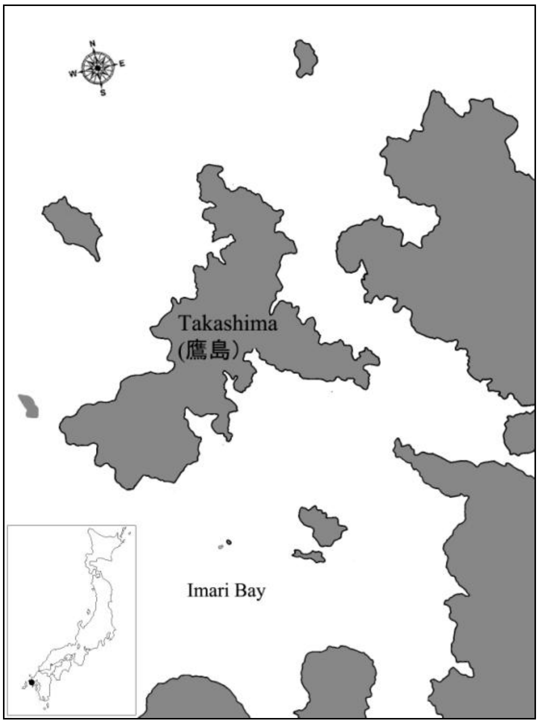

Figure 7-1 Takashima located in the Bay of Imari, Nagasaki Prefecture

VII-1 Site Background

Remains of the hull from the Takashima underwater site are dated to the late thirteenth century approximately the time period of the Quanzhou Ship. The date of the hull remains are associated to the loss of the fleet that occurred in 1281 during the second Mongolian invasion of Japan that followed the first invasion in 1274. The historical background of the site has been reviewed in an archaeological site report and more recently in an English volume (Agency for Cultural Affairs 2000; Delgado 2009). The following brief description about the site background is based on these literatures.

In the thirteenth century, the expansion of the Mongol Empire occurred and was led by Genghis Khan in the Eurasian continent. It had success in China through one of his descendants, Kublai Khan. Kublai founded the Yuan Dynasty after the conquest of the northern part of China, and then he subjugated Korea by using his forces from the Mongolian and Chinese. Failure of diplomatic approaches to a Japanese ruler also made him determine to put Japan under his control through military power. The first attack on Japan took place in 1274, but the fleet and solders were withdrawn immediate after landing in northern Kyushu and destroying Hakata city. The incomplete first attack convinced Kublai of the necessity of organizing a greater force. Seven years after the first invasion, the second invasion was implemented with the despatch of larger fleets.

All the remains found offshore at Takashima originate from the loss of the fleet in the second invasion. By the time of the second invasion of Japan, Kublai could obtain naval forces from the Northern Song Dynasty (960-1127 A.D.). Before the Yuan, the Northern Song Dynasty had reigned over the southern Chinese coasts where many ships and shipbuilding industries had been established, but they were finally conquered in 1279. Immediately after this Kublai decided to send an invasion force to Japan again. According to Dynasty chronicles of the Yuan *Yuan Shi* (History of Yuan 元史) and *Shin Yuan Shi* (Editorial History of Yuan 新元史), in the second invasion, two separate fleets were organized from different regions; the first fleet consisted of about 900 ships carrying approximately 40,000 solders and sailed out from Masan (current Mokpo) at the tip of the Korean Peninsula; the second fleet consisted of about 3,500 ships to carry approximately 100,000 solders and sailed out from Ningbo, a historical port of the middle and southern China. The number of ships and solders appearing in the historical Chinese text may be exaggerated. The fact, however, that two fleets from different points of origin left for Japanese waters is clearly mentioned in the historical texts. The two fleets initially intended to rendezvous in Japanese waters. After some disorder that caused the delay of the missions, the two fleets were finally assembled together and anchored south of Takashima Island in Imari Bay. The concentrated fleets in the Bay suffered from resistance attacks from Japanese local clans, as they were much more prepared than the last battle during the first invasion. Besides, a violent storm later known as the Divine Wind among the Japanese people, struck the fleet in July 1281. Many ships sank to the bottom of the bay and the rest of them could no longer fulfil the mission of conquest.

Imari Bay is a large bay with a surface area of 120 square kilometres, and a maximum depth of 50 metres and average depth of 20 metres. Takashima is located at the mouth of the bay. The historical records mention the loss of the fleet off the southern coast of Takashima, yet it is only recently that archaeological excavations were conducted but details have not been revealed. Many artefacts have been found by underwater archaeological operations. However, the extent of the site is difficult to determine and only a small part of the potential area has been excavated in the last two decades. With regard to those many artefacts, a question has arisen as to whether they are linked to the first fleet that departed from Ningbo or the second fleet from departed from the Korean Peninsula. The study of the ceramics indicates that most of the artefacts are of Chinese origin, while some important Goryeo Dynasty's products were recovered from the waters, including shards of Goryeo celadon and a Goryeo style bronze statue. Moreover, the study of the wooden remains possibly associated to hull structure also suggests that a lot of remains show characteristics of Chinese shipbuilding technology (Sasaki 2008).

Survey and excavation

A series of surveys and excavations previously conducted at the Takashima underwater site have been reported in the archaeological reports edited by the Board of Education of Takashima and a non-profit organization Kyusyu Okinawa Society for Underwater Archaeology (now ARIUA: Asian Research Institute of Underwater Archaeology). A summary of the reports is available in a short article in English (Kimura 2006). The area offshore of the southern coast of the island is registered as a nationally protected zone. Two harbours in the area, Tokonami Harbour and Kozaki Harbour, have been the focal places of rescue excavations legally obligated to be conducted ahead of construction or other development. Although the rescue excavation offshore of Tokonami Harbour in the 1990s resulted in the identification of many artefacts related to the Mongolian invasion, more potential started to be recognized offshore of Kozaki Harbour through rescue excavations since 2000 because of the identification of hull remains and better preserved artefacts. The discovery of wooden anchors *in situ* in 1994 and 1995 allowed one to understand the depth of the original seabed dated to the Mongolian invasion period under the current seabed. The understanding that the anchors had moored the invasion ships increased people's appreciation that this is the site of the shipwreck of the Mongolian fleet. During the rescue excavation in 2001 and 2002, a total of 2,432 artefacts were recovered from the site. From these excavations, it was recognized that buried remains had been substantially disturbed by wave and tidal forces.

VII-2 Previous study of the ship timbers from the site

Recovered artefacts from the 2002 excavation in the waters of Kozaki Harbour number 491 wooden pieces (37.2 % of all recovered artefacts). These wooden remains, however, include not only possible ship construction components but also various wooden fragments, such as charcoal and thin logs, which are probably not hull components. In general, these have been distinguished from the possible ship timbers by looking at the evidence of iron nails having been used, which are considered indicative of hull construction. The ship timbers found as broken or separated pieces have been recognised as difficult to interpret. In addition, the degradation of most wooden remains has discouraged Japanese researchers from conducting extensive research. Interpretation of the disarticulated wooden remains has been made by Randall Sasaki from Texas A&M University. Sasaki (2008) targeted 502 wooden remains from the excavation in Kozaki Harbour recovered from 2001 to 2004 during rescue and academic excavations. His approach was to classify the wooden remains into dimensional categories with the assessment of their preservation status. The result of his study showed that more than 90 % of the wooden remains were in the classification of 1.00 metres or smaller, while only less than 2% of them were larger than 2.00 metres. The status of the serious deterioration was observed on over 60 % of all the wooden remains. Sasaki's approach provides a statistical order for the interpretation of the quality of the wooden remains from the site. The dimensional and degraded state of the wooden remains is firmly related to the fact that these remains were recovered from the area adjacent to the shore where the wave force disturbed and deposited them.

VII-3 Bulkhead remains from the Takashima underwater site

Two bulkhead planks recovered from the site offer more detail for interpretation than other recovered wooden remains. Unlike other degraded wooden remains, these two bulkhead planks were still joined together allowing confident identification as parts of hull structures. The bulkhead remains consist of two large planks fastened by iron nails. The two timbers still held together when they were discovered. However, the degraded iron nails came apart during the excavation processes (Figure 7-2). A few fragments of the iron nails were scattered around the bulkhead in the silty sediment. The bulkhead was an isolated portion and no other timbers associated to the bulkheads could be identified, while miscellaneous artefacts, such as ceramic shards, combs, ceramic hand grenades, and weaponry were discovered around it. The details of the formation processes of how the bulkhead underlay the slit are speculative. However, it appears that the bulkhead planks were covered by silt, along with the other artefacts, immediate after it was separated from the rest of the hull. After exposing the bulkhead from the silt, it remained in its location for recording. The length of time (over a month) it took to carry out and complete the underwater recording might have accelerated the disintegration of the metal remains such as the degraded nails in the bulkhead, but this cannot be confirmed at present. By the time of lifting of the bulkhead from the seabed, the two bulkhead planks were already separated. The lower bulkhead plank was labelled KZK02 - No. 1439 (Figure 7-3). The upper bulkhead plank was labelled KZK02 - No. 1440 (Figure 7-3). These timbers are being stabilized in fresh water tanks.

Figure 7-2 Two bulkhead planks recovered from the Takashima underwater site *Courtesy of Takashima-cho Board of Education*

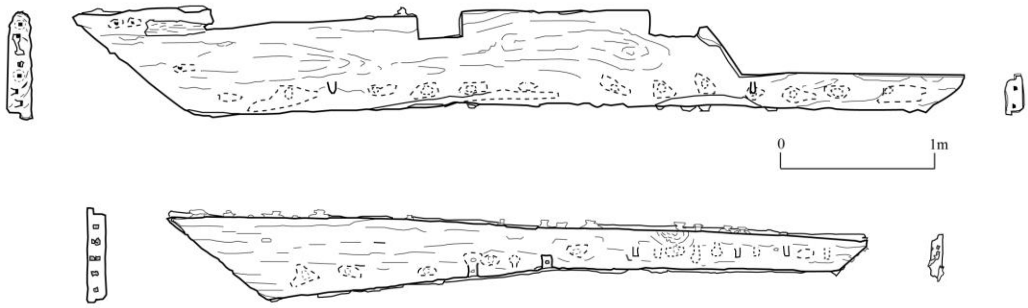

Figure 7-3 Drawing of the bulkhead plank No.1439 (lower image) and No. 1440 (upper image). *Photo by author*

Bulkhead plank - No. 1439

The No. 1439 plank is the lower part of a bulkhead and connected to the No. 1440 plank. The top edge of this plank is connected to the bottom edge of the No. 1440 plank. The length of this seam joining the planks measures approximately 4.50

metres. The length of the bottom is 3.70 metres, representing the length of the top section of a missing lower bulkhead plank. The thickness of No.1439 plank is approximately 120-140 millimetres. The seams of the lower and upper side of the No.1439 plank are rabbeted for a joint of the bulkhead planks. The rabbets are symmetrically grooved on the both lower and upper sides. In general, rabbets cut asymmetrically in each seam is the more normal arrangement, but the No.1439 plank does not show this arrangement.

Figure 7-4 Nail holes on the end of the bulkhead plank No. 1439. *Photo by author*

Figure 7-5 Degraded nail remains on the end of the bulkhead plank No. 1439. *Photo by author*

The plank is neatly shaped. On the larger end, six holes are observed with a regular interval of 100 millimetres (Figure 7-4). Notably, two of the six nail holes are double holes. On the smaller end, the metal concretion and the remains of a corroded iron nail are visible besides one nail hole. The remains of the iron nails are highly degraded, but the configuration of one of the nails can be partly observed. No mineralised iron remains and the original surface of the nail is barely observed as a thin magnetic layer (Figure 7-5). The original nail probably had a square cross-section, which measured a square 15 millimetres on each side. The depth of the nail holes ranges from 80-100 millimetres, indicative of the length of original iron nails driven through the planks which could be more than 100 millimetres. It is presumed that the square-sectioned iron nails measuring 100-150 millimetres in length were driven from the hull planking to the bulkhead.

Figure 7-6 Nail that has been diagonally driven from the surface to the lower seam. *Photo by author*

The use of iron nails can be also seen in the seams that join the bulkhead planks. Several iron nails that used to fasten the No. 1439 to the missing lower bulkhead timbers were diagonally driven from both sides of the No. 1439 plank downward (Figure 7-6). The nail heads are set into small chiselled recesses on the surface of the bulkheads about 13 millimetres above the seam. The nail heads might have been sealed by putty, but most nail holes are covered only by concretions. A total of seventeen iron nail holes are observed on the two sides of the lower seam. At one part, the space of the nails varies from 140-270 millimetres. This irregularity changes at the other part where ten iron nails are narrowly spaced with an almost regular interval of 140 millimetres.

The most interesting feature on the No. 1439 plank is two recesses cut into it around the centre of the surface along the lower seam (Figure 7-7). One recess appears to have holes on its bottom and the recess is a dovetail shape. The recess may have been used for a dovetail joint, but it is more likely that the deterioration of the surface of the timber caused the deterioration of the original rectangular shape to make it look like a dovetail-shape. Another recess has only one nail hole and is carved with a rectangular shape. These recesses have probably functioned as a socket to receive pins or tenons of either the dovetail shape or the rectangular shape. The size of the recesses measures 50-80 millimetres in width, and the depth of the recess measures 10 millimetres, and these present the size of the pins or the tenons that have been slotted into. They have been used to align and hold two bulkhead planks together as a clamp.

Figure 7-7 Edge of the lower seam of the No. 1439 plank has recesses and holes which probably relate to fastenings that have secured the seam of the bulkhead planks. *Photo by author*

Bulkhead plank - No. 1440

The length of the upper edge measures approximately 5.70 metres. The lower seam, which meets the top part of the No. 1439 plank is 4.56 metres in length. The width is 600 millimetres at maximum, and the thickness ranges from 160-180 millimetres. This bulkhead plank does not show a symmetric configuration in its upper section since a part of one end of the upper section is greatly cut away. The seam of the cut away part is grooved forming a rabbet indicating that an extra piece of timber had been originally let in. However, the remaining part of the upper edge is not rabbeted. Many nail holes remain in both the rabbeted part and the non-rabbeted part. Eight nail holes are observed on the rabbeted seam for fastening which further demonstrates that some timber has been originally let in. On the other parts of the top section, a few square nail holes are observed. The lower edge of this bulkhead plank is cut straight and the seam smoothly fits to the upper seam of the No. 1439 plank.

Figure 7-8 Two large recesses in the upper part of the No. 1440 plank. *Photo by author*

There are two large square recesses that are cut on the centre of the upper section (Figure 7-8). These recesses measure approximately 300 millimetres at their bottoms, and their heights are 160 millimetres. With regard to the role of the two recesses on the No. 1440 plank, Sasaki (2008: 73) points out that two longitudinal timbers were probably placed on them to hold a deck or superstructure. There are nail holes on the bottom corner of the recesses, and these indicate that the two recesses were used for structural support. Perhaps, the longitudinal timber had been fixed on the recesses by iron nails as Sasaki mentions. The longitudinal strength of the original hull might be derived from the two baulks possibly running from bow to stern laid across the bulkheads. Many examples regarding hulls adopting this sort of longitudinal structure have been reported in the ethnological boat study of Chinese river and coastal ships (Worcester 1971). As mentioned above, the seam of the upper section where the two recesses are cut is not rabbeted but mostly flat and this arrangement appears to be suitable for a sort of deck structure to be surmounted, not another bulkhead plank. Distinguished from the upper seam, the lower seam is cut for the lap joint to fit to the top of the No .1439 timber.

The ends of this plank show differences in their sizes due to the large cut of the upper section. The same as the No.1439 plank, there are nail holes on these ends. Six nail holes and one corroded nail remain are observed in the larger end (Figure 7-9). The size of the nail holes seems to be irregular. On the smaller end, only two nail holes are observed. The remains of the corroded nail show the use of iron nails to fasten the hull planking to the bulkhead.

Figure 7-9 Nail holes and degraded nail on the end of the No. 1440 plank. *Photo by author*

Figure 7-10 Small nail holes identified on the surface of t the No. 1440 plank.

Three little nail holes are identified on the surface close to the side of the No. 1440 timber (Figure 7-10). The nails have been perpendicularly driven into the bulkhead. However, no evidence is available as to what kind of structures may have been fixed by using these iron nails. Of the three, the size of the two nail holes measures a square 8 millimetres on a side, and one nail hole is 15 millimetres in diameter. Hypothetically, reinforcements for the joint between the bulkheads and planks or between the bulkhead planks might have been originally attached, such as knees, clamps, or frames by those iron nails, but they are insecure fastenings for structural components.

Fifteen iron nails were used on the seam to connect to the top section of the No1439 plank. As mentioned before, the bulkhead timbers of No. 1439 and No. 1440 were still joined together when discovered. However, all iron nails have been fully corroded. Most nail heads remaining on the surface of the bulkheads close to the upper and lower seams show concretion. These are skewed nails irregularly placed with space ranging from 60-300 millimetres. Despite the irregularity, it can be seen that a greater number of iron nails was used in the less wide section.

Another piece of the bulkhead plank

Among the wooden remains from the site, the No.1439 and No. 1440 planks are clearly identified as bulkhead remains. Another piece that may have originally been a part of the bulkhead is the No. 1236 plank found near those two bulkhead planks during the excavation. This plank, however, is smaller, measuring approximately 1.30 metres in length of the remaining part with a maximum thickness of 220 millimetres. It has been suggested that this plank may be a part of the bottommost bulkhead plank in the site report (Takashima-cho Board of Education 2003). However, there is no clear evidence of a bottommost bulkhead in this plank, such as a limber hole or a relevant configuration and fastening manner to fix it onto the hull bottom. The details of this plank has been examined in a previous study (Sasaki 2008: 108-109). The use of several nails have been confirmed, and based on the examination of the original nail pattern, it is concluded that "the timbers were not located at the bottom of the vessel, but perhaps located at a side" (Sasaki 2008: 109). The timber species identified in this plank is camphor, the same species as No. 1439 and No. 1440 planks. Of the various timber species identified from the site, camphor tends to be identified to most large timbers likely used as a ship construction material (See Chapter VIII).

VII-4 Anchors

Except for the bulkhead remains, the discovered anchors are an available resource for detailed interpretation. They were estimated to be the oldest wooden anchors ever found archaeologically in the East Asian regions. While wooden anchors are neither hull components nor involved directly in a ship's construction, they were a critical element in a vessel's outfitting and have been reviewed extensively in previous studies of East Asian nautical technology (Needham 1971; Worcester 1971). Following the concept, the anchors from the site are presented here. This section is followed by next chapter discussing the wood used for these anchors with the other ship timbers.

A rescue excavation offshore of Kozaki Harbour in Takashima revealed nine large wooden anchors. The preservation status of these anchors varies. They all are compound anchors consisting of the wooden shank and arms with separated stone stocks (Table 7-1). From the structure of the anchors and material analysis, they are considered as originated from ships of the Mongolian fleets (Kimura, Sasaki et al. 2011).

	Shank	Arms	Loose tenon	Stakes (to hold stone stocks)	Stone stocks
Anchor No.1	N/A	One arm	N/A	N/A	Identified
Anchor No.2	Identified	Two arms	Identified	Identified	Identified
Anchor No.3	Identified	Two arms	N/A	Identified	Identified
Anchor No.4	Identified	Two arms	Identified	Identified	Identified
Anchor No.5	N/A	Broken pieces	Broken pieces	Identified	Identified
Anchor No.6	Broken pieces	Broken pieces	N/A	N/A	Identified
Anchor No.7	Broken pieces	Broken pieces	Broken pieces	Identified	Identified
Anchor No.8	N/A	N/A	N/A	N/A	Identified
Anchor No.9	Broken pieces	Broken pieces	Broken pieces	N/A	Identified

Table 7-1 Remains of the components of the composite anchors. *From Takashima-cho Board of Education 1996*

The wooden anchors' shanks and arms are mostly broken; however, the anchor components of Anchors No.2, No.3, and No.4 remain relatively intact. Anchor No.3 is the largest anchor in the nine anchors (Figure 7-11). The remains of the shank are 2.74 metres in length and the width of the mid-part measures about 300 millimetres. One arm shows mostly intact condition with a length of 3.15 metres. It has been estimated that the shank may have originally been as long as 5.00 metres (Takashima-cho Board of Education 1996). The broken remnants of the other smaller anchors exhibited an average shank length of over 2.00 metres. The remains of the shank of Anchor No. 2 are 2.55 metres and the width of the mid-part measures 170 millimetres. With regard to the remains of Anchor No.4, the length of the shank is 2.10 metres and the width of the mid-part measures 170 millimetres. The well-preserved anchors are enough to infer their original configuration and construction methods. The shank of the anchor is a baulk of timber and the tip of the shank is diamond-shaped where two arms are attached. The timber of the arms is chamfered and each arm is neatly fitted to the shank by a mortise and tenon joint. Except for the mortise and tenons, a piece of wood penetrating through the tip of the shank to the arms is used to join them together on the crown. Ropes made of bamboo are used to secure the shank and arms. Some anchors have either one or two trapezoidal wooden plates that are attached on both surfaces of the anchor crown by iron nails. They provide additional structural strength to the junction of the shank and arms. Each anchor originally had two arms. The remains of some arms have metal corrosion on their tips. The arms have been toed with iron sheet metal to form flukes. All anchors seem to have used two separate stones as an anchor stock (Figure 7-12). The two stones are separately attached to the middle of the shank and are placed between a pair of wooden stakes that penetrate the shank through holes fix perpendicularly to the arms and are held with bamboo ropes.

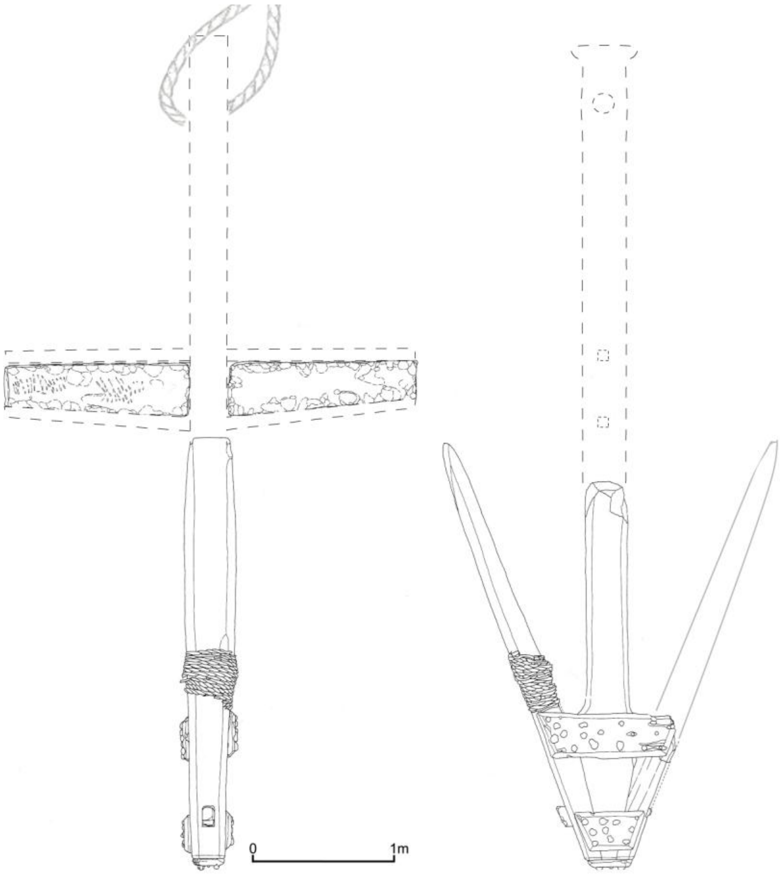

Figure 7-11 Drawing of Anchor No.3 *After Takashima-cho Board of Education 1996*a and photo of the wooden anchor after conservation treatment by PEG. *Photo by author*

Figure 7-12 A set of stone anchor stock for the compound anchor. *Photo by author*

Anchor stocks made of stone have been widely used on East Asian ships over a long period of time. Chinese ships, which commenced being involved in international trading around the tenth century, were probably equipped with anchors using a single stone stock that penetrates the shank of the wooden anchor. Later, they started to use two-piece stone stocks. The use of both two-piece and single stocks appears to have co-existed throughout the thirteenth century, possibly until a much later period. One of the characteristics of the compound anchor is the use of the stone stock that is positioned in the middle of the shank. It has been pointed out that traditional Chinese anchors have been distinguished by the location of the stock on the crown (Worcester 1966; Needham 1971; Worcester 1971). However, the compound anchors used during the Song and Ming Dynasties show the installation of the stone stock into the mid-part of the shank. Two large wooden anchor shanks are kept in the Quanzhou Maritime Museum (Museum of Overseas Communication History) and these have two holes possibly to install stakes to hold a stone stock in the middle of its shank (Figure 7-13). Another similar anchor was discovered from one of four shipwrecks excavated at Penglai Forts in Shandong Province, China. The ship is dated to the end of the Yuan Dynasty or the early Ming Dynasty (1368-1644 A.D.), according to the date of celadon recovered from the wreck and the construction date of the fort’s sluice gate. The wooden anchor recovered from this shipwreck during the 1984 season’s excavation has two holes in the middle of the shank. Compared to the above anchors, the anchors found at the Takashima underwater site is the earliest archaeological evidence of the use of the stone stock in the East Asian region. The result of the most recent radiocarbon dating analysis on the specimen from the shank of Anchor No.3 dated the anchor to 771 ± 19 (770 ± 20) BP which is calibrated to 1269 ± A.D. (Takashima-cho Board of Education

2001: 51). With regard to the origin of the anchors, scientific analysis on the stone stock of the Anchor No.3, which is made of granite stone, has revealed that the chemical composition of the stone is similar to that of granite stones from Quanzhou in China (Kazuhiro, Yoshifumi et al. 2000). Moreover, it is noted that wood used for the shank of the Anchor No.2 appears to originate from the region close to Quanzhou (See Chapter VIII). These offer little clues as to where the ships equipped with the anchors originally came from.

Figure 7-13 Shank of the compound anchor stored in the Museum of Overseas Communication History. *Photo by author*

VII-5 Other ship timbers recovered from the site

Except for the bulkhead planks and the anchors, almost all wooden remains over 500 pieces that have been discovered since 2000 defy classification and identification of function as ship construction components. On some remains, however, there are features suggesting their use as ship timbers. Most of these timbers have been detailed in the previous report and study (Sasaki 2008; Takashima-cho Board of Education 2008). Some timbers defined as ship construction materials are re-examined and summarized specifically for this research in Appendix II. The selected timbers satisfy some of the following elements as ship construction components; the evidence of fastening including nail remains and joints, measuring large dimension, and relevant wood species. The last element is the most important in this research and will be pursued in the following chapter so that detailed species can be comparatively analysed with the data of the Quanzhou ship and Shinan shipwreck. For convenience refer to Appendix II, here the selected timber is listed in chronological order of discovery since 2000.

Ship timbers from 2000 rescue excavation

There are four timber remains (No.8, No.15, No.18, No.19) recovered during the 2000 rescue excavation (Takashima-cho Board of Education 2001). All timbers are considerably deteriorated mostly due to the attack of shipworms. Limited information can be recovered to assess the original configuration of the timber and their usage. Some timbers show evidence of nails. Notably, all timbers are identified as Chinese camphor which is the indigenous tree most commonly used in Chinese and Japanese shipbuilding (See Chapter VIII).

Ship timber from 2001 rescue excavation

A baulk of timber with two square mortises was recovered during the excavation in 2001. The timber labelled as KZK01 No.193 has been presented as a mast step in a previous study (Sasaki 2008: 101-105; Takashima-cho Board of Education 2008: 109-110). The description of this timber presented in Appendix II is based on these previous studies. It is noted that the timber is not chamfered like other known examples of mast steps.

Ship timbers from 2002 rescue excavation (KZK02 -)

A contentious excavation following the 2000 rescue excavation was conducted in 2002 and it was the final year of the rescue excavation associated with the development of Kozaki harbour. From the recovered artefacts, some timbers that can be defined as ship construction materials are listed (KZK02 - No. 221, 601, 909, 949, 1035, 1142, 1236, 1378, 1439, 1440, 1476, 1607, 1863). Four of these are the bulkhead planks previously mentioned in this chapter (No. 1236, 1439, 1440). Appendix II provides a description of the other important timbers probably used as a ship timber.

Ship timbers from 2003 (TKS13 -) and 2004 (TKS14)

The Asia Research Institute of Underwater Archaeology (ARIUA) has been conducting a series of test excavations since the late 1990s offshore of Kozaki harbour. Appendix II is a description of timbers that has been used possibly as a hull component, recovered during the 2003 (TKS13- No.8, 16, 17) and 2004 (TKS14- No.26) test excavations. The No.8 and No. 26 timbers could have been a part of the hull transverse components. The No. 16 and No.17 are the only timbers recovered from the site showing an example of the scarf joint.

VII-6 Characteristics of ship timbers from the Takashima underwater site

The fact that most ship timbers were found as separated pieces at the site defy the interpretation of the remains including the reconstruction of hull and their use as ship construction materials. However, some ship timbers such as the bulkhead planks still allow for some insights.

On the ends of the bulkhead planks, nail holes and a few concretions and corroded remains are found. The lack of nail remains on one end of the bulkhead plank (No. 1339) indicates a weak joint, which has resulted in the separation of the bulkhead from the hull forced by pulling the original nails out. If the ships were driven ashore in a storm, however, they would probably break up, according to an account of the loss of the fleet. That does not necessarily mean that the ships were not sturdily constructed enough. The corrosion remains of the original nails in the ends of the bulkhead planks barely evidence the original configuration of the nails, such as the extant of the square-cross section. It seems that relatively large nails are used for fastening the hull planking to the bulkhead. Nails are skewed from both sides of the seam with a half-lap joint. Around the seam of the bulkhead planks, a lot of corroded nails remain, indicating that a substantial number of the nails were originally driven. The tightness of the bulkhead planks having been fastened has been maintained.

The absence of structural reinforcements associated with other bulkheads including frames and brackets is implied. The remains of the bulkhead do not show evidence of fastening of brackets or frames to No. 1439 and No. 1440 planks. Brackets and frames were used to prevent the bulkheads from forward and aft movement and to secure the fastening of the hull planking and bulkheads. A few iron nail holes on the edge of the surface of the No. 1440 plank are indicative of something being attached. However, the distribution of these nails is not similar to those of the iron brackets of the Quanzhou ship or the wooden brackets of the Shinan shipwreck. The estimated original size of the nails from the holes is not suitable for fastening large frames to the bulkheads. The fastening of the hull planking and bulkheads appears to have been dependent on the large nails.

The two recesses of the No.1440 plank have possibly supported longitudinal timbers running from bow to stern at the deck level and the upper section. The section does not have a rabbeted seam that might have possibly supported a deck structure. It can be estimated that the original vertical location of the bulkhead planks is beneath either the lower or upper deck structure. It is noted that there is a suspicion as to whether Yuan Dynasty's Chinese ships had upper and lower decks. The example of such recesses in the bulkhead can be seen in structure of the Xiangshan Ming Dynasty shipwreck (See Chapter VI). The recesses are cut in some of the second bulkheads of this shipwreck, forming two square shapes. A part of two longitudinal baulks still remain, originally running through the hull. The size of the square recesses is slightly smaller than that of the No.1440 bulkhead plank. The difference of the recesses probably attributes to the proportions of the size of bulkhead planks of the Xiangshan Ming Dynasty shipwreck, which are smaller than the bulkhead planks discovered from the Takashima underwater site.

It is extremely hard to determine the original location — from which section of the hull they are derived — of these isolated bulkhead planks, that is, to determine if they have originally been located in the bow section, mid-section, and stern section of the hull. If the bulkhead planks are derived from the mid-section or its vicinity, the estimated beam of the hull is approximately 6.00 metres, according to the length of the upper section of the No.1440 plank. This is approximately half of the beam of the Quanzhou ship and the Shinan shipwreck. It should be noted that the ends of the bulkhead planks are slightly angled so that it is more likely that the bulkhead has been originally placed at the forward section or the aft section, yet how far from midship is not possible to say. Looking at the assembly of the bulkheads of the Quanzhou ship and the Shinan shipwreck, some of their upper bulkhead tiers consist of not one piece of timber but two pieces of timbers joined. Even if the bulkhead planks from the Takashima underwater site have been originally positioned around the forward or aft sections of the hull, it is likely that the dimensions of the hull are less than those of the Quanzhou Ship and the Shinan Shipwreck.

One of the features of the bulkhead planks from the site may be derived from the dimension of the hull, which is smaller than the hull of the Quanzhou ship and the Shinan shipwreck. Also they may be derived from the hull being constructed based on different construction principles. The estimation of the size of the ship associated to the bulkhead planks has been disputed among researchers. Taking into consideration the previous discovery of the large wooden anchors from the site, the involvement of a few large ships in the Yuan Dynasty’s fleet is presumed. In later periods’ iconographical resource, there is evidence that wooden anchors having about 6.00 metres length in their shanks have been used for oceangoing ships that originated from China. Needless to say, they are a different, later type of anchor, and their dimensional relationship between the hull and anchors is not directly applicable in assessing the hull and anchor in the late thirteenth century. During the excavation on account of the discovery of the bulkhead planks, an expectation of finding a keel rose. The shape of the bulkhead implied by No. 1439 and 1440 belongs to a vessel having plenty of deadrise. It is not from a flat-bottomed design.

Another distinctive feature regarding the bulkhead planks from those bulkheads of the above two ships is the configuration of the ends. The ends of the bulkhead planks of the Quanzhou ship and the Shinan shipwreck are cut likewise with steps to fit to the hull planking which has clinker seams. However, the ends of the No. 1439 and No. 1440 bulkhead planks show no such steps, which suggests carvel planking. The remains of the vessels from Ningbo, such as the Ningbo ship and Xiangshan Ming Dynasty shipwreck, demonstrate the combination of a sharp deadrise and no clinker steps. The bulkhead planks from the Takashima underwater site might have come from a ship like those ships identified in the Ningbo area.

Remains of the ship timbers are of a smaller size and are mostly fragments, presenting the destroyed state of the ships. Under the circumstance that the original configurations of the ships are hardly reconstructed, however, an effort to extract further information will be attempted. The fragmentary ship timbers reviewed in this chapter will be examined in the following chapter, focusing on the assemblage of wood species.

Meanwhile, from the limited information, it may be valid to say that there is an implication in many of the smaller ship timbers with iron nails that these might have been derived from smaller size ships or might be smaller parts of larger ships. The ships comprising the Yuan Dynasty’s Mongolian fleet originated from different parts of China including not only the southern coastal areas, but also the southern estuary and riverine areas such as Hanzhou Bay and Chang River. The diversity of the ship timber species is probably associated with their diverse origins. Moreover the distinctive structure and construction represented on the bulkhead planks of the Takashima underwater site, different from the bulkheads from the Quanzhou ship and the Shinan shipwreck, suggest the use of different shipbuilding principles.

Chapter VIII – Thematic studies on the excavated ships

In designing a wooden ship, one of the primary considerations is its sturdiness against external forces; this can be better understood by examination of the hull's configuration, dimensions, and sailing condition. The hull's sturdiness is also affected by local strength, such as the joints of the hull components. To understand the type of wood used for ships is another important consideration as it accounts for the allowable stress of the timber. The examination of these elements is significant in the study of excavated ships. This chapter will present the results from studies on the hull sturdiness of the Quanzhou ship and the Shinan shipwreck and conduct thematic studies on the data of ship nails and timbers from these two ships and ship timbers of the Takashima underwater site.

VIII-1 Hull sturdiness

Lines plan

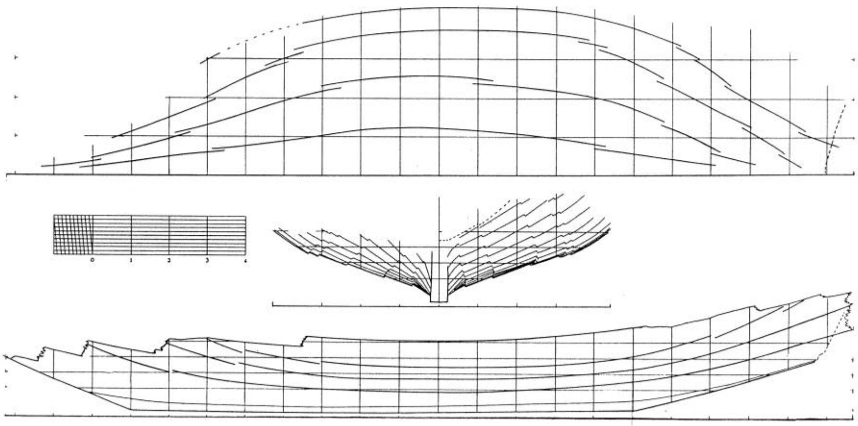

Figure 8-1 Ship lines of the Quanzhou ship. *From Burningham, N. and J. Green 1997, Courtesy of Western Australian Museum*

A detailed lines plan has been produced in the previous study of the Quanzhou ship (Figure 8-1) (Burningham and Green 1997). It is of use for the reconstruction of the original hull. For a similar purpose, this research has attempted to produce a lines plan of the Shinan shipwreck (Figure 8-2). As mentioned previously, the main keel of the Shinan shipwreck is hogged and it was concluded, by Korean researchers, that this was a deliberate design feature. The reconstructed lines plan, however, provides a different interpretation of suggesting that this is more likely to have been caused by natural forces.

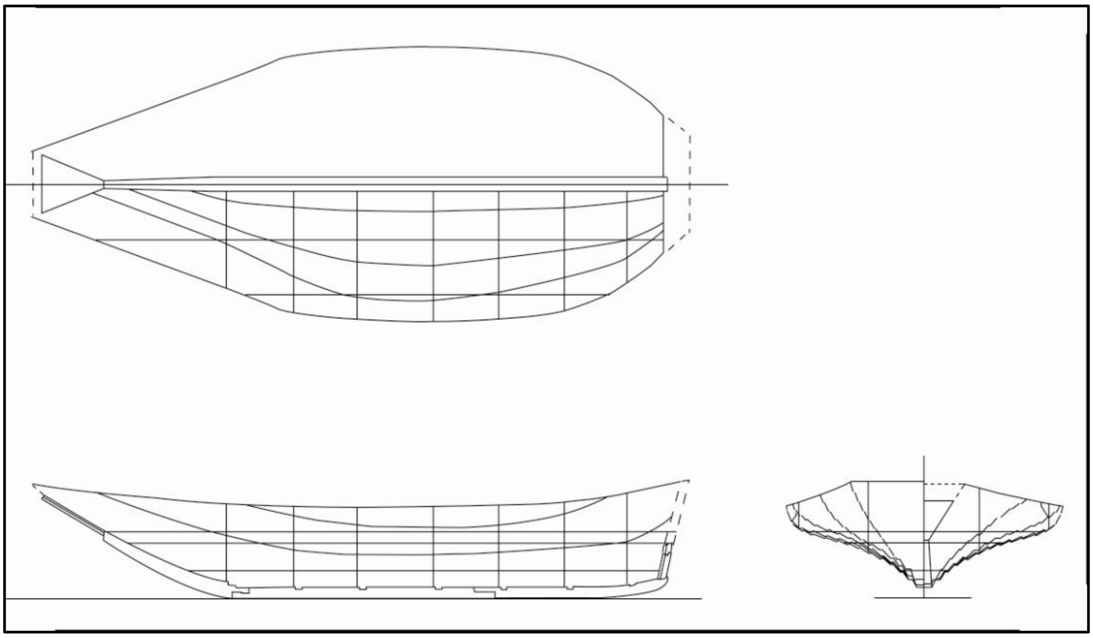

Figure 8-2 Ship lines of the Shinan shipwreck. *Produced by author*

Section drawings of all the seven bulkheads and a transom stern have been produced by staff of the National Research Institute of Marine Cultural Heritage (National Maritime Museum) in Korea, and they were used to reconstruct a body plan of the ship in this research. The bulkheads represent station lines in a reconstructed lines plan, as they are placed at relevant intervals necessary to represent the changing hull shape. Shapes of the station lines show clinker steps, as the sides of the bulkhead planks and the inner surface of the planking appear so. In the reconstructed hull lines, the cross sections of the hull show a sequence of smooth clinker shaped-lines from bow to stern.

The first body plan was produced by drawing station lines at different elevations along the curvature of the main keel; the body plan is based on the hypothesis that the hog of the keel was the original design. During this process, a problem appeared in the reconstructed lines where some clinker shaped lines are overlapped and do not show a smooth transition of the lines afore or abaft (Figure 8-3). This problem shows an improvement when drawing station lines by adjusting the elevation of the bottom plank along the main keel that has a straight shape (Figure 8-3). The reconstruction of the lines indicates that the original configuration of the main keel of the Shinan shipwreck was not bent and the hog appearing on the current keel is not likely to have been deliberate.

The reconstructed lines (Figure 8-2) may need further adjustment. The sheer plank shows an almost straight buttock line in the aft, and the consequence of the great bend of the line appears aft of the seventh station line. This is unlikely to happen as an original feature, unless there would be many frames to bend the planks around by applying a bulkhead first construction. That is; it is unusual that the hull planking runs straight between the six and seventh stations lines then takes a fairly sharp bend around the aft. Yet, this can be improved by hypothesizing the missing part of the stern transom with a much wider shape. If the buttock lines and the waterlines are drawn, continuing almost straight aft of the transom, the shape of the wider stern transom fits the straight line. Alternatively, if the aft part of the keel was angled upwards a little, so that the buttock lines do not have to run such dead straight. The buttock line with a smooth curve may be seen as a more likely reconstruction of the shape of the original Shinan ship, while whether the aft keel originally had a more upward angle than the current state is still open to question.

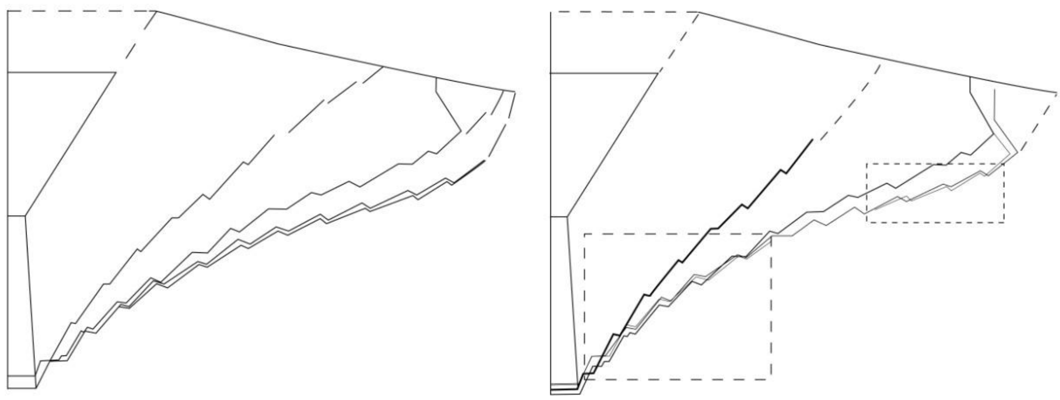

Figure 8-3 Modified buttock lines (*left image*) and non-modified buttock lines (*right image*) which does not show smooth transition of the lines. *Produced by author*

Longitudinal structure

Strain on the hull is considered by taking into account a few factors including bending moment, shearing forces, weight, and buoyancy (Biles 1908). The strain that causes longitudinal bending becomes more problematic in constructing lager wooden ships for oceangoing, such as the Shinan shipwreck. Under the circumstances, longitudinal strength of the hull becomes more important in constructing these ships. The longitudinal strength takes into consideration two stresses: bending moment and shearing forces. Longitudinal bending occurs when the ship is in the trough between two waves or on the crest of a wave and the stress substantially impacts on the keel. The distortion of the hull by shearing forces is another problem related to the longitudinal strength of the hull. Considering shearing forces, not only the keel but also the strength of the planking is considered to be important for longitudinal supports.

Two excavated ships, the Quanzhou ship and the Shinan shipwreck, have layered hull planking. Each strake of both inner and outer hull planks could have provided longitudinal support against the hull distortion by shearing forces. The hull planking of the Quanzhou ship, however, could have been more efficient against bending distortions that would have placed stress on each strake. This is related to the innovation of the strakes' joint combined by the rabbeted carvel- and clinker-seams. The combination adjusts the outer planks to overlay both the carvel- and clinker-seams of the inner planks, and this makes the assemblage of the inner and outer planks firm together as one. The tightly assembled inner and outer planks form a plank-shell, which provides longitudinal strength to the hull.

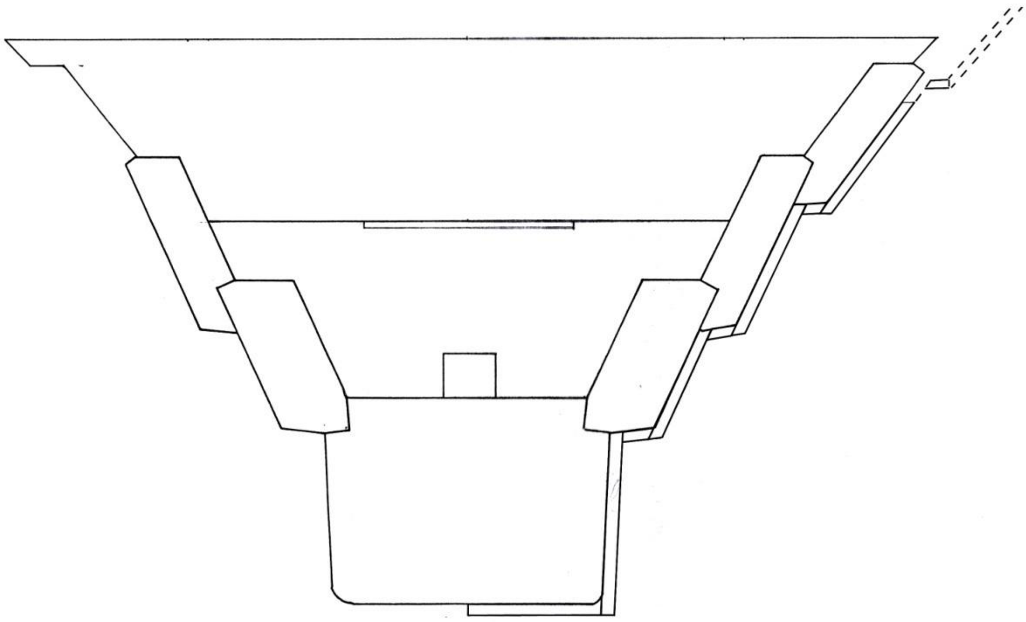

Figure 8-4 Reconstruction of the arrangement of the sheathing planks. *Courtesy of National Maritime Museum of Korea*

The double planking of the Shinan shipwreck might not have been as sturdy as that of the Quanzhou ship in terms of contribution to the longitudinal structural support. The hull planking is edge-jointed with rabbeted clinker seams (except for a part of the bow). The clinker seams appear in each joint of the stake. The outer planks had covered all the parts of the inner planks. As the outer planks have not been restored, the detailed assemblage of the outer planks is unascertained in terms of a method how they had overlayed the inner planks and whether they could have efficiently protected the seams of the inner planks. The rabbeted clinker seam appears in each seam of the hull planking of the Shinan ship. Figure 8-4 is a reconstructed image of the original assembly of the inner and outer plank, according to a Korean explanation (C. Lee, pers. comm. 2010). Figure 8-4 shows that the seams of the inner planks are not necessarily covered by the outer planks; the outer planks are not intended to secure the seams of the inner planks and thus contribute to their tight joins. Primarily, the purpose was to protect the inner planking from marine borers rather than to increase longitudinal strength. The stresses from bending moments and shearing forces could be greater in the hull of the Shinan shipwreck. By way of comparison, the outer planks of the Quanzhou ship have consistent width, and are considered to function as a plank-shell.

- Use of chunam

The use of putty (known as chunam) might have contributed to increase longitudinal strength through a layered plank-shell which requires the inner planking to be firmly secured by the outer planks. The hull planking used putty to protect the planks from damage by marine organisms. The putty appears to have been used for a single layer of planking as well as multiple layered planking. As an example of the former case, the use of putty is reported in the hull of the Goryeo Period's Korean ships that have been constructed by a single planking with rabbeted seams (National Maritime Museum of Korea 2006c). In the previous study, a sample of the lime that coats the planking of the Quanzhou ship was analysed. According to its result, "the lipid content was so low (0.00113 mg per gram) as to suggest that the lime may have been applied as an aqueous slurry rather than an oil based putty" (Burningham and Green 1997: 46).

Apart from several iron nails that fix the outer planks into the inner planks, an adhesive substance might have helped to assemble the planks into a hull plank-shell. The putty was used for caulking the hull planks' seams, and in the hull planking of the Shinan shipwreck a similar white substance was also plastered between the inner and outer planks. In the latter case, the purpose of using putty may relate to the increase of the joint of the double planking layers. It might be better that putty known as chunam would have adhesive properties, as cited from Marco Polo's record in the thirteenth century in the description of chunam by Worcester (Worcester 1971: 35-36). "…, they take some lime and chopped hemp, and these they knead together with a certain wood oil; and when the three are thoroughly amalgamated, they hold like any glue" (*Travels of Marco Polo* quoted in Worcester 1971: 35). The detailed analysis on chunam could not be conducted during this research. There is a need to conduct further study on the different uses of the chunam in the development of multiple layered-planking, apart from caulking the planks' seams and luting the surface of the outer planking.

The development of the use of putty as a sheathing method has not been thematically studied, as its use has been discussed in the context of sealing iron nails and caulking the seam of the planks. A question arises whether the techniques for sheathing co-existed, developed and came to be accepted in relation to the increase of the single planking. Some methods of planking used on the Quanzhou ship and the Shinan ship disappear in the later periods, including the rabbeted seams and heavily multiple-layered planks. Yet, the use of putty appears to be a technique that was still used in the later East Asian shipbuilding tradition.

Transverse structure

Longitudinal and transverse components are interdependent structure and synergistically contribution to the hull strength. Bulkheads appear to have contributed indirectly to longitudinal hull strength, for example, by supporting longitudinal baulks. Bulkhead planks from the Takashima underwater site have two square recesses that could receive baulks. The similar structure refers to bulkheads of the Ming Dynasty (1368-1644 A.D.) Xiangshan ship that support baulks longitudinally run through the inside of the hull from the second to the twelfth bulkheads. Either the bottom or bottom second planks of each bulkhead have two square recesses horizontally at the same elevation in order to receive the baulks. Chinese researchers conclude that the role of the baulks was to support lower decks in the hull (Xi, Yang et al. 2004). While it is not ascertained whether they were part of deck structure due to the loss of the original deck structure, the baulks could have contributed to the longitudinal hull strength.

The bulkheads' planks could be sufficiently sturdy against the distortion of the hull cross section. The excavated ships indicate that their bulkheads were probably sturdy enough to support the longitudinal and transverse strength of the hull, fixed firmly by using bulkhead brackets (iron brackets in the Quanzhou ship and wooden brackets in the Shinan shipwreck) and frames. The joint of the bulkhead planks appears to be strong enough against the pressure of seawater in a flooded hold. While this is a part of the intention of the bulkhead structure is open to discussion, there is a feature that the bulkheads of the Shinan shipwreck used vegetable fibre for caulking the seams of their planks. This watertightness is for securing the hold locally and protecting cargo from getting wet. Water leaking was probably an unpreventable problem. The watertight bulkheads of the excavated ships were not rigidly full-watertight compartments, rather their watertightness prevented hold and cargo from becoming waterlogged.

The distribution of bulkheads prevents distortion of the cross-section. In particular, racking (rolling) of the hull may cause the deformation of the transverse section. A gale and waves cause inclination of the ship and create substantial external forces to generate on one side of the hull. The force would affect the entire section, resulting in distortion of the hull. Appropriate distribution of transverse components with their tight fastening can contribute to the reduction of force repercussion. Therefore, to consider bulkheads' spacing is significant in relation to securing sufficient transverse strength in the entire hull. By looking at the excavated ships, however, there is uncertainty as to how seriously the issue was addressed in their construction. The number of bulkheads used in the hull shows a substantial difference between the Quanzhou ship and Shinan shipwreck; the former consists of twelve bulkheads; the latter consists of seven bulkheads. The difference does not relate to the limits of the proportions of the keel which provides distribution space to place the bulkheads, as the total length of the main and aft keel, where most of the bulkheads sit, shows only an approximate 2.00 metres of difference between the two ships. This is not regarded as an element affecting the difference of the bulkhead spacing. It may be valid to say that the wide spacing of the bulkheads of the Shinan shipwreck is a distinctive feature. For example, a pattern of the bulkheads spacing of the Huaguang Reef No.1 Shipwreck appears to be as narrow as that of the Quanzhou ship. There are eleven bulkheads in the remaining part of the hull that measures approximately 17.00 metres in length. Comparatively, less bulkheads of the Shinan shipwreck might have weaker transverse strength. The longitudinal and transverse structures are correlative in determining the entire hull sturdiness. It is important, as the two components synergistically contribute to hull strength.

VIII-2 Ship nails

China had a long term involvement in iron manufacture, producing various types of iron. Iron is the most important metal used in East Asian shipbuilding technology. The use of iron nails characterizes East Asian shipbuilding tradition, distinguished from Southeast Asian shipbuilding technology (Manguin 1993). The dataset of excavated ships in China presented in Chapter IV indicates that by the Tang Dynasty, Chinese understood the use of carbon in manufacturing of high quality iron which enabled them to produce specific types of iron products suitable for ship construction. The use of iron fastenings is as an important factor as that of bulkheads to characterize Chinese shipbuilding technologies. The detailed study on iron fastenings is relevant to deep understanding of the representative hull components in the region.

The production of iron in China affected the development of iron manufacturing in Korea and Japan and showed progress during the tenth to twelfth centuries (Hartwell 1962; Hartwell 1966; Wagner 1995). An innovative period allowed the Chinese to produce massive amounts of iron. According to Hartwell (1962: 154), "[d]uring the eleventh century, both the technological development and the quantitative expansion of the Chinese iron industry, as well as other metallic and non-metallic industries was comparable to that during an early industrial revolution of England."

This section examines the quality of iron nails used for the Quanzhou ship, the Shinan shipwreck, and ship remains from the Takashima underwater site. For this purpose, the physical structure of iron by a metallurgical approach is attempted. The condition of the remaining iron nails at three different ships is not sufficient fully to understand the structure and components of the metal due to their degradation. However, this research attempts to assess the characteristics of iron that were used for ship nails at the time.

Iron nails used in ancient ships

The development of using iron nails in shipbuilding dates back at least to the Roman Empire period in the Mediterranean. The advent of iron being used in shipbuilding, however, lagged behind that of copper in this region. Passing through the stage of using copper and copper products early, wrought iron began to be used for fastenings for ship construction. The distribution of the technology was coincident to the expansion of the Romanized world. For implications regarding the early use of iron for shipbuilding, as archaeological site of the first century Roman period in Bavaria that evidences a nail-heading anvil and the innovation of the finery process in the fourth century by an indirect iron production method to produce wrought iron by refining cast iron (McCarthy 2005). Evidence for the use of iron nails during the Classical period has been found on a few shipwrecks identified in the Mediterranean (Steffy 1994; Kabanov and Pomey 2004; Duivenvoorde 2005; Beltrame and Gaddi 2007).

Iron productions in early China

Iron manufacturing in early China probably began with the production of cast iron. Cast iron is generally hard but brittle. Its quality is determined by the amount of carbon and silica and the cooling rate which it undergoes. Iron production methods vary even in the past, depending on the qualities people aim at producing. Two distinctive methods are: an indirect iron production method by smelting iron ore with high temperature reduction and processing obtained pig iron for decarbonisation, and a direct iron production method by low temperature reduction with the adjustment of the amount of carbon by using forge and furnace technologies. These methods spread widely in East Asia, originated from Chinese iron industries that could have produced different qualities of iron material chronologically at the different stages. The four methods of iron production in early China are summarised in Table 8-1, according to Osawa's study on ancient iron products in East Asia (2004). The methods producing different iron materials first developed in mainland China impacted later on iron production in Japan and Korea. Later, each region showed endemic features and differences in its technological innovations in iron manufacturing (Osawa 2004).

Sponge iron (by a direct iron production method of low temperature reduction):
The technology appears to have been developed around the ninth century B.C., and is the oldest iron production method. The technology is distinguished from the below three technologies in that it was produced by the direct iron production method of low temperature reduction at 700 degrees. Metallography structure contains non-metallic inclusions consisting of oxidised iron (FeO) and olivine ($2FeO\ SiO_2$) and shows large coarse ferrite.
Malleable cast iron:
The technology appears to have been developed probably by the fifth century B.C. in China. The material was manufactured by annealing white cast iron for decarbonisation with the temperature of 900-950 degrees. The metallography structure contains non-metallic inclusions consisting of iron sulphides (FeS) or manganese sulphides (MnS) with grains of 5-10μm and shows graphite grains with porosity from decarbonisation, and ferrite and pearlite.
Iron casting decarbonised steel:
The technology appears to have been developed probably by the third century B.C. in China. The material was manufactured by smelting pig iron and leading it into square moulds with temperatures about 1,000 degrees with contacting air. After solidifying, it is annealed further and decarbonisation process occurs. The metallography structure contains non-metallic inclusions consisting of iron sulphides (FeS) or manganese sulphides (MnS) with grains of 5-10μm and shows ferrite and pearlite in some cases with porosity from the decarbonisation process.
Paddling steel (Wrought iron):
The technology appears to have been developed probably by the first century B.C. in China. The material was manufactured by smelting pig irons in the furnace, and it was paddled to contact oxygen in the air for decarbonisation and further hammered to exclude contaminations. The metallography structure contains non-metallic inclusions consisting of silicate (Si, Al, Ca, Mg, K, Na) with 20μm and shows fine-grain ferrite.

Table 8-1 Iron production methods developed in early China. *From Osawa 2004*

Iron industries during the periods between the Song and Yuan Dynasties

During the Song Dynasty (960-1279 A.D.), many larger furnaces started to be used in the existent iron production industries that were already using shaft furnaces (blast furnaces), which could have reached a height of over 6.00 metres (Wagner 2001). The structure of the larger furnaces had originated from a kiln, and they allowed the production of pig iron. In the furnaces for smelting iron ore, the usage of coal was an essential factor and probably dated back to the period of the Northern Song Dynasty (960-1127 A.D.). According to Hartwell's historical study (1962), innovations of brick and tile production industries started to replace woods with mineral fuels for the furnaces during the period. In the following centuries, a method of firing coals in forges and furnaces became common. Along with these innovations, blast furnaces came to be used in iron industries in northern part of China (Hartwell 1962). In Chinese history, a socio-economy shows maturity, in particular, throughout the Song Dynasty. During the period various industries grew, demanding a larger amount of iron. For example, during the twelfth century copper coins were most commonly used in the monetary system, but iron was technically still necessary in the copper metallurgy. According to Hartwell (1962: 156),

> *Shortly after the move of the Sung capital south, 1400 tons of iron were consumed annually in the hydrometallurgical process for removing copper from mine waters-a technique which involved the boiling of copper sulphate solution in contact with iron, the iron displacing the copper from its salt*.

North China around the current Hebei Province and areas toward the middle of China around Shandong Province and the northern part of Jiangsu Province were focal areas of iron productions. It has been pointed out that many furnaces were established in some of these areas based on archaeological evidence (Wagner 2001). The massive iron productions in further north China during the twelfth and thirteenth centuries has been studied (Sasada 2009).

It is arguable whether the iron industries in the southern parts of China were as productive as that of the northern parts. There appears to have been some forging industries in the cities of Zhejiang Province, such as Mingzhou (Ningbo) and a few iron industries in Fujian Province. Despite the demand for iron for military purposes in Jiangsu and Zhejiang Provinces, iron industries in these regions could not supply sufficient amounts. While those southern iron industries might have been dominant suppliers, it appears that there was room for them to grow as the consistent local suppliers in the south. Iron yielded from the Fujian Province and further south in an area previously known as Guangnan was traded in the markets of Jiangsu and

Zhejiang Provinces as these areas did not yield iron (Shiba 1968: 300-301). Besides iron, iron products could also have been shipped from the south to these areas (Shiba 1968: 301). Shiba (1968: 301) pointed out that a number of districts in Quanzhou in the Fujian Province were engaged in iron production, relying on manufacturing iron sand, and their iron products were sold in the Jiangsu and Zhejiang Provinces. During the Yuan Dynasty (1271-1368 A.D.), the iron trading network of Fujian and Guangnan expanded to the South China Sea. A few iron products including iron pots and needles from Quanzhou appeared on the list of trading commodities for Cambodia (Zhenla), evidenced in the *Zhenla feng tu ji* (Customs of Cambodia 真臘風土記) (Shiba 1968: 302).

Iron nail production

A historical text describes the involvement of the Song Dynasty's iron industries in shipbuilding. Hartwell (1962: 161) refers to a Song Dynasty's record from the eighteenth century's Chinese historiography, *Xu Zizhi Tongjian Changbian* (Long article of Comprehensive Mirror to Aid in Government 續資治通鑑長編) which says, "shipbuilding at Shan-chou (*sic* Cangzhou), in southern Hopei (*sic* Hebei) along the banks of the Pei River, required supplies of iron and coal". This citation does not clarify the purpose for iron to be used, yet shipbuilding industries in Hebei coincided with iron industries in a relationship of consumer and supplier. From the account of another citation from *Song hui yao ji kao* (Draft re-compilation of the important documents of the Song 宋會要輯稿), "[l]ike the salt works, shipyards often had iron mines and smelters directly attached to them" (Hartwell 1962: 159). Additionally, it is said, "[d]uring the later years of the Northern Sung, these foundries supplied not only anchors and nails, but also iron prows[*sic*] and other armor." (Hartwell 1962: 159). An example that iron forging workshops were placed within the shipyards is evidenced in the Ming Dynasty's shipyard in Nanjing (Church 2010).

The importance of discussing how iron industries were intensively linked with shipbuilding industries is to understand the availability of nails. In terms of the larger perspective, there is a need to consider the impact of the Song Dynasty's development of iron industries on the changing shipbuilding tradition in the southern regions. It is implied that in the areas further south of Quanzhou iron industries might have had less influence, according to a description appearing on the *Lingwai Daida* (Answers to the question about the areas beyond our territory 嶺外代答). This Song Dynasty's historical text mentions that iron nails and tung oil were not easily available in Guangdong where sewn ships had been dominantly used:

"They always used hollow planks leashed with ratten," and dried madder stalks were used to calk the seams (trans Merwin 1977, Lingwais Daida, vol.6, Teng chuan).

造船皆空板穿藤約束而成. 於藤縫中, 以海上所生茜草,…(嶺外代答, 巻 6 藤舟)

With regard to the sewn ship without using iron nails in shipbuilding in Guangdong in southern China, Chinese researchers consider the technologies in south might have lagged behind north- and mid-China (Merwin 1977: 75-76). However, the text continually mentions the excellence of the seaworthiness of the sewn ships with the tight caulking system. The size of these ships appears to have been quite large and people seem to have preferred these ships in the South China Sea. A "tradition" of constructing large ships without iron materials could still be contradicting to the adoption of iron nails in many regions in the Song Dynasty.

Metallurgical approach

The following section highlights details of iron nail remains from the sites: Quanzhou ship, Shinan shipwreck, Takashima underwater site. Most of the iron nails have hardly remained intact and has caused a loss of information necessary for metallographic analysis. A general understanding of corrosion on iron nails follows.

The shaft of an iron nails that has been embedded continues to corrode. This is distinctive from the corrosion process of the nail head which has more contact with oxygen (Huisman 2009). The reduction of oxygen or sulphate occurs along the entire nail as the iron oxidises first. As a film forms over the nail head, further corrosion ceases with reduction of oxygen where iron dissolving becomes less likely. However, this reaction does not occur in the shaft of the nail covered by wood where oxidation of iron continues to occur (Huisman 2009: 102-103). From the remains of the corroded nail, it is extremely difficult to determine the original components. Completely corroded iron objects comprised only of oxidized products and the remains of carbon, iron carbide and slag inclusions (Huisman 2009: 103). Neither a metallurgical approach looking at microstructure nor the analysis of chemical composition is possible on the fully-corroded iron. However, the degree of the corrosion varies, depending on the environments, the site formation processes, post site formation processes including burial processes, and the site excavation and recovery that occurred at each site.

Metallography generally aims at clarifying characteristics of the iron to determine a). Raw material of the iron which has been made of ore or sand; b). Iron production methods: indirect iron production method of high temperature reduction or direct iron production method of low temperature reduction; c). Refinement methods: (annealing, hardening, decarbonisation, carbonisation). The above information will lead to a better understanding about the origin and manufacturing processes of the iron products. Further analysis as to metallurgical approach focuses on non-metal impurities that remained in the iron products. These include oxidised iron, manganese, silicon, and phosphorus, sulphide, and silicate which further determines the characteristics of the iron productions. While in many cases the degree of degradation of the iron is irrelevant to the practice of metallurgical approach, perspectives about the original manufacturing process and use of iron nails will be based on multiple sources of data.

Iron nails for shipbuilding evidenced in East Asian ship remains

- Quanzhou ship

The investigation in 2009 that used a magnet could not identify magnetic reaction on the hull (See Chapter V). It was presumed that the metal of the nails were already missing. Besides, during the investigation, the staff of the Museum informed that the original iron nails did not remain in the hull. The original nails dismantled from the hull were displayed in the exhibition room and they have since degraded. Few studies are useful to acquire information about original configuration of the nails (Xu 1985; Li 2004). According to Li (2004), when modern metal nails were used to replace the degraded nails, only two different types of iron nails were used. Their size follows the original in length: the smaller measures about 150 millimetres, the lager measures about 200–220 millimetres. For the assessment of the original nails, black and white photographs of the nails dismantled from the hull are helpful (Figure 8-5). On the photographs, there are two less degraded nails showing a tapered configuration and they have flat nail heads. The photographs do not show a scale, so it is difficult to determine their dimension.

Figure 8-5 Photograph of the degraded iron nails from the Quanzhou ship. *Courtesy of Museum of Overseas Communication History*

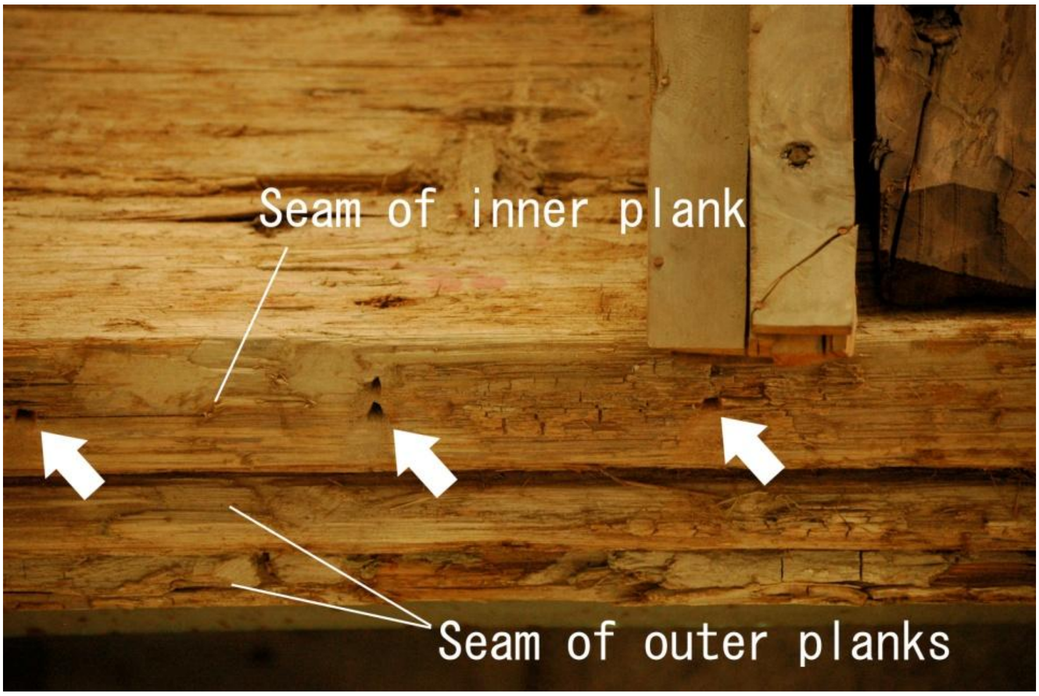

Figure8-6 Photograph of the exposed seams of the uppermost planks of the Quanzhou ship, showing location of nail holes. *Photo by author*

A metallurgical approach could not be conducted to determine the quality of the iron remains on the Quanzhou ship in this research. In the study on nails used for this ship, an examination has been limited to information from what has been observed in the current hull. As mentioned previously (See Chapter V), the uppermost plank remains expose the seam of the hull planks where corroded nails and nail holes are identified. It is noted that most of the nail holes are single square holes but there are some double holes aligned together (Figure 8-6). The reason for the double holes has not been clarified. The configuration of the tapered end of the original nail is observed on the end of Bulkhead No. 8, while the iron of the nail itself has been completely lost already, and a corrosive layer barely forms the configuration of the shaft. From limited information, it is concluded that with regard to general configuration of the nails of the Quanzhou ship, its shaft has a square cross section and its taper is likely to occur only around the end.

- Shinan shipwreck

The detailed study of the iron nails of the Shinan shipwreck has not been conducted previously. Under agreement with the museum staff, a further examination was attempted to identify magnetic remains in the nail remains during the investigation in 2009. Magnetic remains were barely identified in a part of the hull plank of the shipwreck by using magnets. As a result of the sign of the possible extant of magnetic remains in three ship timbers that include a portion of the hull plank (SW-82-182), a sheathing plank (sacrificial plank), and a butt plate, it was necessary to determine further whether this is signs to contain iron remains and whether it could be used for metallurgical approach.

X-ray and CT-scan analyses are a non-destructive approach to reveal the nails' position and driven patterns that cannot be visible from outside. They were conducted to determine the quality of iron remains. All these samples are separated timbers that had not been restored. From the analysis, the quality of the corroded nails seems to vary. X-ray and CT-scan images present fully-corroded iron remains that are shown as a black hollow image with an only thin magnetite layer that indicates the original surface. Some nail remains show white blur images, which suggest possible mineral remains inside the nail. With regard to the white blur images, it is difficult to determine the detailed corrosion status by just looking at the x-ray and CT scan images.

Hull plank (SW-82-182):

This timber is a portion of a hull plank from the Shinan shipwreck (Figure 8-7). The dimensions of the remaining part measures 105 millimetres thick, 395 millimetres width and 1.02 metres long. The original placement of SW-82-182 is yet to be determined clearly. The rabbet, however, appears to be cut at only one seam that likely joins to the lower plank (Figure 8-7). Most parts of the hull planking of the Shinan shipwreck are rabbeted clinker construction, except for the planking in the bow, forward of the first bulkhead shows gradual changes from clinker to carvel. The feature identified with the plank (the rabbet cuts at only one seam) must have been used in the clinker-built part. The pattern indicates that the plank was located at the portside. The plank seam exposes a cross-section of the corroded nail, so that it was expected that a few corroded nails were driven from outside of the rabbeted seam prior to x-ray and CT-scan analyses (Figure 8-8). The x-ray and CT-scan images show that broken remains of four nail shafts are diagonally driven at the rabbeted seam (Figures 8-9 and Figure 8-10). The interval of the four nail shafts shows slight irregularity. Two spaces between three of the nails measure 250 millimetres. The other two nails were very narrowly spaced at about 80 millimetres. Nail length ranges from 95 to 145 millimetres. The nail shaft is slightly skewed and tapered (as seen in the CT-scan image Figure 8-10). The configuration of the nail shaft remaining at this seam evidences that original nails were skewed nails. From the remains of the nail shafts at both the upper and the lower seams, the original length was at least 250 millimetres but is less likely to have exceeded 300 millimetres. The cross-section of these nails measures a square 20 millimetres on each side and the section of one of the nails is exposed on the broken part of the lateral of the plank. From the analyses, the quality of each iron remain seems to be different. The x-ray and CT-scan images present a fully-corroded iron remain that is shown as a black hollow image with a only thin magnetite layer that indicates the presence of the original surface. Some nail remains show white blur images, which suggest possible mineral remains or slugs inside the nail. With regard to the white blur images, it is difficult to determine the detailed corrosion status by just looking at the x-ray and CT scan images.

Figure 8-7 Piece of the hull plank SW-82-182 from the Shinan shipwreck, showing its rabbeted seam. *Photo by author*

Figure 8-8 Cross-section of the nail remaining in the exposed seam. *Photo by author*

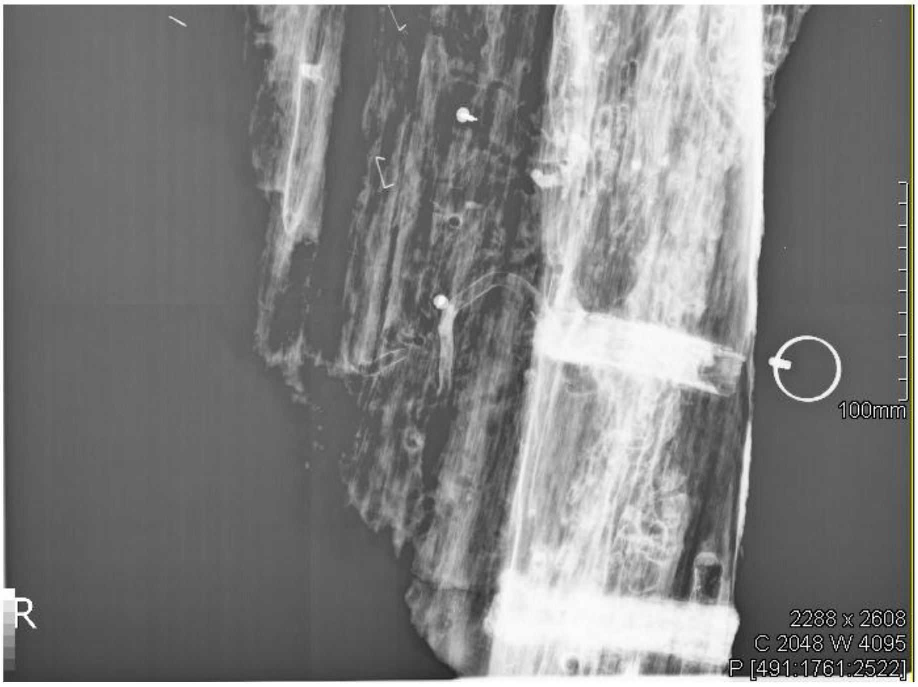

Figure 8-9 X-ray image showing remains of the nail. *Courtesy of National Maritime Museum of Korea*

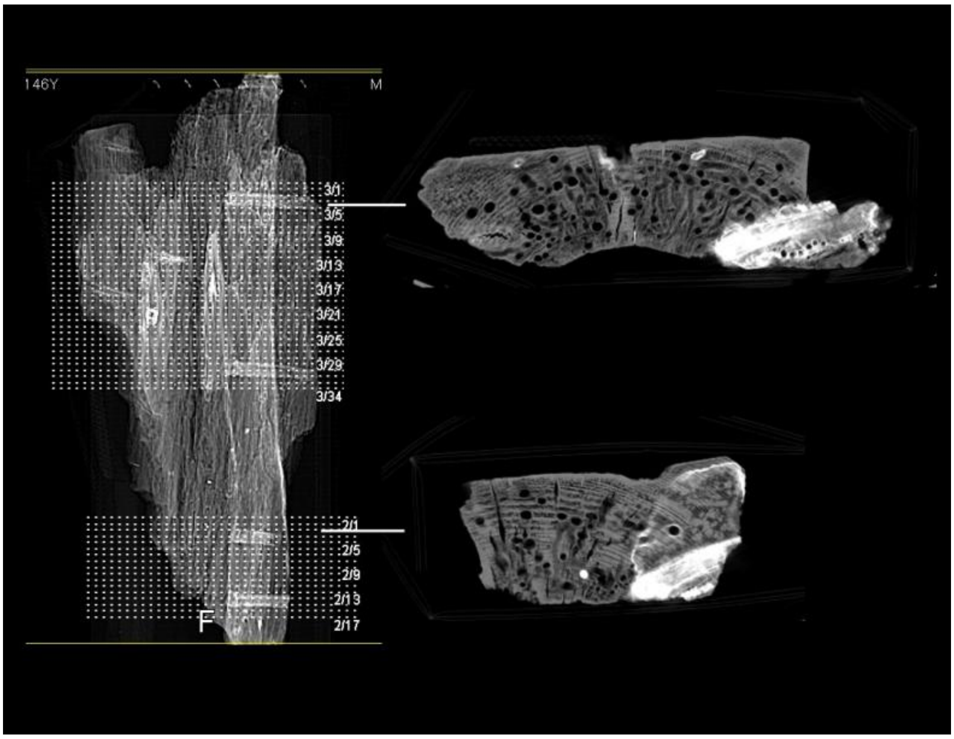

Figure 8-10 CT-scan image showing remains of the nail. *Courtesy of National Maritime Museum of Korea*

Sheathing plank:

The timber is a broken piece of the sheathing planks that were covering the outer hull planking (Figure 8-11). It is difficult to identify the original length of the plank, but the remaining part measures 790 millimetres in length. The original configuration remains with a width of 225 millimetres and a thickness of 35 millimetres. X-ray and CT-scan images reveal the porous inside of the plank damaged by shipworms and the remains of five corroded iron shafts (Figure 8-12). The original nails have been perpendicularly penetrated through the plank to be attached. Considering the thickness of the main hull planks measuring about 120 millimetres on average, the original length of the nail to fasten the sheathing planks onto them could reach 100 millimetres, but not exceed 150 millimetres. The section of the nails measures about a square 15 millimetres, which indicates that the smaller size of nails was used for fastening the sheathing planks than for the main hull planking. The CT-scan image of the cross section of the plank barely evidences that one of the nail shafts might have a flat nail head measuring 22 millimetres. The remains of iron nails observed on the surface looks to be a better condition.

Figure 8-11 Photograph of the sheathing plank used as a specimen for CT-scan. *Courtesy of National Maritime Museum of Korea*

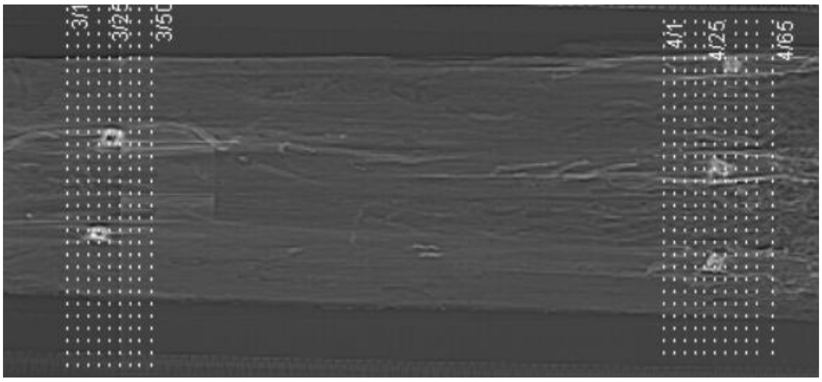

Figure 8-12 CT-scan image of the sheathing plank showing the evidence of the use of five nails. *Courtesy of National Maritime Museum of Korea*

Butt plate:

Large butt plates to clamp the longitudinal joint of the hull planks are fastened by iron nails. A separated piece of one of the butt plates was examined (Figure 8-13). The original location of the butt plate has not been identified. The butt plates preserve the original configuration to form an indeterminate square measuring 664 millimetres in length, 480 millimetres in width, and 83 millimetres in thickness. X-ray and CT-scan images reveal that originally a total of ten iron nails were used to fix the butt plate onto the inner hull planking. There are two sets of aligned nail holes with three iron nails and one set of aligned nail holes with four iron nails and one extra nail is driven between those two sets of three aligned nails. Most of the nails have hardly remained and only a few corroded nail shafts are visible on the images where corrosion products exude out of the wood, and the loss of iron occurs. All original iron must have penetrated the plate to be attached onto the inner hull planks in which the length of the original nail should not greatly exceed the total thickness of the butt plate and the hull plank. The length of the original nail is estimated to about 160 millimetres. The cross section of the nail measures 15–17 millimetres. It is implied that the nail used for fixing the butt plate was not a skewed nail.

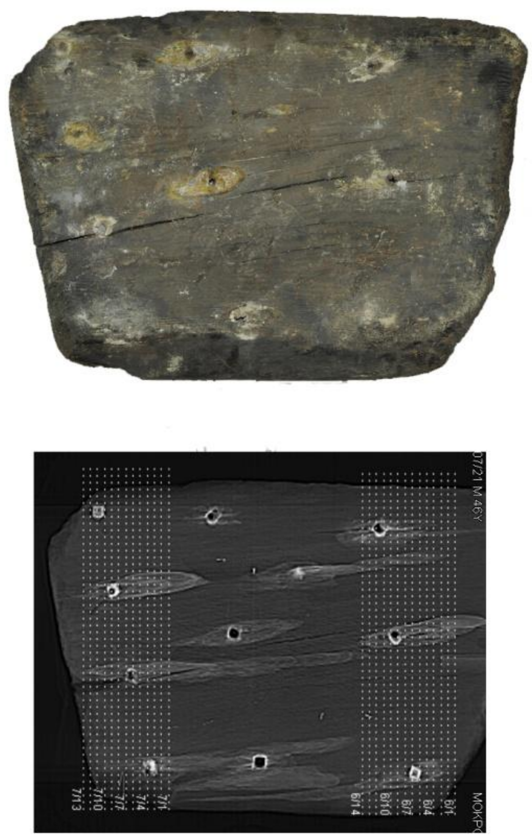

Figure 8-13 Photo image and CT-scan image of the batt plate. *Courtesy of National Maritime Museum of Korea*

Figure 8-14 Specimen cut from the hull plank SW-82-182. *Photo by author*

A specimen of the timber was cut from the hull plank (SW-82-182) for metallurgical study (Figure 8-14). It was provided to the Kyushu Techno Research. Inc. The specimen was further cut to expose sections of the nail and the sections of the microscopic images were produced (Figure 8-15). The microscopically observed structure shows that iron has been fully oxidised and the nail does not contain metal structures. According to Osawa Masami in the Kyushu Techno Research Inc (M. Osawa pers. comm. 2009), the corrosion status of the nail is hydrated iron oxide (goethite: Fe2O3/H2O). The substantial oxidization caused the loss of the metal structure, which restricted the ability to obtain metallurgical information. However, an interpretation how the original nails had been manufactured was attempted based on the minimal information that can be seen in the microscopic images. An as-cast dendritic structure is observed in a part of the image if the product was annealed under charcoal or coke, the atmosphere low O2 is reducing, so instead of red-brown rust, a deep patina of jet-black Fe3O4 magnetite forms in corrosion process (I. Macleod pers. comm.. 2010). While the as-cast dendritic structure indicates the significance of casting procedures in manufacturing, the structure of wrought iron, appears as circular distribution of inclusions. This indicates original working patterns of folded and reforged method, perhaps, by hammering. Iron is a mixture of as-cast dendritic structure and the structure of wrought iron, which represents that the heat working has changed. This results in the section of the nail showing typical inter-granular corrosion.

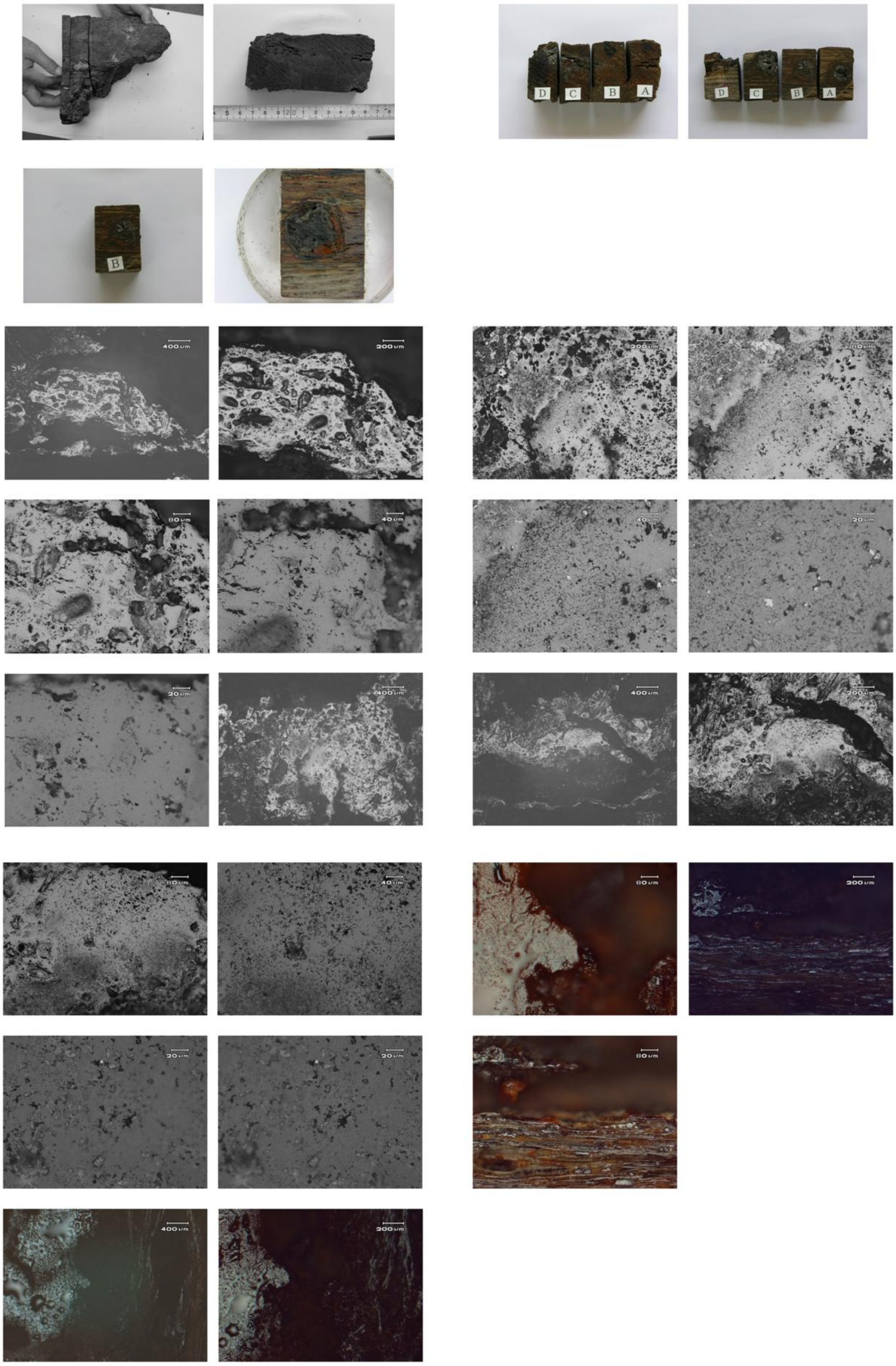

Figure 8-15 Exposed sections of the degraded nail remaining in the specimen and its microscopic images. *Courtesy of Kyushu Techno Research. Inc*

Takashima underwater site

Metallurgical analysis has previously been conducted on corrosion remains of iron nails that probably originated from the Mongolian fleet and the results are available in the site report (Osawa 2005a). Two corrosion remains recovered during the 2002 excavation season were selected for analysis (Takashima-cho Board of Education 2005). One specimen is from one of three iron nails from a disarticulated timber (No.1357) and another specimen is one of the separated nails from bulkhead plank No. 1440 (Figure 8-16). Based on the Osawa's report (Osawa 2005a), the result of inspection on the physical structure of the remains shown in the microscopic image is summarized in Table 8-2.

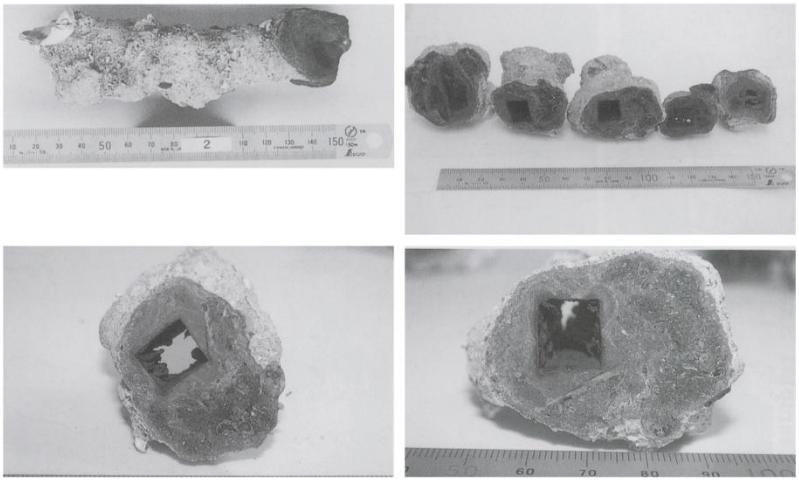

Figure 8-16 Degraded nail from the bulkhead plank No. 1440. *From Takashima-cho Board of Education 2005*

Iron nail (No.1357)	Ferrite barely remains, forming a columnar structure. This structure probably resulted from moulding processes: the increase of cooling rate at the original surface of the nail occurred when molten cast irons were moulded. As solidification processes, abrupt thermal conduction arising from the molten to the mould generated extreme temperature gradient where crystal was formed rapidly from surface to inside. As a result, distribution of multi crystals forms coarse columns.
Iron nail (No. 1440)	Due to substantial oxidative corrosion, ferrite does not remain. However, the cross section shows a square shape in the original surface, indicative of using the same production method as the above sample.

Table 8-2 Description of the iron nails of the bulkhead planks from the perspective of their metallurgical study perspective. *From Osawa 2005a*

The two nails have fully degraded. Thin magnetite layers are formed, yet the inside of the nail is hollow. Metallurgical information to determine manufacturing processes of the original nail is missing. Despite the limited information, Osawa (2005a) inferred that the quality of the iron used for the nails is similar with that of an iron casting decarbonised steel, based on his previous research (See Table 8-1). The manufacturing processes of the nails infer: thin rectangular ingots of cast iron were initially produced by using moulds with 10–15 millimetres cross-section. The cast iron ingots were too brittle to be used for ship nails. Consequently, annealing process must have been conducted by heating them, probably for a few days in the air in which decarbonisation of the iron occurred. As a result, the quality of the iron turned into soft and pliable iron. This was further forged producing nails. The quality of the iron product through the processes is defined as an iron casting decarbonised steel. During the processes, the composition of iron changes:

Cementite (Fe_3C) →3Fe (Austenite) + C (Graphite)
Austenite → Ferrite + C (Graphite)
Austenite → Pearlite + Ferrite

It was suggested that a previous study of iron remains found at the Avraga Site, which is regarded as Genghis Khan's mausoleum, would be of use to infer the original quality of the iron nails from the Takashima underwater site (Osawa 2005a; 2005b). A Japan-Mongolian joint project had identified the evidence of iron manufacturing within the area regarded as a part of Genghis Khan's mausoleum. A few forging iron ingots, which could be products before manufacturing as iron casting decarbonised steels, were found and their chemical components were analysed as it is shown on the Table 8-3.

Chem	C	Si	Mn	P	S	Cu	Ti	V	Cr	Zr
Mass%	2.80	0.89	0.05	0.339	0.53	0.45	0.02	0.01	0.04	<0.01

Table 8-3 Chemical components of an iron ingots from the Avraga Site as a comparable resource for the nail of the Takashima underwater site. *From Osawa 2005b*

According to Osawa (2005b), the quantity of carbon (C) fits the general class of cast iron (2–4% C). The amount of silicon (Si), which also affects iron quality, shows as high a content of silicon that is contained in iron manufacturing by using a refining furnace. The increase of silicon is evidence of the technology used to produce steel around the time. The amount of sulphur (S) originated from iron sulphide ore and the use of coals as fuel, and these two factors affected the increase of sulphur. Besides the high percentage of sulphur, the large quantity of copper (Cu) infers the origin of the ore. In addition to the chemical composition, by reviewing a historical text, it had been concluded that the ore used at the forging place to produce the iron ingots at the Avraga Site in Mongolia originated from the mine in Jinlingzhen (金岭镇), Shandong Province in China. Osawa (2005a: 35) suggested that the similar quality ingots could have been initially produced and used to produce the ship nails found at the Takashima underwater site.

From the Avraga Site, a few iron nail remains were found and the results of studies are available in the report (Osawa 2005b). One of the iron nails (No.2-2-2) measures 45 millimetres long and 5 millimetres in cross-section. Although a corrosion layer is formed, the inside of the nail iron shows magnetite remains. The quality of the iron is an extra soft steel (<0.001% C). The metal structure of the shaft shows crystallised grains comprised of tiny ferrites. Around the nail head, the metal structure shows inconsistency, comprised of a mixture of tiny crystal grains and large grains. There is no direct evidence whether the discovered iron ingots had been used for these iron nails. However, decarbonised iron ingots by annealing appear to have been used for the nails through the process of forging which led to the quality defined as cast iron decarbonised steel. The Avraga Site dates to the thirteenth century and the study of the iron products found at the site provides insights that help appreciate the quality and the manufacturing processes of the nails from not only the Takashima underwater site but also Quanzhou ship and Shinan shipwreck.

Perspectives on ship nails' manufacturing

Iron has been a primary material used for fastening in the construction of oceangoing ships sailing in East Asian waters. This owed a great deal to the development of iron production in China whose industries had been remarkably mature by the time of Song Dynasty. Associated technologies became sophisticated, and even the early stage of iron manufacturing saw the production of various types of iron materials. One of the iron materials is defined as an iron casting decarbonised steel, and the quality of this material is probably similar to the quality of iron nails used for the thirteenth and fourteenth centuries' East Asian oceangoing ships. An attempt to identify possibly original nail remains was made in the hull of Quanzhou ship. There are a few corrosion remains with a state of red-brown rust in some parts of the upper hull where there was presumably less reconstruction work, so they may be the original nail remains. During the investigation of the Shinan shipwreck, three timbers from different hull components (hull plank, sheathing plank, butt plate) have been examined by x-ray and CT-scan to assess the quality of the remains. From this, the nails' driven pattern and their states were ascertained. A specimen was obtained from the hull plank for metallurgical study. It is identified that the nail has fully degraded, showing not red-brown rust but black Fe_3O_4, magnetite or more likely hydrated iron oxide (Fe_2O_3). The section of these degraded nails show inter-granular corrosion. Despite the substantial degradation, from the microscopic images, a mixture of as-cast dendritic structure and wrought structure has been identified, and this is useful for determining manufacturing process of the original nails. Iron ingots were produced first through the casting process and possibly they have then been annealed to be used as ship nails. The process has been examined before in the metallurgical study on the nail remains from the Takashima underwater site and Avraga Site. Apart from the clarification of the manufacturing process, an entire system of obtaining iron nails as a completed product is still unknown. Quanzhou seems to be known as an iron production site. The maturity of the iron industries in the area may have possibly led to the use of iron for a number of fastening tools including nails, brackets, and clamps in the hull of the Quanzhou ship. Mingzhou appears to have had iron forging workshops, and iron ingots, and mass productions from casting might have been brought to the city from other areas and these could have been manufactured into nails. Iron nails found at the Shinan shipwreck and the Takashima underwater site might have originated from this distribution system. The relationship between iron industries and shipbuilding industries clearly requires further study.

VIII-3 Timber analysis

> *On the original specification, the grain-ship is built 52ft. long with planks 2 in. thick. The choicest timber for it is large baulks of* nan-mu*, but the chestnut (li) is also used as second best* (Tian Gong Kai Wu, vol.9, Needham 1971: 411).
>
> 糧船初制．底長五丈二尺．其板厚二寸．採巨木楠爲上．栗之次 (天工開物第九).
>
> *The timber for the mast is usually fir* (shan-mu)*, which must be straight and sound. If the natural size of the spar is not long enough for the mast, two pieces can be coupled together by means of a series of iron bands placed around the joint a few inches apart. …Hull timbers and bulkheads are made of* nan-mu, chu-mu*, camphor wood* (chang-mu)*, elm* (yu-mu)*, or sophora wood* (huai-mu)*. [Camphor wood, if taken from a tree felled in spring or summer, is liable to be attacked by boring insects or worms] Deck planks can be made of any wood. The rudder-post is made of elm, or else of* lang-mu *or of* chu-mu*. The tiller should be of* chou-mu *or of* lang-mu*.The oars should be of fir* (shan-mu) *or*

juniper (kuei-mu) *or catalpa wood* (chhiu-mu) (Tian Gong Kai Wu, vol.9, Needham 1971: 414).

凡木色. 桅用植杉木. 長不足則接. 其表鐵箍逐寸包圍. …梁興枋檣. 用楠木・櫧木・樟木・榆木・槐木. [樟木春夏伐採. 久則粉虹.] 棧板不拘何木. 舵棹用榆木・榔木・櫧木. 關門棒用椆木・櫓用杉木・檜木・楸木. (天工開物 第九)

Description of timbers used as ship construction appear in seventeenth century historical texts in China, such as quoted above. It indicates that a wood preferably used for ships' mast was fir. On the other hand, relatively harder woods, such as, *Machilus* sp. (Nan mu), *Cinnamomum* sp. (Chun mu), *Quercus* sp. (Chang mu), *Ulmus* sp. (Yu mu), and *Styphnolobium* sp. (Huai mu), were used for the main components of the hull. While there are no specific records for the timbers used for superstructure of the ships, the timbers used for components of ship's steering would have been carefully selected. Needham (1971: 645) introduces the early record of the use of timbers from a third century historical text. It is about an emperor's order having the hull of a small boat constructed by using catalpa wood, and by using magnolia wood for yuhlos. Shiba (1968: 223) has pointed out that pine, fir, and camphor trees were the most dominant trees to be used for ship construction during the Song Dynasty. Does archaeological evidence clarify the above information? The following section will examine the details of timbers used for the Quanzhou ship, the Shinan Ship, and ship remains from the Takashima underwater site. The examination highlights comparative study of the identified timber species. The data from the species identification will be integrated into discussion regarding timber industries and shipbuilding industries. The assemblage of the species comprising the hull remains is indicative of the regions of the shipyards where they were built. The section will demonstrate usefulness of species identification in the study of hull components, in particular, in the light of comparative view.

Timber species identifications

Steffy (1994: 256-259) provides major trees used in European shipbuilding in his nautical archaeological study. For the study of woods in East Asia, databases specified for the region necessary refers, including an online database "Flora of China" providing botanical information about China, and online datasets provided by the Forestry and Forest Products Research Institute in Japan are also a useful source to identify available timbers in Japan and Southeast Asia. Information from these sources is worth being integrated into the data of wood used for East Asian ship remains. Primary data of timber species identifications and wood anatomical explanation of the hull structural remains of each site are available in the reports published by the organizations and intuitions (Museum of Overseas Communication History 1987; National Maritime Museum of Korea 2004; Takashima-cho Board of Education 2008). These reports allow us to understand the practices of identification and obtain inventories of identified species and information about anatomical keys of the specimen (Table 8-4). The species identifications appear to have attempted to identify the lowest taxonomic unit. To identify finer taxonomic ranks is more difficult, and the types of woods presented in these reports vary, identified at different levels of taxonomy. The result of the species identification, however, gives insights of the timber species that tended to be used for ship construction in the region in terms of a comparative view. The following is a summary of the identified woods of the timbers of each hull component.

Quanzhou ship			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Main keel	Chinese Pine	Pinus massoniana Lamb	Ma wei song (马尾松)
Forward keel	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
Aft keel	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
Frame	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
Windlass	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
Ceiling plank	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
Garboards	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Planks	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Bulkheads	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Shinan shipwreck			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Main keel	Chinese Pine	Pinus massoniana Lamb	Ma wei song (马尾松)
Forward keel	Chinese Pine	Pinus massoniana Lamb	Ma wei song (马尾松)
Aft keel	Chinese Pine	Pinus massoniana Lamb	Ma wei song (马尾松)
Garboards	Chinese Pine	Pinus massoniana Lamb	Ma wei song (马尾松)
Planks	Chinese Pine	Pinus massoniana Lamb	Ma wei song (马尾松)
Bulkheads	Chinese Pine	Pinus massoniana Lamb	Ma wei song (马尾松)
Sheating (Sacrificial) Planks	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Part of Watertank	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Mast step	Camphor	Cinnamomum sp. (Camphora (L.) Presl ?)	Xiang mu (樟木)
Water tunk bracket	Winter-hazel	Distylium sp.	Wen mu shu (蚊母树)
Unknown timber associated to the keel from the join of the main keel and forward keel	Oak	Cyclobalanopsis sp.	Qing gang (青冈)

Table- 8-4 Types of woods used for the timbers from the Quanzhou ship, Shinan shipwreck, Takashima underwater site. *Original data from previous site reports: Museum of Overseas Communication History 1987, National Maritime Museum of Korea 2004, Takashima-cho Board of Education 2008* (Continued on the following page)

Takashima Underwater Site			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Anchor No.2: Shank (No.15)	Holly Olive	Osmanthus heterophyllus var. bibracteatus (Hayata) P. S. Green	Yi ye dong shu (异叶冬树)
Anchor No.2: Arm (i - No.21)	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.2: Arm (ii- No.51)	N/A	Broadleaf tree (Unidentified)	N/A
Anchor No.2: Wooden stakes to hold stock (No.10 & 13)	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.2: Loose tenon (No.52)	N/A	Broadleaf tree (Unidentified)	
Anchor No.3: Shank (No.24)	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.3: Arm (i - No.54)	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.3: Arm (ii - No.28)	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.3: Wooden stake to hold stock (No. 27)	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.3: Loose tenon on the anchor crown	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.3: Trapezoidal wooden plates the anchor crown	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
Anchor No.4: Shank (No.44)	Oak	Cyclobalanopsis sp.	Qing gang (青冈)
Anchor No.4: Arm (i - No.47)	N/A	Broadleaf tree (Unidentified)	N/A
Anchor No.4: Arm (ii - No.56)	Fig	Ficus L sp.	Rong mu (榕木)
Anchor No.4: Wooden stake to hold stock (No.41 & 42)	N/A	Broadleaf tree (Unidentified)	N/A
Anchor No.4: Loose tenon	N/A	Broadleaf tree (Unidentified)	N/A
No. 8 (Small ship timber)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
No.15 (Large ship timber)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
No.18 (Large ship timber)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
No.19 (Bulkhead?)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
No.193 (Mast step?)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
KZK02 No.221 (Thin ship timber)	N/A	N/A	N/A
KZK02 No. 601 (Hull plank)	Camphor	Cinnamomum Camphora (L.) Presl	N/A
KZK02 No.909 (Hull plank)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
KZK02 No.949 (Hull plank)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
KZK02 No.1142 (Bulkhead? or plank?)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
KZK02 No.1236 (Bulkhead near the 1439 and 1440)	N/A	N/A	N/A
KZK02 No.1439 (Bulkhead plank)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
KZK02 No.1440 (Bulkhead plank)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
KZK02 No.1476 (Frame?)	Castanopsis	Castanopsis sp.	Zhu li (锥栗)
KZK02 No.1607 (Thin ship timber)	Pine	Pinus sp.	Song mu (松木)
KZK02 No.1863 (Plank)	Castanopsis	Castanopsis sp.	Zhu li (锥栗)
TKS13 No.8 (Athwart beam or bulkhead)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)
TKS13 No.16 (Plank)	N/A	Taxodiaceae family	N/A
TKS13 No.17(Plank, joining to No.16)	Pine	Pinus sp. Diploxylon	N/A
TKS14 No.26 (Bulkhead)	Camphor	Cinnamomum Camphora (L.) Presl	Xiang sha (樟树), Xiang zhang (香樟)

- Quanzhou ship

According to a report (Museum of Overseas Communication History 1987), wood species identifications were conducted on the samples from selected parts of the hull of the Quanzhou ship in 1974, 1975, and 1978. A total of sixteen specimens from nine different hull components including: main keel, forward keel, the aft keel, frames, windlass, bottom ceiling planks, garboards, hull planks, and bulkheads. The specimens were compared to modern wood comparative specimens provided by the Forestry Agency of Jinjiang district and Jinjiang Timber Company in Yongchun, Fujian Province for the identifications. Taxonomic specificity of all the samples were identified to species and each sample was classified into one of three species including *Pinus massoniana* Lamb known as Chinese pine, *Cunninghamia lanceolata* (Lamb.) Hook known as Chinese fir, and *Cinnamomum camphora* (L.) Presl known as camphor tree.

During the 2009 investigation, three timber specimens, which are said to have been from the Quanzhou ship, were provided for detailed study. The information about the two specimens “Sample.1” (Specimen No.: BUN-544) and “Sample.2” (Specimen No.: BUN-545) are determined (Figure 8-17 and Figure 8-18). However, Sample. 1 appears to be from a hull plank (See Chapter V). One specimen “Frame” (Specimen No.: BUN-548) is said to be a part of the frame (Figure 8-19). As mentioned in Chapter V, the result of the radiocarbon dating analysis by an Accelerator Mass Spectrometry corresponds to the estimated time period the Quanzhou ship belongs to, ascertaining the specimens are from the hull. For no availabilities of microphotographs of cell structure of the timbers and the microphotographs of cross-checking, the specimens were sent to the Forestry and Forest Products Research Institute in Japan in order to conduct the species identifications. The microphotographs of the specimens are presented in the Figure 8-20 and the Table 8-5 show the result of the analysis:

ID	Specimen No.	Botanic Name	Hull components
Sample.1	BUN-544	*Cunninghamia lanceolata* (Lamb.) Hook.	hull plank?
Sample.2	BUN-545	*Cunninghamia lanceolata* (Lamb.) Hook.	bulkhead (or fairing laths)?
Frame	BUN-548	*Cinnamomum camphora* (L.) Presl.	frame?

Table 8-5 Result of wood species identification on timber samples recovered from the Quanzhou ship in 2009.

Figure 8-17 Specimen, “Sample.1” provided by Museum of Overseas Communication History. *Photo by author*

Figure 8-18 Specimen, “Sample.2” provided by Museum of Overseas Communication History. *Photo by author*

Figure 8-19 Specimen, “Frame” provided by Museum of Overseas Communication History. *Photo by author*

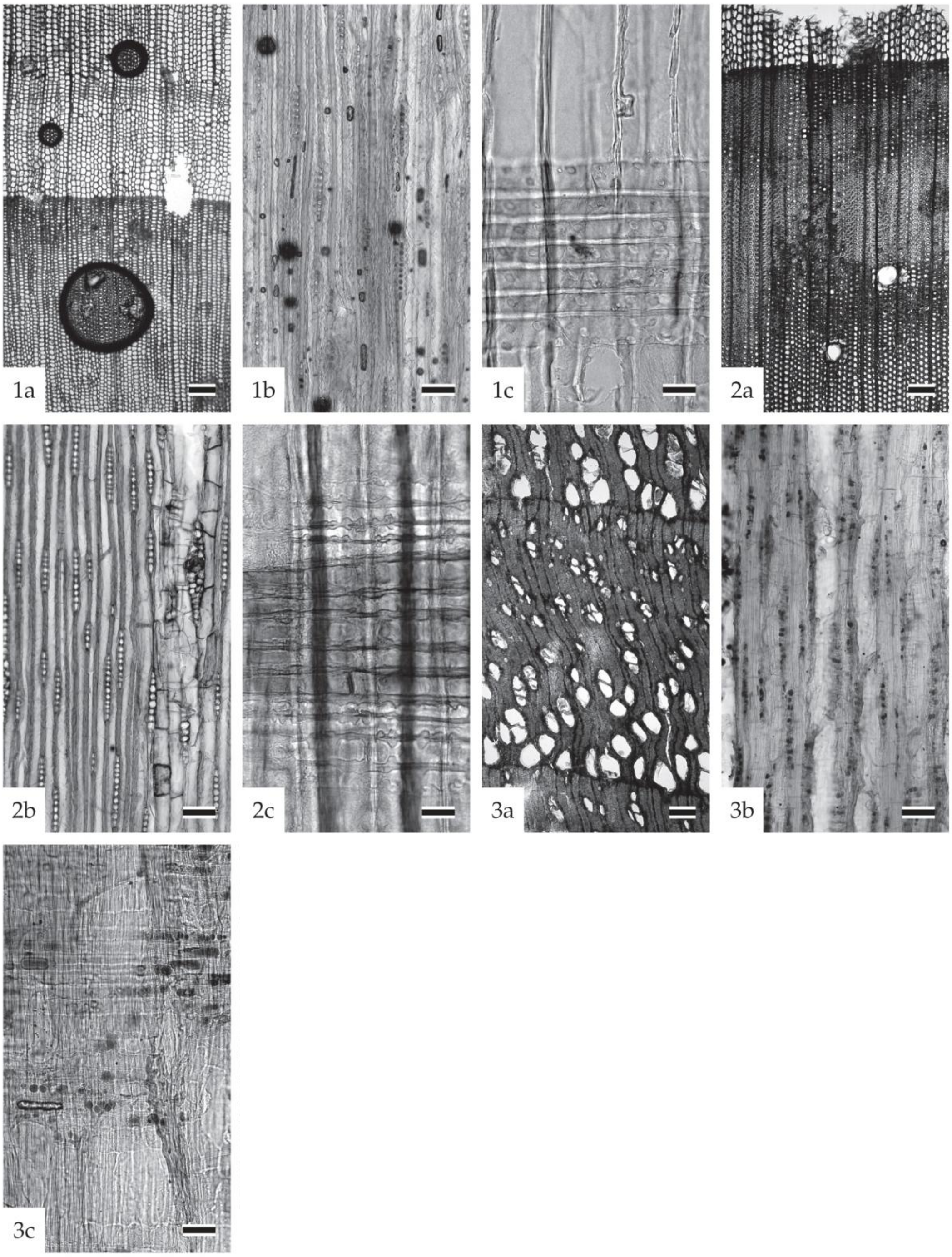

Figure 8-20 Microphotographs of the specimens for wood species identification. *Courtesy of Forestry and Forest Products Research Institute*

The most recent species identifications on the three specimens reveal the use of two different woods, *Cunninghamia lanceolata* (Lamb.) Hook and *Cinnamomum camphora* (L.) Presl, and these are the same species that have been identified in previous research (Museum of Overseas Communication History 1987). The specimen “Frame” identified to *Cinnamomum camphora* (L.) Presl is compared to the previous research that has revealed the use of the species for the frames of the ship. *Cunninghamia lanceolata* (Lamb.) Hook has been identified to garboards, planks, and bulkheads in the previous research. Some features observed on the other two specimens may evidence the correspondence of the timber use for particular hull components of the Quanzhou ship. The sections of Sample.1 show substantial damage by marine borers, which indicates that the original timber has been exposed to the waters, such as hull planks. The configuration of the Sample.2 does not provide apparent evidence to identify from where this timber has originated, yet it has the edge cut off from the timber. The overall dimension supports the idea that it might have been from a plank of the bulkhead or fairing laths, thought the information is insufficient to determine rigidly the origin of the timber.

- Shinan shipwreck

Korean researchers have conducted wood species identifications on different components of the Shinan Shipwreck and the results are available in the reports (National Maritime Museum of Korea 2004; 2006b). The species identifications were conducted on wooden remains consisting of cargo container boxes, tags, cylindrical containers, and hull structural remains. In this research, only the data associated to hull structural remains is discussed. The wood remains were used associated with main hull structure and comprised of the keel, garboards, planks, and bulkheads. The preservation status of their tissues was sufficient for the species identifications to be implemented before conducing chemical conservation on the hull.

All of the specimens from the above main structural components have been identified as *Pinus massoniana* Lamb. This wood is apparently a primary construction material for the Shinan ship. The growth rings of the timbers measures 4–8 millimetres on average, indicating that the timber had originated from trees in favourable environments for significant growth. Some clear rings also are distinctive from substantially growing in spring seasons. *Cunninghamia lanceolata* (Lamb.) Hook has been identified for a few parts of the hull including the sheathing planks and a part of the structure of the water tank. The degradation statuses of the timbers made from this tree vary; the structure of some timbers has been deteriorated, while others still show well-preserved cell structure of the timber. The growth rings of the timbers measure 2 millimetres on average and the ring width is consistent. The mast cheeks were identified as *Cinnamomum* sp.. The report mentions that since this genus has various species, the species was not able to be identified. However, it is likely to be *Cinnamomum camphora* (L.) Presl, considering many cases that this wood is the most common species used for shipbuilding in the region (National Maritime Museum of Korea 2004). Wooden brackets from the water tank have been identified as *Distylium* sp.. The timber shows soft structure and the ring width measures only 0.4-0.6 millimetres. *Distylium* sp. is a hazel family (Hamamelidaceae) and under this family about 18 species are native Chinese trees. *Distylium racemosum* is likely to be the species used for the brackets, yet the details have not been identified. *Cyclobalanopsis* sp. has been used for a small rectangular timber from the join of the forward and main keel. Although the purpose of the use of this timber has not been clarified, *Cyclobalanopsis* sp. is commonly used for hull structure and rigs in the region (National Maritime Museum of Korea 2004). Thus, most of the species found on the hull of the Shinan Shipwreck were coniferous trees originated from the southern parts of China. Well grown trees of *Pinus massoniana* Lamb compose the hull. The trees that had reached around 150-170 years were used for the hull, in particular, the keel and also the trees that had aged around 60-100 years were used for the most other main hull components (National Maritime Museum of Korea 2004: 23).

- Takashima underwater site

Since the 1994 rescue excavation, many wooden remains presumably from the Yuan Dynasty's fleets have been recovered from the area around Kozaki harbour in the Takashima underwater site and the data of the species of the remains are available in the reports (Takashima-cho Board of Education 1996; 2001; 2003; 2008). The following is a summary of the result of wood species identifications based on the available reports.

Wood species identifications were conducted on large wooden anchors recovered during the 1994 and 1995 rescue excavations by a researcher from the Nara National Research Institute for Cultural Properties (Mitsutani 1996). Of the nine discovered anchors, the result of the species identifications on those anchors which have the remains of main components of anchors (Anchors No.2. 3. 4) is summarized on Table 8-4. The structure of these anchors shows consistency, yet two different species of woods have been identified including: *Osmanthus heterophyllus* (G. Don) P. S. Green (Anchor No.2), *Quercus* sp., and *Cyclobalanopsis* sp. (Anchor No.3 and No.4). The species used for the shank of Anchor No.2 is notable in that it is endemic to Taiwan. This fact should be considered in discussing the origin of the

Mongolian fleet; some ships for the fleet might have been constructed in Taiwan. As mentioned in Chapter VII, the chemical analysis conducted on the stone anchor stocks (including one from Anchor No.3) suggests that the stone for the anchor have been probably originated from the coastal areas of China facing the Taiwan Strait. The endemic species does not directly evidence the construction place, considering that there is a possibility of exportation of wood resources by timber industries in Taiwan around the time. The result of the species identifications demonstrates that each anchor component has been made from different woods. The shank and arm of Anchor No. 2 and No. 4 have been made from different woods. While the species of the wood used for the shank and arm of Anchor No.3 is the same, a few parts of the components of this anchor have been made from *Cinnamomum camphora* (L.) Presl.

Species	Number
Cinnamomum camphora	63
Cunninghamia lanceolata (Lamb.)	41
Pinus sp. Diploxylon	34
Ulmus sp.	17
Taxodiaceae family	17
Lauraceae family	14
Pinus sp. Haploxylon	14
Cryptomeria sp.	6
Castanopsis sp.	6
Other	25
Total	237

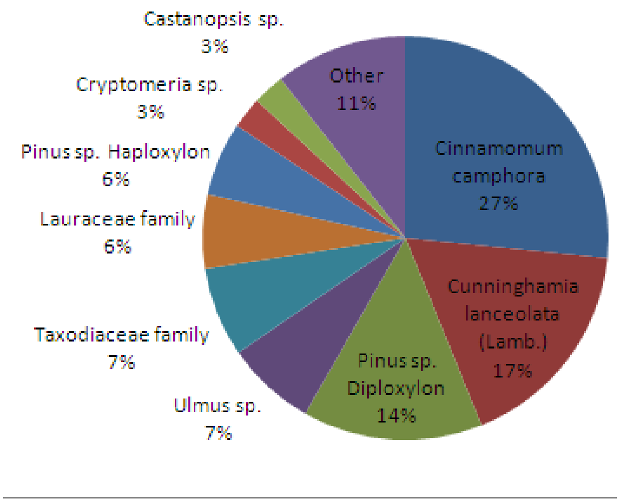

Table 8-6 Assemblage of the wood species of the timbers from the Takashima underwater site. *After Takashima-cho Board of Education 2008*

According to the Nara National Research Institute for Cultural Properties, wooden species of four timbers (No.8, 15, 18, 19) recovered during the rescue excavations in 2000 have been identified as *Cinnamomum camphora* (L.) Presl (Mitsutani 2001). As this wood is native to Taiwan, southern Japan, and southeast China, the previous presumption that the wood remain No.18 might have been associated to the Korean origin boat in the report (Takashima-cho Board of Education 2001: 42-47) need to be carefully re-examined. It is noted that the species of the wood used for traditional Korean ships are different from that of Chinese ships, as shown in the result of wood species identifications on excavated Korean ships later on this section.

In 2005, an inclusive timber species identifications was conducted on a total of 606 specimen from many wooden remains recovered during the 2002 rescue excavations (samples labelled KZK-) and the following series of test excavations (samples labelled TKS-) (Takashima-cho Board of Education 2008). The species analysis was conducted by researchers from Kyoto University and Nanjing Forestry University. During the analysis, the 606 samples have been classified into different categories based on configurations, materials, and purpose of use, such as thin timbers, square timbers, small logs, barks, lacquer products, ship timbers and other miscellaneous artefacts. Of the whole samples, 237 specimens have classified into the ship timbers and the result of the species identifications on these will be focused in here. These identifications demonstrate a wide range consisting of 26 wood taxa (Table 8-6). Only two species, *Cinnamomum camphora* (L.) Presl and *Cunninghamia lanceolata* (Lamb.) Hook, are identified among the 26 wood taxa. The number of the ship timbers that have been identified to these two species is 104 (*Cinnamomum Camphora (L.)*: n = 63, *Cunninghamia lanceolata (Lamb.)*: n = 41). The third greatest number of the identified sample is 34 samples of *Pinus* sp. (Diploxylon). These three woods serve as major trees that comprise 58% of the assemblage of wood remains classified as ship timbers. The assemblage of the other wood remains (42% of the specimens) consists of 23 taxa.

Timbers identified as camphor

Comparing the timber assemblages of the Quanzhou ship and the Shinan shipwreck, there are substantial diversities among the woods recovered from the Takashima underwater site. Use of many different types of ships for the large fleets might have resulted in the identification of the various taxa. There is another issue to be considered whether the 237 specimens that have classified as timbers had been actually from ships or not. Criteria that have classified them into ship timbers were based on the evidence of using nails such as corroded nails and nail holes or the evidence of cut marks or recesses made by carpenters on those recovered timbers.

These are significant criteria, yet the other use as timbers is considered. In the species identification process, no experts in ship structure and construction appear to have been involved. Under the category of the ship timbers, five different species have been identified on the wood remains defined as bulkhead planks (Takashima-cho Board of Education 2008). However, whether all of these had been used as bulkheads is not ascertained. However, as explained in Chapter VII, KZK02 No.1439 and No.1440 are described as bulkhead planks and they were identified as *Cinnamomum camphora* (L.) Presl. The use of camphor tree for hull construction is suggested from this result. It is noted that the wood remain No.19 found during the 2000 excavation, which is said to have been used as bulkhead planks, also used camphor tree. Besides those two bulkhead planks, the planks KZK02-No.601, No.909 and No.949 timbers, which measure over 3.00 metres long, are made from camphor tree (See Appendix II). KZK01-No. 193 is not a large timber, but regarded as a part of ship components, and this timber is made from camphor tree as well. The remains KZK02-No.1142 (consisting of two pieces) is not a large timber, but some characteristics mentioned in Appendix II are indicative of the original use as ship construction materials, and this timber has been identified as camphor tree. A small wood sample KZK02- No. 1236 that had been found close to the KZK02-No.1439 and No.1440 during the excavation has been identified as camphor tree, implying its origin associated to these two bulkhead planks. A relatively large timber TKS13-No.8 having a recess is identified as camphor tree. Camphor tree appears to have been the dominant type of wood for the construction of main components of the hull and this species tends to be used for timbers having large dimensions among the recovered wood remains.

Other wood remains identified

Apart from camphor tree, *Castanopsis* sp. has been identified for two large timbers KZK02-No.1476 and No.1863 that must have been a part of the hull due to their size and recesses and holes for hull construction. However, the use of *Castanopsis* sp. shows up in a very small number in the assemblage (3%, n = 6). KZK02-No.1861 is made from *Ormosia* sp.. While this timber is suggested to have been used as a hull structural material (See Appendix II), this wood remain is the only example identified from this tree in the whole assemblage. A degraded timber KZK01 No.193, regarded as a part of the mast step in previous reports, was identified as *Pinus* sp. (Haploxylon). A thin timber No.1607 regarded as associated to the hull was identified as pine. Two planks TKS13- No. 16 and No.17 thought to have been originally fastened together by nails with a scarf joint, yet interestingly wood of each plank is different. The plank No.16 was identified as Taxodiaceae and the plank No.17 was identified as *Pinus* sp. (Diploxylon).

The use of *Cunninghamia lanceolata* (Lamb.) Hook (Chinese fir) as hull components is less clearly presented in the case of Takashima underwater site. Despite the high percentage of its identification, in terms of the dimension, none of wood remains measuring over 2.00 metres in length have been identified as Chinese fir. The species identifications' report (Takashima-cho Board of Education 2008: 200-202) discussed the dominance of Chinese fir from the site and the similarity of the assemblage of the woods from the Treasure Shipyard (Baochuanchang known as one of shipyards of the Zheng He's expedition fleets) in Nanjing. The number of wood remains identified as *Cunninghamia lanceolata* (Lamb.) Hook (n = 185) shows the remarkable dominance in the species of wood from the shipyard, compared to the number of the second major tree *Tectona* sp. (n = 26). A few species including *Erythrophleum fordii* (n = 13) and *Shorea* sp. (n = 1), which could be defined as ironwoods likely from Southeast Asian region, have not been identified at the Takashima underwater site. On the other hand, some species including *Castanopsis* sp., *Ormosia* sp., and *Pinus* sp. (Haploxylon) have been identified in the remains from the shipyard.

Data of wood species identifications on the other East Asian ships

For comparative study of wood species, more information has become available recently. The theme has been focused on for a long time, yet the ship remains discovered around the 1970s to 80s provided limited information. Early discovered Ningbo shipwreck, for example, barely provide types of wood used for the hull: Chinese fir, pine, and camphor tree (Green 1997). The following section will present more recent achievements from published resources.

- Complementary data from the Penglai Ships

Wood species identifications have been conducted on the components of four Penglai ships (Please see Chapter IV about the details of these shipwrecks). The Penglai ship No.1 of the four shipwrecks was discovered in 1984, and only short summary of the species identifications is available (Liu, Li et al. 2006). The Research Institute of Wood Industry, China Academy of Forestry conducted on the wood species on the other three ship remains in 2005, and the details are available in the report (Liu, Li et al. 2006). The results of the wood species identifications shown on the report are summarised in the table (Table 8-7). During the latest identifications, a total of 49 specimens from hull components of the Penglai ships No.2, No.3, and No.4 were recovered and analysed. In addition to the identified woods on the Penglai ship No.1, the identifications demonstrate that the assemblage of the woods on the four ship remains consisting of 10 taxa: *Pinus* sp., *Castanopsis* sp., *Ulmus* sp., *Cinnamomum* sp., *Cunninghamia lanceolata* (Lamb.) Hook, *Phoebe* sp., *Quercus acutissima*, *Castanea mollissima*, *Erythrophleum* sp., *Alnus* sp.. From the report, *Pinus* sp. appears to be a dominant wood. The main keel of the Penglai Ship No. 1 uses this wood and the main and aft keels of the Penglai Ship No.2 also uses the same taxon of the wood. The bottom structure of the Penglai ship No.3, which shows characteristics of Korean shipbuilding tradition, consists of multiple strakes instead of a keel, and they use *Pinus* sp.. The woods to be used for important components of the hull of Penglai ship No.2 vary including *Ulmus* sp., *Castanopsis* sp., *Cinnamomum* sp., and *Cunninghamia lanceolata* (Lamb.) Hook for the hog piece, the forward keel, the bulkheads, hull planks, frames, and mast steps. There are cases where the same component uses two different woods. For example, *Ulmus* sp. and *Castanopsis* sp. have been identified from the bulkheads. In contrast, the use of the wood on Penglai Ship No.3 shows consistency. Beside the bottom hull, all other hull components including the bulkheads, hull planks, frames, and mast steps are made from *Pinus* sp.. A few other different woods including *Quercus acutissima*, *Castanea mollissima*, and *Alnus* sp. have been identified in wooden nails and dowels. The difference in the wood assemblage between Penglai ships No.2 and No.3 represent a technological difference used for the two ships: the Penglai ship No.2 uses a Chinese shipbuilding principle compared to Penglai ship No.3. showing a Korean shipbuilding technology. There is evidence that *Pinus* sp.. and *Quercus* sp. are the dominant woods that have been identified for Korean local ships as discussed below.

Penglai ship No.1			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Main keel	Pine	Pinus sp.	Song mu (松木)
Aft keel	Camphor	Cinnamomum sp.	Xiang mu (樟木)
Bulkhead	Castanopsis	Castanopsis sp.	Zhu li (锥栗)
Plank (Sample.1)	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Plank (Sample.2)	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Plank (Sample.3)	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Main mast step		Phoebe sp.	Nan mu (楠木)
Stern		Phoebe sp.	Nan mu (楠木)
Penglai ship No.2			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Keel	Pine	Pinus sp.	Song mu(松木)
Garboard on starboard	Pine	Pinus sp.	Song mu(松木)
Hog piece	Elm	Ulmus sp.	Yu mu (榆属)
Forward keel	Elm	Ulmus sp.	Yu mu (榆属)
Bulkhead No.4 second plank	Elm	Ulmus sp.	Yu mu (榆属)
Bulkheads (No. 1 second plank, No.3 planks, No.4 first plank)	Castanopsis	Castanopsis sp.	Zhu li (锥栗)
Frames (No.2, 4, & 5)	Castanopsis	Castanopsis sp.	Zhu li (锥栗)
Mast step	Castanopsis	Castanopsis sp.	Zhu li (锥栗)
Mast longitudinal support ? No.1	Castanopsis	Castanopsis sp.	Zhu li (锥栗)
Mast longitudinal support ? ? No.2	Camphor	Cinnamomum sp.	Xiang mu (樟木)
Plank (Strake No.10 on port side, Strake No.9 on starboard, the other scattered planks inside hull & beneath keel)	Chinese fir	Cunninghamia Lanceolata (Lamb.) Hook	Shan mu (杉木), Sha mu (沙木)
Penglai ship No.3			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Keel	Pine	Pinus sp.	Song mu (松木)
Bulkeads (No.3 first & second planks, No.4 first & second planks, No.5 first & second planks)	Pine	Pinus sp.	Song mu (松木)
Garboards port side and starboard	Pine	Pinus sp.	Song mu (松木)
Planks (Strake No. 3, No.4, & No.6 on port side; No. 2 & No.3 on starboard site)	Pine	Pinus sp.	Song mu (松木)
Frames (No.1, No.2 & No.3)	Pine	Pinus sp.	Song mu (松木)
Mast step (forward & Main)	Pine	Pinus sp.	Song mu (松木)
Transversal bars (run through bottom planks)	Oak	Quercus acutissima	Ma li (麻栎)
Loose tenon (for bulkheads)	Chinese Chestnut	Castanea mollissima	Ban li (板栗)
Sccatered timber (second plank from bottom of the hull)	Alder	Alnus sp.	Qi mu (桤木属)
Penglai ship No.4			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Unknown timber (4b1, 4b2, 4b3)	Pine	Pinus sp.	Song mu (松木)
Others			
Hull component	**Common Name**	**Botanic Name**	**Chinese Descrption**
Unknown timber (incompleted)	Ironwood?	Erythrophleum sp.	Ge mu shu (格木黄耆)

Table 8-7 Woods used for the Penglai shipwreck No.1, 2, 3, and 4.

Wando ship		
Hull component	**Common Name**	**Botanic Name**
Bottom plank 底板	Pine	Pinus sp.
Bottom plank 底板	Kaya (Japanese Nutmeg-yew)	Torreya nucifera (L.) Siebold et Zucc
Plank 外板	Pine	Pinus sp.
Plank 外板	Oak	Quercus sp. (Quercus acutissima?)
Beam A 加龍	Oak	Quercus sp. (Quercus acutissima?)
L-shaped chine strake 彎曲縱通材	Oak	Quercus sp.
L-shaped chine strake 彎曲縱通材	Walnut	Platycarya sp. (Platycarya strobilacea?)
Free tenon 皮槊 (Pisak)	Pine	Pinus sp.
Free tenon 皮槊 (Pisak)	Zelkova	Zelkova sp.
Talido ship		
Hull component	**Common Name**	**Botanic Name**
Bottom plank 底板	Pine	Pinus sp.
Plank 外板	Pine	Pinus sp.
Beam A 加龍	Oak	Quercus sp. (Quercus acutissima?)
Beam B 駕木	Oak	Quercus sp.
Beam C 駕木型加龍	Mulberry	Morus sp.
Free tenon 皮槊 (Pisak)	Mulberry	Morus sp.
Shibidongpado ship		
Hull component	**Common Name**	**Botanic Name**
Bottom plank 底板	Pine	Pinus sp.
Plank 外板	Pine	Pinus sp.
Beam A 加龍	Walnut	Platycarya sp. (Platycarya strobilacea?)
L-shaped chine strake 彎曲縱通材	Walnut	Platycarya sp. (Platycarya strobilacea?)
L-shaped chine strake 彎曲縱通材	Pine	Pinus sp.
Bow plank 船首板材	Pine	Pinus sp.
Free tenon 皮槊 (Pisak)	Walnut	Platycarya sp. (Platycarya strobilacea?)
Free tenon 長槊 (Changsak)	Oak	Quercus sp. (Quercus acutissima?)
Anjwa ship		
Hull component	**Common Name**	**Botanic Name**
Bottom plank 底板	Pine	Pinus sp.
Plank 外板	Pine	Pinus sp.
Beam A 加龍	Oak	Quercus sp. (Quercus acutissima?)
Beam C 駕木型加龍	Pine	Pinus sp.
Stern 船尾板材	Pine	Pinus sp.
Rudder 舵推定	Oak	Quercus sp. (Quercus acutissima?)
Free tenon 皮槊 (Pisak)	Pine	Pinus sp.
tenon 長槊 (Changsak)	Pine	Pinus sp.
Ansan ship		
Hull component	**Common Name**	**Botanic Name**
Bottom plank 底板	Pine	Pinus sp.
Plank 外板	Pine	Pinus sp.
Free tenon 皮槊 (Pisak)	Oak	Quercus sp. (Quercus acutissima?)

Table 8-8 Woods used for the Goryeo Dynasty's ships.

- Complementary data from the Korean shipwrecks

Data on wood used for Goryeo Dynasty's Korean ships can be obtained from the archaeological reports of the shipwrecks (National Maritime Museum of Korea 2006c; National Maritime Museum of Korea 2008a). The species identifications have been conducted on timbers from the tenth–fourteenth century's shipwrecks including Wando ship, Talido ship, Sibidongpado ship, Anjwa ship, and Ansan ship (Table 8-8). These are classified as of Korean origin sailing along the coast of the Korean Peninsula (See Chapter VI). The assemblages of woods indicate that they were locally built ships. One of the characteristics of local building is the use of pine, which has been the most important wood for Korean shipbuilding tradition. Pine has been identified into the bottom strakes of the hulls and most of the hull planking. The wood of the beams, which secure the transverse strength of the hulls, are made from relatively hardwoods, identified as *Quercus* sp., *Platycarya* sp., and *Morus* sp.. Some of these trees are used for those tenons and bars to lock the hull planks. The comparable data of the species identifications on the shipwrecks demonstrates consistency in the selection of particular woods. In Korean shipbuilding tradition, woods have been used as fastening materials for a long time, and for the fastening materials, hardwoods appear to have been selected.

Details of shipbuilding timbers

Technology and materials' availability are synchronistic in their development. Perception of relevant wood species has been a part of shipbuilding tradition. In China, for example, Worcester (1941) introduces a few names of wood used to build native river craft. The river ships in upper Yangtze River were built by using Song mu (pine), Qing gang (oak), Nan mu (camphor tree), Hong chun (camellia), Feng xiang (maple), or Bai mu (cypress). Flora in such a large continent varies, and the endemic use of wood in shipbuilding must have changed throughout time. Nevertheless, from the assemblage of the wood remains of the excavated ships, *Cinnamomum camphora* (L.) (camphor tree), *Pinus massoniana* Lamb, *Cunninghamia lanceolata* (Lamb.) Hook (Chinese fir), and come to the for as the most common species. Botanical information about these species used for shipbuilding is summarized as follows:

Cinnamomum camphora (L.) Presl (camphor tree):

The tree grows 30.00 metres tall to and the trunk to 3.00 metres. Chinese camphor tree is widely cultivated in south of Yangtze River (Chang Jiang) and they also grow in Japan and a part of Korea (not Korean Peninsula but Jeju island). This tree yields oleoresin, which was already mentioned in the Song Dynasty's historical text as chang nao (chun nao 樟脳) (Ptak 2000). In Japan, this tree has been commonly used for shipbuilding as much as *Cryptomeria japonica* (Japanese cedar), yet in Korea the restricted use of this tree is evidenced by the species identifications on the Korean origin ships.

Pinus massoniana Lamb (Chinese pine):

The tree grows up to relevant large size to be used for ship construction; 45 metres tall and the trunk to 1.5 metres. The Chinese pine is important in timber industries and is widely cultivated in modern China. Its distribution can be seen in the southern part, including Anhui, Fujian, Guangdong, Guangxi, Guizhou, Hainan, west Henan, Hubei, Hunan, south Jiangsu, Jiangxi, southeast Shaanxi, Sichuan, east Yunnan, Zhejiang. This is a southern native species in mainland China and Taiwan. In Japan and Korea it is not as common as in China.

Cunninghamia lanceolata (Lamb.) Hook (Chinese fir):
The tree grows 50 metres tall and the trunk to 3 metres. Chinese fir is an indigenous Chinese species, and its distribution shows similarity with camphor tree: Anhui, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hainan, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Shaanxi, Sichuan, Yunan, and Zhejiang. The Flora of China explains that this wood is resistant to rot and termites, and is easily worked. The natures of the tree well explained the use of the Chinese fir as sheathing planks of the Shinan Shipwreck, which have been thin shaped with various sizes and functioned against biotic reactions degrading wood tissues including the effect of shipworm.

Apart from the botanical information above, it is worth looking at the hardness of these timbers. The use of hardwoods is likely to correlate with the sturdiness of the ship structure. Hardwood here is defined as broad-leaved trees, or flowering trees, in comparison to conifer trees, which are defined as softwood. The term “hardwood” is more synonymic with dense or heavy wood. In general, the increase of wood’s weight is in proportion to the increase of hardness. Attributions to determine the weight of woods include the density of the cell and the amount of lignin in the cell walls. Woods, however, have many air spaces in cell lumen (pores) and intercellular and between cell walls, and the percentage of these spaces depends on the type of wood. Without having these spaces, pure cell wall material of wood show a density of about 1.50 grams per cubic centimetres (g/cm^3), yet such a wood does not exist since plants organisms must have space to carry or store water, nutrients, and gas for biological processes. Thus, 1.50 is a weight defined as a specific gravity of woods, so that the weight of wood closer to 1.50 is a heavier wood. The relative weight of different woods based on the specific gravity can be measured by calculating the amount of gas filling up those spaces of completely dried-wood. The resultant value representing the specific gravity of the dried-wood, which is equalized to a volume of pure water, is known as relative density of dry wood or an air-dried wood relative density. The relative density of dried wood of the three woods can refer to a Chinese resource (Cheng 1985: 1258-1294) (Table 8-9). The value of the air-dried wood density presented in the Japanese wood database shows a slight difference from that of *Cinnamomum camphora* (L.) Presl: 0.41-(0.52)-0.69 (N. Shuichi pers. comm. 2010). Another criterion to assess hardness of the wood refers to a brinell hardness. The brinell hardness is used as one of the standards to define the hardness of materials in industry by measuring the scale of penetration loaded on the materials. The brinell hardness of the woods is presented on Table 8-9

	Air-dried wood density (g/cm^3)	Brinell hardness (cross section, radial section, tangential section)
Cinnamomum camphora	0.53-0.58	4000-4200, 3100-3500, 3200-3670
Pinus massoniana	0.44-0.59	2520-4220, 2080-3220, 2540-3600
Cunninghamia lanceolata	0.32-0.39	2140-3040, 1280-1850, 1540-2060

Table 8-9 Density and hardness of the woods.

As the values of the specific gravity correspond to one gram of pure water, the relative density of the wood showing values greater than 1.00 theoretically does not float in pure water, depending on the condition of the wood. About specific gravity, for example, oak regarded as a heavy wood shows the relative dense of 0.90 on the average in many woods. In contrast, from the values of camphor tree and Chinese pine, they appear to be classified into medium-heavy woods that also provide relevant hardness. Their hardness appears to be sufficient to be used for important hull components, from the result of the species identifications on the Quanzhou ship and the Shinan shipwreck. Chinese fir is a lighter tree consisting of soft wood tissues, and it is a convenient tree for mass production of ship timbers. It appears to have been used for hull planking. *Castanopsis* sp., regarded as ship construction material that was identified for a few timbers from Takashima underwater site, shows a similar relative density to camphor tree and Chinese pine (about 0.60 on average). Some of the other wood remains from the sites are identified as heavier woods, such as *Cyclobalanopsis* sp., which is generally regarded as lower-level taxa of oak (a subgenus of *Quercus*). This tree has been used as timbers associated with the keel of the Shinan Shipwreck and the shanks of the two anchors (Anchor No.3 and No.4) from the Takashima underwater site. Anchor No.3, which is the largest anchor on the discovered anchors, consistently comprised of this relatively heavy wood. For constructing hulls, in terms of the air-dried wood densities, the use of wood varies, ranging from 0.30 to 0.60, depending on the component. For the anchors to sink properly, oak or heavier woods have been presumably preferred.

Use of ironwoods in shipbuilding

Wood remains identified as *Erythrophleum fordii* was found at the Ming Dynasty's shipyard in Nanjing and show greater values of relative density (0.90–1.06). However, heavier woods with the relative density of over 1.00 have not been identified among the previously discovered ship remains. Extremely heavy woods have common features including thick and lignified cell walls and the significant concentration of their fibre, and the colour of heartwood of these woods is very dark. Because of their weight and hardness from their structure and the colour, they are commonly called ironwoods. The term ironwood is used for various heavy and hard woods in many places. Ogata (1972) listed approximately 90 woods recognized as ironwoods. A family group having many ironwoods in the lower taxa is Leguminosae (bean family). The above mentioned *Erythrophleum fordii* is the lower taxon of this family group. Heavy and hard woods are also identified to Myrtaceae, Sapotaceae, and Dipterocarpaceae, mostly growing in the tropical regions. Heavy and hard woods have been used as construction materials, while lightness and softness are important in terms of wood's utility. The weight of the timber could have been associated with transportation costs of the woods which are more significant in many cases. The usefulness of the heavy and hard woods, on the other hand, has been understood for a long time in China. A historical text *Ling Wai Tai Ta* (or *Ling Wai Dai Da*, Answers to the question about the areas beyond our territory 嶺外代答) written in 1178 describes those large foreign vessels using a very hardwood for their rudder (Shiba 1968: 224; Needham 1971: 645)

> *The Chinchow coastal mountains have strange woods, of which there are two remarkable kinds. One is the* tzu-ching-mu *(purple thorn tree) as hard as iron and stone, in colour red as cosmetic paint, and straight-grained; as large in girth as two men's reach, and when used for roof beams will last centuries* (Ling Wai Tai Ta, vol. 6, Needham 1971: 645).

> 欽州海山有奇材二種. 一曰紫荊木, 堅類鐵石, 色比燕脂, 易直合抱以為棟梁, 可數百年. 一曰烏婪木, 用以為大船之柂, 極天下之妙也 (嶺外代答卷六).

According to the *Ling Wai Tai Ta*, there were two kinds of special trees originated from coasts and mountains of Qinzhou, which is located in Guangxi Province closer to Vietnam. Beside its colour, the tree "Zu ching mu" (紫荊木) is characterized due to its hardness as much as iron ore. The tree has been identified as *Cercis* sp. (Needham 1971: 645). The historical text mentions another hard tree known as "Wu lan mu" (烏婪木) that was used for the rudders of large ships as the finest wood. However, the details of this tree including species have been not clarified. In the text, there is an explanation of the tree in terms of its greater density and durability, which were necessary for large oceangoing to sail long distance in the southern deep seas. Those foreign ships from Southeast Asia sailing on the South China Sea seem to have used the tree for their steering oars or rudder. In the text, there is a description about the value of the hardwoods outside of the supply: when purchasing the woods, people in Guangdong and Wenzhou must have paid ten times as much as in Qinzhou, since the supply of this wood was only 10 or 20% of the entire demand in these areas, resulted from seaborne problems of the woods (Needham 1971: 645). The description provided evidence for the limited distribution of hardwood from southern regions which could increase their value, and further indicates the existence of timber markets and a distribution system for shipbuilding industries in the twelfth century in China.

Timber industries and shipbuilding industries

The availability of ship construction materials during the tenth to twelfth centuries can be understood from a study on Chinese industries at the time. During the Song Dynasty, ship transportation industries owned by governmental and non-governmental agents were growing and contributed to the wide supply of ship construction materials to shipyards in China (Shiba 1968: 222). Among the substantial growth of various industries, the ship transportation industries appeared to have newly formed and they started to occupy hinterlands of rural areas. These phenomena did not occur all over the Chinese continent where in general timber industries in the north were not as productive as they were in the south. Shiba (1968: 223) cited the description of the twelfth century text, *Zhong Mu Ji* (Collection of Zhong mu 忠穆集) which mentions, the superiority of woods from the southern part of China. These oceangoing ships from Fujian were the finest, from Guangdong and Guanxi were second and from Wenzhou and Mingzhou (Ningbo) following as third. Wood growing in the north was considered inadequate to be used for ships sailing on open seas. Moreover, a paucity of the timber supply environments in north China inferred from descriptions in historical records mention that the construction of cargo ships at the upper Yangtze River ceased due to the insufficiency of relevant timber supply (Shiba 1968: 222-223).

The common use of camphor tree, Chinese pine, and Chinese fir demonstrated in the archaeological data corresponds with historical research. Some geographical names and shipyards using these trees with their botanical characteristics appeared in the historical botanical texts, such as *Zhenglei Bencao* (Classified Materia Medica 証類本草) edited as a materia medica. In the shipyards in the Jiangnan regions around the lower Yangtze River, the camphor tree has served as the most durable ship construction material due to its hardness. There is a record in a different resource regarding the construction of 168 ships using pine trees during the reign of Emperor Xiaozong (1162–1189) around current Hunan Province (Shiba 1968: 223). Shiba (1968: 223) mentions a description in the historical botanical text regarding Chinese fir that was commonly used because of its resistance against water. According to Shiba (1968: 224), some descriptions quoted in the Ming Dynasty's texts including *Ming Shi* (History of Ming 明史) and *Wanli Huidan* (Collected Statutes of Wanli 万暦会典) state the quality of timbers used for ship: cedar is the most relevant and expensive wood, and camphor tree and pine tree follows, yet the quality of pine tree cannot be as good as the other. Woods ideographically described in the texts need to be identified botanically in detail, before assessing their correspondence with wood remains from archaeological sites. However, this is beyond the scope of this research.

The area of Jiangxi Province has been a focal and conjunctive area of inland shipping and known as a hinterland for timber supply. The rise of the shipyards in this area occurred coincidently with the development of forestry. The area could have played a significant role as a source of supply of ship timbers to coastal areas through river transportation and portage systems. The establishment of shipyards on the coasts were substantially related to the hinterland's supplies. Wenzhou in southeastern Zhejiang Province and Mingzhou (current Ningbo city), both flourished as focal areas of shipbuilding industries. Mingzhou, however, could have been more productive by relying on adjacent Chuzhou (Lishui) that was famous for timber industries. Wenzhou and Mingzhou were focal areas to collect and distribution of timbers as important outports. Traders from Guangnan and Fujian, and Japanese merchants visited the two cities for seaborne timber trading. Government shipyards in these two cities were established by the time of reign of Emperor Renzong (1022–1063). Compared to those inland shipyards along rivers, the shipyards in Wenzhou and Mingzhou could have been independently growing. This was because they were a major centre dealing ship construction materials including not only timbers but also other essential products, such as oil, iron products, limes, vegetable fibres, and coals. In the end, the shipyards in Wenzhou undertook construction of seagoing ships, and river ships as well, following the government's order. However, the decline of the shipyards came due to exhaustion of the wood resources. Mingzhou could keep dominance as an international port in the following centuries.

Perspectives on the wood assemblage

Wood remains on the Quanzhou ship, Shinan shipwreck, and Takashima underwater site provide evidence of the assemblage of woods used in the early thirteenth to the late fourteenth century's East Asian oceangoing ships. Three major species, which are *Pinus massoniana* Lamb (Chinese pine), *Cinnamomum camphora* (L.) Presl (camphor tree), and *Cunninghamia lanceolata* (Lamb.) Hook

(Chinese fir), are commonly identified as a result of species identification. There appear to be a few other species used as ship construction materials, from wood remains of the Takashima underwater site and the Penglai shipwrecks. An attempt to determine the characteristics of the species was made by looking at their relative density and brinell hardness (the values represent hardness of the species). The assessment of the hardness is of use basically to understand utility of those woods for ship construction, and further pursuing timber selection for specific hull components to pursue how people could understand the usefulness of different timbers in the practice of shipbuilding.

The result of the species identifications on the Korean local shipwrecks is comparable data, as they show the consistent usage of wood for the hull components, represented in using coherently *Pinus* sp. for the major parts of the hulls. This is a distinctively different from the wood assemblages of the above three sites. The blanket wood identification data shows that there were some endemic patterns in woods' selection within East Asian regions. Such regional difference should also be addressed synergistically in the identification of distinctive shipbuilding traditions.

The underlying idea of using these woods the shipbuilding industries in relation with timber industries was explored by using historical resources. There was a specific demand of using woods from the middle and south China, including hard trees specifically known as ironwoods. By the period of Song Dynasty, timber markets and distribution system were established. On the estuary of southward lower Yangtze River, a number of shipyards during the Song Dynasty rose with support from timber industries. They could function for collection and distribution of various ship construction materials, even exporting them to other regions. In the coastal areas, Wenzhou and Mingzhou had a heyday in particular during the Song Dynasty. In fact, the shipbuilding industries spread in mainland China from north to south. As archaeological evidence indicates, shipyards advanced in the north, and the advancements in the north were less in the following centuries of the Song Dynasty.

Chapter IX - Discussion of hull components

Previous research has been undertaken to assess the characteristics of Chinese ships in terms of archaeological perspectives (Green 1986; McGrail 2001; Tilburg 2007). This chapter will examine hull components identified in excavated ship remains the Quanzhou ship, Shinan shipwrecks, and ship timbers from Takashima underwater site. These will be addressed comparatively with other excavated ships from China. The hull components of these ship remains demonstrate that shipbuilding industries in the twelfth-thirteenth centuries along the coasts of China bordering on the East China Sea had brought the technology of constructing oceangoing ships to a different phase. It is noted that some technologies behind the development can be attributed to techniques from the construction of riverine ships before the tenth century. Moreover, during these periods, the maritime connections between the Chinese coasts, the Korean Peninsula and Japan were well-established by the involvement of different ships, such as those of the Goryeo ships. All the excavated ships of the Goryeo Dynasty (918-1392 A.D.) have been located off the coasts or along the shores of the Korean Peninsula. This may restrict the view of defining them as oceangoing ships. Yet, their role in early seafaring in East Asia is regarded as significant. A similar long-term perspective reorients the discussion of historical influences of construction methods of East Asian oceangoing ships in other regions. For instance, the structures of some shipwrecks in Southeast Asia show a similarity with the Chinese origin's oceangoing ships and this issue is addressed in this discussion.

IX-1 Elements of hull components of East Asian ships

Shipbuilding traditions in Yellow Sea and East China Sea

The state of excavated ships varies, comprising of partial hull bottoms, depending on which parts have survived, such as bow, stern, starboard and portside. All the identified bottom remains in East Asia found so far measure less than 30 metres in length, including the most well-preserved hull remains. The shape of the hull bottom is described with a focus on the cross-section. The mid cross-section is identified into either of the following generic categories: "Flat bottom" (e.g. Tang Dynasty's riverine ships), "Floor with chine" (e.g. Goryeo Dynasty's Korean shipwrecks), "Round bottom" (e.g. Ningbo ship, Penglai No. 1 and 2 ships, Xiangshan ship), "V-bottom hollow deadrise" (e.g. Quanzhou ship), and "V-bottom sharp deadrise" (e.g. Shinan shipwreck).

Flat bottom and Floor with chine

Chinese shipbuilding tradition distinguishes the northern tradition from the southern tradition in terms of the difference in the hull bottom configuration (See Chapter III). The idea that the northern ships show a flat bottom, mentioned in historical texts, has been reviewed previously (Needham 1971: 429; Worcester 1971: 16-17). This was simplified as a norm to represent a typical form of Chinese ship. The example of this is the *Sha-chuan* (sand ship 沙船) which has been treated as a predominant historical Chinese ship from the north. There used to be a perspective that the Chinese Dynasties formed homogenous empires which were based in the north. This led to a viewpoint that Chinese shipbuilding tradition originated from there where the Han-Chinese shipbuilding tradition in the country did not construct a ship having a keel. The historical development of riverine infrastructures and transportation systems is considered to have formed the Han-Chinese shipbuilding tradition in the north. The canals including the Grand Canal between Beijing and Hangzhou, for instance, probably facilitated the increase of riverine ships before the tenth century. The development of river infrastructures by the Tang Dynasty (618-907 A.D.) in the area of Hangzhou Bay northward explain the fact that ships used in the adjacent waters historically became flat bottom ships. This research, however, emphasises the fact that the area of the use of the flat bottom ships extend beyond the Chinese coasts to the waters adjacent to the Korean Peninsula and Japan.

Excavated Goryeo coastal traders in Korean waters in the Yellow Sea evidenced a long-term adoption of the flat bottom. Their floor structure was built by distinctive construction methods from the Chinese tradition. In explaining the Wando ship, McGrail (2001: 361-362) describes the construction of the hull bottom as "[t]he three central strakes of the bottom planking are fastened together edge-to-edge almost in raft fashion, by six transverse timbers ('tenon') which go through the thickness of each strake-…". The construction method to fix the bottom strakes by piecing the transverse timbers is consistently identified with the eleventh to fourteenth centuries' Goryeo Dynasty's ship remains. Moreover, the Ming Dynasty' ships from Penglai on the Shandong Peninsula, which pushes out into the Yellow Sea, show the same construction manner in their bottom structure. The construction method of the hull bottom originated from Korea and is one of locally developed traditions, involving widely the Yellow Sea later. Importantly, this supports the view that the representation of technology used on the Goryeo Dynasty's ships is perceived as an idiosyncrasy. Its distinctive construction method that use chine planks in hull planking and bulkheads as transverse components also endemic Goryeo Dynasty's shipbuilding. These factors classify the cross-section of the

Goryeo traders independently as “Floor with chine”, not merely assigning it into flat bottom ships.

The sixteenth century historical Chinese text, *Chou Hai Tu Bian* (Illustrated Seaboard Strategy 籌海図編) may provide a further perspective that the tradition of the flat bottom ships might extend to Japanese shipbuilding tradition. It says:

> *Japanese ships differ from Chinese ships. They consist of large baulks tightened together, by not using iron nails but iron clamps (strips), and their seams are caulked neither by hemp or by fibre with tang oil, but by short water-weed, which requires much hard labour and many resources.…the bottoms of the Japanese ships are flat, which do not sufficiently cut into the wave* (trans. Chou Hai Tu Bian).

The text mentions that at some stage, presumably by the period the manuscript was written, Japanese oceangoing ships ceased to use the flat bottom. It indicates that the ships that came to be used have a round- or V-shaped bottom. So far, the existence of flat bottom ships has not been the focus of previous studies on traditional Japanese ships and Japanese naval history. The description in the text is indicative of the use of those flat bottom ships as oceangoing ships before the sixteenth century is worth being reviewed owing to the recent identification of the Goryeo Dynasty’s shipbuilding tradition.

Korean ships have been using beams for their transverse structure over centuries, as evidenced in the tenth century coastal trader to early twentieth century fishing boats. It appears that construction methods using beams were also common in the Japanese shipbuilding tradition, as it is evident in the structures of seventeenth and eighteenth century’s coastal traders. Considering the diverse mutual cultural influences and relationships between the two countries, the possibility of historical interactions in shipbuilding may be worth pursuing to clarify this. The prominence of early maritime connections between Korea and Japan can probably be identified even before the rise of the Goryeo Dynasty. Transmission of knowledge and skills regarding shipbuilding to Japan could have occurred during the earlier period. This probably dates back to the period of the heyday of seaborne trade by Silla merchants, and a group of people including ship carpenters might have immigrated from Silla to Japan, while this idea is speculative idea in term of archaeological evidence at present (See Chapter IV). In the later period, technologies related to the Goryeo ships could have been endemically developing as indigenous tradition to construct Korean coastal traders. There has been no research to trace the feasible influence of Korean shipbuilding tradition on the construction methods of indigenous Japanese vessel. Despite the early rise and impact, the reason why shipbuilding tradition from the Korean Peninsula went no further than evolving as technologies for coastal traders locally is still open to question.

Round bottom, V-bottom hollow deadrise and V-bottom sharp deadrise

- Keel

The development of the keel structure in East Asian shipbuilding tradition is an important factor. However, the period when the keel was introduced into Chinese shipbuilding technology has not been determined, neither has the process of its incorporation into the ship structure. While it is presumed that it took time before the technology for constructing ships with keel structure was integrated into Chinese ship construction methods, keel-use appears to have been adopted in the mid- and south- China within a short time, perhaps before the tenth century. It is, however, not arguable until the archaeological discovery of an oceangoing ship of East Asian origin dating back to before the tenth century in China.

Excavated ships engaged in maritime trading along the coast of the mid- and south- China and across the East China Sea, dating to the Song and Yuan Dynasties' periods, have a keel. Garboard planks were almost vertically joined into the keel, so that the extended hull planking forms a V-bottom hollow deadrise and a V-bottom sharp deadrise. Compared to the V-bottom of the Quanzhou ship and Shinan shipwreck, the deadrise angle of the Song Dynasty (960-1279 A.D.) Ningbo ship is less steep. Its cross-section forms a similar configuration with the Yuan-Ming Dynasty's Penglai No. 1 and No. 2 ships (See Chapter IV). The discussion regarding the similarity shows the paucity of evidence, as these ships are dated to later periods than the Ningbo ship and they are from provinces further north. Details of the Ningbo ship including the issue of its structural feature and its exact date cannot be examined anymore due to the destruction of the hull.

Using three members to comprise the keel has been commonly identified on these ship remains (the exceptional case may be in the structure of the Ningbo ships). The length of the main keel of the five excavated ships is: the Quanzhou ship (12.40 metres), the Shinan ship (11.27 metres), the Ningbo ship (7.34 metres), the Penglai No.1 (17.06 metres), and the Penglai No.2 (16.22 metres). Previous studies on the reconstruction of the dimension of most of these ships are estimated to be slightly over 30 metres; for example, the reconstructed length of the hull of the Shinan ship is 33.5 meters, the reconstructed length of the hull of the Penglai No.2 ship is 31.1 meters. In comparison of the proportion of the main keel, however, the main keel of the Penglai ships shows greater length, and the length and beam ratio (L/B) of these two ships are also greater. As these ships are said to have been used as patrol boats or battle ships, the sharp design of the hull appears to indicate their use. On the other hand, whether the hull of the traders in the later periods had a wide beam as great as that of the Song Dynasty's traders may be worth being examined in future study.

- Bulkheads

The role of Chinese ships probably became prominent in seafaring after the ninth and tenth century. Excavated Tang Dynasty ships illustrate the early use of bulkheads on riverine crafts. The bulkheads continued to be used structurally as main transverse components when adopting them in the construction of oceangoing ships. The use of the bulkheads in the hulls of Song Dynasty ships is perceived as slightly different from an initial intention that might have designed bulkheads to produce compartments with the hulls of Tang Dynasty ships. The bulkheads in the Song Dynasty ships were intended to contribute to the transverse strength of the hull. In the way it was used, limber holes were necessarily cut in the bulkheads, while this feature seems to be absent in the Tang Dynasty excavated river craft. The innovation of the bilge system is identified on the remains of the Song Dynasty's ships; in the case of the absence of limber holes in bulkheads, each bulkhead would have had to have a pump in it; if the limber holes were normally secured, then only one pump or a man need to work at the lowest point in the hull. So far, there is no clear archaeological evidence of a system existing to pump out water that collects in the bilge. In Oba's study on the records of Chinese traders that drifted onto the Japanese coast during the nineteenth century, there is a brief explanation about the management of these ships (Oba 2001). According to Oba, the original text of the record mentions a negotiation between Chinese merchants and sailors and Japanese authorities for repairing the hull, including a request Japanese authorities to borrow a pump.

The bulkhead of Song Dynasty ships is interpreted as a component functioning for transverse strength of the ship's structure, rather than producing partitioned space or watertight compartments through the study of the bulkheads of the Quanzhou ship and Shinan shipwreck. For the bulkheads to function effectively as transverse components against lateral pressures, half-frames and brackets are used. The half-frames do not function solely to increase transverse strength. Similarly, the brackets were used to secure the assemblage of bulkheads and hull planking. Considering the complementary role of the brackets that secured the bulkhead planks, they were most likely fixed into the bulkheads that had been assembled.

McGrail (2001) has focused on an arrangement of the brackets' installation to address the building sequence of the thirteenth and fourteenth centuries' Chinese oceangoing ships. McGrail (2001: 372) approached the feature of the brackets used on the Penglai No.1 ship, mentioning that they are embedded within the thickness of the planking. Positioning the brackets this way suggests that the bulkheads had been positioned before the planking was fashioned, fitted, and fastened (McGrail 2001: 375). The Penglai No.2 ship shows a similar manner in its bracket use; they are slotted between the strakes. The bent end is embedded and the brackets are used in the same way between the keel and bulkheads (Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum et al. 2006). The brackets' installation identified in the Quanzhou ship and Shinan shipwreck, however, shows a difference from the Penglai ships. Those brackets pierce through the planking from the outside. The square holes or slits could be opened either before or after fastening of the planking and bulkheads in the way which does not determine whether these ships were built by bulkhead-first or plank-first construction method (See Chapter V for the determination of plank-first construction probably adopted for the Quanzhou ship).

- Planking

Rabbeted seams feature in the planking of the Quanzhou ship and Shinan shipwreck. They form carvel seams or clinker seams. The rabbeted clinker seams make the hull planking appear clinker-like. A combination of rabbeted carvel seams and rabbeted clinker seams is observed on the hull planking of the Quanzhou ship, which the planking of the Shinan shipwreck does not use this combination. The planking of the ships consists of multiple layers where the outer planks are thinner than the inner planks. The outer planks are perceived as sheathing planks to protect the inner planks from marine borers. These features are not similarly identified on the planking of the "Round bottom" ships (e.g. the Ningbo ship, the Xiangshan ship, and the Penglai No. 1 and 2 ships). These round bottom ships do not use sheathing planks. The single layer planking is composed of baulks and thick planks. The first strakes (alike garboards) are fixed into the sides of the keel, not placed on the top of the keel. The cross-section profile of the Penglai No. 2 ship shows the fastening pattern of its planking (See Chapter IV). Besides skew nails that fasten the seams of the planking, spikes are driven from the seam of the upper plank through to the lower plank. Penetrating such spikes would be difficult for the hull planking of the "V-bottom" ships using thinner planks. The discovery of the Song Dynasty's V-bottom ships revealed the existence of the technique that uses sheathing planks by extending multiple planking layers, which had been evident previously only in historical texts. The technique, however, might not have been a widespread innovation used in Chinese shipbuilding tradition. The planking observed on the "Round bottom" ships, which were also another common type of seagoing ship in East China Sea, does not adopt multiple planking layer. The V-bottom ships' planking is appreciated as an endemically developed technique during the Song and Yuan Dynasties, attributed to ships from the southern areas (maybe further south from Ningbo) that conducted voyages in the East China Sea and South China Sea.

- Iron fastenings

Fastening methods using iron materials were common in Chinese shipbuilding. In China, early innovations of iron production facilitated the use of iron for ship construction materials. Iron was used for nails, clamps, and brackets during the Song Dynasty, evidenced in the Quanzhou ship. These are probably three major types of iron fastenings in the East China Sea's shipbuilding industries around the period. The nails were used mainly for hull planking. The clamps were utilized for fastening bulkhead planks, and brackets functioned as fastenings between the planking and bulkheads. These fastenings have been developed mainly for the joint of the transverse component and its joining into the longitudinal component. Iron fastening tools except for nails, have been focused on the study of the later period Chinese junks (Worcester 1941). The adoption of iron materials for various types of fastenings at least derived from that of the Song Dynasty. In anticipation of the future discovery of iron fastenings from shipwrecks dated to this period, it is emphasised that the identification of less degraded nails, clamps, and brackets are important since their study would lead to a proper assessment of the quality of iron. In future, well-preserved ship fastenings from archaeological sites in future may occur at the shipwreck sites as well as at shipyard sites. Its study would need to extend from the iron remains that are identified at the wreck site into what is potentially identified at the sites of the shipyards and other maritime infrastructures including ports. This will contribute to the clarification of aspects of the production, distribution, and use of the iron fastenings which are regarded as one of the most important ship construction materials in East Asian shipbuilding tradition.

Through this research, it is recognized that iron was not necessarily a dominant fastening material for ship construction within an entire region of East Asia. Throughout the eleventh to fourteenth centuries, for example, Korean shipbuilding shows the consistent use of wooden material for fastening. The fastening methods used in the hull planking of the fifteenth century's Penglai No.3 ship in China are wooden nails, mortises and tenons. Distinctive fastening methods in Korean shipbuilding are highlighted in its comparable study with the Chinese origin's Penglai No.2 ship. This helped Chinese researchers to determine that the hull of the

Penglai No.3 ship was constructed according to the Korean shipbuilding tradition (Yuan 2006). By the fifteenth century, it is presumed that iron industries in the Korean Peninsula were well established. Research has yet to provide answers to the details of the inherent use of wooden fastenings that have been lengthy existed in the Korean Peninsula. Future study need to focus on the interaction between iron industries and shipbuilding industries. Based on a clearer evidence of the state of iron industries, the reason why there is a limited use of iron in shipbuilding may be discussed. The coherent long-term use of wooden fastenings evidenced throughout the Goryeo Dynasty's shipwrecks and Ming Dynasty's shipwrecks indicates a conventional aspect of the East Asian shipbuilding tradition.

- Timber species

There are three major trees likely to be identified in excavated ships from mid-southern China including *Pinus massoniana* Lamb (Chinese pine), *Cunninghamia lanceolata* (Lamb.) Hook (Chinese fir), and *Cinnamomum camphora* (L.) Presl (camphor tree). Selecting favourable woods for ship construction is associated with utility and availability. In this research, the former has been addressed in terms of timber utilization as a ship construction material with a focus on the characteristics of the wood, such as hardness and resistance against degradation. The latter has been examined taking into consideration timber industries during the Song Dynasty.

The significance of the pursuit of timber's utility is for better appreciation of shipwrights' perception in the way to use different woods for different parts of the hull components based on those woods' characteristics. This has been examined by clarifying a linkage in the use of harder woods for fundamental components, such as keel and bulkheads and softer woods for flimsy components, such as sheathing planks. The distribution system of ship timbers was already well-established during the Song Dynasty, and this allowed access to diverse timber resources depending on demand. The wood assemblage of the hull components still shows the endemic tradition in each region where shipbuilding has been practised with a coherent wood selection. The result of the identification of the wood assemblage on the hull of the Goryeo Dynasties' shipwrecks is probably related to the availability of timber resources around the Korean Peninsula, different from the mid-southern Chinese regions. The intention of this research is to demonstrate the significance of timber assemblage through a comparative study with the aim of understanding the use of different timbers for shipbuilding within East Asian regions. Moreover, this research has demonstrated the significance of practices of wood species identification as an interdisciplinary study within the archaeological hull component analysis through cooperation with specialists in wood identification in Japan.

IX-2 Diffusion of East Asian shipbuilding tradition into Southeast Asia

South China Sea shipbuilding tradition

As the final stage of technological innovations, it is recognised that shipbuilding technologies mentioned above, attributing to the Yellow Sea and East China Sea shipbuilding traditions, were integrated into Southeast Asia. In particular, the East China Sea shipbuilding traditions developed during the Song Dynasty period through the construction of oceangoing ships to sail widely in East Asian and Southeast Asian waters. The role of the Chinese traders continued to be important in the following the period of the Yuan Dynasty (1271-1368 A.D.). Even politically the hegemony of the Yuan Dynasty's reign beyond the Chinese continent impacted on various aspects including countries' relationship through seaborne trading. Maritime activities by Chinese merchants could expand. The expansion substantially occurred in Southeast Asia by them directly sailing into the region. The consequence of this probably included the diffusion of the Chinese shipbuilding tradition into the region. The pursuit of detailed archaeological data in Southeast Asia is beyond the scope of this research, so that here only selected data of the ship remains are presented in order to trace the formation of shipbuilding traditions that derived from East Asia.

An inventory of ship remains and wreck sites in the waters of the Philippines, Thailand and Indonesia is presented in Appendix III. Only a few sites possibly dating to the Song Dynasty have been identified in these countries. In the Philippines, some ceramic remains and stone anchor stocks that might date back to the period have been found at sites in Bolinao (Clark, Conese et al. 1989). The stone anchor stock from the Bolinao II site, at the north of Silaqui Island, appears to form a Chinese origin stone stock, similar to the ones discovered in Quanzhou in China and along the Japanese coasts. While determining the date of a site based on a typological approach to anchors is likely to be imprecise, the date of this site can be deduced from the overall artefact assemblage. The identified shipwrecks in Thailand are mostly located in the east coast of the Gulf of Thailand where significant historical ports were established later than the Song Dynasty period. In Indonesian waters, ship cargo dated to the Song Dynasty was discovered, known as the Pulau Buaya wreck site (Ridho and McKinnon 1998; McKinnon 2001). The cargo consisted of diverse trading commodities including over 32,000 pieces of ceramics, ingots, copper coins, and glass wares, and probably some personal items including wooden dice. The archaeological report presents intensive information about the cargo contents, but whether there are any hull remains or not has been ascertained. Neither of these sites provides information about the details of what types of ships carried the commodities. The matter of the active use of the Chinese origin ships in Southeast Asian waters has hardly been addressed and only those within the contexts of the trading commodities attributed to China that have been discovered at terrestrial sites in region.

While the hulls of the Song and Yuan Dynasties' shipwrecks have not been clearly identified in Southeast Asian waters, a few shipwrecks dating to the period of the Ming Dynasty (1368-1644 A.D.) have been discovered in the Philippines. Among the commercially salvaged shipwrecks in the country, the study of the Santa Cruz shipwreck is useful for obtaining a perspective regarding a Southeast Asian trader constructed owing to the Chinese shipbuilding tradition. The Santa Cruz is a late fifteenth-early sixteenth century merchant ship, discovered offshore off the municipality of Santa Cruz, Zambales Province, according to Orillaneda's ceramic analysis of the cargo (Orillaneda 2008). The hull of the shipwreck measures approximately 25.00 metres long and 6.00 metres wide. The remaining parts include a keel, sixteen bulkheads and half frames. Eleven or twelve strakes appear to remain. The hull strakes are edge-joined, showing three layered planking which use wooden dowels for the fastening of inner planks and iron nails to fasten the inner planking to the outer planking. The hull use bulkheads as main transverse structure. According to Orillaneda (2008: 35), the hull was built by technique of Chinese shipbuilding tradition, but the method of planking using wooden dowels for the inner planking is identified to Southeast Asian shipbuilding tradition. The result of the wood species identification on the timbers suggests that the Santa Cruz ship is a locally built ship (Orillaneda 2008).

Since the 1980s, underwater archaeological excavations started to be implemented in Southeast Asian waters, cooperating with researchers from overseas (Green and Harper 1982; Green and Harper 1983; Green and Intakosai 1983; Green, Harper et al. 1987; Green, Vosmer et al. 1992; Clark, Green et al. 1993; Green, Vosmer et al. 1995). Its consequence led to the discovery of ship remains that evidenced possible technological interaction in shipbuilding between Southeast Asia and China. In Thailand, particularly, the Underwater Archaeology Division (UAD) under the Department of Fine Arts, has conducted a number of underwater surveys and excavations. The shipwrecks identified through the collaborative projects include the underwater excavation at Si Chang island and Pattaya, in the list of Thailand shipwrecks in Appendix III. In this inventory, the Ko Rang Kwien shipwreck shows the earliest period dating to the fourteenth and early fifteenth centuries among the identified shipwrecks. The hull has been substantially damaged and only a part of the ship remains, including some keel timbers survive. The keel scarf has holes for the placing of copper coins or a mirror, which is a part Chinese shipwright custom, the same as presented in the Song and Yuan Dynasties' ships in this research. Bulkhead planks have not been identified, yet the ribs (frames) are fastened into the hull planks by wooden pegs. While it is not exactly confirmed whether the hull originally had a bulkhead structure or not, bulkheads have been probably missing. Thai researchers interpreted the Ko Rang Kwien shipwreck as a locally built ship, yet it has been constructed based on Chinese shipbuilding tradition. The tradition in this sense includes the transfer of not only construction skills but also symbolic practices in shipbuilding. How easily were such shipwright beliefs and behaviour transferable from one country to another? Is this suggestive of a migration of a group of people that have been practising the convention, not merely the diffusion, of the technological innovation? The Ko Si Chang 2 shipwreck is another interesting example in terms of aspects addressing these matters. The hull has been dated to the similar time period to the Ko Rang Kwien shipwreck by radio carbon dating (1290±60) (Atkinson, Green et al. 1989). However, the two ships appear to be different, as Chinese shipbuilding tradition appears to be more influential in the hull structure and construction methods of the Ko Si Chang 2.

The UAD has actively continued underwater archaeological expeditions after ceasing the collaborative projects with overseas experts. One of the shipwrecks that has been extensively excavated by the UAD is the Bangkachai II. The structural data was collected in the process of developing the above inventory. An internal site report is available only in Thai language, so that the summary below based on it and communication with the UAD, when translated, might be ambiguous.

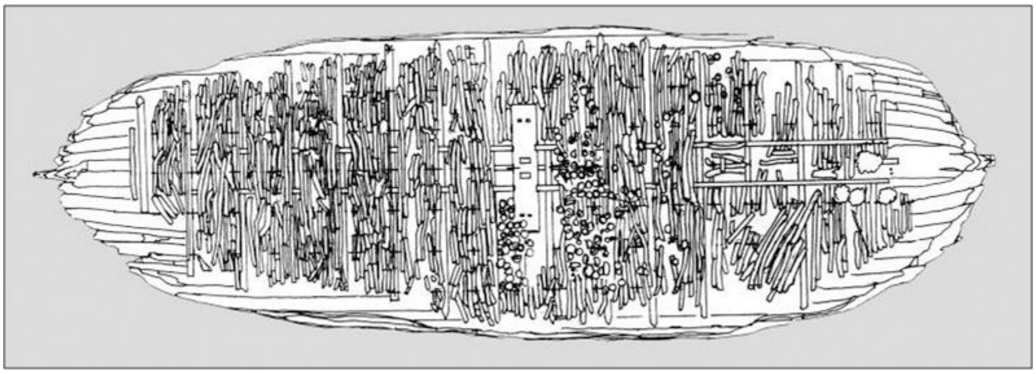

Figure 9-1 Plan of the Bangkachai II Shipwreck. *Courtesy of Thai Underwater Archaeology Division*

Bangkachai II was discovered in 1992 in 8.00 metres of water in the Bangkachai Bay, around 2 kilometres offshore from the coast of the Bangkachai community. The hull remained in good condition when discovered. The remaining part of the hull measures approximately 24.00 metres in length and 6.00 metres in width. The cross-section of the hull bottom shows a round shape. The bottom is composed of a keel and thick garboards with a fastening of wooden dowels (nails?). Some hog pieces reinforce the joint of the keel members. At one of the joints between the keel members, the evidence of Basongkong is identified. Longitudinals seem to run through from the bow to the stern, penetrating the bulkheads. Nineteen bulkheads remain. The bulkhead planks appear to show different thicknesses between the lower planks and upper planks. These planks are joined mainly by wooden dowels. Yet in some parts skew iron nails are used and driven in both forward and aft faces of the bulkheads. These bulkheads have limber holes that cut triangularly. A bamboo stick was found next to the limber hole and it had probably been used to clear the bilge water way, not to seal the hole (W. Hassapak, pers. comm. 2009). Twelve strakes remain in the portside and nine strakes remain in the starboard side. The hull planking seems to use sheathing planks extending to the triple layers. The width of the planks measures 200-250 millimetres and the thickness shows a difference where the inner planks measure 50-80 millimetres and in the outer planks measure 40-60 millimetres. The strakes appear to have been edged-joined (the planking uses wood and iron materials for fastenings). Wooden dowels seem to have been used for the butt joint of the strakes. Two mast steps are found; the forward mast step measures athwartship with a length of 2.98 metres and the main mast step measures athwartship with a length of 3.18 metres. Two recesses cut in order to hold the heels of mast cheeks (Figure 9-1). Three large wooden anchors were recovered. The main hull components were constructed from tropical woods, identified as *Cotylelobium lanceolatum*. Craib and *Tectona grandis* Linn F (Teak). This suggests that the ship was built in the Southeast Asian regions. Radiocarbon dating shows the year of 360±70 BP, and the approximate date of the wrecking is estimated around the 1610s from the result of the analysis and cross-date by Chinese ceramics dated to the Ming Dynasty's Wanli reign period (1573-1619) and by Chinese inscriptions on a wooden box storing small lead ingots. Bangkochai II is regarded as a merchant ship due to a number of artefacts consisting of trading materials. The main cargo was probably a large number of fragrant woods consisting of sappanwood (approximately 20,000 pieces), and some other plants including pieces of Burmese ironwood (*Xylia xylocarpa*), terminalia, beetle nuts and peppers. Many copper ingots with different shapes were also found totalling 10 tons. The amount of ceramics is low among the discovered artefacts, indicating that they were not major trading materials or, perhaps, they were personal belongings on board. Some jars contain tamarinds, peppers, animal and fish bones. Some stonewares and earthenwares are from Thailand's Noi River, Sangbui Province, and some Sangkalok wares, such as green glazed ceramics, are from the Sukhothai period. The discovered ceramics include overseas products from Vietnam and China. The other miscellaneous artefacts include carpentary tools, music instruments, and mirrors. The ship is equipped with two large cannons, and small canons.

Some characteristics of the above shipwrecks from the Philippines and Thailand are approximated to some of the features identified in the early-mid fifteenth century Bukit Jakas site found in Indonesia, which has been reviewed by Pierre-Yves Manguin while pursuing the endemic shipbuilding tradition in the South China Seas. Manguin (2010: 345) has recently reviewed the Ming Dynasty's innovation in shipbuilding in Southeast Asia and it has been discussed with the dawn of the hybridization of shipbuilding technologies. Yet he has noted that "this South China sea tradition is not a technical family that can be defined in clear-cut terms; it is not a homogenous group, since this tradition clearly bridges national borders and is identifiable in both China-built and Southeast Asia-built vessels." One approach to discussing the innovation in the ship structure and construction methods is to establish a framework beyond a linear evolution theory and the naval history of one country. Through this research, it is recognized that East Asian shipbuilding technologies formed regional traditions chronologically from the advent of the Goryeo traders to the hybridization of Chinese shipbuilding tradition and Southeast Asian shipbuilding tradition. The regional traditions can be related to developed shipbuilding in different maritime areas.

- **Yellow Sea shipbuilding tradition**
  Technologies are evidenced in 1) Excavated Tang Dynasty's riverine ships before the tenth century, might have been used for seafaring, show flat bottom and uses bulkheads and iron fastenings; 2) Excavated Goryeo coastal traders of the eleventh to fourteenth centuries that show the hull of the floor with chines and use beams for transverse components and wooden fastenings; 3) Excavated Yuan and Ming Dynasties' ships that have a keel and show round bottom, and the hull is constructed by single layered planking (baulks) and uses bulkheads. 4) Excavated flat bottom keel-less ships that are constructed by Goryeo shipbuilding technologies yet use bulkheads and both iron and wooden fastenings.

- **East China Sea shipbuilding tradition**
  Technologies are evidenced in 1) Excavated oceangoing ships of the thirteenth and fourteenth centuries that show V-bottom deadrise by the use of a keel and garboards. The transverse component composes bulkheads that are secured by half frames and brackets to the hull planking. The hull is constructed by layered

planking and uses various types of iron fastenings; 2) Excavated ships dating from the Song to Ming Dynasty show a round bottom that uses a keel. The hull is constructed by single layered planking (baulks) and uses bulkheads.

- **South China Sea shipbuilding tradition**
  Technologies are evidenced in several shipwrecks, mostly dated to the fourteenth century and afterwards, found in Southeast Asian waters. They use a keel, showing a round bottom. The transverse components use bulkheads and, likely, half frames. The hull planking is multiply layered and the main planking (innermost planking) use wooden fastenings with compensatory uses of iron fastenings.

In the above presentations, the focus on transverse components helps to develop the chronological sequence of East Asian shipbuilding tradition. The utilization of the bulkhead probably derived from its use in fluvial ships before the tenth century in China. Some of these ships could have been used to sail along coasts, perhaps even during the early seafaring into the ocean. The bulkhead came to be used in the structure of the Song Dynasty's oceangoing ships. The innovation on this is linked with keel-use. The innovation lately impacted on further southern Chinese regions, such as the coasts of modern Guangdong and Guangxi where shipbuilding technologies had been influenced by the Southeast Asian indigenous tradition and perhaps by the Persians and Arabs. These regions in the sphere of the South China Sea historically had relationships with Southeast Asia and were probably the focus of exporting East Asian shipbuilding traditions. South China Sea shipbuilding gradually formed under the strong influence of technologies from the southern Chinese coast, perhaps at least during the Yuan Dynasty probably becoming more prominent during the Ming Dynasty.

In terms of a long term perspective, the South China Sea has been a melting pot in shipbuilding technology built on the growth of indigenous technology and innovations from outside of the region. The innovation of the East China Sea shipbuilding tradition in the region impacted on the advent of the South China Sea shipbuilding tradition. It further propelled its endemic development, and finally the matured shipbuilding industries came to be recognized by merchants from outside the region. Nagazumi (2001: 61) mentions that in the 1620s, The Dutch East India Company (VOC) placed an order with shipbuilding industries in Ayutthaya for Chinese type junks that would be employed in order to sail to Japan. According to the same reference of Nagazumi's study on the trading of the Red Seal Vessel, in Manila such Chinese type junks were traded for Japanese merchants and these junks were built in Ayutthaya. What is referred to Chinese type junks here is probably a vessel constructed by the South China Sea shipbuilding tradition. In the late sixteenth to the early seventeenth century, Japanese merchants attempted to make more direct inroads into maritime trade with Southeast Asia. Many of them were not reluctant to use these South China Sea built ships. Based on the above discussion, some technologies used for these ships can be assumed to have descended from East Asia. It is an innovation that has been diffusing for a lengthy period. The shipbuilding technologies are not to be understood directly in a simple linear development. However, there were certain linkages and mutual influences in the development of shipbuilding traditions in each maritime area. The bulkhead structure identified on excavated ships in East Asia and Southeast Asia is a significant component that clarifies the matter.

Chapter X - Conclusion

This archaeological research primarily examines the thirteenth and fourteenth centuries' excavated ships in East Asia. It relates to the broad aim of this thesis that clarifies the historical development of shipbuilding technologies in the region. Its primary focus lies on structure and construction methods of oceangoing ships with focus on bulkheads adopted by such ships. Chapter I examined the significance of the bulkhead, which has been recognized as a representative structure of the ships historically involved in maritime activities in the region. The approach of this research examines the bulkhead in detail as a dispensable hull component for long-distance voyaging for the provision of an exclusive framework to a concept of oceangoing ships. The research demonstrates that this transverse component can be used as a parameter to evaluate the formation of regional shipbuilding traditions.

X-1 Perspectives on East Asian shipbuilding technologies

In order to address the broader perspective at the regional level, Chapter II conducts an extensive review of previous historical and archaeological studies on East Asian ships. The aim of this multidisciplinary review is to integrate all the recent regional and non-regional scholars' works together into a single research. This Chapter also intensively addresses the detailed contexts of the bulkhead, focussing on controversial issues in its historical use. This review suggests how to assess of the bulkhead in terms of its functional and structural aspects. It clarifies the importance of examination of structure and construction methods and orients the approach of this research into detailed hull components' analysis.

The development of regional shipbuilding technology is explained relevant to the pursuit of the meaning of technological innovations. The integration of the hull components and the hybridization of ship construction methods are considered as key factors to explain the formation of shipbuilding traditions in East Asia, and Southeast Asia as well. While the significance of technological hybridization had been advocated before, this research identified that such phenomena were historically recognized and observed as evidenced in historical and iconographical resources (Chapter III). In past records, the term "mestizo" was used to describe those ships which had hybrid features. The identification of the mestizo ships in the historical records illustrates the relevance of the pursuit of hybridization in archaeological study.

The examination of historical resources extends to the assessments of environmental factors and material availability, which could impact on the formation of regional shipbuilding traditions (Chapter III). The long-term dominance of the use of flat bottom ships traditionally in northern waters of East Asia is illustrated based on various resources. While the definition of southern shipbuilding traditions of East Asia are not explicit, some fragmentary historical records indicate that those ships which were used by Chinese monks crossing over the South China Sea and maritime trades before the tenth century were Austronesia ships. Some ports in southern China provided significant access to the South China Sea before the tenth century and onwards.

From archaeological evidence, the Austronesian ships that visited these areas are identical to the remains of the excavated hull that belonged to the Butuan ship in the Philippines and the Punjulharjo ship in Indonesia. However, the historical linkage of the Austronesian shipbuilding traditions to technologies in southern China and their impact on technologies in this area has yet to be elucidated. Similarly, the argument as to the effect of the Persian and Arabian ships that actively visited southern China until the end of the Tang Dynasty period is still open to question.

X-2 Principles in East Asian shipbuilding traditions

The following section is a summary of detailed hull components' analysis based on archaeological examination on excavated ships in East Asia. The development of East Asian shipbuilding is clarified with the identification of three shipbuilding traditions in the region.

The development of the flat bottom ship was first mentioned together with the emergence of the shipbuilding tradition in the Yellow Sea. This is outlined based on the dataset of excavated ships (Chapter IV) with a focus on their structural details. In China, the use of bulkheads traces back to before the tenth century during the Tang Dynasty (618-907 A.D.), according to the dataset of excavated ships in China. Bulkheads initially appeared in the structure of riverine ships prior to their adoption on oceangoing ships. The bulkheads, which are regarded as a representative characteristic of historical Chinese ships, are likely to have been originally used for a flat bottom hull with no keel suitable for riverine ships. Two Tang Dynasty ships have been discovered inland of the Jiangsu Province in China. The provenance of the bulkhead could be that of the riverine ships. Similar types of the flat bottom ships having bulkheads, however, might have been used for sailing out to sea in early China. People around the coasts of the Yellow Sea could probably embark using flat bottom ships. The Jiangsu Province and the southerly adjacent Zhejiang Province (See Figure 1-1) had ports for ships that carried out distant voyages before the tenth century. These were focal ports for many envoys and trading ships involved in early maritime interactions between the Chinese continent and Japan during the Tang Dynasty. While we can only deduce the structure of those ships for seafaring between the two countries by crossing over the East China Sea, it is more likely that there might not have been substantial differences in Chinese ships for the purpose of riverine and oceangoing seafaring. Looking at the example even in the nineteenth and twentieth centuries, the *Sha-chuan* (sand ships), represented as a Hangzhou Bay trader, were still perceived as ships used for riverine and oceangoing purposes in the Yellow Sea and the northern East China Sea (Chapter III). From the limited evidence available, it has been inferred that at the early stage of shipbuilding in the northern coasts of China, the structure and construction methods of oceangoing ships in this region are fundamentally identical to those of the excavated riverine ships.

The keel-less ship itself was not only prevalent in Chinese riverine ships. The Goryeo Dynasty’s (918-1392 A.D.) ships excavated in the area of the Yellow Sea in Korea have flat bottoms. In comparison with Chinese ships, however, it has been noted that the Goryeo Dynasty’s ships used beams, not bulkheads. There was distinctive shipbuilding technology developed in the Korean Peninsula and it existed as another lasting shipbuilding tradition in early East Asia. The excavated ships have been dated to the eleventh through fourteenth centuries and evidence the consistent development of the shipbuilding tradition endemic in the Korean Peninsula. In more detail, these are represented by the following: baulks for longitudinal structures of flat bottom hull, athwart beams for transverse structures, and wooden fastenings. These Goryeo ships are coastal traders designed to sail muddy and shallow waters of the Yellow Sea. They illustrate the dominance of seaborne activities by merchants from the Korean Peninsula in the East Asian waters before the tenth century, as mentioned in historical records. This research has specifically underlined the significance of the early prominence of the Korean shipbuilding tradition in terms of the possibility that it might have influenced the formation of Japanese shipbuilding traditions (Chapter IV and also see Chapter IX).

The technologies of flat bottom ships, represented by northern Chinese ships for riverine use, the Goryeo Dynasty’s coastal traders, and the possible adoption in early Japanese shipbuilding technology, comprise an ancestral group of East Asian shipbuilding traditions. This is indicative of the provenance of the “Yellow Sea shipbuilding tradition”. Whether technological interactions and mutual influences at the embryonic stage in relevant to the wide use of flat bottom ships in the Yellow Sea existed or not is still a speculative argument. The processes of the advent and evolvement of the various types of flat bottom ships still require more archaeological data for further examination.

The second sphere of shipbuilding traditions is identified by examining ships originated from the East China Sea. There is still the lack of direct evidence to address the formation of the shipbuilding traditions, including the exact time period and areas of the advent. Mid and southern China should be regarded a focal region where transition in the use of riverine to seagoing vessels occurred during the Song Dynasty (960-1279 A.D.) or maybe even earlier. The embryo of the “East China Sea shipbuilding tradition” is probably identified in the coastal areas southward around Hangzhou Bay where shipbuilding industries that could supply oceangoing ships gradually grew.

Two excavated ships including the second half of the thirteenth century’s Quanzhou ship and the first quarter of the fourteenth century’s Shinan ship are focused in this research in order to examine the East China Sea shipbuilding tradition (Chapter V and VI). They evidence the standardization of the structure of these periods’ oceangoing ships. Structure and construction methods identified in the ships are interpreted as one stage of the completion of technological integration or clustering of hull components. The technological innovations can be addressed in terms of the presumption of hybridization; shipbuilding industries started to use a keel with bulkheads at some stage and the former hull component probably was non- East China Sea origin.

The keel and hull planking synergistically contribute to longitudinal strength. The keel is composed of three members and thick garboards are fixed. The hull planking that extends from the garboards forms a steep deadrise angle. The hull planking is edge-fastened by skew nailing with rabbeted seams. The system of multiple layered planking has also been standardised for the protection of the innermost planks and functions as a plank-shell. The bulkheads are a dispensable hull component, providing transverse strength, and they are typically used with large half frames and brackets. These structural characteristics are common elements observed in the East China Sea shipbuilding traditions.

The detailed assessment of the excavated ships reveals not only similarities but also differences within the East China Sea shipbuilding tradition. The study of the longitudinal and transverse components indicates that the structure of the Shinan ship appears to be less sturdy than that of the Quanzhou ship (Chapter VIII). The structural difference of the layered hull planking between the two ships is clear. The layered planking of the Quanzhou contributes to both the protection of the inner planks and the increase longitudinal strength of the hull. This is compared to that of the Shinan ship; the original intention of the layered planking of the Shinan shipwreck was for it to function as sheathing planks against marine borers, not for the increase of the longitudinal strength of the hull. The possible structural weakness from this might have caused the distortion of the hull that is evident in the contemporarily hogged keel, which is identified as not an original feature based on the reconstruction of the ship lines. With regard to transverse components, the number of bulkheads of the Shinan ship is less than that of the Quanzhou ship and this arrangement could allow the hull to stow a relatively large size cargo. On the other hand, it might have maximized potential frailty in the transverse strength. The distinctive arrangement of the bulkheads of the Shinan ship is recognized in comparison with that of the Quanzhou ship. In previous studies, each of these ships was individually assessed. The intensive approach to these ships together has revealed the significance of comparative assessment on the structural details and construction methods, which can be systematically understood as principles associated to the East China Sea shipbuilding tradition.

The comparative approach has extended to the archaeological examination of ship construction materials including ship fastenings and timbers (Chapter VIII). This has brought better understanding into the East China Sea shipbuilding tradition. The specimens are obtained from the hull remains of the Quanzhou ship and the Shinan ship. The data of ship remains from the Takashima underwater site statistically complements the analysis of the above specimens, considering the unique origin of the remains from the ships that were requisitioned from different origins for the Mongol Empire's fleet (Chapter VII). The ship construction materials are addressed in terms of not only their quality o but also industries that provided them.

The remains of the ship nails from the Shinan shipwreck are comparatively examined and assessed with nail remains from the Takashima underwater site. Metallurgical approach has attempted to identify the quality of the iron used for the nails. The CT scan and X-ray images of the remains of iron nails from the hull plank of the Shinan shipwreck have revealed that the configuration of the nail is skewed. Since the nail has been fully degraded, its original metal structure could not be identified. However, the microscopic image of the cross-section of the Shinan ship's nail barely indicates that the manufacturing processes of the iron nail is similar to that of the iron nails from the Takashima underwater site; the nails could have been manufactured first from thin bar iron ingots with a square cross-section and then the quality of the iron of these ingots was improved by being made softer and more pliable through the process of decarbonisation in order to be used as ship nails. It is inferred that annealing work for the decarbonisation was probably conducted in the smithy and iron workshops built on the shipyards. Perhaps, future studies of iron nails used for historical East Asian ships necessarily extends to iron remains from the archaeological site of shipyards. Such an inclusive approach will bring a more comprehensive argument into the long-term use of iron fastenings in East Asian shipbuilding traditions.

The types of woods are focused to address the timbers' assemblage of the hull components. The wood identifications on samples from the Quanzhou ship have been conducted and their results have been compared to the wood species data of the Shinan shipwreck and the Takashima underwater site from previous researches. This reveals a pattern of woods' usage. There are three major species which can be commonly seen in ships built by the East China Sea shipbuilding tradition: *Pinus massoniana* Lamb known as the Chinese pine, *Cunninghamia lanceolata* (Lamb.) Hook known as the Chinese fir, and *Cinnamomum camphora* (L.) Presl known as the camphor tree. The timber analysis from the Takashima underwater site had demonstrated that *Cinnamomum camphora* and *Cunninghamia lanceolata* occupy the majority of the assemblage among the various identified species. *Pinus massoniana* is a dominant species used for most of the hull components of the Shinan shipwreck. The wood assemblage of the Quanzhou ship consists of all the above three species, and it indicates that each hull component uses a specific type of wood. The keel, for instance, consists of *Pinus massoniana* and *Cinnamomum camphora* which are harder than *Cunninghamia lanceolata* that is used for hull planks. *Cunninghamia lanceolata* is used for sheathing planks of the Shinan shipwreck, probably due to the wood being softer and lighter and relatively easy to be cut and worked on, and it has reasonable resistance against marine borers. The above data has been further compared to the data of wood species identified in the other excavated ships in East Asia, which include the Goryeo Dynasty's ships. This reveals the difference in the use of the types of wood between Chinese shipbuilding traditions and Korean shipbuilding traditions.

The archaeological study on the types of wood complements historical texts which mostly only provide the names of the various types of wood used for ships. Also, there is the fact that these historical texts tend to provide bias information about the specific types of valuable wood, such as ironwood. The implementation of wood identifications on the remains of ship timbers is significant in terms of concrete testimony regarding the use of non-precious wood for the hull. From the clarification of the detailed assemblage of the types of wood, the existence of the selection of the woods for constructing the hull component in the East China shipbuilding tradition is explicit. This probably occurred in relation to the maturity of the network between timber industries and shipbuilding industries during the Song Dynasty period. These industries synergistically flourished at some ports along the Chinese coasts around the East China Sea.

There is diversity in the East China Sea shipbuilding tradition. Some excavated ships clearly show differences in structural characteristics from the Quanzhou ship and Shinan ship (Chapter IX). As an example of the distinctiveness, it has been remarked that the hulls of those excavated ships do not have multiple layered planking. The Xiangshan Ming Dynasty shipwreck from Ningbo, for example, has single layered planking (See Chapter IV). Perhaps, during the Ming Dynasty (1368-1644 A.D.), such diversity could have expanded within the region. Notably, the structure and configuration of the Xiangshan Ming Dynasty shipwreck are similar with the Penglai ships of the Ming Dynasty form the Yellow Sea area. Besides the similarity of their planking methods, both of these ships have longitudinally longer hulls in the length/beam ratio than the hulls identified in previous periods. Furthermore, it is noted that the four discovered ships in Penglai directly evidence the historical interaction of the East China Sea shipbuilding tradition and Yellow Sea shipbuilding tradition. The basis of the structure and construction methods of the two ships (Penglai No. 1 and No.2 ships) straightforwardly originates from the East China Sea. The feature of the other two ships are identical with that of the Korean ship of the Goryeo Dynasty; however, these two ships use bulkheads, instead of transverse beams, which are identified in the Korean ships dated to the Goryeo Dynasty. It indicates that hybridization of technologies between the Chinese shipbuilding tradition and Korean shipbuilding tradition had occurred.

Finally, it is emphasized that the phenomenon of hybridization is recognized in technological interaction of shipbuilding between East Asia and Southeast Asia, which leads to a better understanding of the third sphere of shipbuilding tradition known as the “South China Sea tradition”. Shipwrecks excavated in Southeast Asian waters, dating to the fifteenth century and afterwards, reveal the adoption of technologies that originates from China, implicated by the uses of bulkheads (Chapter IX). The South China Sea had been a focal area of the technological hybridization through a long-term maritime history. As mentioned before, there were ships described by using the term mestizo. Some of them are identical to the excavated ships from the South China Sea that have hybrid features. While the framework of the South China Sea shipbuilding tradition was not clear in previous studies, it is clear through this extensive research that the formation of this shipbuilding tradition is related to the formation and expansion of the East China Sea shipbuilding tradition. In relation to this, the pursuit of the detailed structure and construction methods of hull components with a focus on bulkhead is substantially significant. It results in linking shipbuilding traditions over these waters and locating them in a long-term chronological framework.

Appendix I (Contents of discovered materials from the Quanzhou ship)

Type of Material	Holds No	1	2	3	4	5	6	7	8	9	10	11	12	13 (Aft most hold	At keel joints (Bao shou kong)	Total (Approx.)
Fragrant materials/ Medicine	Fragrant wood (Lakawood 絳真香: *Lignum Dubagiae* , Sandal wood 檀香: *Lignum Santat* , Garuwood 沈香: *Dignum Ciguilacae)*	Yes (Y)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			2,350kg
	Pepper (Frutetus Piperis)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			7.5kg
	Betel nut (Semen Grecae? or Areca catechu?)			4			13			2	12	1	9	10		51
	Olibanum or Frankincense		Y	Y			Y	Y		Y	Y			Y		6.3g
	Ambergris		Y	Y			Y	Y		Y	Y			Y		1.1g
	Cinnabar			Y	Y											4.6g
	Mercury			Y	Y											385g
	Tortoise shell (Eretmochelys imbricata)												1			1
Wooden strip	Label/tag	7	3	3		12	43	1		1	12		7	5		94
Coins	Copper coin	10	15	122	14	4	101	128	37	5	5	4	7	37	13	504
	Iron coin														7	7
Ceramics	Pottery	11	4				3	2	1	4		4	1	4		34
	Porcelain	3		2		1	1	1	1		1	10		4		24
Metal Objects	Unknown copper			1												1
	Copper spoon			1												1
	Copper wire												2	1		3
	Copper hook													1		1
	Copper Mirror										1				2	2
	Copper chain															1
	Hand ax												1			1
	Iron hook	1														1
	Iron punch												1			1
Wooden Material	Bamboo ruler												1			1
	Mallet						1									1
	Scraper											1				1
	Container			1												1
	Pan lid						1									1
	Mast step reinforcement		2	2												4
	Wedge				2		2	2								6
	Chopsticks												2			2
	Lid	4	5	6			10		1	39		6	13			82
	Seal												1			1
	Handle											1				1
	Cork											2	2			4
	Hat						1			6						7
Woven material	Bamboo sheet		1	4		1	2	2		2						12
	Latticework sheet			Y							Y		Y			
	Rope	1	12	6			6	1		4	3	1				34
Leather	Unknown product			1												1
Cultural objects	Ivory chess piece			1			1				1	1	4	13		21
	Piece of paper												1			1
Accessories	Coral bead							1								1
	Crystal bead												1			1
Seed/Nut	Coconut shell		1	2			7					3		1		14
	Peach seed	1	1	1								1	19	30		53
	Prune seed												1	1		2
	Plum seed												3	2		5
	Coconut seed						1							7		8
	Ginkgo nut												1			1
	Litchi seed			1						4			6			11
Shell	Clam Shell	11	17	50	48		12			###			69	###		2286
	Spiral shell			3			2	7		1						13
	Coral															14.9g
Bone	Wild boar	4		5		3		1	3					3		19
	Sheep								3	5						8
	Dog		2													2
	Rat		23	2			1		2	7						38
	Fish/Bird								1	3			3	2		9
Others	Crystal	Y	Y		Y											2.52g
	Ashed scale?									Y						45g
	Unknown yellow substance		Y													0.03g

Appendix II (Ship timbers from the Takashima underwater site)

Labelled ID	Dimensions	Details (nailing, cut marks)
No.8	Flat surface measuring 664 millimetres and 68 millimetres thick	The dimensions do not present its original configuration. Only one corroded nail is found in it, perhaps indicating that the timber was used for ship construction. The actual usage of this timber is not determined.
No.15	1.95 metres length, width measures 615 millimetres, and 290 millimetres thick.	One of the largest timbers identified during the excavation. While the original surface of one side of the timber is almost completely lost by the damage of marine borers, one nail hole is confirmed on the surface. The other side of the timber is less damaged, yet there is no evidence of fastening. The surface is cut to form some sort of curvature. The actual usage cannot be identified
No.18	1.84 metres length, width measures 475 millimetres, and the thickness is 210 millimetres.	A handle or lug on its surface has been made by hollowing the timber. This timber is said to have been possibly a part of the bottom plank of a planked-up dugout canoe and the lug could hold a beam to fasten planks to the dugout base. It is said that this lug is a comparable to a Korean indigenous boat discovered at the site of Anapchi in Kyongju province dating to the twelfth century (Takashima-cho Board of Education 2001: 46). The possibility that this timber is from a Korean origin boat has been pointed out (Takashima-cho Board of Education 2001: 42-47; Sasaki 2008: 50-51). However, the timber species used for this timber is unlikely to be used in Korean shipbuilding tradition. The No.15 timber as large as the No.18 timber, identified to the same taxon, and also shows the use of iron nails, which is also an unusual characteristic in Korean ships around the thirteenth century.
No.19	The length measures 552 metres, width is 128 millimetres, and the thickness is 128 millimetres	Four broken pieces of a deteriorated timber. The timber is substantially deteriorated by marine borers. The original surface of the timber can be seen around a few corroded nail remains or nail holes. From the nail distribution pattern, the timber is identified as possibly a part of the bulkhead plank. Three corroded nails can be seen on one end. They may have functioned to fix hull planking to the bulkhead plank (Takashima-cho Board of Education 2001: 42). One broken piece is fastened to the other piece mentioned above by a diagonally driven iron nail. This is look like a skew-driven nail like the fastening used to join together bulkhead plank

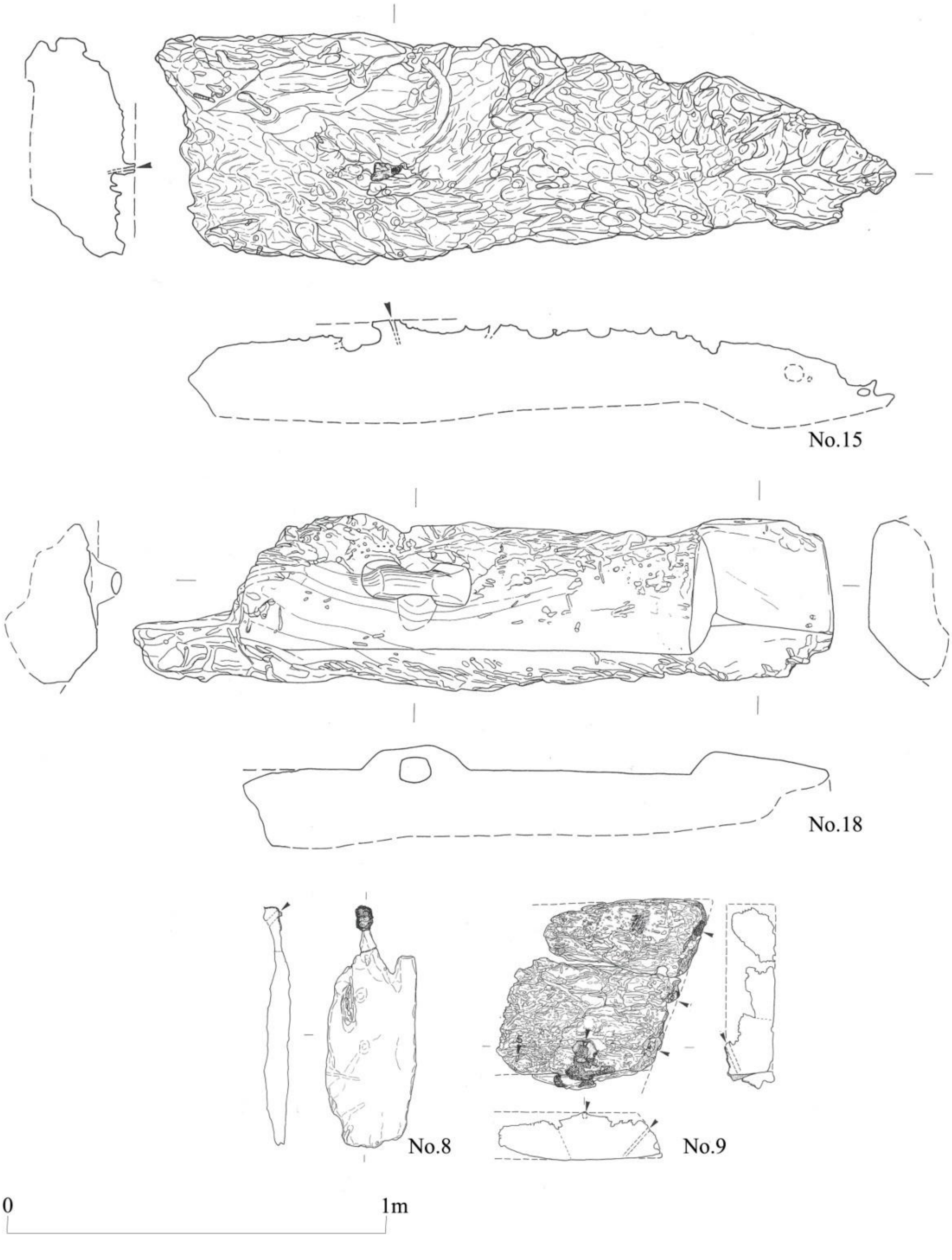

Figure I-1 Drawing of the No. 9, 15, 18, and 19 planks. *From Takashima-cho Board of Education 2001*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
KZK01 No.193	1.30 metres athwartships (assuming that it is a mast step), 300 millimetres fore and aft and 180 millimetres in depth	There are square mortises (inferring as mortises to receive the heel of masts or mast foots in the previous studies). One mortise measures 130x100 millimetres and another measures 120x90 millimetres and they are about 350 millimetres apart. The tabernacle timbers placed into the mortises could be fastened by wooden pegs, which is evidenced by three holes (about 100x50 millimetres) that would allow the pegs to penetrate into the mortises; one peg fore and aft in each mortise; and one extra peg athwartships in only one mortise. Four nails to fasten the timber into the hull can be seen. Unlike the upper surface, the bottom of the timber is completely flat. The flat bottom has a recess running through fore and aft around middle part. A putty for sealing purpose has been identified in the recess, implied the fact that this timber has been tightly placed on a timber longitudinally run the hull. The two mortises do not neatly align along athwartships, and the recess is diagonally groove.

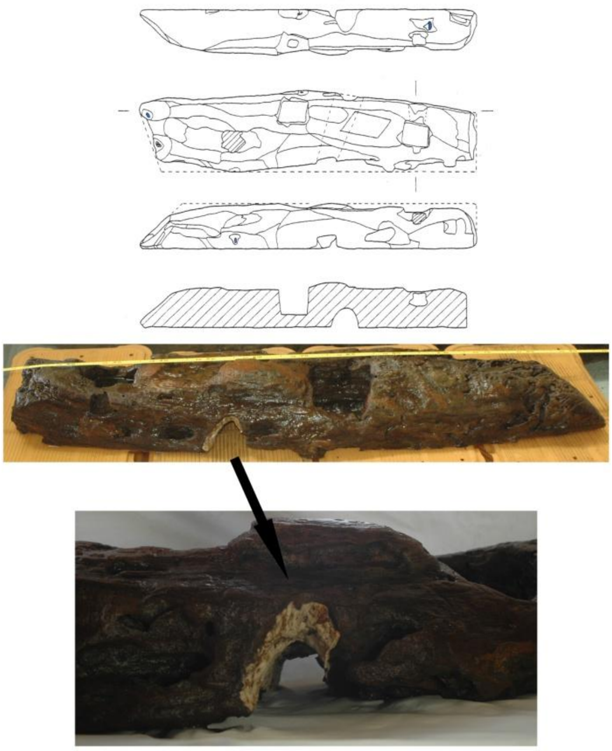

Figure I-2 Drawing and photo image of the KZK01 No.193 plank. *From Takashima-cho Board of Education 2008 and Sasaki 2008*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.221	1.46 metres long, 180 millimetres wide, and the thickness is 40 millimetres	Thin timber. One end of the timber is shaped for a scarf joint. A large number of nails are used for this timber. Corroded nail remains or nail holes provide evidence that twenty nails have been perpendicularly driven into the timber and another nine nails have been skewed to fasten this timber to a lower timber. The diameter of the nails measures 10 millimetres, the same as most nails from the site. The distribution pattern of the nails appears random. It might be sheathing planking, but the method for the joint of sheathing planks being skew nailed together are unusual and not seen elsewhere.

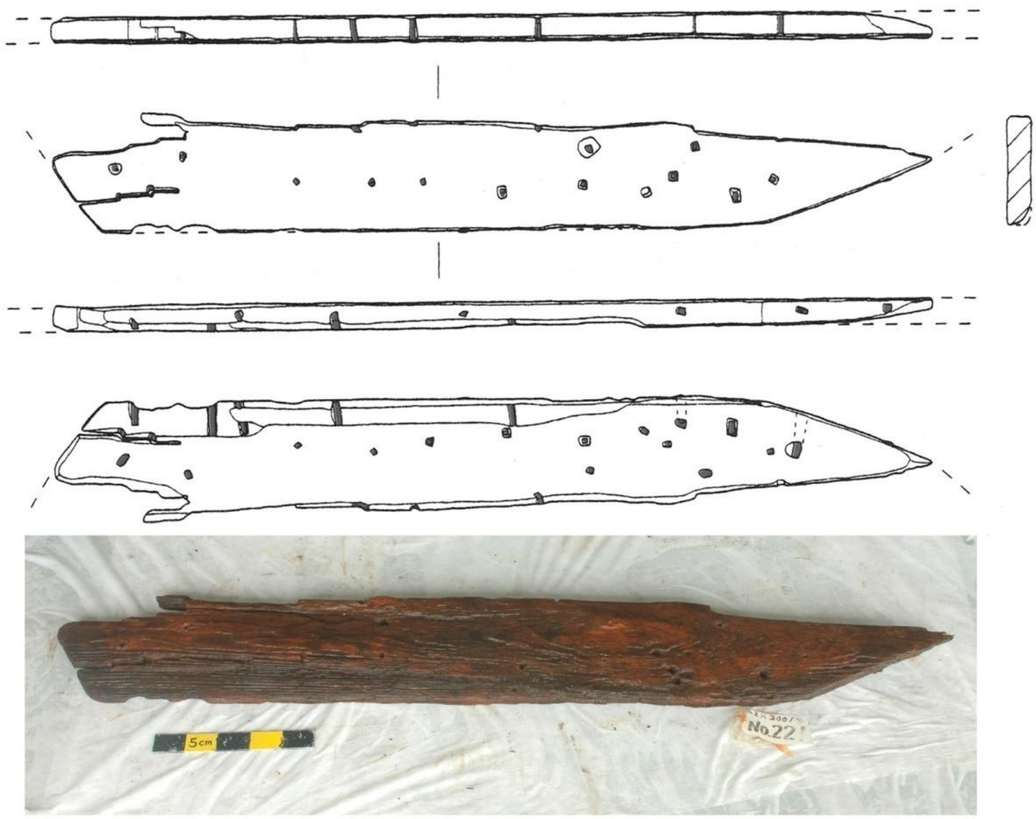

Figure I-3 Drawing and photo image of the No.221 plank. *From Takashima-cho Board of Education 2008 and photo by author*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.601	3.31 metres long, 450 millimetres wide, 180 millimetres thick.	One of large timbers that have the greatest thickness among discovered timbers. There is a recess of a trapezoid-shape (25x17x9) close to the edge of the timber, but the purpose of this recess has not been identified. Two small nail corrosions are close to the recess. However, the relation between the recess and nail us unclear. The recess might hold a beam. However, a part of the timber is missing, and logical explanation about the actual use of this timber cannot be provided.
No.909	About 4.00 metres and 540 millimetres wide. The thickness is 120 millimetres.	A large timber. Some parts retain original features. One end is cut to form a knob where there is the evidence of putty. This indicates that this end has been joined to the another timber. Another end is a recess which reduces the width to one third. There is the evidence that four nail have been perpendicularly driven into the timber. Four corroded nails are on the recessed part and they are presumably used to join another timber to this timber. The use of this timber has not been clarified, yet due to its size and wood species, it is likely to have been a part of hull.
No.949	3.17 metres and 470 millimetres in width. The thickness of this timber is 120 millimetres (the same as that of the timber No.909).	Sturdy large plank. One edge of the timber is rabbeted while the other side is not. Both edges are regarded as seams that planks have been joined into. On the non-rabbeted seam, nail remains cannot be seen; however, a lot of corroded nails remain close to the seams. Many nail remains are concentrated on the centre of the surface of the plank. Almost all nail remains form concretions. This makes it difficult to assess the original nail pattern and ascertain how these nail are driven in the timber. An archaeological report (Takashima-cho Board of Education 2003: 13) has suggested that this timber is probably a hull planking. One of the interests is the fact that the use of the nail is identified only on the rabbeted seam. This indicates that it is unlikely to have been used as a hull plank unless it is the uppermost plank.

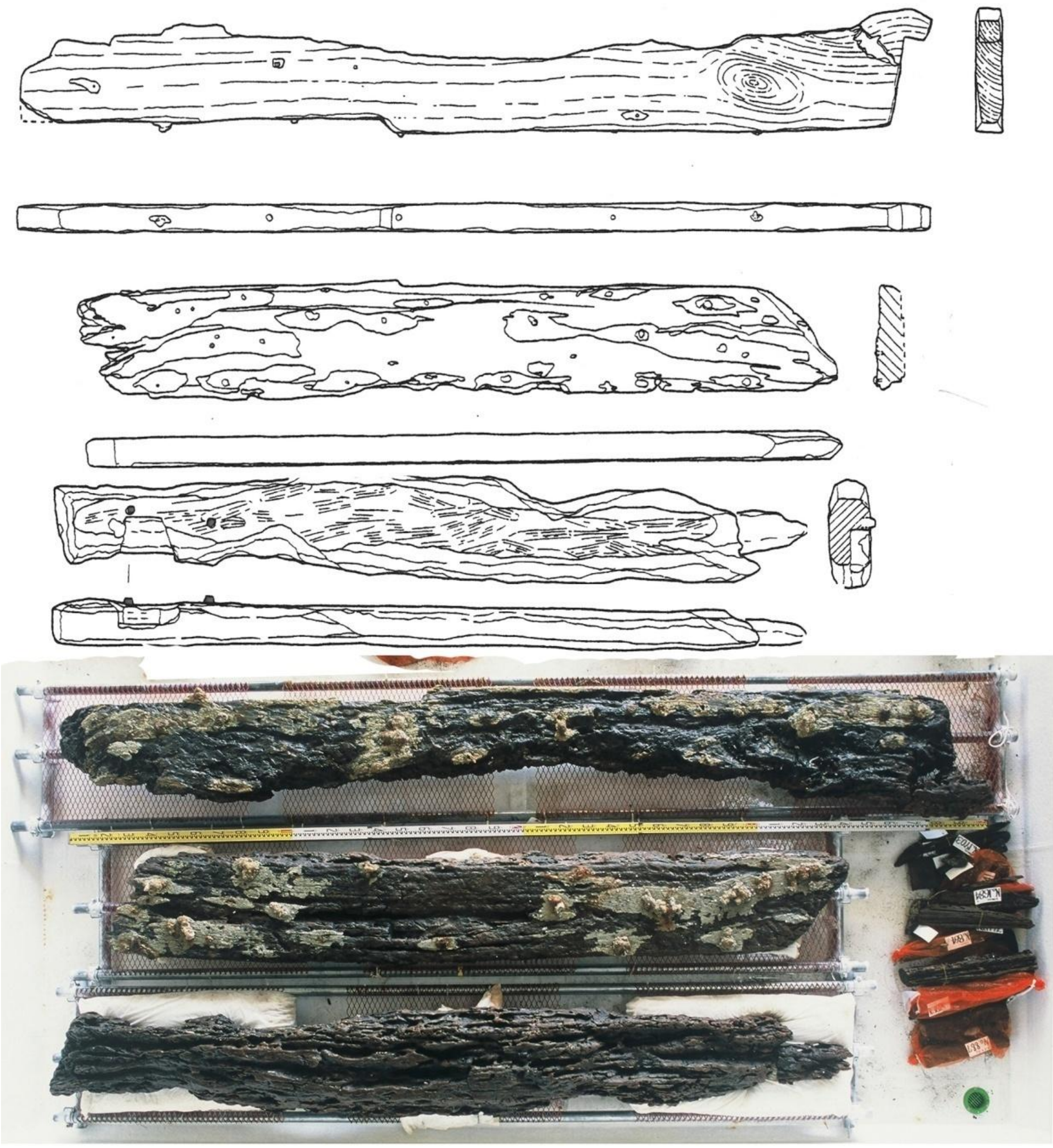

Figure I-4 Drawings and photo images of the No.601, 909, and 949 planks. *From Takashima-cho Board of Education 2008 and courtesy of Takashima-cho Board of Education*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.1035	960 millimetres long and 210 millimetres wide, 30-40 millimetres in thickness.	A thin timber. One end of the timber is cut for a scarf joint. On the surface of the timber, there is the evidence of two nails have been diagonally driven through it. From one nail hole, a wooden piece that appear to have obscured the nail head was discovered. The purpose of using the wood piece is unknown.

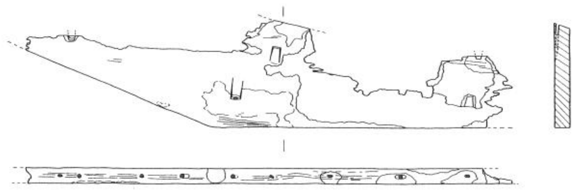

Figure I-5 Drawing of the No.1035 plank. *From Takashima-cho Board of Education 2008*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.1142	1.02 metres and 270 millimetres width. The thickness is 90 millimetres (Larger timber).	The timber consists of two timbers. One edge of the larger timber, remaining about 500 millimetres, is rabbeted where there is the evidence that five nails have been driven onto this timber from another smaller timber. The smaller timber that has been attached by nails has a few nail holes which are not associated for the join into the larger timber. The number of the nails driven into the smaller timber is greater than the large timber. It is disputable whether the smaller plank functioned as an upper plank or the larger plank functioned as an upper plank. Besides the rabbets on the seams, the fact that the wood has been identified as camphor is indicative of use for important hull components.

Figure I-6 Photo images and cross-section showing a driven nail of the No.1142 planks. *Photo by Sasaki and author*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.1476	2.60 metres in length and 320 millimetres at the point of maximum width	A large timber showing relatively intact condition. The timber has a curved-shape and its surface is rounded in one side. From this surface, several nails have been driven through to the other and presumably functioned to fasten this timber to other components. Although the nails are corroded and form concretions, the interval of the nailing is identified to range from 200 to 300 millimetres. The side attached to another component by these nails is flat. A part of this side is recessed, and this is presumably minor adjustment for tight fit. On this side, there is the evidence of putty which remains as a white substances. The timber might have been used as some sort of frame. In which the case, corroded nails remaining on the ends might be for join of this timber and hull planking.

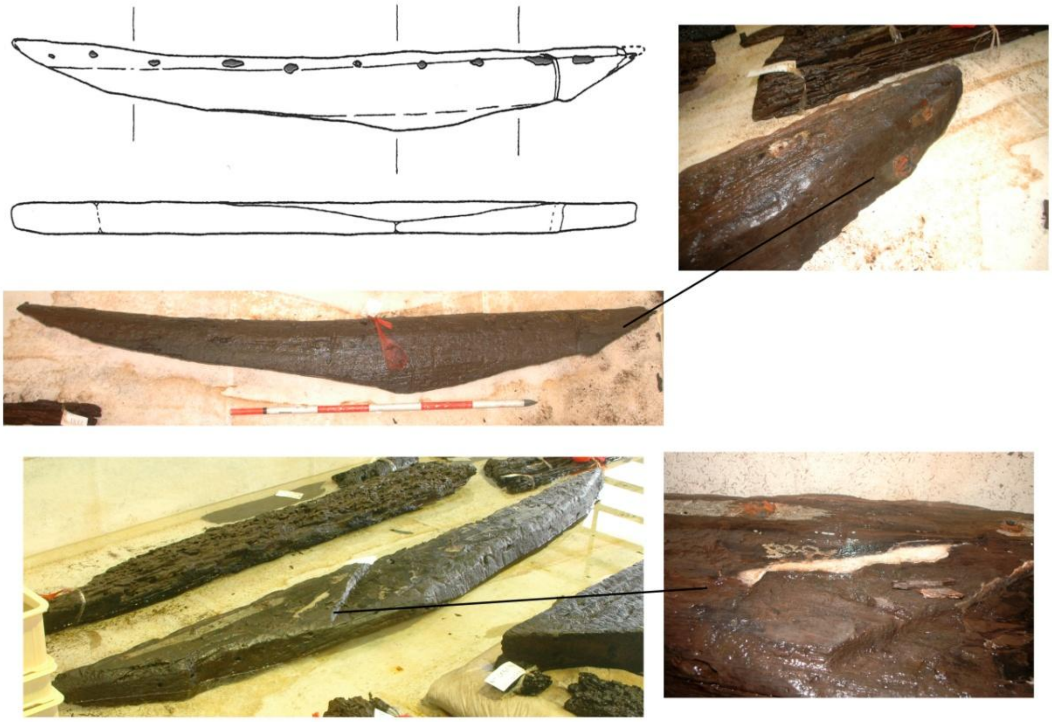

Figure I-7 Drawing and photo image of the No.1476 plank. *From Takashima-cho Board of Education 2008 and photo by author*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.1607	960 millimetres and width is 210 millimetres.	A thin timber. The end of the timber is cut diagonally. There are two corroded nail remains on the surface of this timber. However, the purpose of use of this timber, if it has been used as ship construction component, is disputable. The most notable feature is that almost all edges of this timber are covered by metal corrosion. Such a metal use has not been identified.

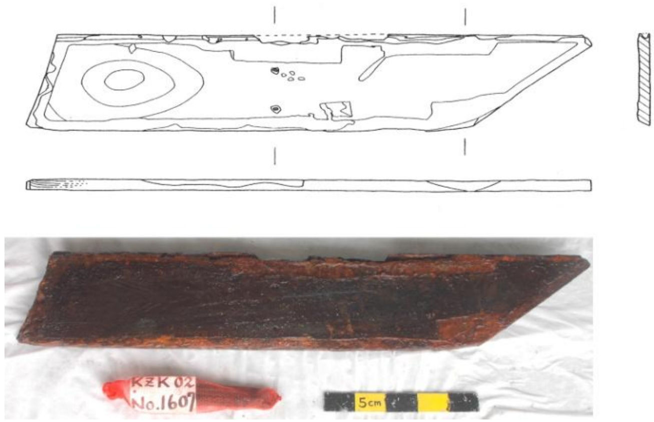

Figure I-8 Drawing and photo image of the No.1607 plank. *From Takashima-cho Board of Education 2008 and photo by author*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.1863	1.93 metres and width is 380 millimetres. The thickness is about 120 millimetres.	A large timber. The timber is relatively well-preserved. One end of the timber shows intact condition and is neatly planed with chamfered edge. Close to one edge there are three triangularly shaped-recesses which could have received some components.

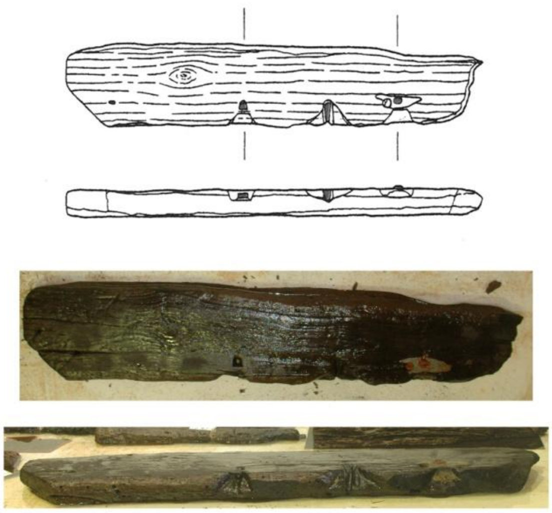

Figure I-9 Drawing and photo image of the No.1863 plank. *From Takashima-cho Board of Education 2008 and photo by author*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.8	1.77 metres in long (athwartships), 198 millimetres in wide 120-150 millimetres in thick	A large timber. The middle part of the timber is recessed. It is presumed that this recessed part can hold a longitudinal component of the ship. This timber is regarded as a part of the transverse component of the hull.

Figure I-10 Drawing and photo image of the No.8 plank. *From Takashima-cho Board of Education 2008 and photo by author*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No. 16 No. 17	821 millimetres and -width is 227 millimetres. 399 millimetres and 97 millimetres in width.	The No.16 and No.17 timbers were fastened together. Only in a few the joint of the two timbers can be seen. A large part of both timbers is missing. The details of fastening of these timbers have been well explained in the previous studies (Takashima-cho Board of Education 2004: 17-20; Sasaki 2008: 171). The end of the timber No.16 is cut for scarf joint and fastened into the timber No.16. There is the evidence of using ten nails on the seam of the timber No.17, yet five nails are only functioned for the join of the two timbers. Three nails are diagonally driven from the surface of the timber No.17 to the timber No.16 through the scarf. Of the five, the other two nails are driven from the upper seam of the timber No. 17 penetrating through the seam with the timber No.16. Except for the nails remains on the seam, there are a few nails on the surface of the timber No.17. It is said that the plank has been used as a bulkhead plank (Sasaki 2008: 170). The interesting fact is that wooden species used for two timbers are identified to different taxa (See Chapter VII).

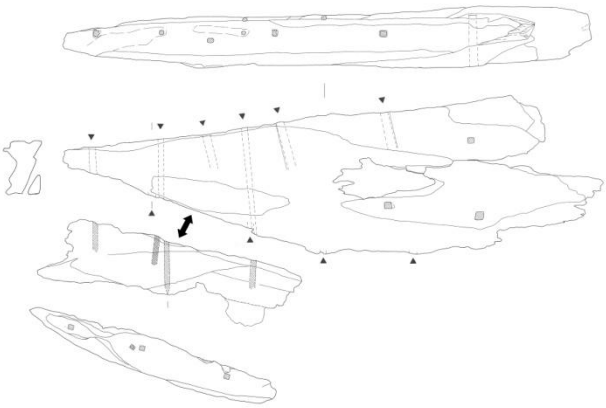

Figure I-11 Drawing of the No. 16 (Large piece) and No.17 (Small piece) planks. *From Takashima-cho Board of Education 2004*

Labelled ID	DIMENSIONS	DETAILS (nailing, cut marks)
No.26	1.75 metres and 230 millimetres in width. The thickness ranges from 110 to 130 millimetres.	A large timber. A part of the timber is missing, yet it is well preserved. The details of this timber have been explained in the previous studies (Takashima-cho Board of Education 2004: 18-20; Sasaki 2008: 172-173). The middle part of the underside, which has been presumably attached to the hull, is recessed, and moreover the recess has a small square cross-section shape (40x40 millimetres). The recess may secure the timber to sit onto a hog piece or perhaps might be a limber hole. There are a number of corroded nails or nail holes on the underside of the timber. On the recessed part there are two nail holes, and there are eleven nail holes on one side of the recessed part and another six nail holes are on the other side of the recessed part. There are no nail remains on the upper part of the timber, indicating that this timber functioned as a single piece to be fastened to the hull bottom. Like most large timbers from the site, it is made of camphor.

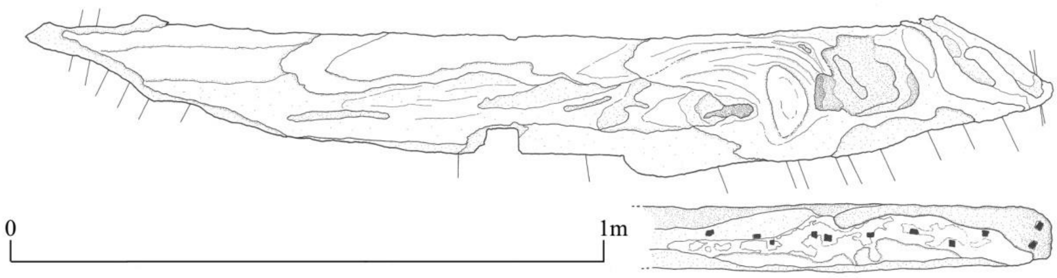

Figure I-12 Drawing of the TKS14- No.26 plank. *From Sasaki 2008*

Appendix III

Philippines										
Site	Discovered Location	Dating	Origin	Status of Hull remains	Preservation Status	Year Discovered	Salvaged	Surveyed	Excavated	Purpose
Butuan (Balangay) No.1	Butuan, Agusan Valley, Mindanao	320?	Philippines	Low	Chemical Conservation	1976	No	No	Yes	Coastal transportation?
Butuan No.2	Butuan, Agusan Valley, Mindanao	1250?	Philippines	Medium	Chemical Conservation	1986?	No	No	Yes	Coastal transportation?
Butuan No.5	Butuan, Agusan Valley, Mindanao	1215?	Philippines	Low	Chemical Conservation	1986	No	No	Yes	Coastal transportation?
Breaker Reef wreck	Breaker Reef, Palawan	N/A	Song Dynasty?	N/A (No hull remains)	N/A	1991	Yes	No	Yes	Trader?
Investigator Shoal wreck	Investigator Shoal, Palawan	N/A	Yuan Dynasty	N/A (No hull remains)	N/A	1990	Yes	No	Yes	Trader?
Lena Shoal wreck	Lena Shoal, Busuanga, Palawan	N/A	Ming Dynasty	High	Non-treatment	1997	Yes	No	Yes	Trader
Marinduque wreck (junk)	Gaspar Island, Gasan, Marinduque	N/A	Ming Dynasty? or Siam origin?	Low	Non-treatment	1980	Yes	No	Yes	Trader
Pandanan Wreck	Pandanan Island, Palawan	15th century	South China Sea/Vietnamese?	N/A (No hull remains)	N/A	1993	Yes	Yes	Yes	Trader
Puerto Galera wreck	Puerto Galera, Mindoro	N/A	South China Sea?	N/A (No hull remains)	N/A	1983	Yes	No	Yes	Trader
Santa Cruz wreck	Sta. Cruz, Zambales	Late 15th century	South China Sea	High	Non-treatment	2001	Yes	No	Yes	Trader
San Isidro wreck	San Isidro, Zambales	16th century	Southeast Asia?	Low	Non-treatment	1996	Yes	No	Yes	Trader

List of ship remains discovered in the Philippines. *Courtesy of the National Museum of the Philippines*

Thailand										
Site	Discovered Location	Dating	Origin	Status of Hull remains	Preservation Status	Year Discovered	Salvaged	Surveyed	Excavated	Purpose
Ko Rang Kwien Shipwreck	About 800m north from Rang Kwien island, West of Bang Sarea Bay	14-early 15th century	N/A	Low	Non-treatment	1978	N/A	Yes	Yes	Oceangoing trader
Bang sak shipwreck	1.6 km from Thabtawan beach, Phang Nga	Radiocarbon date of 760±220 B.P.	N/A	Low	Non-treatment	2008	N/A	Yes	No	N/A
Ko Si Chang 1	Ko Sichang, Chonburi	Late 16th century	N/A	Low	Non-treatment	1982	N/A	Yes	Yes	Oceangoing trader
Ko Si Chang 2	Ko Sichang, Chonburi	14-15th century	South China Sea	Low	Non-treatment	1982	N/A	Yes	Yes	Oceangoing trader
Ko Si Chang 3	Ko Sichang, Chonburi	Mid-16th century	Siamese?	Low	Non-treatment	1985	N/A	Yes	Yes	Coastal trader
Ko Khram or Sattahip Shipwreck	Near ko Kram Island which faces Sattahip Bay, Chonburi	1450-1475	N/A	Low	Non-treatment	1974	N/A	Yes	Yes	Oceangoing trader
Klang Aow 2	At the middle in the gulf of Thailand, 100km from Sattahip Chonburi	16th century	N/A		Non-treatment	2004	N/A	Yes	No	N/A
Hin Bush wreck site	N/A Rayong province?	16th century	N/A	Low	Non-treatment		N/A	Yes	Yes	Oceangoing Trade
Ko Kra	14km from Ko Kra, 94 km from Pak Panang	16th century	N/A		Non-treatment	2005	N/A	Yes	No	Oceangoing trader
Ko Tao	N/A	16th century	N/A	Low	Non-treatment	2009	N/A	Yes	No	
Klang Aow 1 Shipwreck	At the middle in the gulf of Thailand, 89km from Sattahip Chonburi	1500-1530	N/A	Low	Non-treatment	1991	N/A	Yes	No	Oceangoing trader
Ko Kradat Shipwreck	1 km north of the northern end of the island in Trad	1522-1566	S.E.A	N/A (No hull remains)	Non-treatment	1977	N/A	Yes	Yes	Oceangoing trader
Ko Rin wreck site	N/A	1558-1757	N/A	N/A (No hull remains)	N/A	1988	N/A	Yes	No	N/A
Ko Samae San Shipwreck	N/A	1658-1857	N/A	N/A	N/A	1985	N/A	Yes	No	N/A
Ko Samui Shipwreck	In the waters between Samui island and Tan island	1658-1857	N/A	Low	Non-treatment	1984	N/A	Yes	Yes	Oceangoing trader
Prachuap Khiri Khan wreck site	N/A	1558-1757	N/A	Low	N/A	1987	N/A	Yes	No	N/A
Pattaya Shipwreck	In the waters between Pattaya beach and Lan island	1558-1657	N/A	Low	Non-treatment	1977	N/A	Yes	Yes	Oceangoing trader
Rayong wreck site	N/A	1657-1757	N/A	N/A	N/A	1977	N/A	Yes	No	N/A
Nakhon si Tammarat	N/A	Radiocarbon date 450 B.P.	N/A	N/A	N/A	1978	N/A	Yes	No	N/A
Bangkachai I	Bangkachai Bay	N/A	N/A	N/A (No hull remains)	Non-treatment	1989	N/A	Yes	No	N/A
Bangkachai II	In the waters 2km away from the seashore, Bangkachai Bay	early 17th century	Siamese?	Low	Non-treatment	1992	N/A	Yes	Yes	Oceangoing trader
Samed Ngam	At the riverbank around the mouth of Hanthabiuri river, Tambon	18-19th century	Fujian junk?	Low	Preserved in situ in fresh	1982	N/A	Yes	Yes	Oceangoing trader

List of ship remains discovered in Thailand. *Courtesy of Underwater Archaeology Division*

Indonesia										
Site	Discovered Location	Dating	Origin	Status of Hull remains	Preservation Status	Year Discovered	Salvaged	Surveyed	Excavated	Purpose
Cirebon Wreck	Northern Java Sea	973	Five Dynasty Period, Arab or India origin?	Low	Non-treatment	2003	Yes	Yes	No	Trader
Belitung shipwreck	Offshore Belitung Island	9th century?	Arab or India origin?	High	Non-treatment	1998	Yes	Yes	No	Trader
Intan Shipwreck	N/A	10th century?	Arab or India origin?	High	Non-treatment	1997?	Yes	Yes	No	Trader
Java Sea Shipwreck	N/A	13th century?	Indonesian origin?	Low	Non-treatment	N/A	Yes	Yes	Yes	Indonesian trader
Pulau Buaya Wreck	Pulau Buaya - Kepulauan Riau	1300s	Song Dynasty	N/A (No hull remains)	Others	1989	Yes	Yes	No	Trader
Belanakan Shipwreck	Belanakan waters, Subang, West Java	14th century	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bukit Jakes Shipwreck	Bintan Island	1400-1460	Ming Dynasty	High	In situ preservation	1981?	No	Yes	Yes	Trader
Teluk Sumpat Wreck	Bintan Island	1700s	Yuan and Ming Dynasties	N/A (No hull remains)	Non-treatment	2005	Yes	Yes	Yes	N/A

List of ship remains discovered in Indonesia. *Courtesy of Ministry of Marine Affairs and Fisheries*

References

Adachi, H. 1998. *Nihon no fune: wasen hen (Ships in Japan: traditional Japanese ships)*. Tokyo: Museum of Maritime Science.

Adams, J. 2001. Ships and boats as archaeological source material. *World Archaeology* 32 (3):292-310.

Agency for Cultural Affairs. 2000. Iseki hozon hoho no kento: suichu iseki (Considering methods for protection of archaeological site: underwater site) Tokyo: Agency for Cultural Affairs.

Atkinson, K. 1990. The first stage of a maritime archaeological training programme in the People's Republic of China: a brief summary of the aims, procedures and results. *The International Journal of Nautical Archaeology* 19 (3):255-258.

Atkinson, K., J. Green, R. Harper, and V. Intakosai. 1989. Joint Thai - Australian underwater archaeological project 1987-1988. Part 1: archaeological survey of wreck sites in the Gulf of Thailand, 1987-1988. *The International Journal of Nautical Archaeology* 18 (4):299-315.

Basch, L. 1972. Ancient wrecks and the archaeology of ships. *The International Journal of Nautical Archaeology* 1:1-58.

Bass, G. F. 1983. A plea for historical particularism in nautical archaeology. In *Shipwreck anthropology*, ed. Richard Gould, 91-104. Albuquerque: University of New Mexico Press.

Bellwood, P., J. Cameron, N. V. Viet, and B. V. Liem. 2007. Ancient boats, boat timbers, and locked mortise-and-tenon joints from Bronze/Iron-Age Northern Vietnam. *The International Journal of Nautical Archaeology* 36 (1):2-20.

Beltrame, C., and D. Gaddi. 2007. Preliminary analysis of the hull of the Roman ship from Grado, Gorizia, Italy. *The International Journal of Nautical Archaeology* 36 (1):138-147.

Bernard, W. D. 1844. *Narrative of the voyages and services of the Nemesis from 1840 to 1843, and of the combined naval and military operations in China, comprising a complete account of the colony of Hong-Kong and remarks on the character and habits of the Chinese / from notes of Commander W. H. Hall, R. N. ; with personal observations by W. D. Bernard*. 2nd Aufl. London: Henry Colburn.

Biles, J. H. 1908. *The design and construction of ships*. London: C. Griffin and company, limited.

Blot, J. Y. 2006. Naval engineering concepts and cultural bias in the analysis of longitudinal stiffness when applied to ancient Chinese shipbuilding. Paper presented at the International symposium on Penglai ancient ship, Penglai,

Burningham, N., and J. Green. 1997. Description of the Quanzhou ship. In *Maritime archaeology in the People's Republic of China*, ed. Jeremy Green, 32-48. vol. Special publication No.1 Australian National Centre of Excellence for Maritime Archaeology. Fremantle: Western Australia Museum.

Cai, W., C. Li, and L. Xi. 2010. Watertight bulkheads and limber holes in ancient Chinese boats. In *Shipwreck ASIA: thematic studies in East Asian maritime archaeology*, ed. Jun Kimura, 26-31. Adelaide: Maritime Archaeology Program.

Caira, G. 2008. The Cholne: an iron age dugout canoe from Russia. *The Newsletter of the Nautical Archaeology Society*

Cheng, J. (ed.) 1985. *Mu cai xue (Timber study)*, Zhongguo Linye Chubanshe, Beijing.

Childe, V. G. 1929. *The Danube in prehistory, by V. Gordon Childe* ... Oxford: The Clarendon Press.

Choi, H.-S. 2004. A naval architectural study on the sunken ship at Shinan, Korea. In *The conservation and restoration of Shinan Ship, the 20 years history*, ed. National Maritime Museum of Korea, 162-169. Mokpo: National Maritime Museum of Korea.

Choi, W.-G. 2006. *The traditional ships of Korea*. Trans. Jean Young Lee. Seoul: Ewha Womans University Press.

Church, S. K. 2005. Zheng He: an investigation into the plausibility of 450-ft treasure ships. *Monumenta Serica* LIII:1-42.

Church, S. K. 2008. The Ming treasure shipyard archaeological report, ed. Susan Langley & Victor Mastone: Advisory Council on Underwater Archaeology.

Church, S. K. 2010. Two Ming Dynasty shipyards in Nanjing and their infrastructure. In *Shipwreck ASIA: thematic studies in East Asian maritime archaeology*, ed. Jun Kimura, 32-49. Adelaide: Maritime Archaeology Program.

Clark, P., E. Conese, N. Nicolas, and J. Green. 1989. Philippines archaeological site survey, February 1988. *The International Journal of Nautical Archaeology* 18 (3):255-262.

Clark, P., J. Green, T. Vosmer, and R. Santiago. 1993. The Butuan Two boat known as a balangay in the National Museum, Manila, Philippines. *The International Journal of Nautical Archaeology* 22 (2):143-159.

Clarke, D. L. 1968. *Analytical Archaeology*. London: Methuen.

CSNAME - Marine History Research Group. 1985. *Marine history research*.

Transactions of CSNAME - Marine History Research Group. Shanghai: CSNAME - Marine History Research Group.
Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum, and Cultural Relics Bureau of Penglai City. 2006. *Ancient ships from Penglai*. Beijing: Wenwu Press.
Dai, K. 1985. Notes on the origination of ancient Chinese junks based upon study of unearthed dug-out canoes. *Marine History Research, Transactions of CSNAME Marine History Research Group* (1):4-17.
Danjo, H. 2005. Ming Dai kaikin no zitsuzo (Fact of sea ban in Ming Dynasty). In *Minatomati to Kaiiki sekai*, ed. Shosuke Murai, 145-177. vol. Minatomati no Sekaishi. Tokyo: Aoki Shoten.
Deguchi, A. 1991. Dugouts of Japan: hull structure, construction and propulsion. In *International Sailing Ships History Conference*, eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.
Deguchi, A. 1995. *Nippon to syuhen Asia no dentou-teki-senpaku (Traditional ships in Japan and the Asian region: the study of cultural geography)*. Tokyo: Bunken Shuppan.
Deguchi, A. 2001. *Marukibune (Dugout)*. Mono to ningen no bunkashi (Cultural history of materials and human). Tokyo: Hosei daigaku syuppankyoku (Hosei University Press).
Delgado, J. P. 2009. *Khubilai Khan's lost fleet: in search of a legendary armada*. California: University of California Press.
Delgado, J. P. (ed.) 1997. *Encyclopaedia of underwater and maritime archaeology*, British Museum Press, London.
Donnelly, I. 1925. Early Chinese ships and trade. *The Mariner's Mirror* XI:344-354.
Donnelly, I. A. 1923. Foochow pole junks. *The Mariner's Mirror* 9:226-231.
Donnelly, I. A. 1924. River craft of the Yangtzekiang. *The Mariner's Mirror*:4-16.
Donnelly, I. A. 1926. The "Oculus" in Chinese Craft. *The Mariner's Mirror* XII:339-340.
Donnelly, I. A. 1930. *Chinese junks and other native craft*. 2nd Aufl. Shanghai: Kelly and Walsh, Ltd.
Donnelly, I. A. 1936. Strange craft of China's inland waters. *The Mariner's Mirror* 22:410-421.
Duivenvoorde, W. V. 2005. The fifth-century B.C. shipwreck at Tektas Burnu, Turkey: evidence for the ship's hull from nail concretions. In *Tropis IX: Proceedings of the 9th International Symposium on Ship Construction in Antiquity, Agia Napa 2005*, ed. Tzalas H. Athens.
Enomoto, W. 2008. Chugoku jin no kaijo sinsyutsu to kaijo teikoku toshiteno

Chugoku (Advent of Chinese merchant in maritime activities and China as a maritime empire. In *Kaiiki Asia shi kenkyu nyumon (Reader for the history of maritime area of Asia)*, ed. Shiro Momoki, 16-22. Tokyo: Iwanami shoten.

Farris, W. W. 2009. Shipbuilding and nautical technology in Japanese maritime history: origins to 1600. *The Mariner's Mirror* 95 (3):260-283.

Flatman, J., and M. Staniforth. 2006. Historical maritime archaeology. In *The Cambridge companion to historical archaeology*, eds. Dan Hicks, and Mary C. Beaudry, 168-188. Cambridge: Cambridge University Press.

Gawronski, J. H. 1991. The archaeological and historical research of the Dutch East Indiaman Amsterdam (1749). In *Carvel construction technique: fifth International symposium on boat and ship archaeology, Amsterdam 1988*, eds. Reinder Reinders, and Kees Paul, 81-84. Oxford: Oxbow Books.

Gibbins, D., and J. Adams. 2001. Shipwrecks and maritime archaeology. *World Archaeology* 32 (3):279-291.

Goddio, F., M. Crick, P. Lam, S. Pierson, and R. Scott. 2002. *Lost at sea: the strange route of the Lena Shoal junk*. London: Periplus Publishing London Ltd.

Gong, C., Y. Ding, X. Chu, and L. Xi. 2008. Zhejiang Ningbo Heyilu chutu guchuan fuyuan yanjiu (Study on the reconstruction of the ancient ship from Zhejiang Ningbo Heyilu). *Ningbo Wenwu Kaogu Yonjiu Wenshi (Bulletin for Research of Cultural Relic and Archaeology in Ningbo)* 2:183-194.

Gould, R. (ed.) 1983. *Shipwreck anthropology*, University of New Mexico Press, Albuquerque.

Green, J. 1983a. The Song Dynasty shipwreck at Quanzhou, Fujian Province, People's Republic of China. *The International Journal of Nautical Archaeology* 12 (3):253-261.

Green, J. 1983b. The Shinan excavation, Korea: an interim report on the hull structure. *The International Journal of Nautical Archaeology* 12 (4):293-301.

Green, J. 1986. Eastern shipbuilding traditions: a review of the evidence. *the Bulletin of the Australasian Institute for Maritime Archaeology* 12:2.

Green, J. 1990. Maritime archaeology in Southeast and East Asia. *Antiquity* 64:347-363.

Green, J. 1997a. Archaeological evidence East Asian vessels. In *Maritime archaeology in the People's Republic of China*, ed. Jeremy Green, 19-24. Special Publication. Fremantle: Western Australia Maritime Museum.

Green, J. 1997b. Chinese shipbuilding in a historical context. In *Maritime archaeology in the People's Republic of China*, ed. Jeremy Green, 1-18. vol.

Special Publication No.1 Australian National Centre of Exellence for Maritime Archaeology. Fremantle: Western Australia Museum.

Green, J. 1998. The archaeological contribute to the knowledge of the extra-European shipbuilding at the time of the Medieval and Modern Iberian-Atlantic tradition. Paper presented at the International Symposium on Archaeology of Medieval and Modern Ships of Iberian-Atlantic tradition,

Green, J. 2006. Nautical archaeology in Australia, the Indian Ocean and Asia. In *Maritime archaeology: Australian approaches*, eds. Mark Staniforth, and Michael Nash, 97-109. New York: Springer.

Green, J., N. Burningham, and Museum of Overseas Communication History. 1998. The ship from Quanzhou, Fujian Province, People's Republic of China. *The International Journal of Nautical Archaeology* 27 (4):277-301.

Green, J., and P. Clark. 1993. The maritime archaeological, historical and ethnographic investigation of maritime technology in the pre-modern period, particular reference to Asian built ships, ed. Western Australian Maritime Museum Department of Maritime Archaeology.

Green, J., P. Clark, and K. Millar. 1993. The Academies' Australia - China exchange in the humanities and social science: Report on a Visit to China, ed. Western Australian Maritime Museum Department of Maritime Archaeology: Academy of the Social Sciences in Australia and the Australian Academy of the Humanities.

Green, J., and R. Harper. 1982. The excavation of the Ko Kradat wreck site, Thailand. *The International Journal of Nautical Archaeology* 11 (2):164-171.

Green, J., and R. Harper. 1983. The excavation of the Pattaya wreck site and survey of three other sites Thailand 1982. In *Australian Institution for Maritime Archaeology Special Publication No. 1*. Fremantle: Australian Institution for Maritime Archaeology.

Green, J., R. Harper, and V. Intakosi. 1987. *The maritime archaeology of shipwrecks and ceramics in Southeast Asia, the maritime connection / Jeremy Green and Rosemary Harper. The Ko Si Chang three shipwreck excavation 1986 / Jeremy Green, Rosemary Harper and Vidya Intakosi*. Albert Park, Vic: The Australian Institute for Maritime Archaeology.

Green, J., and V. Intakosai. 1983. The Pattaya wreck site excavation, Thailand. An interim report. *The International Journal of Nautical Archaeology* 12 (1):3-13.

Green, J., and Z. G. Kim. 1989. The Shinan and Wando sites, Korea: further information. *The International Journal of Nautical Archaeology* 18 (2):33-41.

Green, J., T. Vosmer, P. Clark, R. Santiago, and M. Alvares. 1992. Interim report on the joint Australian–Philippines Butuan boat project, October 1992. Fremantle: Western Australian maritime Museum.

Green, J., T. Vosmer, P. Clark, R. Santiago, and M. Alvares. 1995. Interim report on the joint Australian–Philippines Butuan boat project, October 1992. *The International Journal of Nautical Archaeology* 24 (3):177-188.

Greenhill, B. 1976. *Archaeology of the boat: a new Introductory study*. London: A. and C. Black.

Guy, J. 1980. *Oriental trade ceramics in Southeast Asia 10th to 16th century: selected from Australian collection, including the Art Gallery of South Australia and Bodor collection*. Melbourne: National Gallery of Victoria.

Guy, J. 2006. Early ninth-century Chinese export ceramics and the Persian Gulf connection: the Belitung shipwreck evidence. *SFECO (Societe Francaise d'Etude de la Ceramique Orientale* 4:9-20.

Hall, K. R. 1985. *Maritime trade and state development in early Southeast Asia*. Honolulu: University of Hawaii Press.

Hartwell, R. 1962. A revolution in the Chinese iron and coal industries during the Northern Sung, 960-1126 A.D. *The Journal of Asian Studies* 21 (2):153-162.

Hartwell, R. 1966. Markets, technology, and the structure of enterprise in the development of the eleventh-century Chinese iron and steel industry. *The Journal of Economic History* 26 (1):29-58.

Hayashida, K. 2006. Present and future of underwater archaeology in Japan. In *Shinan Underwater Relics and 14th Century Asian Marine Trades: International Symposium in Celebration of the 30th Anniversary of the Shinan Wreck Excavation*, ed. National Maritime Museum of Korea. Mokpo.

He, G. 1991. Measurement and research of the ancient Ming ship unearthed in Liangshan. In *International Sailing Ships History Conference*, eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Hoagland, P. 1997. Managing the underwater cultural resources of the China Seas: a comparison of public policies in Mainland China and Taiwan. *The International Journal of Marine and Coastal Law* 12 (2):265-283.

Hoagland, P. 1999. Historic shipwreck policy in China. In *Legal protection of the underwater cultural heritage: national and international perspectives*, ed. Sarah Dromgoole, 19-41. U.K: Kluwer Law International Ltd.

Hocker, F. M. 2004. Shipbuilding: philosophy, practice, and research. In *The philosophy of shipbuilding: conceptual approaches to the study of wooden ships*, eds. Frederick M. Hocker, and Cheryl A. Bass, 1-11. College station Texas A&M University Press.

Hornell, J. 1934. The origin of the Junk and Sampan. *The Mariner's Mirror* 30:331-337.

Hornell, J. 1946. *Water transport: origins and early evolution*. Cambridge: Cambridge University Press.

Huisman, H. D. J. 2009. Iron. In *Degradation of archaeological remains*, ed. Hans D.J. Huisman, 91-109. Sdu Integers.

Ikuta, S. 1975. Higashi Asia no fune (Ships of East Asia). In *Fune: nihon kodai bunka no tankyu,* ed. Taryo Obayashi, 181-217. Tokyo: Shakai Shisosha.

Ishii, K. 1957. *Nihon no fune (Ships in Japan)*. Tokyo: Sogensha.

Ishii, K. 1995a. *Wasen I (A Japanese vessel I)*. 3 Aufl. Mono to ningen no bunkashi (Cultural history of materials and human). Tokyo: Hosei daigaku syuppankyoku (Hosei University Press).

Ishii, K. 1995b. *Wasen II (A Japanese vessel II)*. 3 Aufl. Mono to ningen no bunkashi (Cultural history of materials and human). Tokyo: Hosei daigaku syuppankyoku (Hosei University Press).

Ito, A. 1975. Sekai no fune (Ships of the world). In *Fune: nihon kodai bunka no tankyu*, ed. Taryo Obayashi, 142-179. Tokyo: Shakai Shisosha.

Ji, S. 1987. Brief report on the ancient boat from the Dazhi River, Nahui Country, Shanghai. *The Bulletin of the Shanghai Museum* 4:175-178.

Johnson, M. 1999. *Archaeological theory: an introduction*. Oxford: Blackwell.

Kabanov, Y., and P. Pomey. 2004. The Greek sewn shipbuilding tradition and the ma'agan mikhael ship: a comparison with Mediterranean parallels from the sixth to the fourth centuries BC. *The Mariner's Mirror* 90 (1):6-28.

Kazuhiro, S., K. Yoshifumi, and K. Yasuhiko. 2000. Provenance of granitic anchor stones recovered from the Takashima submerged site: an approach using the CHIME method for dating of zircons. *Proceedings of the Japan Academy. Ser. B, Physical and Biological Sciences* 76 (9):139-144.

Keith, D. H. 1980. A fourteenth-century shipwreck at Sinan-gun. *Archaeology* 33 (2):33-43.

Keith, D. H., and C. J. Buys. 1981. New light on medieval Chinese seagoing ship construction. *The International Journal of Nautical Archaeology* 10 (20):119-132.

Kenderdine, S. 1995. Bai Jiao 1 - the excavation of a Song Dynasty shipwreck in the Dinghai area, Fujian Province, China, 1995. *The International Journal of Nautical Archaeology* 24 (4):247-266.

Kenderdine, S. 1997. The Bai jiao excavations. In *Maritime archaeology in the People's Republic of China*, ed. Jeremy Green, 53-93. Fremantle: Western Australia Maritime Museum.

Kerchove, R. D. 1961. International maritime dictionary: an encyclopedic dictionary of useful maritime terms and phrases, together with equivalents in French and German. New York: D. Van Nostrand Company, INC.

Kim, S.-B. 2006. Current situation and perspective of underwater archaeology in Korea and Shinan underwater relics. In *Shinan Underwater Relics and 14th Century Asian Marine Trades: International Symposium in Celebration of the 30th Anniversary of the Shinan Wreck Excavation*. Mokpo.

Kim, Y.-H. 2004. A study on the structure of Shinan Shipwreck. In *The conservation and restoration of Shinan Ship, the 20 years history*, ed. National Maritime Museum of Korea, 106-121. Mokpo: National Maritime Museum of Korea.

Kim, Z.-G. 1991. The wreck excavated for the Wando-Island. In *International Sailing Ships History Conference*, eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Kim, Z.-G. 1994. *Sok hanguk seonbaksa yeongu (Research sequel to the history of Korean ships)*. Seoul: Seoul National University Press.

Kimura, J. 2006. Recent survey and excavation on the Mongolian fleet sunk off Japan: the Takashima underwater site. *the Bulletin of the Australasian Institute for Maritime Archaeology* 30 (7-13).

Kimura, J. (ed.) 2010a. *Shipwreck ASIA: thematic studies in East Asian maritime archaeology*, Maritime Archaeology Program, Adelaide.

Kimura, J., R. Sasaki, and V. T. Long. 2011. Historical development of Asian anchors, as evidenced by two wooden anchors found in northern Vietnam. *The International Journal of Nautical Archaeology* 40 (1):*in process*.

Kobayashi, S. (ed.) 1941. *Junk: Chugoku no hansen (Chinese sailing ship)*, Chuuishi Junk Kyokai (Society for Chinese Junk), Shanghai.

Kuwabara, J. 1989. *Ho juko no jiseki (Records of Ho juko)*. Toyo Bunko. Tokyo: Heibonsha.

Kuwata, R. 1954. Note on the ancient history of Southeast Asia. *Memoris of the Faculty of Literature Osaka University* III:1-43.

L'Hour, M. (ed.) 2003. *The sunken treasures of Brunei darussalam*, Art Exhibitions Australia, Sydney.

Lee, C.-E. 1991. A study on the structural and fluid characteristics of a rabbetted clinker type ship (The sunken ship salvaged Off Shinan). In *International Sailing Ships History Conference* eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Lee, C.-H. 2004. The study on the restoration of the Shinan Ship. In *The conservation and restoration of Shinan Ship, the 20 years history*, ed. National Maritime Museum of Korea, 144-159. Mokpo: National Maritime

Museum of Korea.

Li, G. 1989. Archaeological evidence for the use of 'chu-nam' on the 13th century Quanzhou ship, Fujian Province, China. *The International Journal of Nautical Archaeology* 18 (4):277-283.

Li, G. 2004. Zhongguo Quanzhou gu-chuan baohu xiufu (Preservation and restoration of the Quanzhou ship in China) In *The conservation and restoration of Shinan Ship, the 20 years history*, ed. National Maritime Museum of Korea, 80-87. Mokpo: National Maritime Museum of Korea.

Lin, S., G. Du, and J. Green. 1991. Waterfront excavation at Dongmenkou, Ningbo, Zhe Jiang Province, PRC. *The International Journal of Nautical Archaeology* 20 (4):299-311.

Liu, X., H. Li, Y. Chen, X. Yao, and X. Zhang. 2006. Penglai shuicheng xiaohai guchuan caizhi zhuang kuang ji shuzhong peizhi (Quality and use of timbers from Penglai ships). In *Ancient ships from Penglai*, eds. Cultural Relics and Archaeological Institute of Shandong Province, Yantai Municipal Museum, and Cultural Relics Bureau of Penglai City, 120-138. Beijing: Wenwu Press.

Maarleveld, T. J. 1995. Type or technique. Some thoughts on boat and ship finds as indicative or cultural traditions. *The International Journal of Nautical Archaeology* 24 (1):3-7.

Manguin, P.-Y. 1984. Relationship and cross-influence between Southeast Asia and Chinese shipbuilding traditions. In *SPAFA consultative workshop on research on maritime shipping and trade networks in Southeast Asia*. Cisarusa, West Java, Indonesia.

Manguin, P.-Y. 1993. Trading ships of the South China Sea: shipbuilding techniques and their role in the history of the development of Asian trade networks. *The Journal of the Economic and Social History of the Orient* 36 (3):253-280.

Manguin, P.-Y. 2009. The boat remains of Punjulhrjo: a preliminary report.

Manguin, P.-Y. 2010. New ships for new networks: trends in shipbuilding in the South China Sea in the 15th and 16th centuries. In *Southeast Asia in the fifteenth century: the China factor,* eds. Geoff Wade, and Sun Laichen, 333-358. Singapore: NUS Press.

Matsunami, H. 2006. 9 seiki Nippon no koueki katsudou to Chouhoko (Ninth century maritime activity by Japan and Jang Bogo). In *A person in the Silla, Jang Bogo*, ed. National Maritime Museum, 143-149. Mokpo: National Maritime Museum.

Matsuura, A. 1995. *Chugoku no kaizoku (Pirates in China)*. Tokyo: Toho Shoten.

Matsuura, A. 2008a. The activities of Chinese junks on East Asian seas from the seventeenth to the nineteenth centuries: mainly based on Sand Junks and

Bird Junks. *The Mariner's Mirror* 94 (2):150-159.

Matsuura, A. 2008b. Modern East Asian cultural interaction and Chinese ships. *The Journal of East Asian Cultural Interaction Studies*:41-62.

McCarthy, M. 2005. *Ships' fastenings: from sewn boat to steamship*. College Station: Texas A&M University Press.

McGrail, S. 1985. Classification of water transport. *World Archaeology* 16 (3):289-303.

McGrail, S. 2001. *Boats of the world: from the Stone Age to Medieval Times*. Oxford: Oxford University Press.

McKinnon, E. E. 2001. Ancient Shipwrecks in Indonesian Waters.

Merwin, D. 1977. Selections from Wen-wu on the excavation of a Sung Dynasty seagoing vessel in Chuan-chou. *Chinese Sociology and Anthropology* IX (3):3-106.

Miksic, J. N. 2010. Before and after Zheng He: comparing some Southeast Asian archaeological sites of the 14th and 15th centuries. In *Southeast Asia in the fifteenth century: the China factor*, eds. Geoff Wade, and Sun Laichen, 384-408. Singapore: NUS Press.

Mitsutani, T. 1996. Takashima Kaitei Iseki (Kozaki-ko) syutudo mokuzai no zyusyu (Wood species of recovered timbers from Takashima Underwater Site). In *Takashima Kaitei Iseki III (The Takashima Underwater Site III)*, ed. Nagasaki-ken Takashima-cho Board of Education, 73-80. Nagasaki: Nagazaki-ken Takashima-cho Board of Education,.

Mitsutani, T. 2001. Takashima Kaitei Iseki (Kozaki-ko) syutudo mokuzai no zyusyu (Wood species of recovered timbers from Takashima Underwater Site). In *Takashima Kaitei Iseki V (The Takashima Underwater Site V)*, ed. Nagasaki-ken Takashima-cho Board of Education, 52-53. Nagasaki.

Miyashita, H. 2006. Ancient ships of Japan. Texas A&M University, College Station.

Momoki, S. (ed.) 2008. *Kaiiki Asia shi kenkyu nyumon (Reader for the history of maritime area of Asia)*, Iwanami Shoten, Tokyo.

Muckelroy, K. 1978. *Maritime archaeology*. Cambridge: Cambridge University Press.

Murai, S. 2005. Zisha zoueiryo tosen wo minaosu: boueki, bunka kouryu, chinsen (Reviewing temple-shrine chartered Chinese ships). In *Minatomati to Kaiiki sekai*, ed. Shosuke Murai, 113-143. vol. Minatomati no Sekaishi. Tokyo: Aoki Shoten.

Museum of Overseas Communication History. 1987. Quanzhouwan Song dai haichuan fajue yu yanjiu (Excavation and research of the Song Dynasty ship found on the Quanzhou Bay). In *Quanzhouwan Song Dai Haichuan Fajue* *yu Yanjiu*, ed. Museum of Overseas Communication History, 3-68. Beijing: Ocean Press.

Nagazumi, Y. 2001. *Shuinsen (Red seal vessel)*. Tokyo: Yoshikawakobunkan.

National Maritime Museum of Korea. 2004. The conservation and restoration report of Shinan ship. Mokpo.

National Maritime Museum of Korea. 2005a. Guide book for permanent exhibits. Mokpo: National Maritime Museum.

National Maritime Museum of Korea. 2005b. The underwater excavation of the sea off Sibidongpado, Gunsan. Mokpo: National Maritime Museum.

National Maritime Museum of Korea. 2006a. Shinan underwater relics and 14th century Asian marine trades. In *International Symposium in Celebration of the 30th Anniversary of the Shinan Wreck Excavation*. Mokpo: National Maritime Museum of Korea.

National Maritime Museum of Korea. 2006b. The Shinan Wreck I. Mokpo: National Maritime Museum of Korea.

National Maritime Museum of Korea. 2006c. The excavation of Anjwa ship, Sinan. Mokpo: National Maritime Museum.

National Maritime Museum of Korea. 2008a. Ansan Daebudo sea site: submarine excavation. In *Report of the Research of Antiquities of the National Maritime Museum No.XIII*. Mokpo: National Maritime Museum.

National Maritime Museum of Korea. 2008b. Korean ship and shipbuilding tools in the modern times. Mokpo: National Maritime Museum, .

National Research Institute of Maritime Cultural Heritage. 2009. Taean treasure ship: submarine excavation. In *Report of the Research of Antiquities of the National Research Institute of Maritime Cultural Heritage No.17*. Mokpo: National Research Institute of Maritime Cultural Heritage, .

Needham, J. 1971. *Science and civilization in China: vol.4 physics and physical technology - civil engineering and nautics*. London: Cambridge University Press.

Nogami, T. 2004. An internal report of the excavation of the underwater site off Mogi harbor. *Newsletter* 18:17-19.

Oba, O. 1974. Scroll painting of Chinese junks which sailed to Nagasaki in the 18th century and their equipment. *The Mariner's Mirror* 60 (4):351-362.

Oba, O. 1980. *Edo jidai no Nitchu hiwa (Unknown episodes between Japan and China during the Edo period)*. Touhou Sensho. Tokyo: Touhou Shoten.

Oba, O. 1991. Portraits of Chinese junks painted by Japanese painters in the Edo period. In *International Sailing Ships History Conference* eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Oba, O. (ed.) 2003. *Nagasaki tokanzu shusei (The compilation of paintings of the Chinese residences (Tokan) in Nagasaki),* Kansai Daigaku Shuppanbu, Osaka.

Ogata, K. 1972. Light woods and heavy woods: (II) Heavy woods. *The Tropical Forestry* 24:1-15.

Okita, M. 2000. Fune no koukogaku myou (About archaeology of ship). In *Zenkindai higashi Asia ni okeru kaiiki koryu seiritsu zyouken ni kansuru kiso teki kenkyu (Fundamental Study about factors to form maritime exchange before pre-modern period of East Asia),* ed. Kaiiki Kouryuushi Kenkyuukai (Society for Historical Research of Maritime Exchange), 21-31. Tokyo: Toyota Foundation.

Okorokov, A. V. 1995. Archaeological finds of ancient dugouts in Russia and the Ukraine. *The International Journal of Nautical Archaeology* 24 (1):33-45.

Orillaneda, B. C. 2008. The Santa Cruz, Zambales Shipwreck Ceramics: Understanding Southeast Asian Ceramic Trade during the Late 15th Century C.E., University of the Philippines, Quezon City.

Osawa, M. 2004. Irons in Japan and the Korean Peninsula based on metallurgy. *Bulletin of the National Museum of Japanese History* 110:89-122.

Osawa, M. 2005a. Metallurgical analysis on the iron nails from the Takashima Underwater Site. In *Takashima Kaitei Iseki XI (Takashima Underwater Site XI),* ed. Nagasaki-ken Takashima-cho Board of Education, 33-46. Nagasaki.

Osawa, M. 2005b. One of the forms of iron producing in the Mongol Empire obtained In *The Avraga Site: preliminary report of the excavation of the palace of Genghis Khan in Mongolia 2001-2004,* ed. Kokugakuin University, 45-62. Niigata: Department of Archaeology Niigata University, .

Pearson, R., M. Li, and G. Li. 2002. Quanzhou archaeology: a brief review. *International Journal of Historical Archaeology* 6 (1):23-37.

Peng, D. (ed.) 1988. *Zhongguo chuan pu (Ships of China)*, Renmin Jiaotong Chubanshe, Beijing.

Preucel, R., and I. Hodder (eds) 1996. *Contemporary archaeology in theory: a reader*, Wiley-Blackwell, Oxford.

Ptak, R. 2000. Camphor in East and Southeast Asian trade, c. 1500: A synthesis of Portuguese and Asian Sources. In *Vasco da Gama and the Linking of Europe and Asia, eds. Anthony Disney, and Emily Booth*, 142-166. New Delhi: Oxford University Press.

Reid, A. 1988-1993. *Southeast Asia in the age of commerce, 1450-1680*. New Haven: Yale University Press.

Reid, A. 2010. Hybrid identities in the 15th-century straits. In *Southeast Asia in the fifteenth century: the China factor,* eds. Geoff Wade, and Sun Laichen, 307-332. Singapore: NUS Press.

Reischauer, E. O. 1940. Notes on T'ang Dynasty Sea Routes. *Harvard Journal of Asiatic Studies* 5 (2):142-164.

Reischauer, E. O. 1955. *Ennin's travels in T'ang China*. New York: The Ronald Press Company.

Ridho, A., and E. E. McKinnon. 1998. *The Pulau Buaya wreck*. The Ceramic Society of Indonesia Monograph Series. Jakarta: Ceramic Society of Indonesia.

Rogers, E. M. 2003. *Diffusion of innovations* 5th ed Aufl. New York: Free Press.

Sasada, T. 2009. Hokuto Asia no tetsu seisan (Iron production in northeast Asia). In *Chusei higashi Asia no shuhen sekai*, eds. Tetsuya Amano, Eishi Ikeda, and Isao Usuki, 74-85. Tokyo: Douseisha.

Sasaki, R., and C. H. Lee. 2010. Goryeo Dynasty (918-1392), shipwrecks in Korea. In *Shipwreck ASIA: thematic studies in East Asian maritime archaeology*, 56-73. Adelaide: Maritime Archaeology Program.

Sasaki, R. J. 2008. The Origin of the Lost Fleet of The Mongol Empire. Texas A&M University, College Station.

Shennan, S. 1996. Cultural transmission and cultural change. In *Contemporary archaeology in theory: a reader*, eds. Robert Preucel, and Ian Hodder, 282-296. Oxford: Wiley-Blackwell.

Shiba, Y. 1968. *Commercial activities during the Sung Dynasty*. Tokyo: Kazamashobo.

Shiga Prefectural Association for Cultural Heritage (ed.) 2006. *Marukibune no zidai: Biwako to kodaijin (Time period of dugout canoe: Lake Biwa and ancient people)*, Shiga Prefectural Association for Cultural Heritage, , Otsu.

Shimizu, J. 1968. Kodai no fune: Nihon no marukibune wo chushin ni (Ancient ships: from the study of dugout canoes in Japan). In *Fune*, ed. T Sudo, 31-55. Tokyo: Hosei University Press.

Shimizu, J. 1975. Nihon kodai no fune (Ancient Japanese ships). In *Fune: Nihon Kodai Bunka no Tankyu*, ed. Taryo Obayashi, 12-83. Tokyo: Shakai Shisosha.

Sigaut, E. 1960. A northern type of Chinese junk. *The Mariner's Mirror* 46 (3):161-174.

Sokoloff, V. A. 1982. *Navios da China, ships of China*. Macao: Banco Nacional Ultramarino, S. A.

Staniforth, M. 2002. *Material culture and consumer society: dependent colonies in colonial Australia*. The Plenum series in underwater archaeology. New York: Kluwer Academic/Plenum Publishers.

Steffy, J. 1994. *Wooden ship building and the interpretation of shipwrecks*. College station: Texas A&M University Press.

Steffy, R. 1991. The Mediterranean shell to skeleton transition: a northwest European parallel?? In *Carvel construction technique: fifth international symposium on boat and ship archaeology, Amsterdam 1988,* eds. Reinder Reinders, and Kees Paul, 1-9. Oxford: Oxbow Books.

Takashima-cho Board of Education. 1996. Takashima Kaitei Iseki III (Takashima Underwater Site III). In *Takashima-cho Bunkazai Chosa Hokokusho (A Series Survey Report of Cultural Properties in Takashima-cho).* Nagasaki: Nagasaki-ken Takashima-cho Board of Education.

Takashima-cho Board of Education. 2001. Takashima Kaitei Iseki V (Takashima Underwater Site V). In *Takashima-cho Bunkazai Chosa Hokokusho (A Series Survey Report of Cultural Properties in Takashima-cho).* Nagasaki: Nagasaki-ken Takashima-cho Board of Education.

Takashima-cho Board of Education. 2003. Takashima Kaitei Iseki VIII (Takashima Underwater Site VIII). In *Takashima-cho Bunkazai Chosa Hokokusho (A Series Survey Report of Cultural Properties in Takashima-cho).* Nagasaki: Nagasaki-ken Takashima-cho Board of Education.

Takashima-cho Board of Education. 2005. Takashima Kaitei Iseki XI (Takashima Underwater Site XI). In *Takashima-cho Bunkazai Chosa Hokokusho (A Series Survey Report of Cultural Properties in Takashima-cho).* Nagasaki: Takashima-cho Board of Education.

Takashima-cho Board of Education. 2008. Matsuura-shi Takashima Kaitei Iseki (Matsuura city Takashima Underwater Site). In *Matsuura-shi Bunkazai Chosa Hokokusho (A Series Survey Report of Cultural Properties in Matsuura city).* Matsuura: Nagazaki-ken Matsuura-shi Takashima-cho Board of Education.

Tanaka, K., and A. Matsuura. 1986. *Materials concerning to the Chinese ship casted away on the coast of Sizuoka Prefecture in 1826 (Bunsei 9).* Materials' Series of Chinese Ships Cased Away on the Coast of Japanese Islands. Osaka: Kansai Daigaku Shuppanbu.

Tang, Z. 1991. The influence of the sail on the development of the ancient navy. In *International Sailing Ships History Conference* eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Tilburg, H. V. 2007. *Chinese junks on the Pacific: views from a different deck*. New Perspectives on Maritime History and Nautical Archaeology. Gainesville: University Press of Florida.

Uezato, T. 2008. Ryukyu okoku no keisei to tenkai (Formation and development of the Ryuku Kingdom). In *Kaiiki Asia shi kenkyu nyumon*, ed. Shiro Momoki.

Tokyo: Iwanami Shoten.
Underwood, H. H. 1979. Korean Boats and Ships. In *English Publication No. II The Literary Department Chosen Chirtian Collage*. Seoul: Yonsei University Press.
Wade, G. 2003. The pre-modern East Asian maritime realm: an overview of European-language studies. In *Asia Research Institute Working Paper Series No. 16*: Asia Research Institute National University of Singapore.
Wade, G. 2010. Southeast Asia in the 15th century. In *Southeast Asia in the fifteenth century: the China factor*, eds. Geoff Wade, and Sun Laichen, 3-43. Singapore: NUS Press.
Wagner, D. B. 1995. The traditional Chinese iron industry and its modern fate. *Chinese Science* 12:138–161.
Wagner, D. B. 2001. Blast furnaces in Song-Yuan China. *East Asian science, technology, and medicine* 18:41-74.
Wang, G. 1958. The Nanhai trade: a study of the early history of Chinese trade in the South China Sea. *Journal of the Malayan Branch Royal Asiatic Society* XXXI (2):1-135.
Wang, G. 2000. *Zhongguo gu chuan tu pu (Catalogue of ancient Chinese ships)*. Beijing: Sanlian Shudian.
Watanabe, T. 1985. Ancient Cambodia Funan as described by Zhu Ying and Kang Tai : a collection of fragments written by a mission to Cambodia in Three Kingdoms Wu period. *Proceedings of the Faculty of Letters of Tokai University* 43:7-28.
Waters, D. W. 1938. Chinese junks: Antung trader. *The Mariner's Mirror* 24:49-67.
Waters, D. W. 1939. Chinese junks: the Pechili trader. *The Mariner's Mirror* 25:62-88.
Waters, D. W. 1946. Chinese junks: the Twaqo. *The Mariner's Mirror* 32:155-167.
Waters, D. W. 1947. Chinese junks: the Hangchow bay trader and fisher. *The Mariner's Mirror* 33:28-38.
Worcester, G. R. G. 1941. *Notes on the crooked-bow and crooked-stern junks of Szechwan*. Maritime customs. III, Miscellaneous series. Shanghai: Statistical Dept. of the Inspectorate General of Customs.
Worcester, G. R. G. 1966. *Sail and sweep in China: the history and development of the Chinese junk as illustrated by the collection of junk models in the science museum*. London: Science Museum.
Worcester, G. R. G. 1971. *The junks and sampans of the Yangtze*. Annapolis: United States Naval Institute.
Wright, T. 1854. *The travels of Marco Polo: the Venetian, the translation of Marsden Revised, with a section of his notes*. London: Henry G. Bohn.

Xi, L. 2000. *Zhongguo zaochuan shi (History of Chinese shipbuilding)*. Hubei: Hubei Education Publisher.

Xi, L. (ed.) 1989. *Penglai Gunchuan Yu Dengzhou Gugang (Ancient Penglai ship and Ancient Dengzhou port)*, Dalian Haiyun Xueyuan Chuban she, Dalian.

Xi, L. (ed.) 2008. *Chuan wenhua (Ship culture)* China Communication Press, Beijing.

Xi, L., and D. W. Chalmers. 2004. The rise and decline of Chinese shipbuilding in the Middle Ages. *The International Journal of Maritime Engineering*

Xi, L., and Y. Xin. 1991. Preliminary research on the historical period and restoration design of the ancient ship unearthed in Penglai. In *International Sailing Ships History Conference*, eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Xi, L., X. Yang, and X. Tang (eds) 2004. *Zhongguo kexue jishu shi: jiaotong juan (The history of science and technology in China: transportation)*, Science Press, Beijing.

Xin, Y., and S. Yuan. 1991. The blue ribbon holder in the Medieval Age: Chinese junks. In *International Sailing Ships History Conference*, eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Xu, Y. 1985. Origin and technique of "Gua-ju" (Iron Cramp) connections in wooden craft construction. *Marine History Research, Transactions of CSNAME Marine History Research Group* (1):64-71.

Yamauchi, S. 2008. Nihon reto to kaiiki sekai (Japan archipelago and maritime space). In *Kaiiki Asia shi kenkyu nyumon*, ed. Shiro Momoki, 39-47. Tokyo: Iwanami Shoten.

Yang, Y. 1989. Maritime fortress Penglai in Shandong Province and Ming combat vessel. In *Penglai guchuan yu dengzhou gugang (Ancient Penglai ship and ancient Dengzhou port)*, ed. LongFei Xi, 60-66. Dalian: Dalian Haiyun Xueyuan Chubanshe.

Yang, Z. 2009. An Introduction to the hull of Huaguang Reef one shipwreck site of the Song Dynasty in Xisha Islands. Paper presented at the Of Ships and Men, the Sino-French Workshop, Ningbo, November 2009

Young, C. F. T. 1867. *The fouling and corrosion of iron ships: their causes and means of prevention, with the mode of application to the existing iron-clads*. London: The London Drawing Association.

Yuan, X. 2006. The excavation and accomplishment of the shipwreck on Penglai area in China. In *Shinan Underwater Relics and 14th Century Asian Marine Trades: International Symposium in Celebration of the 30th Anniversary of* *the Shinan Wreck Excavation*, ed. National Maritime Museum of Korea. Mokpo.

Yule, H. 1993. The Travels of Marco Polo: The Complete Yule-Cordier Edition. Courier Dover Publications. (Orig. pub.

Zhang, C., Z. You, Z. Wu, and Y. Liu (eds) 2004. *Zhongguo jixie gongchen faming shi (History of technological and mechanical invention in China)*, Singh University Press, Beijing.

Zhang, W. 2006a. The application of the basic principles and methods of the underwater archaeology in China In *Shinan Underwater Relics and 14th Century Asian Marine Trades: International Symposium in Celebration of the 30th Anniversary of the Shinan Wreck Excavation*, ed. National Maritime Museum of Korea. Mokpo.

Zhang, W. 2006b. Preface. In *Xisha shuixia kaogu (1998-1999) (Underwater archaeology in Xisha islands)*, eds. Underwater Archaeology Research Center of the National Museum of China, and Cultural Heritage Administration Office of Hainan Province, v-xi. Series of Underwater Archaeology Report. Beijing: Science Press.

Zhang, W. 2006c. Qianyan (Preface). In *Donghai Pingtan Wanjiao yihao chushui ciqi (Porcelain from the shipwreck no. 1 of the Wanjiao Reefs from Pingtan in the South China Sea)*, ed. Underwater Archaeology Team of Wanjiao No.1, 1-2. Beijing: Science Press.

Zhang, W. (ed.) 2001. *Suizhong Sandaogang Yuandai Chenchuan (Yuan Dynasty Shipwreck in Suizhong Shandaogang)*, Science Press, Beijing.

Zhao, H. 1992. Recent development in the legal protection of historic shipwrecks in China. *Ocean Development and International Law* 23:305-333.

Zheng, Y. 1991. Zheng He's naval expeditions and the development of marine economy of early Ming Dynasty. In *International Sailing Ships History Conference*, eds. Shanghai Society of Naval Architecture & Marine Engineering, and Marine History Researchers' Association of CSNAME. Shanghai.

Zou, Y., and X. Yuan. 1989. A study of date and use of ancient Penglai ship. In *Penglai guchuan yu Dengzhou gugang (Ancient Penglai ship and ancient Dengzhou port)*, ed. LongFei Xi, 74-79, 177. Dalian Dalian Haiyun Xueyuan Chuban she.

Glossary

This small glossary of nautical terms is developed to understand medieval East Asian shipbuilding technology. The description of these terms rely by default of the western nautical terms presented in *International Maritime Dictionary* and follows terminology that has been developed in previous Chinese junk's study in Worcester and Van Tilburg. A few new terms appear in this glossary resulting from this research in order to explain features of excavated ships in the region.

athwartships	At right angles to the fore-and-aft line of a vessel (International Marine Dictionary).
balanced rudder	A rudder in which part of the blade surface, generally from 12 percents to 20 percents, is forward of the axis so that the water pressure on this portion counterbalances that on the after part (International Marine Dictionary).
bao shou kong	Literally, a hole for holding longevity. It is holes in the scarfs or joints of the keel of traditional Chinese ships. They are for placing copper coins represent the Great Bear constellation and a mirror represents a full moon. It appears to be a common among shipwrights in the southern part of Fujian.
batten	A small spar, usually of bamboo, secured to, and lying across, a sail so as to extend leech (Worcester 1966).
beam	A transverse structural member of the ship's framing. Beams as joists support the deck against pressures that may be sustained from cargo or from masses of ties and struts they support and hold at fixed distance the vessel's sides and check racking tendencies in the transverse section (International Marine Dictionary).
body plan	A plan of ship lines from an end view showings curves of the sides of the ship. See **sheer plan** and **half-breadth plan** (International Marine Dictionary).
bow transom	A foremost transverse baulks forming bow.
bracket	A fastening to fix the hull planking and bulkheads tightly together and to hold bulkhead planks.
bulkhead	A name given to any vertical partition, whether fore and aft or athwartships, which separates different compartments or spaces from one another (International Marine Dictionary).
bulkhead stiffeners	Bars of rolled section, angles, bulb angles, or channels, welded or rivets vertically on one side of a bulkhead to strength it. The scantlines of stiffeners are regulated according to the water pressure to which bulkhead may be subjected. Stiffeners fitted with brackets or

lug attachment at both ends (International Marine Dictionary).

bulwark plank — Planks running each side of the vessels, serving as a fence, to keep the decks dry (International Marine Dictionary).

bulwark stanchion — In the wooden hulls the upper part of top timbers extending above the plank sheer and supporting the bulwark planking (International Marine Dictionary).

butt — The end of the two planks which exactly meet endwise.

butt joint — A term applied where the connection between two parts is made by brining their ends or edges together, fastening them with different joint methods: e.g., lap-joints, tongue and groove joints.

butt strap — Strip of plating which connects the plates of a butt joint.

buttock lines — Vertical lines paralleled to the centre line of the ship in a body plan, longitudinal lines paralleled to the centre line of the ship in the half-breath plan, or curve lines in the sheer plan (International Marine Dictionary).

carvel-built — Said of a boat constructed with carvel planking (International Marine Dictionary).

carvel planking — A system of planking in which the outside planking of a vessel or boat is flush: the edges meeting and giving the shell a smooth surface instead of overlapping as in the clinker system. The lines for carvel-built boats are laid down on a floor-just as in the building of large vessels-molds made, and bevelings taken for the timbers (International Marine Dictionary).

chine — The line of intersection between the sides and the bottom a flat or V-bottom (International Marine Dictionary).

chine strake — The strakes create the chine between the bottom and the sides, specifically for those planks appear in the Goryeo Dynasty ships having L-shape cross-section.

clinker-built — Said of a boat constructed with clinker planking (International Marine Dictionary).

clinker planking — A method of planking used for watercraft in which the lower edge of each strake overlaps the upper edge of the strake next below (International Marine Dictionary).

coaming — The raised borders about the edge of hatches and scuttles for preventing water on deck from running below (International Marine Dictionary).

compound anchor — A type of anchor consisting of wooden shanks and arms with a stone anchor stock (stone stocks).

chunam — Substance traditionally used in Chinese shipbuilding as putty for caulking and luting, generally known as a material made from ash of lime stone (or shells) and vegetable fibre mixtured with wood oil (tung oil).

deadrise	An angle that measures upward from a horizontal plane at keel (International Marine Dictionary).
deadweight	The vessel's lifting capacity when loaded includes crew, passengers, language, fresh water in storage tanks, and cargo (International Marine Dictionary).
displacement	The number of tons of water displaced by a vessel afloat (International Marine Dictionary).
dunnage	Material stowed among and beneath the cargo of a vessel to protect it from chafing and getting wet (International Marine Dictionary).
draft	The depth of water which a ship requires to float freely. The depth of a vessel below the water line, measured vertically to the lowest part of the hull or other reference points (International Marine Dictionary).
frame	A transverse structural member forming the ribs of the hull and extending from the keel to the highest continuous deck (International Marine Dictionary). For oceangoing ships of East Asian origin, half-frames attached to the bulkheads are used.
frame-fast technique	A construction method to describe the procedure in the way which constructions the hull by first erecting frames and then attaching hull planks to them.
freeboard	The vertical distance from load waterline to the uppermost complete deck (International Marine Dictionary).
gua ju	A "gua ju" (挂锔) is literary, a hook bracket. The use of metal brackets in Chinese shipbuilding tradition has been introduced with examples of the use of wooden brackets and various iron cramps (Xu 1985; Zhang, You et al. 2004: 288-290). The procedure of the installation may show the similarity with an L-shaped wrought-iron spike or dog to fasten the bulkheads to hull bottom planks of Chinese river junks to have been used by the recent times. Needham (1972: 115) mentions the size of metal brackets. Worcester's study provides brackets used in traditional Chinese shipbuilding (Worcester 1941, 1971).
half-breadth plan	A plan or top view of half of a ship divided into longitudinally (International Marine Dictionary).
half-frame	The short frame timbers, or for medieval oceangoing ships of East Asian origin, it is described as a frame consisting of two members of timbers meeting the centre line of the ship.

hog piece	A fore-and-aft piece of timber fastened to the top of the keel, providing a good landing edge for the garboards (International Marine Dictionary). In some of traditional Chinese ships, it is used as a solid longitudinal foundation where transverse components such as bulkheads can neatly sit.
junk	A term used to describe a wooden sailing vessel of oriental build and rig specifically to describe a traditional type of Chinese ships in western nautical terminology. In the sense, as it has been used by only by foreigners to describe watercraft operating in Chinese waters, there is no Chinese ideograms in the same meaning, apart from a substitute character (戎克) tentatively used by the Japanese.
keel	A keel, known as" longwu" (竜骨) in Chinese shipbuilding terminology, is likely to consists of three timbers; a main keel, a forward keel, and an aft keel. It is noted that the centre keel is definitive as a main keel in that it underlies the main internal structure, namely the bulkheads. Bulkheads are also built over the aft keel. The forward keel functions as an extension of the main keel but not likely underlie bulkheads. The term longwu, therefore, is applicable only for the main and aft keel members. It means a backbone of the ship to support physically the upper parts of the hull by the way it is ideogrammatically described in the Chinese characters. Most of archaeologically identified ships originated from eastern Asia show similar longitudinal structure of the keel based on three components.
leeboard	A plate or frame of planks lowered over the lee side of a shallow-draft boat with flat bottom. It lessens the leeway, by giving increased lateral resistance (International Marine Dictionary).
leech	The side of a square sail, or the afteredge of a fore- and aft- sail (International Marine Dictionary).
light displacement	The weight of a vessel when unloaded. Also called light weight including hull, fitting, permanent ballast, and feed water (International Marine Dictionary).
limber holes	Holes cut in the lower part of frames or bulkheads in the centre line or in the vicinity of the keel for drainage purpose.
load waterline	The line of immerse when a vessel is loaded.
mast heel	The lower end of a mast.
mast step	The chamfered block where the heel of a mast meets, likely to have two square recesses to recessive the end of the tabernacle cheeks.
oculus	The eyes depicted on the bow

plank-fast technique A construction method to describe the procedure in the way which constructions the hull by building up a plank-shell first.

planked-up dugout A type of dugout canoe by extending its sides upwardly by adding extra side strakes.

protruding-tongue scarf A scarf joint showing a half-lap with a protruding-tongue used in the bottom strakes of the Goryeo Dynasty's ships. A protruding-tongue like a tenon is made in the joint of a longitudinal member, which join into the recess cut in another member.

rabbeted carvel seam The rabbeted carvel seam is that where "the edge-joint between two adjacent strakes is rabbeted along the whole of the seam by a type of step-joint". The term has been developed in previous study of the hull of the Quanzhou ship by Nick Burningham and Jeremy Green.

rabbeted clinker seam The rabbeted clinker seam is that where "a rabbet is cut into the inside of the lower edge of the upper strake; the upper (unrabbeted) edge of the lower is set in this rabbet, giving an external appearance of a clinker overlap, but the thickness of the step between the strakes at the surface is reduced by the depth of rabbet". In the case of the Shinan ship, the rabbets cut in both lower and upper edge of some strakes around the bow where the hull planking changes from the clinker- to carvel-built.

rudder blade The main flat proportion of the rudder which provides the necessary surface for the impinging action and side pressure of the water (International Marine Dictionary)

rudder gudgeons (rudder socket) A device retaining a rudder. Three different types rudder gudgeons (socket) identified, according to Worcester's study: the .open, half-open, closed gudgeons.

rudder post A part of a rudder in which acts as a shaft to receive a rudder blade.

rudder tiller A heavy bar or leaver with one end board to fit on the rudder post. Its function is to turn the rudder (International Marine Dictionary).

sacrificial planking A covering wooden planks fastened to the underwater body of wooden hulls as a protection against ship worms and marine growths of all kinds.

scarf A join by which two members are connected longitudinally into a continuous piece, the ends being halved, notched, or cut away so as to fit into each other with mutual overlapping. The typical scarfs appears in are a stopped scarf and a hooked scarf.

scupper One of the drains set in decks to carry off accumulation of rain or sea water (International Marine Dictionary).

scupper hole A drain hole cut through the gunwale angle bar and adjoining shell

	plate to allow water to run directly overboard from the gutter or waterway (International Marine Dictionary).
sheer plan	A plan showing the longitudinal, vertical section passing through the median line of a ship (International Marine Dictionary).
skewed nail	A type of an iron nail, its shaft is bent and is typically used for hull planking. According to Li In Chinese shipbuilding, various types of the iron nails were used for the planking including “Diao ding” literary (hanging nails 吊钉), “Bie ding” literary (split nails 别钉), and “Cha ding” literary (spike nails 插钉), and they are distinctive in their shapes, length, and cross sections (Li 1989).
station lines	Projected lines in the body plan through which the sections paralleled to the vertical longitudinal plane cut the moulded surface of the hull (International Marine Dictionary).
stiffener	Sections or shapes used for increasing the rigidity of plating, as bulkhead stiffeners, Also called stiffening bar. See **bulkhead stiffener** (International Marine Dictionary).
strake	A continuous line of planking in the hull extending the whole length of the vessel. There are several or more varieties of strakes, according their position; e.g. a range of the planks in the bottom of the Korean ships is described as bottom strakes (Worcester 1966).
structural bulkhead	A bulkhead, generally water- or oiltigh, which forms one of the boundaries of the mains compartments and contributes to the strength of the hull. Its depth usually extends through several decks. (International Marine Dictionary).
stern transom	Aftermost athwartship baulks giving shape to and forming a stern, partly supporting the extremities of the deck. See **transom stern**
tabernacle	A vertical trunk to support the lower part of the mast.
tabernacle cheek	Vertical partners on each side of the lower end of the mast.
transom-mounted rudder	A rudder inserted into a round aperture cut through stern transom or a hole of the gudgeons fixed onto the stern transom. See also the rudder gudgeons
transom stern	A form of stern in which the upper part of the hull aft terminates in a large flat surface, vertical, or nearly so, and square to the central longitudinal plane.
turret construction	A barrel-shaped hull with comparatively narrow deck superimposed upon it (Worcester 1966).
watertight bulkhead	Vertical partitions in a ship that are strongly built, with joints which are tight enough to withstand the pressure of the hydrostatic head and prevent water escaping onto adjoining spaces if the compartment fills

with water. Watertight bulkheads also contribute to the structural strength of the ship (International Marine Dictionary).

waterline Horizontal lines parallel to the base line in the body plan, horizontal lines parallel to the base line in the sheer plan, or curve lines in the half-breath plan (International Marine Dictionary).

windlass A type of winch used to hoist the anchors, house them safely, and warp the ship when in harbor (International Marine Dictionary).

yuloh A type of sculling sweep used in small Chinese watercrafts, placed in the stern, which consist of two parts, a loom and a blade. (International Marine Dictionary).