A COMPARATIVE ANALYSIS OF EARLY MEDIEVAL SHIPWRECKS
FROM THE SOUTHERN SHORES OF THE BALTIC SEA

A Thesis
by
GEORGE INDRUSZEWSKI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of
MASTER OF ARTS

May 1996

Major Subject: Anthropology
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Approved as to style and content by:

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May 1996
Major Subject: Anthropology
ABSTRACT

A Comparative Analysis of Early Medieval Shipwrecks from the Southern Shores of the Baltic Sea. (May 1996)
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Chair of Advisory Committee: Dr. F. H. van Doorninck, Jr.

Most shipwrecks discovered on the southern shore of the Baltic have been attributed a Scandinavian or Germanic origin. However, the archaeological data corroborated in a concise comparative analysis reveal the commonness of technical details among these shipwrecks which points to the existence of a regional shipbuilding tradition in this area. The technical differences between Scandinavian shipwrecks and Southern Baltic shipwrecks further strengthen the idea of a regional shipbuilding tradition developed in the Early Middle Age on the southern shores of the Baltic Sea. The Scandinavian archaeological material outlines that a seemingly reciprocal exchange took place between Scandinavian shipbuilding on one hand and Southern Baltic shipbuilding on the other. The wrecks representing the latter tradition seem to fulfill the main characteristics attributed to the Wendish ships in historical sources. Although scarce, these sources are conducive in outlining the role of Slavic naval and commercial seafaring in the Baltic. This compatibility between historical sources and archaeological evidence indicates that the shipwrecks under discussion ought to be regarded as products of a Slavic shipbuilding tradition that was manifested in its full potential during the 11th and the 12th centuries. The final conclusions stress the
main characteristics of Slavic vessels, while further introspections are made into the difficult problems related to the origin and evolution of the Slavic/Wendish shipbuilding tradition. An attempt to define the shipwrecks from a chronological point of view reveals the difficulties of such a task, partially caused by the improper or uncertain dating of the archaeological material. The final chapter calls for further research pertaining to the shipbuilding tradition in this area, research vital for understanding the interactive mechanisms between the maritime societies of the Baltic Sea.
Totus tuus.
ACKNOWLEDGMENTS

The work contained in this thesis was possible only with the help and understanding of my wife, Kasia, and my two little boys, Tadeusz and Józef, to whom I dedicate the fruits of this work. Without the material sent by my parents from Bucharest, this thesis would have been incomplete. The unswerving help of Kasia’s parents provided the necessary support for my research in Poland.

On an academic level, I should stress that all Committee members contributed with their personal vision and knowledge to the scholarly aspect of this work. Dr. Frederick H. van Doorninck Jr., as Chairperson, was opportune in guiding me not only through the orthographic requirements of a scholarly writing, but also through the entire bureaucratic process related to this thesis. As president of the Institute of Nautical Archaeology, Dr. Frederick M. Hocker, declared his support for the subject of research analyzed in this thesis, and was instrumental in securing the funds necessary for a trip to Poland. Dr. Zoltan J. Kosztolnyik's benefic influence excelled in providing me with avenues of research in the medieval history of Eastern and Central Europe and with an unquenched spirit of optimism. Through his presence in the Advisory Committee, Mr. Ole Crumlin-Pedersen brought not only the much needed strength to the technical aspects of this work, but also validated the importance of such a research topic. Of special importance was the critical review of the thesis made by Professor Richard J. Steffy and the suggestions resulting therefrom.

The material presented in this thesis was gathered through kind permission of several persons to whom I
express my sincere gratitude. Professor Andrzej Kola from Toruń was very kind in providing me with material published by the Nicolaus Copernicus University. Professor Władysław Filipowiak from Szczecin hosted my presence at the National Museum in a true spirit of Polish hospitality, and much of the paragraphs on finds from the Odra region could not have been written without his assistance. Dr. Andrzej Zbierski and Dr. Jerzy Litwin from the Central Maritime Museum in Gdańsk provided me with the opportunity of research in the Museum's collections of artifacts. Dr. Henryk Paner allowed me to use the material contained in the library of the Archaeological Museum of Gdańsk. I am indebted to Ms. Świderska for her opportune help in finding the shortest way into the library of the Polish Academy of Sciences of Gdańsk. The material provided by Ms. Zeylandowa regarding her excavation at Ład was irreplaceable as a source information.

With this occasion I express my sincere thanks to Mr. Arne Emil Christensen from Oslo, Mr. Jon Godal from Rissa, Mrs. Maaike Andersen from Roskilde, and Mr. Werner Dammann from Hamburg for their contributions. Through his presence in College Station, Mr. Jan Bill from Roskilde provided me with an excellent opportunity to discover details otherwise unknown to me.

Through their timely advice Mrs. Rebecca Holloway and Mrs. Claudia LeDoux contributed fundamentally to the rhythm of writing and composition of this work. Mrs. Holloway's contribution was instrumental in the decision-making process related to the 1995 trip to Poland.

The research material for this thesis was provided also through the constant support of InterLoan Services personnel of the Evans Library. Their meticulous search for rare articles and documentary material constituted the
backbone of the entire thesis.

The constant support and encouragements of our friends from College Station, Robert and Maryla Klima, helped me overcome the difficulties related to the technical aspects of this work.

This seemingly endless list of helpful people would not be complete without mentioning Mr. and Mrs. Sundberg and Mrs. Eugenia Lawrence from Phoenix, Rev. John D. Spaulding from Scottsdale, and Dr. Glen Rice from Arizona State University, who helped us outweigh all difficulties related to our coming to College Station. A heartfelt thanks goes to Dr. George Bass who offered his help to recover the documents necessary for my admission into the Nautical Archaeology Program. The trip to Poland could not have been possible without the brilliant inspiration of Dr. Kevin Crisman, who was the first to suggest such an enterprise. Many, many thanks to Dr. Shelley Wachsmann, Dr. Donald L. Hamilton, and Mr. Cemal Pulak who gave their helpful advice in various moments of decision. Endless discussions with Ms. Maria Jacobsen helped me to clarify the purpose of my work. Last but not least, I thank all my colleagues from the Nautical Archaeology Program who helped me to better understand the meaning of my presence in the Nautical Archaeology Program.
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CHAPTER I

INTRODUCTION

The beginning of research into the nature of seafaring and the methods of shipbuilding on the southern shore of the Baltic Sea can be traced back to the second half of the 19th century, when shipwrecks and ship-related fragments were reported in the Gdańsk area.

The first wreck brought to the attention of the Pomeranian public was found in 1873 at Gdańsk-Brzeżno (Danzig-Brösen), and apparently it represented the remains of a cog. The shipwreck was dismantled and reused as fuel.1

The first archaeological research started with the excavation of the Bagart/Baumgarth (Gdańsk/Danzig district) shipwreck in 1895. On the basis of certain peculiar features, the shipwreck was interpreted by Hugo Conwentz, the director of the Provincial Museum of Danzig, as the remnant of a Viking Age Scandinavian fishing boat.2 In 1927 Reitan published his own reconstruction of the Bagart ship in which he strongly rejected the idea that the Bagart shipwreck was a fishing vessel.3 Nevertheless, he not only

This thesis follows the format of the American Journal of Archaeology.

1 For details see M. Bischoff, "Ausgrabung eines 600-jährigen Wracks am Ostseestrand bei Danzig," Leipziger Illustrierte 1542 (18-01-1873) 43-44.


accepted the idea of a Scandinavian origin for the vessel, but also tried to prove its use as a burial chamber for a Viking chieftain.\(^4\)

In 1895 another shipwreck was found inland near Frombork/Frauenburg, about 200 m from the shoreline of the Vistula lagoon. J. Heydeck, who undertook the reconstruction, stated that on the basis of comparison with the finds from Nydam and Gokstad, the Frombork ship had to be dated in between, i.e. in the 6th-7th century. His conclusion was that the shipwreck was the remnant of a Viking vessel.\(^5\)

In the years preceding the beginning of the First World War, Hugo Lemcke published two excavated shipwrecks found at Charbrowo/Charbrow; the first one, Charbrowo 1, was excavated in 1898, while the second, Charbrowo 2, was left in place and surveyed in 1931. The ceramic fragments found inside the hull of the Charbrowo 1 shipwreck were identified as Wendish, and consequently the entire site was dated to the Viking Age.\(^6\) Convinced of its Scandinavian origin, Lemcke reconstructed the vessel after the oak ship found at Nydam in 1863.

The Charbrowo 3 (Czarnoswo 1) shipwreck was surveyed in 1934 by O. Lienau, who suggested that the vessel was similar in construction with the Gdańsk-Orunia shipwrecks.\(^7\)

\(^4\) Supra n. 3, 21-22.


\(^7\) O. Lienau, "Die Bootsfunde von Danzig-Ohra aus der Wikingerzeit," *Quellen und Darstellungen zur Geschichte Westpreußens* 17 (1934) 35.
In 1933-1934 Lienau excavated and published three shipwrecks found in the nearby fields of Gdańsk-Orunia/Danzig-Ohra. In his opinion these shipwrecks were products of the same shipbuilding tradition," and "the building of treenailed ships ought to be assigned to those Rugier, Goths, and Gepids who remained in the territory between the Vistula and the Lake Leba."9

These opinions were echoed by authors such as F. O. Busch and H. Docter, who stated that the Bagart shipwreck was the "remains of a Germanic ship,"10 and the shipwrecks from Charkrowo (1) and Frombork were probably remains of Viking vessels. In the same spirit, K. Langenheim related the Bagart shipwreck to the Viking movement abroad, since "[t]he Vikings were the ones who carried out the trade in the Baltic in this early period."11 In his opinion the shipwreck indicated the existence of Viking settlements on the Hel peninsula, possibility suggested also by toponyms like Oxsdorf, Rixdorf, and Heisternest.

All these opinions combined to form the theory of Germanic or Scandinavian origin of shipbuilding on the southern shore of the Baltic. Before the beginning of the Second World War, this theory was used also for purposes with strong political implications.12

The Germanic/Scandinavian origin of shipwrecks found

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8 Supra n. 7, 46.

9 Supra n. 7, 46.


on the southern shore of the Baltic was firmly rejected by the postwar Polish school of research, whose adherents argued that the shipwrecks were vestiges of Slavic/Wendish shipbuilding. P. Smolarek affirmed that the Slavic tradition was to be counted among the various Northern shipbuilding schools and that the reciprocal technical borrowing did not diminish its originality. In his extensive study on trade connections between Scandinavia and the Western Slavs, on the other hand, J. Żak considered Slavic shipbuilding insufficiently developed to have contributed to the early Baltic maritime traffic. His contention was furthered by T. Delimat, who believed that,

"...none of these premises is a proof of the completely native origin of Pomeranian boats. Of equal weight...are the facts that the Pomeranian boats were built only after the culmination of Scandinavian expansion in the Baltic and that there are surprising similarities in the construction of Pomeranian and Scandinavian boats."

The scientific dilemma of the origin and the evolution of Pomeranian shipbuilding reverberated in the Scandinavian


literature. The wrecks found on the southern Baltic shore were tentatively associated with the influence of Scandinavian shipbuilding exercised in that area during the Viking Age. The constructional differences between the Scandinavian and the Slavic shipbuilding noted by O. Crumlin-Pedersen did not change the idea of a Slavic apprenticeship at Scandinavian shipyards. The Scandinavian provenience of shipwrecks from the Southern Baltic region was overemphasized by S. McGrail, who stated that "[o]ther Scandinavian finds partly treenail fastened include Hedeby, Schuby, Ralswick ..."

However, the need to define technical characteristics in medieval Scandinavian shipbuilding has recently created a new perspective. This approach emphasizes the possibility of reciprocal influences between the Scandinavian and the Wendish/Slavic cultures, and even the existence of a

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distinctly Slavic shipbuilding tradition. In Goldmann's opinion, this tradition is manifested strongly in the development of a complex network of inland canals which can be seen as a major economic achievement in the lands of the Wends. In the light of this new understanding, the shipwrecks, previously labeled as Scandinavian or German, ought to be seen as products of a "different shipbuilding tradition" attributed to the inhabitants of that area, i.e. to the Slavs. Given the existence of at least two different shipbuilding traditions in the same maritime area, M. Müller-Wille accentuated the close relationship which must have existed between two nautical schools similar in appearance but different in technical detail.

Nevertheless, this common appreciation of a well-defined shipbuilding tradition among the Baltic Slavs does not resolve the dispute over the origin and the evolution of this technique. Sites such as Janów Pomorski, near Elblag, where traces of nine clinker-built (?) vessels were found in connection with artifacts of Scandinavian and Arab origin, suggest that Southern Baltic shipbuilding is a far


more complex issue than previously thought.  

Under these circumstances it becomes necessary to clarify technical issues within each shipbuilding school. Fortunately enough, Scandinavian finds are, with several exceptions, well represented and carefully researched. In the light of this research effort, it is imperative to establish what is noncharacteristic for the Scandinavian shipbuilding, i.e. technical features such as the regional use of treenails and moss luting. This task is undertaken in the present work in the form of a comparative analysis of the archaeological material found on the southern shore of the Baltic. The analysis tries to identify the diagnostic attributes characteristic for the group of shipwrecks and ship-related artifacts from this area; attributes which substantiate Southern Baltic shipbuilding as a separate entity. The shipwreck material does not include the pram from Elbląg, and implicitly other prams such as those from Falsterbo and Egernsund, because they represent an inland shipbuilding tradition not related typologically to the keeled vessels which constitute the subject of this analysis.

The analysis is furthered by a comparison between the Scandinavian shipwreck material and the Southern Baltic shipwreck group in order to clarify the degree of similarity or originality of technical features common to both groups. In this manner, a solid basis is provided for further work regarding the aspects of reciprocal borrowing between regional traditions within the Baltic realm.

Since the shipwreck material is datable to a period when the Slavs occupied the entire Baltic coast from the

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Schlei in the west to the Bay of Gdańsk in the east, the present work will incorporate those historical sources which contain information related to Slavic ships and shipbuilding. The purpose is to identify the extent to which the historical information corresponds with the archaeological evidence, and which of the technical capabilities of the vessels under discussion match the contemporary assessments.

As the Baltic political, economic, and cultural milieu started to change by the end of the 12th century, the historical circumstances influencing shipbuilding in the Southern Baltic entered a new phase of development in which Hanseatic shipping and shipbuilding played a role. The analysis will therefore consider datable archaeological material no later than the beginning of the 13th century. The earlier chronological limit is given by the earliest finds of keeled vessels on the southern Baltic shore.
CHAPTER II

THE ARCHAEOLOGICAL EVIDENCE

The information presented in this chapter describes ship remains and ship-related artifacts found on the southern shores of the Baltic Sea (fig. 1). Although in most of the original publications the finds were described as shipwrecks, the scarcity of artifacts and the configuration of the ship remains in situ suggest that some of these finds might represent derelicts.

1. The Eckernförder Bay site

The discovery in 1979 of several ship fragments accompanied by ceramic material in the vicinity of Dörphof village (Rendsburg-Eckernförder district) led to a full-scale archaeological investigation conducted by the Landesmuseum für Vor- und Frühgeschichte of Schleswig-Holstein.26

The site, located about 60 m off the spit of land which separates the Schwansener lagoon from the open sea, formed a wide strip parallel with the shore at about 100 m south of the mouth of the lagoon. Situated at a depth of 1.50-1.70 m, the shipwreck was partially buried under a layer of pebbles and gravel which was subsequently covered by a 0.20-0.30 m stratum of neritic deposition. Besides the ship fragments, the bottom layer contained also straight and curved fragments of wood not belonging to the wreck itself. Marks on some of these fragments suggest that they

Fig. 1 Shipwrecks in the Southern Baltic region
had been worked with an axe or axe-like tool. Traces of burning were observed on ship remains, and also on the other wooden fragments.

As the site was in shallow water, few structural elements were recovered in a good state of preservation. A rockered keel was preserved for a length of 8.20 m. In its widest part it was 0.12 m moulded and 0.18 m sided. The cross-section here had a T-shaped form which gradually changed into a trapezoidal form toward the ends of the keel. A shallow V-form mark was incised on the upper surface of the flange close to the scarfed end of the keel. Apparently the mark had no practical purpose.27

At one end, the keel was joined to a post by means of a vertical flat scarf 0.15 m long. The post was preserved only for the length of the scarf, which was fastened with iron nails driven at right angles to the plane of the joint.

Only four strakes, made of oak (Quercus sp.), survived from the entire hull. They were 0.215 m to 0.220 m wide and 0.018 m to 0.022 m thick. The strakes were joined together in the lapstrake manner with a land about 0.045 m wide, and fastened with willow (Salix sp.) treenails driven into 0.012 m holes at intervals of 0.07-0.11 m. The treenails were wedged from inside for about two thirds their total length. The strakes in the preserved hull section were made of several planks scarfed together with an overlap of 0.10 m.28 Each scarf was secured by two treenails approximately 0.133 m apart.

To ensure the watertightness of the seams, cattle

27 Supra n. 26, 172.

28 Supra n. 26, fig. 8.
hair\textsuperscript{29} was used to fill in a 0.02-m-wide and 0.004-m-deep luting cove carved along the inner surface of each plank. The cove, situated in the middle of the land, was flanked by two adjacent lines, one on either side.

With the exception of two loose frame fragments, no other structural elements inside the planking were preserved. The first fragment constituted half a floor timber,\textsuperscript{30} while the second was the lower segment of a forward or after frame. The latter fragment was carved out of a naturally curved timber. There was no hole drilled through the lowermost part of the frame, which suggests that the frame was not fastened to the garboard strake. The frame fragments were fastened to the planks with treenails with an approximate diameter of 0.025 m; there was one treenail per strake. With the exception of the garboard strake, the treenails were driven into the middle of each plank. The distance between the holes used to hold these treenails suggests that the frame interval was 0.90-0.93 m. No fastenings joining the frames and the keel were observed.

The signs of burning observed on the shipwreck remains and other wooden fragments suggest that the vessel had been damaged by fire. The burned area observed at the upper end of the floor fragment coincides, in the reconstructed hull, with the upper edge of the fourth strake, the uppermost preserved strake. This suggests that the fire destroyed the

\textsuperscript{29} The brown-reddish animal hair was not twisted in the groove and at the time of excavation had a thickness of less than 1 mm.

\textsuperscript{30} The floor timber fragment was burnt at the uppermost end. It had a concave shape when viewed from transverse profile, and above the keel was 0.15 m moulded. Sided dimensions are as follows: 0.07 m above the keel; 0.009 m between strake no. 2 and no. 3; and 0.07 m at strake no. 4. The fragment leaves an overall impression of robustness. A 0.04-m semicircular notch was observed at the base of the floor timber, which was juggled to fit the edge run of the planking.
entire upper body of the vessel above the fourth strake. However, the scarcity of finds does not allow for a firm resolution of the question of how the ship met its end.

There is similar doubt concerning the dating of the site. The only helpful element is ceramic material associated with the shipwreck. The sherds were identified as the remains of Menkendorfer type ceramics and consequently tentatively dated to the 9th-10th century. The results of a C14 analysis, corrected by dendochronological analysis, dated the shipwreck to 750-830.31

2. The ship remains from Ralswick

The archaeological site at Ralswick, situated on the island of Rügen (Rugia), was the subject of an intensive and lengthy research effort32 (1967-1980) that led to the discovery and analysis of four ship remnants and ship-related fragments.33 The first three, Ralswick 1, 2, and 3,

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33 Excavations of eight grave mounds conducted in 1980 in the Schwarzen Bergen have shown that six of the grave mounds contained iron nails and rivets. Although the iron nails and rivets from five of these graves were interpreted as fastenings of the coffin, the other grave presented a different situation. Situated at the peak elevation of the burial area, the excavation of the grave yielded approximately 410 rivets, from which 335 had a length between 0.03-0.04 m, about 40 rivets less than 0.01 m, and about 30 more than 0.01 m long. From approximately 100 measurable nails, 40 were between 0.05-0.08 in length and 30 were less than 0.01 m. This led to the conclusion that in grave no. 192 "ein seetüchtiges Boot skandinavischer Bauart im Grabritual dieses Hügels Verwendung fand." For details see D. Warnke, "Eine Bestattung mit skandinavischen Schifferresten aus den Schwarzen Bergen bei Ralswick," Ausgrabungen und Funde 26 (1981) 159-165.
were uncovered in the proximity of the so-called "Southern Settlement", while the last remnant, Ralswiek 4, was unearthed close to the northernmost tip of the main settlement area.

Ralswiek 1 - The 1967 excavation season brought to light two well-preserved derelicts labeled Ralswiek 1 and 2. They were situated about 11 m apart. Ralswiek 1, oriented on a northwest-southeast axis, was buried under a thick stratum of peaty sediment deposited over a thin stratum of sand. Several loose ship fragments, mentioned in the excavation report, were found underneath it. Among them was a 2.6 m floor timber, fragments of floor timbers, five naturally curved knees, and two boards sharpened on both ends.

The keel, made of oak, was preserved for its entire original length of 9.40 m. Its T-shaped cross-section changed gradually toward the ends of the keel: amidships the keel was sided 0.21 m; at the ends, only 0.11 m. The ends were obliquely cut for the vertical scarf joint with the sternpost and the stem, both of which did not survive.

Six starboard strakes and part of the port garboard were the only plank remains. With a maximum width of 0.22-0.25 m and a thickness of 0.018-0.024 m, the radially cleft strakes overlapped with a 0.03 to 0.04-m-wide land, in which grooves were carved for the luting material, animal and human hair in this case. The seams were secured with softwood treenails 0.012-0.014 m in diameter set 0.06 m apart. The scarfs in the strakes were riveted. The length of planks ranged between 1.70 m and 3.20 m.

Only one floor timber was preserved in situ, but

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34 Three rivets secured the joint: two in the planking, the third driven through the seam. The ends of the rivets were hammered over 0.02 x 0.02 m square roves.
traces of nine floor timbers were easily recognised inside the hull. The preserved floor timber, found upside down in the hull, was joggled for the run of the planks. Two rounded notches were carved on both sides of its central part. The floor timber was 0.12 m moulded and 0.12 m sided. Treenails 0.025 m in diameter were used to fasten the floor timbers to the hull at an interval of 0.85-1.10 m. No fastening was observed between floor timbers, garboards, and keel. A board fragment nailed to the third strake indicates that the vessel underwent repairs. According to Herfert, the vessel, 13-14 m long and 3.4 m wide, displays constructional features characteristic of 9th-12th century shipbuilding. However, the stratum which sealed the vessel context contained Fresendorfer type ceramic material which gives a terminus post quem sometime during the 9th century.

Ralswiek 2 - Ralswiek 2 was found listing 17 degrees to port. Its keel, preserved for a length of 7 m, measured 0.24 m sided in its widest part and 0.09-0.10 m at the ends, which were vertically scarfed. It was rabbeted toward the ends. The preserved stem fragment was sided 0.21 m and moulded 0.08-0.10 m. According to the investigator the stem had a V-shaped cross-section.

35 Herfert (supra n. 32) 217.

36 Herfert wrote that on both sides of the stem a "mehrfach profilierte Zierolle" was carved, but he did not detail whether this is a full rabbot or just shallow incisions made for decoration purposes. Also, Herfert (supra n. 32) 218-220, stated that the ends of strakes were fastened to the stepped stem through wings: "Die Planke schließt am Ende rechtwinklig und ist auf schrägen Stoß gearbeitet. Das dadurch im oberen Drittel jeder Planke fehlende spitze Stück bis zum Anschlag an die Spanung des Stevens wurde durch mehr oder weniger lange, dreieckige angesetzte Plankenstücke hergestellt." This opinion was confirmed by J. Bill (personal communication). On the other hand, Fircks maintains that the stem was curved, without any steps, and had a clear rabbot carved on either side. For details see J. von Firck, Ewer, Seesenboot und andere ältere Fischereifahrzeuge (Rostock, Germany 1982) fig. 27, 43, and table 2.
The port side consisted of seven strakes including the sheer strake, while on the starboard side only three strakes were preserved. Made of up to three overlapped planks fastened with two rivets locked in place by square roves at each scarf, the strakes were 0.26-0.27 m wide and 0.012-0.015 m thick. The shortest planks in the hull measured 0.78 m and 0.98 m in length and were located in the starboard second and third strake. The strakes were joined in the lapstrake manner and secured with softwood treenails 0.012-0.014 m in diameter. The treenails were driven at 0.07-0.09 m intervals. The strakes overlapped for about 0.02-0.03 m. The luting was of animal and human hair, which filled the cove in the land of each seam. The excavation report does not mention in which plank the luting cove was carved. The hood ends of the strakes were fastened with iron nails to the stem and sternpost. In several places, repair boards were nailed to the hull. A wedge was found driven under the aftermost preserved floor timber.

The preserved portion of the sheer strake was 3.44 m long and 0.26 m wide. Four round side-slit oarports (0.08 m diameter + 0.04 m slit length) were cut into it. The oarports were set at intervals of 0.78-0.85 m; each one was situated about half-way between frame stations. An inwale 0.059 m wide and 0.048 m thick was fastened to it with treenails 0.43-0.048 m apart. Two holes 0.02 m in diameter set 0.09 m apart were driven in the sheer strake just below the inwale. These holes are located precisely to one side of the mast-step.

The floor timbers, made of oak, were moulded 0.12 m and sided 0.08 m. All five floor timbers found inside the hull were fastened to it with treenails with a diameter of 0.025 m. The frame interval was 0.80-1.14 m. As in the case
of Ralswiek 1, the floor timbers were not fastened to the keel. The timber used as a mast floor was situated 0.12 m forward of the middle of the keel. The mast-step consisted of a notched piece of wood treenailed against an open, square notch carved in the side of the mast-floor. The mast-step mortise measured 0.082 m x 0.097 m.

The three uppermost strakes were reinforced by vertical knees. Two of them were found in situ, fastened with treenails 0.025 m in diameter to the beam fragments.

Woolen fragments, osteological fragments, and other worked wooden fragments were found at this site. Human skeletal remains were also found here. Herfert dated the vessel to the Slavic period. He believed that its original dimensions were 9.5 m in length and 2.5 m in breadth.

Ralswiek 4 - Situated about 50 m off the present shore, Ralswiek 4 was found lying in alluvial silt at an approximate depth of 1.00-1.10 m below the bottom of the Großer Jasmunder Bodden. Its state of preservation was unusually good.

The T-shaped keel of the vessel, preserved for a length of only 8.65 m, was carved out of a single oak.

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37 Herfert (supra n. 32) 221: "Zu Boot II kann festgestellt werden, daß es zu den am besten erhaltenen, bisher bekanntgewordenen slawenzeitlichen Bootsfunden gehört."

38 The stratigraphic observations revealed that the stratum directly underneath the wreck, stratum 3, contained osteological remains, stones, wooden fragments, and Frezendorfer type ceramic material. Immediately above it, a sedimentary layer of fine sand, stratum 4, covered the shipwreck and protected it from further biological degradation. Strata 5 and 6 fulfilled the same function. The whole complex was sealed by stratum 7, which constituted the second shoreline. The subsequent strata (9-11) contained Early Slavic ceramic material, while higher up subbottom layers of neritic sediments formed the actual sea bottom.

39 The wood, although in a waterlogged condition, was in a good state of preservation. The wreck was partially damaged by a backhoe when the foundation of a water-purification bunker was laid.
trunk. Its maximum sided dimension was 0.28 m. At 1.08 m from the after end, the keel measured 0.12 m sided and 0.12 m moulded. At 0.50 m and 1.30 m from the after end, two square mortises were cut in the keel's upper surface. While the first was placed on the center line, the second was carved almost entirely into the port flange. Both were carved to a depth of approximately 0.03 m and did not have any apparent structural function.

The stem and the sternpost did not survive, but their traces were observed in the sandy layer covering the wreck.

The initial observations have shown that the rake of the sternpost was approximately 1.30-1.47 m, while the stem had a rake of about 1.80 m. In the investigator's opinion the length of the stem was double the length of the sternpost. Both elements were joined to the keel by a vertical flat scarf secured in the middle by a treenail with a diameter of 0.012 m.

Five strakes were preserved on either side of the keel. They were joined together in the lapstrake manner with a land about 0.02-0.03 m wide. The strakes were fastened to each other with pine (Pinus sp.) treenails with a diameter of about 0.012 m driven at an interval of 0.06-0.08 m. Every third or fourth treenail was wedged. The luting in the seams was of sheep wool impregnated with coniferous tar. Each strake, made of oak, was up to 0.30 m wide and 0.018-0.026 m thick. In the preserved hull section, the strakes were made out of two planks joined together with an overlap of 0.05-0.10 m. Each scarf was secured by 2 to 3 iron rivets.

iron nails were found in the same stratum at about 1.29 m from the after end of the keel. It was assumed that these nails fastened the hood ends of the upper planks to the sternpost. Their location would indicate the length of the sternpost.
Two of the preserved planks revealed traces of repair. A crack in port strake 2 was caulked and covered with a board. A second crack in port strake 1 was covered with a beech (Fagus sp.) board that was never nailed or riveted. Herrmann advanced the possibility that this garboard damage could have been the reason for the ship's abandonment and/or scuttling. In his opinion, this idea is strengthened by the finding of two wedges inserted in between the planking and floor 3, which was broken and never repaired or reutilized.\textsuperscript{41}

Very few frame fragments were found. Four floor timbers were removed before the wreck was covered with sand,\textsuperscript{42} while one floor timber was pulled out by a mechanical excavator. Only two floor timbers were preserved in situ. The frames were set in the hull at about 1 m interval. The floor timbers were fastened to the hull strakes, with the exception of the garboards, with poplar (Populus sp.) treenails. The treenails had a diameter between 0.025-0.03 m and were wedged on the inside. Two vertical knees were found together with the disturbed material, one of them being fastened to a plank from the sixth strake. No beams were recovered from this site.

A loop made of willow (Salix sp.) bast was found in situ close to frame 5. The loop was fastened onto starboard strake 1 and 2 and its long axis was parallel with the aforementioned frame. In the investigator's opinion the loop could have served to fasten fixed rigging. He suggested also that the vessel was between 12 m and 13 m in length and 3.30 m in breadth. The correlation between the ship remnant and the settlement stratigraphic sequences

\textsuperscript{41} Herrmann (supra n. 32) 151, 153.

\textsuperscript{42} Supra n. 32, 151.
permitted the investigator to conclude that the abandonment occurred sometime during the 9th century.

3. The Gdańsk-Orunia (Danzig-Ohra) shipwrecks

The work of deepening the irrigation canals in the fields adjacent to the Radunia/Radaune canal (Gdańsk-Orunia/Danzig-Ohra district) have led to the identification, excavation, and conservation of three wrecks. The Orunia 1 and 2 shipwrecks were found and excavated in 1933, and Orunia 3 was uncovered a year later. Lienau reported a fourth wreck which was never excavated. Besides these shipwrecks, a dugout was found to the north of the site of Orunia.43

Gdańsk-Orunia 1 - Located at the intersection of two irrigation canals, wreck 1 was preserved in a peat layer situated at a depth of 1.5-1.6 m from the modern surface (fig. 2). The midship section was almost entirely missing as a result of an earlier deepening of the canal intersection. The best preserved elements were in the after part of the hull: the sternpost, after part of keel, five frames, and the bottom planking.

The keel, of oak, was preserved only for a length of approximately 5.30 m. In the middle body, the keel had a T-shaped form which changed toward the preserved end into a rectangular block form. The flanges reached a maximum of 0.025 m in width and 0.035 m in thickness. The keel was 0.105 m moulded44 and 0.135 m sided.

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43 For details see O. Lienau (supra n. 7).

44 A discrepancy is noted between the dimension of the flange given in the text on p. 14 (25 mm) and the 0.04 m value given in the table on p. 15.
Figure 1 (after Lienau)
The sternpost,\(^45\) carved from a single piece of oak, was joined to the keel through a vertical flat scarf. The joint, with a length of about 0.13 m, was secured with three treenails driven at right angles to the longitudinal axis of the scarf. In cross-section, the sternpost had an almost triangular shape with an extremely sharp outer face. The maximum 0.32 m moulded dimension was observed in the lower section of the sternpost. Both inner edges were stepped. The first step received directly the garboard, while the second and the third steps were joined to the planks through wings. The only wing found with the shipwreck was the starboard wing for strakes 2 and 3. In Lienau's opinion there were two wings attached to either side of the sternpost; the middle wing received the hood ends of two strakes and the uppermost wing the hood ends of the last three strakes.

Up to six strakes, all of oak, were found on either side of the keel. Planking thickness decreased from 0.022 m in the middle body to about 0.015 m at the ends. The maximum width of planking was 0.30 m. Only two scarfs were observed in the preserved strakes, both situated in the second port strake. The hood ends of the planking strakes were fastened to the wings through a scarf with a length of 0.07 m. The joint was secured with treenails. The strakes were joined in the lapstrake manner and fastened with pine treenails 0.012 m in diameter driven from outside at 0.08-0.10 m intervals. They were wedged from the inside for a

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\(^{45}\) The only post found with the ship remains was interpreted as the sternpost on account of a 0.04 m hole bored at right angle into the right arm of the adjacent V-shaped frame. The orifice, which corresponded with the land between the 4th and the 5th strake, was drilled between two "normal" 0.018 m holes used for the frame-to-plank fastening with the 4th and the 5th strake. Since the 0.04 m hole was not intended for this kind of fastening purpose, Lienau concluded that it was bored for the withy of the quarter-rudder, which would indicate that the preserved post was actually the sternpost of the vessel.
distance of about 2/3rds the total nail length. In the stern the strakes were fastened to each other with iron nails.

**Moss (Drepanocladus sp.)** soaked in tar was used for luting. Each overlap between strakes had a semicircular cove° 0.035 m wide and 0.005 m deep filled with this luting material, which was used also in the joints between the keel, the sternpost, and the planks.

Five recovered floor timbers, carved out of naturally curved oak branches, reached 0.09 m moulded and 0.07 m sided in the center and were 0.05 moulded and 0.07 sided at the heads. Each floor timber was fastened to the planking strakes with wedged treenails driven from outside, one treenail per strake. The nails were 0.018 m in diameter. The floor timbers, inserted at 0.88 m intervals, were not fastened to the keel. The underside of each one was joggled to correspond with the upper edge of the hull planks.

The beams (thwarts?), made out of oak boards, measured 0.04 m moulded and 0.08-0.10 m sided. They rested on a shelf, which was fastened with treenails to the upper part of the 5th strake. The shelf ran from the 1st to the 13th frame, and had small notches carved on the underside in order to fit over the heads of the floor timbers. Its cross-sectional dimensions were 0.035 x 0.06 m.

The upper structure of the vessel was reinforced by vertical knees fastened with one treenail to the sheer strake and two treenails to each beam end. The sheer strake was strengthened by an inwale 0.10 m wide and 0.04 m thick. Notches were cut into its underside for the ends of the vertical knees. The inwale was fastened to the 6th strake.

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° Lienau does not mention whether the luting cove was carved into the outer surface of the lower strake or into the inner surface of the upper strake.
with treenails 0.018 m in diameter driven at about 0.40 m intervals. The end of the inwale was joined to a breast hook fastened with treenails only to the sheer strake. The breast hook measured 0.03-0.035 m moulded and 0.05 m sided.

In Lienau's reconstruction the vessel, 12.76 m long and 2.37 m wide, had eighteen oarlocks, nine on either side. Each oarlock consisted of two elements: the oar groove and the thole-pin. The thole-pin was inserted in a 0.048 m x 0.02 m rectangular slot carved into the inwale. The oarlocks were positioned between frame stations, from frame 2 in the stern to frame 11. Each triangular-shaped thole pin had a hole in the middle for the insertion of a thole bight.

Gdańsk-Orunia 2 - Discovered at a depth of about 2 m in the same irrigation canal, wreck 2 was located circa 100 m south of the first wreck site (fig. 3). With a length of about 7.50 m, the keel, made of oak, was preserved close to its original dimensions. In the middle body it had a T-shaped form which changed gradually toward the ends. The keel measured a maximum 0.10 m moulded and 0.20 m sided. At the joint with the stem, the keel was 0.08 m moulded and 0.10 m sided.

The stem had a simpler shape than the sternpost of Gdans-Orunia 1. It was found in two pieces with the middle segment missing. A step was carved in the inner edges of

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47 Lienau (supra n. 7) 22: "Vom Vorsteven, der als solcher an dem Loch für das Befestigungstau erkennbar war..." At about 0.40 m under the uppermost end of the stem a hole was drilled near the outer edge. This feature constituted in Lienau's opinion the proof that this element was the stem of the vessel, since the hole could have been used for mooring purposes. Apart from this, the run of the plank scarfs also indicate that the post might have been the stem of the vessel.

48 Supra n. 7, 22: "...durch ein Zwischenstück ergänzt werden mußten." Although Lienau does not specify, it seems that the lower end of the upper segment and the upper end of the lower segment were cut
Fig. 3. Gdańsk-Orunia 2
the stem for the garboard strakes. The stem, moulded 0.28 m and sided 0.08 m, was almost triangular in cross-section. It was fastened to the keel through a vertical, flat scarf about 0.10 m long.

The hull was preserved particularly well. Seven strake fragments were recovered from the port side, and five from the starboard side. The planks had a thickness of 0.022-0.025 m and a width of about 0.25 m.49

The strakes were made out of several oak planks joined through vertical flat scarfs. The overlapping between the strakes was secured with pine treenails 0.012 m in diameter driven from outside at 0.08-0.09 m intervals. The luting cove in the land of each seam was 0.03 m wide and 0.002 m deep; it was filled with moss. The hood ends of the planks were fastened to the stem and the end of the keel with iron nails about 0.008 m in diameter.

The uppermost strake fragment on the port side was reinforced by a stringer 0.02 m x 0.025 m in cross-section, which in Lienau’s reconstruction was attached on the outer side of the strake. The stringer was fastened to the strake with treenails 0.012 m in diameter driven at 0.40 m intervals. The plank fragment of the 7th strake had cut at its after end an oval opening about 0.10 m in diameter, which was interpreted as part of an oarport.

A total of 9 frame fragments were found. The arrangement of the frames within the hull indicates that the vessel had a total of 11 frames. They have been numbered 1 through 11 from stern to bow. The floor timbers, made of oak, were fastened to each strake with treenails obliquely for a vertical scarf. In this case, the Gdańsk-Grunia 2 vessel was built with a composite stem made out of three separate pieces.

49 The last two strakes measured about 0.010 m in thickness.
0.018 m in diameter. On the average they measured 0.13 m moulded and 0.07 m sided. Floor timbers 2, 3, 6 (midship frame), and 10 had a shallow hole drilled in the center of their upper surface. This feature was not observed in floor timbers 4, 5, 7, 8, and 9. The frame interval varied between 0.75 m and 0.80 m (from edge to edge).

Only one fragmented beam was found with the ship remains. It was 0.04 moulded and 0.10 m sided. The investigator reported the recovery of fragments of vertical knees as well.\(^5^0\) No fragments of mast-step, rigging, or steering device were recovered from this wreck. Lienau reconstructed the vessel with a length of 11 m and a breadth of 2.27 m.

Gdańsk-Orunia 3 - The third wreck was found in 1934 about 300 m south of the second wreck site (fig. 4). Although most of the upper hull was badly destroyed by vegetation, the remainder of the vessel was preserved in good condition. The depth of deposition was estimated to reach 1.30 m below the modern surface.

A keel of oak was preserved through its entire original length of 9.1 m. Its maximum dimensions in section were 0.125 m moulded and 0.22 m sided; it had a T-shaped cross-section in the middle body.

A rabbeted post,\(^5^1\) considered to be the stem of the vessel, was preserved for the entire length of 2.80 m. At its lower end a step was carved into the inner side for the garboard strakes. A perpendicular cut was made forward of the step into either side of the stem for the ends of the

\[^{50}\] Lienau (supra n. 7) 21 and pl. 18.

\[^{51}\] Supra n. 7, 26: "Die Planken laufen bis auf einen Gang, der abgesetzt ist, sämtlich in den Steven ein ...."
garboard strakes. The stem cross-section gradually decreased from the lower to the upper end; the lower end was 0.20 moulded and 0.07 m sided. The post was joined to the keel by a vertical flat scarf about 0.10 m to 0.15 m long.

Twelve strakes, six on either side, were preserved in a fragmentary state. Made out of several planks joined together by flat vertical scarfs, they were on average 0.20-0.30 m wide and 0.022 m thick. The fifth strake did not extend into the rabbet of the post; its end was nailed onto the fourth strake before reaching the aftermost frame station. The overlaps were fastened with pine treenails 0.012 m in diameter. The nails were split from the inside by oak wedges. Iron nails were used to fasten the strakes to the post and to the keel's ends. Moss was used as luting material in the strake seams and all other joints in the hull.

In contrast with Gdańsk-Orunia 2, only two frame fragments were recovered from this wreck. The last frame, considered to be the aftermost frame, was situated on top of the missing post. The frame next to it was fastened adjacent to the joint between the keel and the post. The floor timbers were fastened to the strakes with wedged pine treenails 0.026 m in diameter driven from outside. No fastening was observed between floor timbers and keel. Floor timbers were moulded 0.07 m and sided 0.12 m.

Two short knees and two long knees were recovered from this site. At the second after frame the beam curved upward and was fastened to the uppermost port strakes as a vertical knee. The straight end of the beam was fastened to a vertical knee with treenails. The beams were 0.06 m moulded and 0.10 m sided.

The only stringer fragment found at this site
exhibited three grooves. According to Lienau the first groove, carved into the upper surface of the stringer, was an oar groove, which suggested that the vessel was propelled by oars. Therefore, he reconstructed the vessel, 13.30 m long and 2.46 m wide, fitted with twenty oarlocks, ten on either side. Nevertheless, the second groove with a diameter of 0.026 m and the third somewhat larger were of a less apparent function.\(^{52}\)

Attempts were made to establish a close dating of all three vessels on the basis of stratigraphic interpretation correlated with the constructional features of the vessels and the pollen analysis of strata from each individual site. The invalidity of these correlations notwithstanding, Lienau concluded that the vessels could be dated to the 10th-11th century.

4. The Bağart/Dzierzgoń (Baumgarth) shipwreck

In 1895 the Provincial Museum in Gdańsk led an archaeological survey in the riparian zone of the Dzierzgoń (Sorge) river. At about 10 km distance from the shores of Lake Drużno (Drausen), the team found the remains of a partially preserved wooden shipwreck (fig. 5).\(^{53}\) Remains of a second wreck were reported as being not far from the site of the first shipwreck. Unlike Bağart 1 the remains of the second wreck were never excavated.

The keel, carved out of a single piece of wood, had a

\(^{52}\) Supra n. 7, 26: "..denn es finden sich in den Dollbaumstücken an zwei Stellen noch zwei größere Löcher von 26 und mehr mm Durchmesser..

\(^{53}\) Lying with the keel in a ESE-WNW direction, the ship remains were embedded in a thick (1 m) stratum of peaty soil which covered an earlier sequence of sand sediments. The shipwreck was damaged during the construction of an irrigation canal. For details see H. Conwentz (supra n. 2).
Fig. 5. Bogart (aft)
preserved length of 6.82 m; a portion at one end was missing. Its maximum dimensions in section were 0.11 m moulded and 0.25 m sided; at the ends it was 0.065 m moulded and 0.10 m sided. At its widest section the keel had a T-shaped cross-section which gradually changed toward the ends.

No traces of sternpost or stem were found at the time of excavation. However, the complete end of the keel was carved to receive another element, probably one of the posts.54

Several plank fragments of oak were preserved enough to assess their construction. The planks had a thickness of approximately 0.025 m and a width of approximately 0.24 m. The strakes were made from several overlapped planks fastened with rivets. The seams between strakes were also fastened with rivets driven from outside at an interval of 0.14-0.15 m. The square shafts had a length of approximately 0.04-0.06 m. They were secured from inside with small rhomboidal roves over which they were bent. The luting consisted of twisted animal hair.55 A small oak board about 1.30 m long and 0.10 m wide was riveted from the inside over a damaged bottom plank.

Ten floor timbers/ribs were found at this site. Carved out of naturally-grown oak branches, they were on average sided 0.055 m and moulded 0.12 m above the keel and 0.055 m at the ends. The joggled floor timbers/ribs were fastened to the planking with treenails, one for each strake. The distance between the holes left by these treenails in the

54 In his reconstruction Reitan states that "...nicht weit davon ist das ehemals vorhandene Ende, nach meiner Auffassung das Achterende, durch Beilhiebe abgetrennt." This statement suggests that the keel had one end carved as for a scarf joint. For details see E. Reitan (supra n. 3) 11-22.

55 Conwentz (supra n. 2) 53.
planking suggest that the frames were set in the hull at an interval of about 1 m. The largest frame had three mortises carved in the middle of its upper surface. The central mortise, considered to be the mast-step, was 0.115 m x 0.075 m. The approximate dimensions of the frame at the mast-step mortise was around 0.14 m moulded and 0.13 m sided. The after- or forwardmost preserved frame had traces of repair. Two short pieces of wood were fastened on one side of the grooved upper surface. Another floor timber/rib had a similar groove carved in its upper surface. In Conwentz's opinion, the groove had received a board inserted from above, which transformed the floor timber/rib into a bulkhead.\textsuperscript{56} A board fragment 1.55 m wide and 0.37 m high was recovered from the site. Its thickness varied from 0.05 m in the center to 0.03 m at the edges.

Among the ship remains, the investigator found also two beam fragments.\textsuperscript{57} Their thicker ends seem to have been notched on the underside for a distance of about 0.08 m.\textsuperscript{58} The best preserved beam was 2.52 m long, moulded 0.025-0.05 m in the center and 0.08 m at the ends, and sided from 0.125 m to 0.23 m. The beam had in its center an elliptical hole 0.125 m x 0.145 m in diameter. On either side of the hole, a small square mortise was carved on the underside.

Three poles made of oak were found in the vicinity of

\textsuperscript{56} Supra n. 2, 54: "Hiernach besaß das Fahrzeug drei Hauptabtheile und ausserdem noch am Ende einen Verschlag, der wohl zum Unterbringen kleinerer Bootsgerate gedient haben mag."

\textsuperscript{57} Supra n. 2, 54. However, a third beam was found in 1927 when the shipwreck was the subject of a new reconstruction.

\textsuperscript{58} Reitan (supra n. 3) 11-22: "Die drei erhaltenen Dukten sind am Ende dicker und zeigen durch Spuren an der Unterseite, daß die Auflagerlänge etwa 3 Zoll (80 mm) betrug." The report published by Conwentz did not specify such a detail for the end of the thwarts.
the shipwreck. They varied between 2.14 m and 2.80 m in length and between 0.10 m and 0.15 m in diameter. Each pole had at its thicker end a rectangular notch carved into the side. The open notch measured in cross-section 0.13 m x 0.02-0.04 m.

Among the smaller finds, the investigator's attention was drawn to several 0.18-to-0.30-m-long square treenails made out of oak and pine. No remains of rigging were found with the shipwreck. The reconstructed vessel, in Conwentz's version, was 11.90 m long and 2.52 m wide. Conwentz dated the vessel from Bagart to the Viking Age (8th-11th c.) on the basis of a comparative interpretation of different artifacts found in the Drużno lake area.

5. The ship remains from Frombork (Frauenburg)

In 1895 several ship fragments were discovered at a depth of 1.50 m beneath the ground during the drainage of a field near Frombork (fig. 6). The ship fragments were located about 200 m from the shoreline of the Vistula lagoon (Zalew Wiślany/Frisches Haff) in a thick peat layer.

A shallow keel, carved out of a single oak tree, was preserved for a length of 15.30 m. Its cross-section changed from a wide T-shaped form in the middle body to a rectangular form at the ends. Its maximum dimensions were 0.112 m moulded and 0.49 m sided.60

At one of its ends, the shallow keel was joined to a raked post through a vertical flat scarf. Rectangular in cross-section, the post was rabbeted on either side. Its

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59 Although the upper hull was destroyed by exposure to thermal variation of the ground water, the lower body was preserved in an excellent condition. At the time of excavation, the wood suffered only minor discolorations. For details see J. Heydeck (supra n. 5).

60 Lienau, (supra n. 7) 15, indicated a 0.44 m value for the sided dimension of the Frombork shallow keel.
moulded dimension decreased gradually toward the upper end. The other end of the keel also had a flat scarf, which indicates that a similar joint was used for fastening the second post to the keel.

Several planks were collected from the site, none of them still fastened to the keel, post, or frames. The planks were 0.03 m thick and were preserved for a length of about 2.5-3.0 m. They were worked to the required shape with the axe. The strakes were joined in the clinker method of construction and fastened with square iron nails driven from outside. The end of each nail was hammered from the inside over square roves. Cattle hair was used for luting in the seams of the hull.

A total of six floor timbers/ribs, found in a very good condition, were 0.14 m moulded and 0.17 m sided. They were fastened to the hull with treenails. No fastening was observed between the frames and the shallow keel. The floor timbers/ribs were inserted in the hull at an interval of about 1 m. A heavy floor timber/rib was found with a round mortise about 0.11 m in diameter carved into its upper surface. This feature suggests that this timber fulfilled the role of a mast-step. The reconstructed vessel was 17.36 m long and 2.78 m wide.

No upper parts were found with the ship remains. Two smaller artifacts were also part of the site assemblage. The first was a wood fragment marked on one side by a chisel. It was interpreted as part of a rudder. The second was a 0.31-m-long and 0.13-m-wide woolen cloth piece. To give the cloth a 0.02 m thickness woolen thread was sewn on either side of it. In the investigator's opinion, the piece was originally part of a mail coat which was reused later

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41 Supra n. 7, 15.
for caulking.\textsuperscript{62} The wreck was tentatively dated by Heydeck to the 6th or 7th c. by interpretive comparison with the Nydam and Gokstad finds.

6. The Puck Bay shipwrecks

In 1977 several wooden fragments and ceramic material were recovered from the shallow waters of the Puck Bay, Gdańsk district.\textsuperscript{63} The underwater survey led to the discovery of a large site whose limit was located 118-119 m from the actual shore line. A full scale excavation was mounted by the Center of Studies and Documentation of Monuments in Łódź in cooperation with the Puck Regional Museum.

A total of five wrecks, numbered 1 through 5, were discovered. Four represented remains of plank boats; the other wreck was a dugout.\textsuperscript{64}

\textsuperscript{62} Heydeck (supra n. 5) 72: "Dieses Stück kann ursprünglich von einem Panzer, etwa einer Brüste, herrühren und hat wohl zuletzt zum Kalfatern gedient, denn es war vollständig mit Theer durchtränkt."

\textsuperscript{63} The first five years were spent in outlining the site boundary and defining the site infrastructure. By the end of the 1983 excavation season, a total of 18,000 sq. m. were mapped. During these earlier efforts, four wrecks were located in different positions within the site. For details see W. Stepień "Odkrycia archeologiczne w Zatoce Puckiej," Nautologia 1/9 (1986) 79-83; Stepień "Odkrycia archeologiczne w Zatoce Puckiej," IX Sesja pomorzansczc Gdańsc, 22-23 III 1984 (1984a) 71-78; also Stepień "Archaeological excavations in Puck Harbour, Gdańsk District, Poland," The International Journal of Nautical Archaeology and Underwater Exploration 13.4 (1984b) 311-321. After five years of interruption, the work resumed in 1990, when the site boundary was further delimited and the work on the shipwrecks continued with the discovery of a fifth wreck. For details see W. Szulta, "Z badań nad tzw. wczesnośredniowiecznym portem w Zatoce Puckiej," in J. Chudziakowa ed., Badania Archeologiczne Ośrodka Toruńskiego w latach 1989-1992 (Toruń, Poland 1993) 163-168.

\textsuperscript{64} Labeled as wreck 4, the dugout was preserved for a length of about 4 m and had a breadth of about 0.80 m. The craft was compartmented by two bulkheads, one fixed and the other removable. It was dated to the 8th century. A. Zbierski, "Z kregu problematyki związanej z badaniami kompleksowymi nad początkami portu puckiego," Peribalticum 4 (1986) 123-142, gives 0.60 m for the breadth of the dugout.
Puck 1 - One of the posts of wreck 1 was fastened to the keel with one treenail.\textsuperscript{65} The strakes were fastened together in the clinker method of construction with rivets.\textsuperscript{66} Wide floor timbers preserved inside the hull were set at intervals of 0.50-0.60 m. During the investigation it was observed that the hull was repaired in one place, where a board was nailed from the inside and caulked with fabric. The shipwreck was dated by C14 analysis to 1250 +/- 15.

Puck 3 - Wreck 3 was initially uncovered at one end for a length of approximately 2 m. In 1990 the wreck was raised and transported to the Conservation Laboratory of the Polish Central Maritime Museum where it is presently undergoing conservation treatment.\textsuperscript{67}

A T-shaped keel was flatly cut at one end for the vertical joint with the stem or the sternpost. At this end, three shallow, square mortises were cut into its upper surface. Carved out of a naturally curved timber, the post, triangular in cross-section, appeared to be the stem.\textsuperscript{68} A step was carved into its inner side for the garboard strake. Forward of the step vertical shallow cuts were made on both sides of the stem. A shallow groove, resembling a rabbet, was carved along its sides. Below the lowest end of the rabbet, a rectangular hole was cut through the stem.

\textsuperscript{65} Stępień (supra n. 63) 82: "Stewa tylna prosta połączona ze stępką czopem."

\textsuperscript{66} Zbierski (supra n. 64) 134: "Odkryto stalowe podkładki pod nitach."

\textsuperscript{67} For details see J. Litwin, "The Puck Bay wrecks - an opportunity for a "Polish Skuldelev," in O. Olsen, J. Skamby Madsen, and F. Rieck eda., Shipshape - essays for Ole Crumlin-Pedersen on the occasion of his 60th anniversary February 24th 1995 (Roskilde, Denmark 1995) 136-150.

\textsuperscript{68} Supra n. 67, 145.
The hood ends of the four lowermost strakes were connected to the stem through wings nailed to either side of it. 69

The strakes, made of overlapped planks with lengths varying between 1 m and 3 m, were joined in the lapstrake manner and fastened to each other with trenails. Moss was used for luting. A forwardmost frame was found in situ fastened to the strakes but not to the keel. The floor timbers, carved out of naturally-curved wood, were inserted in the hull at 0.85-1.35-m intervals. 70 Beams were set on top of floor timbers. The upper hull was further reinforced by vertical knees fastened on top of the beams. The longest beam had a semicircular notch carved into the side. The wreck was dated by C14 analysis to the 9th-10th century. 71

Puck 5 - During the 1990 excavation season, wreck 5 was located adjacent to wreck 3. Lying on a N-S axis, the wreck, whose length reached approximately 12 m, was buried under 1 m of sediments. 72 The missing stem or sternpost was fastened to the keel through a vertical flat scarf. Up to

69 Supra n. 67, 145: "...naturally bent beam, to the sides of which were nailed suitably shaped pieces of wood containing the rabbets for the lower strakes of the planking." Also Stępień (supra n. 63) 82: "stewa posiadała przybite do swych boków deski łącznikowe do klepek poszycia."


71 Supra n. 70, 78: "The ship had a mast." Litwin (supra n. 67) 146: "In one of these thwarths, the longest of those recovered, there is a semicircular cut-out. This must have been part of the mast yoke, so the boat itself must have been a sailing vessel. Unfortunately, there is no sign of the mast-step in the wreck..."

72 Litwin (supra n. 67) 141: the wreck was exposed for about a third of its total area, recorded and reburied for future investigation.
nine strakes on either side of the keel were joined to each other in the lapstrake manner with treenails. Moss was used as luting material. The dendrochronological dating for this wreck indicated that the timber from which the sampled element was carved had been felled in 1248.

Puck 2 - The upper end of wreck 2 protruded from the seabed which was at 1.75 m below the surface (fig. 7). The keel, made of oak, was preserved in a very good condition. With maximum dimensions of 0.12 m moulded and 0.21 m sided, the rabbeted keel was T-shaped in its middle section. Close to its broken end, it was 0.19 m sided.

A post fragment, presumably part of shipwreck 2, was found in close proximity to the excavation area. The post had a cross-section identical to that of an equilateral

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73 Supra n. 67, 141-142: "...there were nine strakes in the widest exposed part." Eight strakes are shown on either side of the keel in fig. 6, p. 141.

74 The wreck was covered with a mixed stratum of sand and neritic sediment about 0.10 m thick. Immediately underneath it a stratum of 0.60-m thickness composed of hard sand, gravel, and remains of calcareous invertebrates (Mollusca sp.) covered the wreck itself. The wreck was located to the west of a main pier. The investigator concluded that the wreck was broken and that part of its starboard side was pierced by the wooden posts of the pier. For details see W. Stepień, "Wczesnośredniowieczny wrak łodzi klepkowej W-2 z Zatoki Puckiej," Prace i Materiały Muzeum Archeologicznego i Etnograficznego w Łodzi 34 (1987) 139-144.

75 Two test units were excavated at the wreck site. The first unit uncovered the wreck for a length of 2 m; the length of the preserved keel was approximately 1 m. In the second trench the keel was preserved for about 3 m, which gives a combined length of 4 m. Assuming that the keel was also preserved for the entire length of the unexcavated portion left between the two testing units, then a minimum value of 5.70 m can be considered for the keel length.

76 Based on the observations recorded during the excavation of the first unit, the investigator concluded that the wreck was broken.

77 Stepień (supra n. 74) 144: "Posuwając się dalej, wzdłuż osi wraku, natrafiono w odległości około 14 m od momentu przełamania łodzi na najpewniejszej dziobnicę."
Fig. 7. Puck 2 reconstruction.
triangle with a side of 0.15 m.

Six strakes were preserved on either side of the keel (reconstruction drawings in fig. 7 show a 15.86 m long and 2.54 m wide vessel with nine strakes on either side). Their width varied from 0.17 m (starboard strake 3) to 0.30 m (port strake 4). Also a slight variation in thickness was observed between the starboard strakes (0.02 m) and the port strakes (0.017-0.019 m). The strakes were made of overlapping planks joined through 0.085-m-long scarfs. The hull was built in the lapstrake manner with a land 0.050-0.065 m wide. The strakes were fastened to each other with wedged treenails driven from outside at intervals of about 0.071-0.095 m. The diameter of the treenails varied from 0.011 m to 0.013 m. Animal hair was used as luting material in all joints.

At least 6 frames were preserved from the internal structure. They consisted of floor timbers, beams, and vertical knees. The floor timbers, carved from naturally curved oak wood, were inserted in the hull at intervals of 0.72-0.74 m and fastened to the strakes with treenails of various diameters. One floor timber, situated in the after part of the vessel, was fastened to the keel with one treenail. Each floor timber was jogged in order to fit

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78 Oblique scarfs were located as follows: in starboard strake 4 in between frame 1 and 2 and strake 1 in between frame 4 and 5. Each scarf was secured with two treenails (?). The frames are numbered beginning from the after end of the vessel.

79 The total number of preserved frames is greater than the 6 frames uncovered in testing trenches. Stępień (supra n. 74) 152: "Zaleganie łodzi stwierdzono na odcinku 11.5 m, potwierdziły to wykopy sondażowe, jak i wystające, po odnumieniu dna, wierzchołki kolanek burtowych."

80 The diameter varies from 0.023 m to 0.028 m.

81 Stępień (supra n. 74) 146, fig. 8a, 148: "Denniki związane były z dnem łodzi poprzez drewniane kołki wpędzane i klinowane od wewnątrz." The statement that "the floors were fastened to the bottom of the boat with
the run of the planks. Two floor timbers, situated aft of the mast-step timber, had also semicircular holes at the end of the garboard step (corresponding to the end of the keel's flange in port) and at the following three steps. The dimensions of the uncovered floor timbers were as follows:

<table>
<thead>
<tr>
<th>Floor</th>
<th>Moulded(m)</th>
<th>Sided(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.075</td>
<td>0.065</td>
</tr>
<tr>
<td>2</td>
<td>0.080</td>
<td>0.045</td>
</tr>
<tr>
<td>4</td>
<td>0.110</td>
<td>0.070</td>
</tr>
<tr>
<td>5</td>
<td>0.130</td>
<td>0.065</td>
</tr>
<tr>
<td>6</td>
<td>0.120</td>
<td>0.065</td>
</tr>
<tr>
<td>7</td>
<td>0.110</td>
<td>0.070</td>
</tr>
</tbody>
</table>

Four beams, uncovered in situ, rested on the heads of floor timbers. Each beam was supported in the center by a stanchion 0.02-0.03 m in diameter. The ends of the beams were cut to fit the angle of inclination of that particular strake in the hull. The main beam was notched at its after face in order to receive the vertical stump of the mast-

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82 Floor numbers and dimension values are reproduced from the data presented by the investigator; Stepień (supra n. 74) 149, table 2.

83 Two stanchions were found in situ: a circular stanchion 0.03 m in diameter and the other rhombic with a side of 0.03 m. Their lower ends were inserted in the respective floor timbers, while their upper ends went through the corresponding beams. The ends were smaller in diameter compared to the center of the stanchion. A second hole of similar diameter was observed to starboard near the center hole of one of the beams. Stepień assumed this indicated a second stanchion at that frame station. Similar holes were observed in other two beams.
step. The dimensions of the uncovered beams were as follows:

Table 2. Principal dimensions of Puck 2 beams

<table>
<thead>
<tr>
<th>Beam</th>
<th>Length (m)</th>
<th>Moulded (m)</th>
<th>Sided (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.58</td>
<td>0.03</td>
<td>0.13</td>
</tr>
<tr>
<td>4</td>
<td>1.75</td>
<td>0.03</td>
<td>0.13</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>0.03</td>
<td>0.12</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>0.03-0.04</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Vertical knees were fastened at the ends of each beam. Their vertical outer face was jogged to receive the side planking. At one frame the port knee was fastened to the beams with two treenails, while the starboard knee was fastened with four treenails. The two knees were fastened to the side planking with one treenail.

Two stringers completed the inner structure. The first stringer, 0.11 m x 0.065 m in cross-section, was notched over the vertical arm of the knees. Made out of poplar (Populus sp.) or birch (Betula sp.), the stringer was set with the shortest side against the planking. In the excavated section, no fastening was observed between stringer, planking and knees. A vertical hole, still holding a treenail 0.018 m in diameter, was observed near an after frame. A second stringer was supported by the

44 Stępień (supra n. 74) 149, table 3.
45 The diameter of treenails varies between 0.022 m and 0.025 m.
46 Stępień (supra n. 74) 150, and 147, fig. 8b.
47 The stringer collapsed and broke into pieces during the excavation.
upper tip of the vertical knees and fastened inside the uppermost edge of a starboard strake.\textsuperscript{88} It was 0.045 m thick and 0.135 m wide.

A mast-step timber was found \textit{in situ} notched over four floor timbers. Carved out of a single oak trunk, the mast-step timber was preserved in an exceptional condition. It had a length of 2.75 m with a maximum breadth of 0.15 m. At the middle of the mast-step timber, a 0.80-m-long, naturally grown stump was left as support for the mast. A square mortise 0.11 m long, 0.08 m wide, and 0.08 m deep was carved in the mast-step timber just behind the stump. All edges of the timber were rounded. Its underface between the four floor timbers it rested on was carved down. It was placed slightly to the starboard of the center line of the keel.

Although several C14 probes were analysed, no close dating was produced for the shipwreck. The earliest date obtained was 550 A. D.,\textsuperscript{89} while the latest date was the second half of the 8th century.\textsuperscript{90} Decorated ceramic material was found inside at the bottom of the hull. The ornament pattern resembles ceramics of the Menkendorfer type dated to the 8th-9th centuries in the Southern Baltic region.

7. The Mechlinek (Mechlinken) shipwreck

In 1906 remnants of a shipwreck were accidentally discovered in a drainage canal near the village of Mechlinek (Mechlinken) on the Rewa river (fig. 8 shows

\textsuperscript{88} Stepień (supra n. 74) 152: "Przy jednej z krawędzi prawej burty odnaleziono po stronie wewnętrznej fragment klepki relingowej lub rodzaj wzdużnika, opierającego się na wierzołku kotanka ..."

\textsuperscript{89} Supra n. 63, 319.

\textsuperscript{90} Supra n. 74, 153.
Fig. 8. Mechline
Lienau's reconstruction of a 9.32 m long and 2.47 m wide vessel). The wreck, situated not far from the seashore, was buried in a one-meter-thick neritic stratum superimposed over a very thin stratum of white sand.

An oak keel, carved from a single piece of wood, was preserved for a length of 6.72 m. In its widest part it had a T-shaped cross-section and was 0.145 m moulded and 0.29 m sided. The keel was vertically scarfed at both ends. Scarfs 0.245 m and 0.24 m long were cut for the joints with the sternpost and the stem; the posts did not survive.

Five strakes on one side of the hull and six strakes on the other were preserved. They were fastened to each other with wedged treenails in diameter driven at intervals of 0.010–0.012 m. Moss (Sphagnum cuspidatum sp.) was used to fill 0.035-m-wide and 0.005-m-

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91 The site was investigated by Kumm, the custodian of the Provincial Museum in Danzig, and the wreck was recorded by the naval engineer Schwartpfeger. For details see H. Conway, Antiker Bericht des Westpreussischen Provinzial-Museum Danzig 27 (1906) 28–29; O. Lienau (supra n. 7) 30; also D. Ellmers, Frühmittelalterliche Handelschiffahrt in Mittel- und Nordeuropa (Neumünster, Germany 1972) 308.

92 Smolarek (supra n. 14) 235, n. 17: "... Dane dotyczące stępki mechaliskiej także w tekście [n. 30] nie odpowiadają stanowi faktycznemu." Smolarek wrote that the keel was moulded 0.15–0.16 m and sided 0.297 m and that Lienau's data were not reliable. Lienau (supra n. 7) 30, table 14 gave two values for the same measurement: height of keel below flange was 0.00 m in text (p. 30) and 0.12 m in table 14. In this case the keel would be 0.105–0.145 m moulded, i.e. the divergence in opinions occurs over the height of the web. However, his maximum value (0.145 m) is sufficiently close to Smolarek's data, and thus taken here as the moulded value of the keel. The 0.007-m-difference in the sided dimension given by the two researchers is insignificant since it could have been the result of shrinkage and/or wood distortion.

93 Ellmers (supra n. 91) 308 stated that the fastenings between keel, sternpost, and stem were secured with iron nails.

94 Conway (supra n. 91) 28: "... auf der einen Seite noch sechs, auf der anderen, weniger gut erhaltenen Seite nur noch fünf..."

95 Supra n. 91, 29; the majority of treenails were of pine, but occasionally oak treenails were noted; Lienau (supra n. 7) 32 indicated that the wedges were of oak.
deep grooves carved in the land of each seam. The garboards were fastened to the keel with treenails, 47 on the port side and 45 on the starboard side, but their ends were nailed with iron nails to the keel.96 The strakes were made of up to three planks with an overlap of 0.22-0.30 m.97 The scarfs were caulked with the same kind of moss used for strake fastening. The maximum strake width was 0.30 m amidship and 0.14 m toward the bow and the stern; strake thickness varied between 0.015 m and 0.02 m. The lower inner edge and the upper outer edge of each strake were beveled to render the necessary curvature of the hull.98

Eleven preserved frames consisted of two or three elements, a floor timber with a naturally-curved end and a futtock or a floor timber with two futtocks. These elements were fastened together by horizontal flat scarf joints secured with iron nails.99 The intervals between frames varied between 0.47 m and 0.80 m.100 Five out of a total of twelve floor timbers were closely spaced in the widest part

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96 Smolarek (supra n. 14) 239; the treenails stop before the scarf joints between the keel and the posts.

97 Supra n. 14, 278, n. 64. Smolarek considers that the original length might have been altered in the course of reconstruction. Lienau, (supra n. 7) 32, indicated 0.20-0.30 m for the same measurement.

98 Supra n. 14, 283; the width of the bevel reached approximatively 0.06 m.

99 Supra n. 14, 309: "... wreg lub tet z dennika z jednym ramieniem wregowym naturalnie wyrównytem, a drugim przybitym kolkami drewnianymi." Conwentz (supra n. 91) 29: "... Eisennägel fanden sich ... an der Stellen wo die seitlichen Ansatzstücke der Spanten an den Mittelstücke befestigt waren." Ellmers (supra n. 91) 90, 308 shared Conwentz' opinion when he wrote that the joints ":... über waagerechte... Laschen durch Eisennägel miteinander verbunden und reichten bis zum Dollbord."

100 Smolarek (supra n. 14) 309 gives 0.40 m for the lowest interval space.
of the hull, which was in the forward part of the hull.\textsuperscript{101} The floor timbers were 0.11 m moulded and 0.10 m sided. In Lienau's reconstruction the frames were numbered consecutively 1 through 12 starting from the bow. Floor timbers 2 and 10 had four vertical mortises carved into their upper side.\textsuperscript{102} In the bow and in the stern, the frames were made out of naturally curved timbers. Each floor timber was fastened to the hull with pine treenails\textsuperscript{103} 0.025 m in diameter, one treenail per strake.

No traces of a mast or mast-step were found at the site. The ceramic material found with the shipwreck dated the site to the 11th-12th century.\textsuperscript{104}

8. The Charbrowo/Czarnowsko (Charbrow/Lebasee) shipwrecks

Charbrowo 1 - A shipwreck, preserved in a 1-m-thick sandy stratum covered by 0.50 m neritic sediment, was found on the western bank of the Czarnowsko channel at the intersection of two irrigation ditches (fig. 9). Discovered in 1896 by the landowner, the wreck was investigated in 1898, excavated and transported in 1900 to the Museum in Szczecin, and reconstructed in 1905 by Hugo Lemcke.\textsuperscript{105} In

\begin{itemize}
\item \textsuperscript{101} In Lienau's reconstruction the widest breadth is in the forward half of the hull Lienau (supra n. 7) 31, fig. 28. Smolarek (supra n. 14) 310 asserted that the boat was at its widest in its after part: "...w części rufowej, gdzie łoże była najszersza...".

\item \textsuperscript{102} Lienau (supra n. 7) 30 concluded that these mortises served as steps for stanchions which supported the beams or as steps for bulkheads.

\item \textsuperscript{103} Supra n. 7, 32; some treenails were of oak.

\item \textsuperscript{104} Supra n. 7, 33: ". . . etwa 35 cm höher als die untere Seite des Kiels, Teile eines mit Wellenlinie verzierten Topfes gefunden wurden . . . und nach Mitteilung von Prof. Dr. La Baume dem 11. oder 12. Jahrhundert nach Chr. Geb. angehören sollen."

\item \textsuperscript{105} For details see Lemcke (supra n. 6).
\end{itemize}
a. overall view from the stern

Fig. 9. Charbrowo 1
b. scarf floor timber-futtock

c. aftermost preserved floor timber/rib

Fig. 9 (continued)
d. shallow mortise in main floor timber

Fig. 9. (continued)
his reconstruction, the vessel had a length of 13.20 m and
a breadth of 3.30 m.

Its T-shaped keel, carved from a single oak log, was
preserved for a length of 9.60 m; it was sided 0.30 m\textsuperscript{106} and
moulded 0.115 m. Although the sternpost and the stem were
missing, the ends of the keel indicated that they were
fastened to the keel through vertical flat scarf joints.\textsuperscript{107}

At least seven strakes\textsuperscript{108} were preserved on either side
of the keel. They were 0.018–0.02 m thick and 0.20 m wide.
The strakes, with a land 0.04 m wide, were fastened to each
other with juniper (Juniperus communis) treenails driven at
0.09 m intervals. Soaked moss (Hypnum fluitans) was used
for luting.

A total of thirteen floor timbers were preserved.
Inserted in the hull at 0.90–1 m intervals, the floor
timbers were moulded 0.16–0.18 m, sided 0.075 m, and
fastened with treenails to the planking. Only the after-
and forwardmost floor timbers were joggled to fit the
planking. The other eleven floor timbers were not carved to
fit. Instead notches with an angle under 60 degrees were
cut at intervals on the underside. A rectangular notch of
very shallow depth was carved into the upper surface of the
largest floor timber. To the side of it an additional board
was lashed for reinforcement purposes.

The finding of burnt ceramic material in the after
part of the hull\textsuperscript{109} led Kunkel and La Baume to date the

\textsuperscript{106} Supra n. 6, 202; the keel dimensions decreased toward the ends
to 0.10 m sided.

\textsuperscript{107} Ellmers (supra n. 91) 80, 302-303.

\textsuperscript{108} Supra n. 91, 303: "Die wenigstens sieben Plankengänge waren .."

\textsuperscript{109} Lemcke (supra n. 6) 309: "Beim Abräumen des Achterteils fanden
sich etwa in der Mitte, zwischen der Mastspur und der Stelle des
Achterstevens, die einzigen Spuren der früheren Benutzer, länglich
entire site to the 11th–12th century.\textsuperscript{110} The C14 analysis carried out in 1985 produced median dates of 920–930.\textsuperscript{111}

Charbrowo 2 - A second wreck, Charbrowo 2, was located in the vicinity of a ditch. Several osteological remains and an axe fragment were found with this wreck, which, in Lemcke's opinion, was similar with Charbrowo 1. Although the frames were missing, the bottom planks were still in a good state of preservation. The wreck was not excavated.

Czarnowsko 1 - A third wreck, found in 1931 at Charbrowo (Charbrowo 3 = Czarnowsko 1), was investigated by Lienau in 1934 and 1937, and excavated in 1957 by a team from the National Museum in Szczecin (fig. 10).\textsuperscript{112} After it was gespaltene und vom Feuer geschwärzte Findlingsbrocken, wie sie bei uns in wendischen Ansiedlungen als Unterlage und Ummauerung von Heerdten gediengt haben und bei, und in Burgwällen häufig begegnet; die aus Gneis bestehenden waren vom Feuer so zermürbt, dass sie sich in der Hand zerdrücken liessen ..."

\textsuperscript{110} Supra n. 6, 309. Lemcke stated that the ceramic material found in the wreck "[m]indemien der wendischen Zeit zuzurechnen sind; diese aber fällt mit der Wikingerzeit zusammen." Furthermore, he considered that given the flat, harbourless Pomeranian coast this type of boat was not suited to the local condition of navigation. Lemcke (p. 317) reached the conclusion that "[a]lle Umstände sprechen für die Entstehung im skandinavischen Norden." Munkel and La Baume considered that "[g]ehören diese Scherben etwa der Zeit zwischen 1000–1200 n. Chr. Geb. an": Lienau (supra n. 7) 33.


\textsuperscript{112} The wreck was lying on its keel in a gravel stratum at approximately 0.50–0.60 m distance below the modern ground level. A stratum of sand sealed the entire cultural context. Above it a thin stratum of neritic sediment was observed. After the initial testing, Lienau, Stielow, and Ostendorf uncovered the wreck for recording purposes. For details see O. Lienau, "Auszgrabungen und zeichnerische Wiederherstellung des frühgeschichtlichen Bootes vom Ufer des Lebasses bei Leibafelde Nr. Lauenburg," Monatsblätter der Gesellschaft für pommersche Geschichte und Altertumskunde 8 (1939) 145–150 and P. Smolarek, "Lokalizacja stanowiska łodzi "Charbrow III," Sprawozdania Archeologiczne 4 (1957) 200–207. In 1957 the wreck was excavated and taken for conservation to Szczecin. On this occasion several treenails and a knee fragment were found underneath
a. main floor timber and mast-step

b. floor timbers (view from the bow)

Fig. 10. Czarnowski 1
c. plank scarf in starboard

Fig. 10. (continued)
e. keel scarf and aftermost floor timber

d. forwardmost preserved floor timber

Fig. 10. (continued)
excavated, the wreck was raised and transported to Szczecin, where the conservation treatment was carried out.\textsuperscript{113}

A T-shaped keel measured 0.20 m sided; the vertical foot of the keel was moulded 0.10 m and sided 0.10 m.\textsuperscript{114} The keel was vertically scarfed at both ends for the joint with the sternpost and the stem; the posts did not survive. The scarf joints were riveted.

Seven planking strakes on the port side and nine strakes on the starboard side were preserved in good condition. With a maximum thickness of 0.025 m and a width of 0.18–0.20 m, the strakes were assembled in the lapstrake manner. The luting was of moss, animal hair, and textile material.\textsuperscript{115} The seams were secured with pine treenails 0.012–0.013 m in diameter.

From a total of eleven preserved frames, six were shorter and had mortises cut in the upper side above the the wreck. One of those treenails protruded the hull between two strakes. In this place, a fascine was also uncovered. Under these circumstances Filipiak interpreted the wreck as a "... [i]6dz ... stary wrak pozostała nieużyteczna w miejscu przystawania o czym świadczy kołki i faszy." Filipiak, considering the numerous repair traces, concluded that the wreck was used between the 10th–12th century. This date was also suggested by the ceramic material found near the place where Chabrowo 1 was found. Filipiak also stated that the ship was rowed initially, the mast and sail being a later addition. For details see W. Filipiak, "Badania archeologiczne nad jeziorem Leba," \textit{Materiały Zachodnio-Pomorskie} 3 (1957) 342–345.

\textsuperscript{113} The raising of the wreck by flooding the entire site with water indicates that the wood, although in a waterlogged condition, retained its mechanical properties. The conservation started with a 10% formalin solution, then a 75% terebentin and 25% flax oil solution was used at 80 degrees Celsius. The wreck was brushed regularly with this solution to which colophon (5%) and carbolumin (5%) was added later. For details see W. Garezyński, "Transport i konserwacja wcześnieśredniorolnej łodzi ze wsi Czarnowsko, pow. Lębork," \textit{Materiały Zachodnio-Pomorskie} 4 (1958) 393–397.

\textsuperscript{114} Smolarek (supra n. 14) 204 stated that the principal dimensions of the foot of the keel were "11 x 10 cm".

\textsuperscript{115} Filipiak (supra n. 112) 345.
center line of the keel.116 The other frames (five preserved and a sixth added in Lienau’s reconstruction) were made of floor timbers and futtocks; two futtocks were joined to a floor timber through horizontal scarfs located at the turn of the bilge.117 These frames reached up to the sheer strake. The floor timbers measured 0.13–0.15 m moulded and 0.07 m sided.118 Notched at almost each planking seam, the floor timbers were fastened with treenails to the planking. A mast-step timber made out of birch (Betula sp.) was lashed with willow (Salix sp.) twigs to one side of the main floor timber and was set above the keel. The wreck, remnant of a 13.76-m-long and 3.35-m-wide vessel, was dated by Lienau to the last quarter of the 10th century. In 1985 samples taken for C14 dating gave median results of 910–1010.119

Czarnowsko 2 – A fourth wreck, known as Czarnowsko 2, was found in 1962 and excavated in 1983.120 The T-shaped keel

116 In Lienau’s reconstruction, frames were numbered consecutively 1 through 12 starting from the stern. Frames 1, 2, 3, 4, 7, 10, and 11 are composite structures, in that that each had a floor timber, and a stanchion as support for the upper beam. Frames 5, 6, 8, and 9 were reconstructed as ribs within the hull.

117 The scarf length covered part of the fifth and seventh strake, and the entire sixth strake. According to Smolarek, the scarfs were secured with treenails. For details see Smolarek (supra n. 14) 313, fig. 83, 314; also Ellmers (supra n. 91) 308. Prosnak omitted this detail in his reconstruction of the Czarnowsko 1 shipwreck (fig. 12). For details see M. Prosnak, “Zachodnio-słowiańska sztuka korabnicza wczesnego średniowiecza,” Materiały Zachodnio-Pomorskie 9 (1963) 241-271.

118 Smolarek (supra n. 112) 204 stated that the floor timbers were moulded 0.10–0.20 m and sided 0.08 m.

119 Pazdur (supra n. 111).

120 The wreck was damaged by a backhoe during hydrotechnical works carried out in the nearby area. For details see P. Smolarek, “Wraci z Czarnowska, Ładu i Tolmkicza,” Nautologia 1 (1986) 73–78; Smolarek, “The Underwater Investigations of the Polish Maritime Museum in Gdańsk from 1982 to 1985,” Acta Universitatis Nicolai Copernici – Archeologia XV –
measured approximately 11-12 m in length. The surviving stem was joined to the keel through a vertical flat scarf joggled in the middle. The stem had on its inner side at the lower end a step for the fastening of the garboard strakes.\textsuperscript{121} The garboards were fastened in this place with iron nails. The hooding ends of the upper strakes were also fastened with iron nails to the stem.

The strakes, 0.24-0.29 m wide and 0.022-0.025 m thick, were joined together in the lapstrake manner and fastened with wedged treenails driven at intervals of 0.06-0.065 m. The luting in the seams was of moss. A total of five planking strakes to port and six to starboard were preserved. Nine recovered frames had been inserted in the hull at 0.70-1.00 m intervals. The floor timbers, joggled to fit the planking, were fastened to the hull with treenails. The recovery of a knee fragment led Smolarek to assume that beams or thwarts may have been part of the inner skeleton of the vessel. The wreck was dated by C14 analysis to the 9th-11th century.

9. The Szczecin shipwreck

Archaeological excavations carried out in 1962 uncovered a shipwreck located near the medieval castle of the Pomeranian counts in Szczecin (fig. 11).\textsuperscript{122}

\textit{Archaeologia podwodna} 3 (1991) 8-9.

\textsuperscript{121} In this place the inner side was carved. Smolarek (supra n. 120) 74 stated that this feature eased the wedging of treenails, although in this particular case iron nails were used: "W tych ostatnich złobieniach owe ułatwiały przybijanie posycia kołkami i klinowanie tychże kołków."

a. overall view from the bow

Fig. 11. The Szczecin vessel
b. long knee and floor head in the aft

Fig. 11. (continued)
The sternpost and the stem, which did not survive, were attached to a robust keel-plank\textsuperscript{123} through vertical flat scarfs. The scarfs were secured with iron nails. The keel-plank, preserved for a length of 6.2 m, was about 0.145 m thick and 0.35 m wide.

Four strakes were preserved on either side of the keel. The planks averaged about 0.20–0.30 m in width and 0.015–0.02 m in thickness.\textsuperscript{124} The strakes were made out of either a single plank or two overlapped planks with the scarf secured by two iron nails. Moss was used as luting material for the hull seams, and animal hair was used for caulking repair patches.\textsuperscript{125} The strakes were joined in the lapstrake manner and secured with pine treenails.

Two different kinds of framing were observed in this shipwreck: a floor timber with a naturally curved end and a futtock added to the straight end, and floor timbers/ribs made out of a single piece of wood. Only one beam, with a naturally curved end, was found with the shipwreck remains.

Several traces of repair were noted. A short oar-paddle, an iron fish hook, a plank board, a pole fragment with one end carved into a zoomorphic head, and a scoop (?) were found together with the shipwreck. The vessel was reconstructed with a length of 8.25 m and a breadth of 2.10 m. The wreck was dated by C14 analysis to the 6th-9th

\textsuperscript{123} Carved from a half-log the keel-plank changed its cross-section from a semicircular shape in the middle body to that of an almost rectangular element toward its ends. According to Filipowiak (supra n. 122) 85, fig. 3, the keel-plank was 0.15 m thick and 0.35 m wide, but in the same article, on p. 83, he gives 0.32 m for the same measurement. In another article (supra n. 31, 33), the same author states that the width of the keel-plank was 0.30 m, while the accompanying drawing (fig. 2) shows a keel-plank about 0.143 m thick and 0.36 m wide.

\textsuperscript{124} S. Wesołowski, "Najnowsze odkrycia archeologiczne - odkrycie łodzi słowiańskiej na podgrodziu w Szczecinie," Z Ochroni Niewków 29/4 (1963) 254–258; Wesołowski noted that the keel was 0.35 m sided.

\textsuperscript{125} Filipowiak (supra n. 31) 37.
century, while the dendrochronological analysis indicated
the 9th century as the most probable date.126

10. The shipwreck from Ład

Remains of a shipwreck were uncovered during the
archaeological excavations carried out in 1983 at the site
of the medieval fortress at Ład on the Warta river.127

A T-shaped keel was preserved for a length of 7.2 m.
Carved from a single piece of wood, the keel was in its
widest part 0.10 m moulded and 0.21 m sided. At its after
end the keel had a rectangular cross-section and was 0.085
m moulded and 0.068 m sided.

A rabbeted128 sternpost, preserved for a length of
1.325 m, was fastened to the keel through a horizontal flat
scarf joint.129 Although the outer edge of the sternpost was

126 Filipowisk (supra n. 122) 83; the following C14 dates were
obtained:
- moss luting in the planking: 780/870 +/- 75
- moss luting in the keel: 650 +/- 70
- keel-plank: 650 +/- 75
- treenail in the keel: 660 +/- 65
- keel: 540 +/- 75
The dendrochronology dated the vessel between 834-896.

127 The wreck was found at about 1.5 m outside the fortification
ring 1 m below the actual ground level. It was lying parallel to the outer
line of the fortification wall in the defensive ditch which surrounded the
fortress on its western side. The ditch was filled with water from the
Warta river, which encircles the site on its eastern side. For details see
M. Zeylandowa, "Wczesnośredniowieczna łódź kępowska z Ładu, woj. Konin,"
Fontes Archeologiczni Poznaniensis 33 (1984) 168-170; and P. Smolarek,
"Znalezisko wczesnośredniowiecznej łodzi z Ładu nad Wartą," Kwartalnik

128 Smolarek (supra n. 127) 176; the depth of the rabbet was 0.006 m
near the scarf and 0.01 m at the broken end of the sternpost. The width of
the rabbet was 0.045-0.057 m on the port side and 0.044-0.050 m on the
starboard side.

129 The measurements, taken one year after the excavation, were:
0.085 m moulded; 0.068 m inner sided and 0.023 m outer sided; length of
scarf 0.23 m.
damaged, the post's original triangular shape was still recognizable. Fastened to the keel with four iron nails, the straight sternpost had a considerable rake as a result of the scarf angle.

There had been seven strakes to either side of the keel. All seven had survived in the starboard side, while only three strakes were preserved on the port side. The end of strake 6 on the port side was not nailed to the sternpost; instead it was scarfed to the fifth strake. The strakes were assembled in the lapstrake manner with a land of 0.045-0.055 m wide, and fastened with treenails 0.01-0.012 m in diameter. The wedged treenails were driven from outside at an interval of 0.085-0.095 m.

The dimensions of the planking strakes is given in Table 3.

Table 3. Principal dimensions of Lad planking strakes

<table>
<thead>
<tr>
<th>Strake</th>
<th>Width(cm)</th>
<th>Thickness(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.7-21.8</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>22-23.8</td>
<td>2.2</td>
</tr>
<tr>
<td>3</td>
<td>23.2-23.3</td>
<td>2.4</td>
</tr>
<tr>
<td>4</td>
<td>23.7-24.2</td>
<td>1.75</td>
</tr>
<tr>
<td>5</td>
<td>26.6-27.4</td>
<td>2.05</td>
</tr>
<tr>
<td>6</td>
<td>23.2-25.5</td>
<td>1.4</td>
</tr>
<tr>
<td>7</td>
<td>19.3</td>
<td>1.7</td>
</tr>
</tbody>
</table>

The hood ends of the planks were fastened to the sternpost with iron nails. The strakes were made of two or more overlapped planks joined through scarfs secured with

\[130\] The average thickness for the middle of the plank is given here. For detailed measurement see Smolarek (supra n. 127) 177, table 1.
treenails. Moss (Drepanocladus aduncus var. Kneiffi, Drepanocladus revolvens) and animal hair were used for luting, while only moss was used in the planking scarfs.

A total of 16 frames, numbered 1 through 16 from the stern to the bow, were preserved. They consisted of straight floor timbers with futtocks alternating with half-frames. No fastening was observed between futtocks and floor timbers. The floor timbers were fastened to the hull with pine treenails, one for each strake. The naturally curved half-frames were not fastened to every strake in the hull. No fastening was observed between frames and keel. On the average the spacing between frames was 0.40-0.46 m. The aftermost-preserved floor timber was 0.09 m moulded and 0.067 m sided.

The inner structure was reinforced by a birch stringer notched over the floor timbers. Some of the half-frames were set over the stringer which was notched at these joints. At the sheer strake the hull was reinforced by a rubbing strake made of ash wood (Fraxinus sp.). The rubbing strake, fastened by treenails to the upper edge of the sheer strake, was 0.053 m thick and 0.088-0.091 m wide and was scarfed close to the sternpost where it was

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131 The location of scarfs are as follows: on the port side, the garboard at frame 4 and 6, the second strake at frame 5, the third strake at frame 6, the fourth strake at frame 4; on the starboard side, the garboard at frame 4.

132 Smolarek (supra n. 127) 177 reported that close to the sternpost between the third and the fourth strake the luting material was of animal provenience.

133 At frame 7 the end of the floor timber rises to meet the tip of a futtock in a loose flat scarf. A hole was drilled through the tip of the floor timber, but not through the tip of the futtock. No fastening was observed at this scarf joint.

134 The stringer disintegrated during the excavation, but Smolarek found in the Poznań Museum two fragments with a 0.06 by 0.073 m section which he believed were part of that stringer.
possibly joined to a breast hook.\textsuperscript{135} Three additional elements were fastened to the hull from the inside in the stern quarter (fig. 12). Made of naturally curved branches, the longer arm of each knee-like timber was fastened to the inner side of the hull, while the shorter arm extended over the sheer strake and the rubbing strake. Smolarek thought that these timbers were an earlier version of the so-called pachołki, a kind of bitt used in the medieval and modern periods to moor a ship to the quay. He estimated that the vessel could have reached a length of 10.70 m and a breadth of 2.35 m. The shipwreck was dated by C14 analysis to the 9th-11th century.

11. The Kamień Pomorski shipwreck

Hydrotechnic work carried out in 1984 at the mouth of the Dziwna river led to the accidental discovery of a medieval shipwreck.\textsuperscript{136} Its keel was preserved for a length of 4.15 m and was T-shaped in cross-section. Where it attained its maximum cross-sectional dimensions, the keel was 0.10 m moulded and 0.19 m sided. Only a 0.45-m-long fragment was preserved from the original stem.\textsuperscript{137}

A total of six strakes were preserved on the port

\textsuperscript{135} Smolarek (supra n. 127) 181.

\textsuperscript{136} The investigation was conducted by a team from the National Museum in Szczecin. The wreck was damaged by a backhoe during the deepening of the river bed. Originally, it was situated on a east-west axis, parallel with the course of the shoreline. Situated at about 400 m north of the medieval harbour of Kamień Pomorski, the wreck was covered by approximately 1.20 m of neritic sediments and clay deposition. From a stratigraphic point of view, Filipowiak considers that the fifth stratum, where the wreck was actually found, can be dated to the 12th century. The stratum immediately above it contained fragments of 11th-12th century ceramic material. Stratum 3 contained ceramic material from the 13th-14th century. The upper strata, 1 and 2, were naturally deposited and of no archaeological significance. For details see W. Filipowiak, "Słowiński statek z XII wieku z Kamienia Pomorskiego," Nautologia 1/81 (1986) 84-86.

\textsuperscript{137} Filipowiak considers the fragment as part of the original stem.
Fig. 12. The Ląd ship remains
side, while only four strakes were found on the starboard side. Their width ranged from 0.20 m (garboard) to 0.34 m (sheer strake). The strakes averaged 0.015 m in thickness, were joined in the lapstrake manner, and fastened with treenails 0.012–0.015 m in diameter. The treenails used to fasten the strakes to each other were replaced with iron nails only at the hood ends of the planks, the scarf between the keel and the stem, the scarfs in the planking, and in fastening knees to the beams. The reconstructed vessel attains an overall length of 12.10 m and a maximum breadth of 2.70 m. The wreck was dated by C14 analysis to the second half of the 12th or the beginning of the 13th century.138

138 The median dates obtained ranged from 1140–1210. For details see Pazdur (supra n. 111) 178–180.
CHAPTER III

COMPARATIVE ANALYSIS OF PRINCIPAL MEMBERS

The previous chapter summarized the main characteristics of the published shipwreck material found on the southern shore of the Baltic Sea. Inasmuch as this material offers sufficient information about hull timbers, the analysis undertaken in the present chapter tries to underline, on a comparative basis, the technical details of timbers from the same class. The data is presented in a tabular format, which permits an easy comparison of attributes of similar timbers from different shipwrecks without appealing to the descriptive text.

1. Keel

Material - All keels under discussion were made of single trunks of oak. This characteristic seems to suggest not only availability of oak on the southern shore of the Baltic, but also that oak was given a certain preference over the other wood species.

Dimensions - The dimensional analysis concentrates on two major aspects. The first aspect takes into consideration the association between dimensional attributes, configuration of keel cross-section, and size of vessel, while the second aspect stresses the dimensional variability of southern Baltic keels. The description of keels is presented below in the form of numerical attributes vs. the principal dimensions of the reconstructed vessels:
### Table 4. Principal dimensions of vessels and keels

<table>
<thead>
<tr>
<th>Ship</th>
<th>Loa</th>
<th>B</th>
<th>L</th>
<th>M</th>
<th>S</th>
<th>Mv*</th>
<th>Sv*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>13-14</td>
<td>3.4</td>
<td>9.40</td>
<td>0.12</td>
<td>0.18</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td>R2</td>
<td>9.50</td>
<td>2.5</td>
<td>7.00</td>
<td></td>
<td>0.21</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>9.50</td>
<td>2.5</td>
<td>6.25</td>
<td></td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>12-13</td>
<td>3.3</td>
<td>8.65</td>
<td>0.14</td>
<td>0.28</td>
<td>0.07</td>
<td>0.15</td>
</tr>
<tr>
<td>G-O1</td>
<td>12.76</td>
<td>2.37</td>
<td>5.30</td>
<td>0.105</td>
<td>0.135</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>G-O2</td>
<td>11.00</td>
<td>2.27</td>
<td>7.50</td>
<td>0.10</td>
<td>0.20</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>G-O3</td>
<td>13.30</td>
<td>2.46</td>
<td>9.10</td>
<td>0.125</td>
<td>0.22</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>Bq</td>
<td>11.90</td>
<td>2.52</td>
<td>6.82</td>
<td>0.11</td>
<td>0.25</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td>Fr</td>
<td>17.36</td>
<td>2.78</td>
<td>15.3</td>
<td>0.112</td>
<td>0.49</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>P1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>15.86</td>
<td>2.54</td>
<td>0.12</td>
<td></td>
<td>0.21</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>P3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Me</td>
<td>9.32</td>
<td>2.47</td>
<td>6.72</td>
<td>0.145</td>
<td>0.29</td>
<td>0.12</td>
<td>0.08</td>
</tr>
<tr>
<td>Chl</td>
<td>13.20</td>
<td>3.30</td>
<td>9.60</td>
<td>0.115</td>
<td>0.30</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td>Cz1</td>
<td>13.76</td>
<td>3.35</td>
<td>0.12</td>
<td></td>
<td>0.20</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>Cz2</td>
<td></td>
<td></td>
<td>11-12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sz</td>
<td>8.25</td>
<td>2.10</td>
<td>0.145</td>
<td></td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ląd</td>
<td>10.70</td>
<td>2.35</td>
<td>7.20</td>
<td>0.10</td>
<td>0.21</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>KP</td>
<td>12.10</td>
<td>2.70</td>
<td>4.15</td>
<td>0.10</td>
<td>0.19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note** - All values are given in meters. Loa - overall length of vessel. B - breadth of vessel. L - preserved length of keel (G-O3 keel preserved entirely). M - moulded. S - sided. Mv - height of web below bearding line. Sv - maximum width of web. * denotes dimensional attributes with approximate values rounded to the nearest centimeter.

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139 Lienau (supra n. 112) 150. Also Lienau, (supra n. 7) 15, gives for Czarnowsko 1 a length of 11-12 m and a beam of 3.1 m.
In general, a keel is thought to be proportional to the length and the breadth of a vessel, i.e. the larger a vessel the more robust its keel should be. A close comparison of web areas ($A_{web} = S_v \times M$) reveals that southern Baltic keels can be divided into two clusters, the first between 0.005 sq.m. and 0.01 sq.m. and the second between 0.01 sq.m. and 0.015 sq.m. A further comparison between the two clusters and the length and breadth of the reconstructed vessels reveals that the clusters overlap in both dimensions:

1st cluster - Loa range=10.70-15.86m; B range=2.27-3.3m.
2nd cluster - Loa range=9.32-17.36m; B range=2.47-3.35m.

This confirms that web robustness in T-shaped keels from the southern Baltic is not related to the actual size of the vessel. Although most keels were not preserved for their entire original length, it seems that the other dimension most closely related to the length of the ship is the length of its keel.

Another way to examine T-shaped keels in a more meaningful manner is to compare the width of the web ($S_v$) with the following flange thickness values: Me (0.03 m), G-02 (0.02 m), Bg (0.025 m), Eck (0.028 m), R4 (0.04 m), G-01 (0.025 m), Ch1 (0.025 m), G-03 (0.035 m), Cz1 (0.03 m), P2 (0.05 m), Fr (0.032 m). In almost all keels the difference between the width of the web and the flange thickness ranges between 3.6 and 5 cm; relatively large values were obtained only for Frombork (6.8 cm), Czarnowski 1 (7 cm), and Eckernförder (7.2 cm) keels. If these differences are plotted against the length of the vessels (Loa) the result shows a random distribution of these values. This suggests that robustness in both flanges and web is not related to
the vessel size. The result is surprising inasmuch as these vessels differ in the reconstructed length as much as 9.11 m.

A further comparison can be made between the moulded value of the web below the bearding line and the method of propulsion. This comparison enables us to evaluate each keel as an anti-leeway device, which consequently constitutes an indicator concerning the sailing capability of that vessel. The $M_v$ values, given in table 4, indicate that Frombork, Bağart, Ralswiek 4, Charbrowo 1, and Czarnowsko 1, all considered to be vessels with a mixed (sailing/rowing) propulsion, approach or surpass the 0.08-m-value. However, the fact that in most keels the web extends between 0.06 and 0.08 m below the bearding line suggests that the keels of sailing ships do not necessarily have higher moulded dimensions compared with keels of ships propelled by oars only. An extreme example is given by the keel of the Mechlinek shipwreck (rowing propulsion only) which has a larger web (0.12 m below the bearding line) than the keel of shipwreck 2 from Puck (mixed propulsion). Thus, the data seem to indicate that the method of propulsion did not influence the principal dimensions of the keel.

The T-shaped keels under discussion exhibit some differences in cross-sectional dimensions (fig. 13). These differences are caused by their configuration, namely the width and thickness of flanges, and the height and width of the web. The major variation is observed in the width of flanges and web, which contributes substantially to the robust or thin appearance of the keel. If flange width, obtained by subtracting the width of the web ($S_v$) from the total sided dimension ($S$) and dividing by two, is compared with the number of strakes in the reconstructed hull the
Fig. 13. Keels from the Southern Baltic region
result is as follows:

1. six-strakes - 0.03 m
2. seven-strakes - 0.04-0.09 m
3. eight-strakes - 0.065-0.195 m
4. nine-strakes - 0.05-0.075 m

This suggests that no relation of proportionality seems to exist between flange width and number of strakes in a vessel. Moreover, if flange width is compared with the length of the vessel, the result is as follows:

1. Loa= 8.25-11.00 m - 0.065-0.105 m
2. Loa= 11.9-13.76 m - 0.03-0.115 m
3. Loa= 15.86-17.36 m - 0.075-0.195 m

Thus, flange width is not necessarily related to the number of planking strakes in the hull or to the vessel length. In other words, a wider flange did not substitute as garboard strakes in smaller vessels and, conversely, a narrow flange did not necessarily result in an additional strake in hulls with larger dimensions. The results indicate, however, that biases are likely to occur, especially because of the sample size currently available.

The second aspect considered in this section is related to the variability of certain dimensional attributes. The information on keels appears sufficient enough to display the data at the most simplistic level of exploratory data analysis, in which the rank ordering of dimensional attributes enables the reader to understand better the differences between keels from the southern shore of the Baltic. Thus, if we plot the total moulded dimension of the keels (cm) in a linear progression, we
find that the values fall at intervals of 0.5 cm in all but one case within a total range of only 4.5 cm.

Table 5. Linear progression of moulded dimensions

<table>
<thead>
<tr>
<th></th>
<th>10(3)</th>
<th>10.5</th>
<th>11(2)</th>
<th>11.5</th>
<th>12(3)</th>
<th>12.5</th>
<th>14(3)</th>
<th>14.5(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1.5</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Note - number in parantheses refers to the frequency of that value in the sample group.

This indicates a minimal difference in these moulded dimensions. The display of the same data in a resistant summary (all values are in cm)

Table 6. Resistant summary of moulded dimensions

<table>
<thead>
<tr>
<th></th>
<th>10</th>
<th>10.5</th>
<th>11.75</th>
<th>12.5</th>
<th>14.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
<td>1.25</td>
<td>0.75</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.75</td>
<td>2.0</td>
<td></td>
<td></td>
<td>2.75</td>
</tr>
</tbody>
</table>

reveals that the median point is at 11.75 cm, while the bottom quartile and the upper quartile are to be found at 10.5 and 12.5 cm respectively. The third row indicates that the lowspread is smaller than the highspread value (1.75 * 2.75 cm), while the second row shows that the distance between the median and the lower quartile is higher than the distance between the median and the upper quartile (1.25 * 0.75). Furthermore, the distance between the lower
extreme value (10) and the lower quartile is 0.5 cm, while
the distance between the upper extreme value (14.5) and the
upper quartile is 2 cm. These comparisons show that none of
the conditions of equality are satisfied for a normal
distribution about the median 11.75. On the contrary, the
values seem to concentrate at the lower quartile and in
between the median and the upper quartile. A stem-and-leaf
display of the same data

1|0.0 0.0 0.0
1|0.5
1|1.0 1.0
1|1.5
1|2.0 2.0 2.0
1|2.5
1|4.0
1|4.5 4.5

confirms that what appears to be a normal distribution is
actually a bimodal distribution which is negatively skewed:
this means that keels tend to have moulded dimensions
concentrated either at the 10 or the 12 value, and in
between these values. The apparent conclusion confirms that
keels have minimal differences in the moulded dimension.

A similar progression for the sided dimension, given
here as the sum (cm) of the widths of both flanges and web,
reveals

Table 7. Linear progression of sided dimensions

<table>
<thead>
<tr>
<th>13.5</th>
<th>18</th>
<th>19</th>
<th>20(2)</th>
<th>21(3)</th>
<th>22</th>
<th>24</th>
<th>25</th>
<th>28</th>
<th>29</th>
<th>30</th>
<th>35</th>
<th>49</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

Note - number in parantheses indicates frequency.
that with the exception of the Frombork shallow keel (0.49 m), the values fall at intervals of 5 cm or less within a total range of 21.5 cm range. However, the display of the same data in resistant statistics form reveals that keels vary more in the sided than in the moulded dimension. The resistant summary gives 21.5 as the median point, 20 as the lower quartile and 28.5 as the upper quartile, and it shows that none of the conditions of equality are fulfilled. The highspread (27.5) is more than three times the value of the lowspread (8). Compared with the distance between the median and the upper quartile, the median is minimally distanced from the lower quartile.

Table 8. Resistant summary for sided dimensions

<table>
<thead>
<tr>
<th></th>
<th>13.5</th>
<th>20</th>
<th>21.5</th>
<th>28.5</th>
<th>49</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>1.5</td>
<td>7</td>
<td>20.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8.5</td>
<td>27.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Finally, the difference between the lower quartile (20) and the lower extreme value (13.5) is only a third of the distance between the upper quartile (28.5) and the upper extreme value (49). Thus, with the exception of a cluster located in between the median and the lower quartile, the keel widths seem uniformly distributed along the 13.5-49 range. The same result is obtained by displaying the data in a stem-and-leaf distribution:
With the exception of two values (20.0 and 21.0) the distribution seems to be uniform. The spread may be the result more of the small sample size than the actual tendency of the data. Nonetheless, the uniform distribution within this sample size seems to suggest a certain degree of homogeneity. This homogeneity in both moulded and sided dimensions is surprising for ships of different sizes.

The ordering of keels into regional clusters, as shown in table 4, does not indicate intraclass distinctions. This is shown by the random values obtained within each group for the moulded and sided dimensions, and by the presence of identical or similar values in different groups. It seems that within this sample size the keels do not have a dimensional distribution related to their geographic locations.

Shape - With the exception of the Szczecin shipwreck, all the other finds had keels with T-shaped cross-sections in the middle body. The m/s ratio, obtained by dividing the total moulded (M) to the total sided (S) dimension, show that keels from the southern Baltic region are shallow:

\[
\begin{align*}
\text{Sz} & \ (0.41), \ \text{Me} \ (0.52), \ \text{G-O2} \ (0.50), \ \text{Bg} \ (0.44), \\
\text{Eck} & \ (0.67), \ \text{KP} \ (0.53), \ \text{R4} \ (0.50), \ \text{G-O1} \ (0.78),
\end{align*}
\]
Ch1 (0.38), G-O3 (0.57), Cz1 (0.60), P2 (0.57), Fr (0.23)

About half of the keels are sided roughly twice the moulded dimension. The general trend observed in those keels was that the T-shapped cross-section changed gradually toward the ends of the keel. The shape of the keel at its ends was trapezoidal (Eckernförder), rectangular (Gdańsk-Orunia 1, 2, Bałgár, Frombork, Charbrow 1, Czarnowsko 1, Szczecin, Kamień Pomorski), square (Ralswiek 4), or triangular (Puck 2, 3). This change in shape indicates that the keel was "brought" to match the cross-section of the stem and the stern-post of that particular vessel. A direct consequence of this change in shape was that the maximum dimensions were situated about midway along the length of the keel. This resulted in the center of weight of the keel being located somewhere in this area.

Deadrise angle - By virtue of the T-shaped cross-section, the back rabbet line is directly related to the position and the dimensions of flanges at the uppermost end of the web. Although Gdańsk-Orunia 2, Kamień Pomorski, and Czarnowsko 2 keels show a slight rise of the underside of flanges, most keels exhibit an almost right angle at the joint of the underside of flanges with the web. This angle dictated the deadrise of the garboard strakes, which in most cases approached zero degrees.

The Puck 2 keel exhibits a T-shaped cross-section. The lowermost part of the web is rounded as in the Szczecin keel-plank, perhaps because of wear, but flanges are clearly cut into the keel. A rabbet was carved in each flange for a tight joint with the garboard strake. This resulted in a joggled appearance of the underside of the
flanges. The rise of the back rabbet line indicates a slight deadrise of the garboard strakes. These elements, coupled with the unusual thickness of the flanges, confers the Puck 2 keel a special position within the group of T-shaped keels from the Southern Baltic region.

The keel-plank from Szczecin exhibits a cross-shape similar to that of the reused keel-plank from the quay of the medieval harbour in Wolin. Its semicircular shape was well adapted for navigation in shallow water; as a result of this shape the 0.10-0.11 m projection outside the bearding line confers more strength to the hull than lateral resistance. The 0.42 m/s ratio obtained for this keel-plank can be deceptive in itself, since approximately the same value was obtained for the Ralswiek 4, Bągart, and Charbrowo 1 shipwrecks whose keels had T-shaped cross-sections. Furthermore, Charbrowo 1 and Bągart were remains of sailing ships. In this case, the shape outside the hull establishes this element as a keel-plank, while the ratio seems to indicate proportions within this particular shape.

Scarfs - Another common feature of these keels is the presence of vertical oblique scarfs at both ends. The scarf is either to the starboard or port side. Its length differs with each individual keel. A particular case is presented by the keel of Czarnowsko 2, which has a hook scarf, a

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140 The Wolin keel-plank was preserved for a length of 10.04 m. At one of its ends, the keel-plank had a vertical oblique scarf probably for the scarf joint with the stem or the sternpost. In its widest preserved part, it was approximately 0.22 m sided and 0.06-0.07 m moulded. The keel-plank seems to widen toward its broken end. For details see Filipowia (supra n. 122) 85, fig. 4 and (supra n. 31) 33-34. The keel plank was dated by C14 to 690-770 +/- 50, but stratigraphically the keel was dated in the second half of the 9th c. For details see W. Filipowia, "Wolin i żegluga u ujścia Odry w świetle chronologii radiowęglowej," Zeszyty Naukowe Politechniki Śląskiej Matematyka-Fizyka 70 Geochronometria 9 (1994) 113-125. In the same publication Pazdur gives a C14 median date of 510 A. D. for the keel. For details see Pazdur (supra n. 111) 171, table 5.
design considered superior to the straight oblique scarf.\textsuperscript{141}

The scarf used in the Låd boat constitutes an exception. The sternpost was attached to the keel through an oblique horizontal scarf joint. The angle of inclination of the scarf joining the keel and sternpost is to be related to the rake of the sternpost, these two elements combined to give the ultimate shape of the stern.

2. Stem and sternpost

The double-ended hull was the model used in most of the reconstructions made of the ships under discussion. On this basis it was understood that the stem and the sternpost were identical in shape, dimensions, and cross-sections. This principle was influenced also by the fact that very few sternposts and stems were found with the wrecks. The posts found at these sites can be classified as follows:

Table 9. Classification of Southern Baltic posts

<table>
<thead>
<tr>
<th>Wreck</th>
<th>Raked\textsuperscript{142}</th>
<th>Rabbet</th>
<th>Curved</th>
<th>Wings</th>
<th>Step(s)</th>
<th>Fst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>nail</td>
</tr>
<tr>
<td>R2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>?</td>
<td>tnail</td>
</tr>
<tr>
<td>R4</td>
<td>●</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>tnails</td>
</tr>
<tr>
<td>G-01</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>G-02</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>G-03</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

\textsuperscript{141} Smolarek (supra n. 14) 239.

\textsuperscript{142} Rake is the projected length of the curvature of the post. It equals the horizontal distance between the end of the keel and the perpendicular raised to the uppermost end of the post. Only posts with a long rake were marked under this heading.
Table 9. (continued)

<table>
<thead>
<tr>
<th>Wreck</th>
<th>Raked</th>
<th>Rabbet</th>
<th>Curved</th>
<th>Wings</th>
<th>Step(s)</th>
<th>Fst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fr</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P3</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>●</td>
<td>●</td>
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</tr>
<tr>
<td>Cz2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Lad</td>
<td>●</td>
<td>●</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>nails</td>
</tr>
<tr>
<td>KP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note - ● means present, - means absent. Under "fst" (fastening): nail=iron nail, tnail=treenail. ? - denotes probability.

The data presented in tabular form indicate two relatively distinct post types: the curved/stepped post with or without wings, and the raked/rabbeted post, both with several variants (fig. 14). The curved/stepped type is known from the Gdańsk-Orunia 1 and 2 shipwrecks, and from loose finds from Gdańsk.\(^{143}\) The Gdańsk-Orunia 1 sternpost has a tight-curve transition from a short horizontal component to a long vertical component. The relative abruptness of the transition gave rise to a weak point situated about the upper end of the horizontal arm. This weakness was compensated for by the moulded dimension of the sternpost, which is at its maximum (0.32 m) at this particular point. Additional support was given by the garboard strakes, which, unlike the other planking strakes, were directly fastened to the sternpost. The garboards also

\(^{143}\) In Gdańsk two post fragments (Gdańsk 1-catalog no. 1949/1241 and Gdańsk 2-catalog no. 1949/1281) were found in secondary use. Both posts were stratigraphically dated to the first half of the 13th century: Smolarek (supra n. 14) 247.
Fig. 14. Posts from the Southern Baltic region
reinforced the joint with the keel. As noted in the previous chapter, the hood ends of the strakes were not fastened directly to the sternpost, but to wings, two on either side of the sternpost. The first wing received two strakes, while the second, uppermost one received three strakes. The preserved wing fragment was formed by two segments of different length. On this basis, Lienau reconstructed the joints between the hood ends of the strakes and the wings.\textsuperscript{144} The visible result was that a vertical alignment of joints was avoided, and the sternpost received more support from the planking.

The closest parallel to this post found on the southern shore of the Baltic is the Gdańsk 2 post. However, several distinctions are present. The post configuration displays a long curvature, and in this respect it resembles the configuration of raked/rabbeted posts. Three steps were carved on the inner side for joints between the post and the strake ends. On either side five small "vertical rabbets" were carved into the surface of the post. Their number suggests that the strakes were received directly without intermediary elements, although their narrowness suggests quite the contrary. The post has a V-shaped cross-section, and its moulded dimension stays the same for the entire length of the preserved fragment. This suggests that the post might have been an interesting combination between the two main types specified earlier.

The stem of the second shipwreck from Orunia is the only known stem from the Southern Baltic shore which has a composite structure. Judging by the dimensions of the ends of the lower and upper fragments, it is apparent that the original stem was made out of three parts scarfed together.

\textsuperscript{144} Lienau (supra n. 7) 14.
The curvature is less abrupt than that of the sternpost of the Gdańsk-Orunia 1 shipwreck. In this respect the stem shows a harmonious rise along its curvature. A characteristic common to all posts found at Gdańsk-Orunia is the presence of a step close to the lower end, and the "vertical rabbets" on either side of the post. With the exception of the garboard step, the Gdańsk-Orunia 2 stem does not have steps. The stem is moulded relatively constant except where its moulded dimension increases somewhat in the after direction just above the sheer strake. This irregularity in the width of the stem offers extra support for the end of the sheer strake. The stem does not have a rabbet. This stem, like the Gdańsk 2 post, stands by itself and cannot be integrated into either the curved/stepped or raked/rabbeted category.

The second category comprises posts which exhibits a long rake. As a consequence of this rake, the length of the post is greater than would otherwise be the case. A rabbet is present on both sides of the post. The cross-section varies but usually exhibits a triangular shape. The posts from Gdańsk-Orunia 3, Frombork, Ład, Wolin, Gdańsk 1 and the hypothetical post from Ralswiek 4 belong to this category.

The stem of Gdańsk-Orunia 3 is a representative example. On either side of the stem, a rabbet was carved for better seating of the hooping ends. The step for the garboard seating is farther forward than are the steps on the Gdańsk-Orunia 1 and 2 posts. Three square mortises were carved into the upper face of the Gdańsk-Orunia 3 stem: one abaft the step, the second into the step, and the third forward of the step. Such a complex of mortises were also observed on the upper face of the Puck 3 stem. The mortises have shallow depths and do not affect the stem from a
structural point of view.

The Puck 3 stem and the Ralswieck 2 post are similar in appearance to the Gdańsk-Orunia 3 stem. Their mild curvature and the rabbet carved into the sides classifies them in the raked/rabbeted stem category. However, these posts were joined to the hood ends of the strakes through wings, one on either side of the stem. The all-receiving wing type was used in this case. This combination is presently unique to the southern shore of the Baltic, and it might well form a special category of posts.

The sternpost found at Łąd on the Warta river exhibits the main characteristics of a post from the second category. It is raked and rabbeted on either side. The rate of curvature is very slight giving an almost straight appearance to the sternpost. The post was fastened to the keel through an oblique horizontal scarf joint.

Although of larger dimensions, the post of the Frombork shipwreck exhibits certain similarities with the sternpost from Łąd. It has an almost straight appearance in profile and was rabbeted on both sides. However, it was fastened to the keel through a vertical oblique scarf.

The post from Wolin\(^\text{145}\) with its short step at its lower end appears similar in profile to the Gdańsk-Orunia 3 post. The difference is that the post from Wolin is shorter and has a greater moulded dimension. Also, its curvature is more accentuated than the Gdańsk-Orunia 3 post. Its irregular cut at the uppermost end and the abrupt end of

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\(^{145}\) The post was found in between two residential compounds as an isolated find in stratum 15. On the basis of stratigraphical correlations, Filipowiak dated the artifacts from this stratum to the beginning of the 11th century. He stated that the post was never used. Judging by its position in situ, the post does not seem to be either reused or located in an area of depositional refuse: W. Filipowiak, "Sprawozdanie z prac wykopaliskowych w Wolinie w latach 1953-54," Sprawozdania Archeologiczne 1 (1955) 182, 190, fig. 4, 191, fig. 5.
the curvature suggest that the post was broken in the upper part in spite of the fact that it may have been never used.

The apparent post found in Kołobrzeg has raised doubts about its original function. It had a length of 1.25 m and was trapezoidal in cross-section. The absence of diagnostic details restrains any affirmative statement about its use in shipbuilding.

3. Hull planking

The common denominator of these hull remains is the lapstrake method of construction. One of its principal advantages is that, with a minimum amount of material, it gives greater strength to the shell than does the flush-laid planking of skeletal-built hulls. This strength is due to the integration of strakes into a single structure. From a functional point of view, this is much like the strength contributed by stringers within a hull.

The planking of the shipwrecks under discussion offers several interesting details. All of the ships without exception had hulls built of oak. The main characteristics of planks can be summarized as follows:

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146 The excavation of the early medieval stronghold in Kołobrzeg led to the discovery of an oak fragment at the foot of the fortification rampart. The timber was found in stratum 7, which was dated to the 9th century. At one end it was sharpened, while the other end was broken. S. Tabaczyński wrote that "[f]orma nie zaciosanej części kołka wskazywała, że mamy tu do czynienia z przedmiotem wykonanym w innym celu i wtórnie użytym jako uzupełnienie przywałowej konstrukcji drewnianej": S. Tabaczyński, "Stewa statku z IX w. z Kołobrzegu," Wiadomości Archeologiczne 23/3 (1956) 270-271. In other words, his hypothesis about the primary use of the artifact as a sternpost or stem was based solely on the trapezoidal shape of the find. However, Tabaczyński recognized the dilemma of a stem or sternpost in secondary use, inasmuch as the post found at Wolin was clearly not reutilized. Smolarek (supra n. 14) 247-248 addressed the issue very prudently when he wrote that the artifact was "supposedly a sternpost or a stem." Litwin also expressed great reservation about Tabaczyński's affirmation (oral communication).
Table 10. Principal characteristics of planking and fastening nails

<table>
<thead>
<tr>
<th>Ship</th>
<th>W(cm)</th>
<th>T(cm)</th>
<th>F</th>
<th>D(cm)</th>
<th>I(cm)</th>
<th>I/D M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>7?</td>
<td>21.5-22</td>
<td>1.8-2.2</td>
<td>tn</td>
<td>1.2</td>
<td>7-11</td>
</tr>
<tr>
<td>R1</td>
<td>22-25</td>
<td>1.8-2.4</td>
<td>tn</td>
<td>1.2-1.4</td>
<td>6</td>
<td>4.6</td>
</tr>
<tr>
<td>R2</td>
<td>7</td>
<td>26-27</td>
<td>1.2-1.5</td>
<td>tn</td>
<td>1.2-1.4</td>
<td>7-9</td>
</tr>
<tr>
<td>R3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R4</td>
<td>8?</td>
<td>30</td>
<td>1.8-2.6</td>
<td>tn</td>
<td>1.2</td>
<td>6-8</td>
</tr>
<tr>
<td>G-O1</td>
<td>6</td>
<td>30</td>
<td>1.5-2.2</td>
<td>tn</td>
<td>1.2</td>
<td>8-10</td>
</tr>
<tr>
<td>G-O2</td>
<td>7</td>
<td>18-25</td>
<td>1-2.5</td>
<td>tn</td>
<td>1.2</td>
<td>8-9</td>
</tr>
<tr>
<td>G-O3</td>
<td>7</td>
<td>20-30</td>
<td>2.2</td>
<td>tn</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td>Bg</td>
<td>7</td>
<td>24</td>
<td>2.5</td>
<td>r</td>
<td>0.9</td>
<td>14-15</td>
</tr>
<tr>
<td>Fr</td>
<td>8</td>
<td>-</td>
<td>3</td>
<td>r</td>
<td>-</td>
<td>- i</td>
</tr>
<tr>
<td>P1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>r</td>
<td>-</td>
<td>- i</td>
</tr>
<tr>
<td>P2</td>
<td>9</td>
<td>17-30</td>
<td>1.7-2</td>
<td>tn</td>
<td>1.1-1.3</td>
<td>7.1-9.5</td>
</tr>
<tr>
<td>P3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>tn</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Me</td>
<td>8</td>
<td>14-30</td>
<td>1.5-2</td>
<td>tn</td>
<td>1.4-1.5</td>
<td>10-12</td>
</tr>
<tr>
<td>Ch1</td>
<td>8</td>
<td>20</td>
<td>1.8-2</td>
<td>tn</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Cz1</td>
<td>9?</td>
<td>18-20</td>
<td>2.5</td>
<td>tn</td>
<td>1.2-1.3</td>
<td>-</td>
</tr>
<tr>
<td>Cz2</td>
<td>24-29</td>
<td>2.2-2.5</td>
<td>tn</td>
<td>-</td>
<td>6-6.5</td>
<td>-</td>
</tr>
<tr>
<td>Sz</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>tn</td>
<td>-</td>
<td>- p?</td>
</tr>
<tr>
<td>KP</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>tn</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lad</td>
<td>7</td>
<td>19.3-27.4</td>
<td>1.55-2.4</td>
<td>tn</td>
<td>1-1.2</td>
<td>8.5-9.5</td>
</tr>
</tbody>
</table>


147 Smolarek, (supra n. 14) 267, gives 0.15-0.25 m instead of 0.30 m, which is the maximum value offered by Lienau. Lienau's value should be closer to the original dimension, since Smolarek took his measurement at least thirty years after the excavation.
A comparison of the values in the first two columns (number of strakes and width) suggests that strake width is closely related to number of strakes within the hull. Ships with eight to nine strakes on either side of the hull have the lowest widths and the largest variation in strake width (Mechlinek, Puck 2, Charbrowo 1, Czarnowsko 1). The other extreme is represented by ships with less strakes per side but with larger widths (Gdańsk-Orunia 1 and 2, Ralswiek 2). In between there is a group of ships with a large variation in planking width within lower width limits (Gdańsk-Orunia 3, Lad, Eckernförder). However, the basis of this comparison is weakened by the fact that large width variation exists in different places within the same hull. For example, strake 3 in starboard of wreck 2 from Puck is 0.17 m wide towards the after end, while in the middle body it attains a width of about 0.20 m; the 0.30 m maximum width recorded in the middle body of the Mechlinki shipwreck decreases to 0.14 m toward the ends. Nevertheless, this can be partially eliminated by replacing range values with the mean value representative for that particular ship. The result is:

1. six-strake ship - 30 cm
2. seven-strake ships - 21.5-26.5 cm
3. eight-strake ships - 21 cm
4. nine-strake ships - 19-23.5 cm

If the extreme values are taken out, the trend seems to be a decrease in planking width with an increase in the number of planking strakes in the hull. This points to variation in hull construction, i.e. the strake width seems to be dependent on the number of strakes in a hull. If maximum widths are compared, however, a different result
is obtained:

1. nine-strakes - 30 cm
2. eight-strakes - 20-30 cm
3. seven-strakes - 22-30 cm
4. six-strakes - 30 cm

This result seems to show nondependence between the number and width of planking strakes. However, this is not the case. The above mentioned data shows only that the same maximum width for the planking in these vessels can occur in hulls with different numbers of strakes. But in reality this result involves only 1/3 of all the reconstructed hulls and therefore cannot be representative of the group. On the other hand, this result does indicate the dependence between minimum width and the number of planking strakes in a hull. In other words, it seems less probable to find relatively low widths in hulls with a smaller number of strakes than in hulls with a greater number of strakes. However, this assertion cannot be fully grounded, mainly because of the incompleteness of detailed information. In addition, it is noteworthy to mention that all hulls with 0.30 m planking widths were found in the Vistula region.

When widths are grouped in regional clusters the following correlations emerge:

1. Western region - 21.5-30 cm
2. Vistula river - 14-30 cm
3. Baltic coast - 18-29 cm
4. Odra system - 19.3-27.4 cm

Shipwrecks found in the Vistula estuary region and the adjacent Baltic coast seem to have a greater range of
widths than shipwrecks from other regions. However, the values from the Western region, the Vistula river, and the Odra system seem to range with about the same limits: they all have in common the 21.5-27.4 cm range. The ships found on the Baltic coast, near the shores of the Leba lake, seem to stand apart, although they can be contained in both the Odra system and the Vistula river groups.

The thickness of hull planking offers a new insight. The comparison of values (in cm) classified in regional clusters (table 11) shows that the scale of values ranges between 0.01-0.03 m. If the extreme value recorded for the Frombork planks is set aside (considering the ship's greater overall dimensions), then the thickness varies between 0.01-0.026 m.

Table 11. Plank thickness in regional clusters

<table>
<thead>
<tr>
<th>Region</th>
<th>1.2</th>
<th>1.5</th>
<th>1.8</th>
<th>2.2</th>
<th>2.4</th>
<th>2.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vistula 1.0</td>
<td>1.5</td>
<td>1.7</td>
<td>1.8</td>
<td>2.0</td>
<td>2.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Baltic</td>
<td></td>
<td></td>
<td>1.8</td>
<td>2.0</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>Odra</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.4</td>
</tr>
</tbody>
</table>

The thickness values of 1.5 cm, 1.8 cm, and 2.4-2.5 cm seem to be spread in almost all groups. This commonness suggests, among other things, that these ships as a group were built with thin planks, desirable in hull shaping because of their elasticity. There is a certain continuity

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148 The same impression is given by the data provided by Smolarek regarding singular planks found in secondary use in Gdańsk. The widths of these planks (41 fragments) ranged between 0.12-0.40 m. They were stratigraphically dated between 980 and 1205. For details see Smolarek (supra n. 14) 262-263, table 12.
observed in those clusters like the Vistula or the Western groups. In the Vistula region the intragroup difference, without counting extreme values, stays almost the same: 2–3 mm. The same trend seems to exist in the Western cluster. It is surprising how close are the thickness values within the same group, and between groups, inasmuch as the sample size under analysis is very modest, and especially when planks could normally differ by more than 3 mm in thickness within the same hull. This again points to uniformity rather than regionality.

Another common characteristic is the material used for fastening. With three exceptions (Frombork, Bagart, and Puck 1) all shipwrecks had planking strakes fastened together with treenails. Iron nails were used only to fasten the ends of the planks to the stem, the sternpost, and the keel.\textsuperscript{149} The wings from Gdańsk-Orunia 1 were fastened to the sternpost with iron nails, and to the planks with treenails.\textsuperscript{150} The rivets used in the hull of the Bagart ship were 0.008 m in diameter and were driven at an interval of 0.14–0.15 m. Iron nails with a similar diameter were used in Gdańsk-Orunia 2 to fasten the hooding ends of the planking to the keel and the stem. The treenails without exception were driven from outside through the land and the luting material. The wedged inner end was cut flush to the inner side of the plank. Usually the wedge was inserted for about two thirds the length of the treenail and at right angles to the grain of the plank in order to

\textsuperscript{149} Recorded in the Gdańsk-Orunia 3, Mechlinek, and Ład shipwrecks.

\textsuperscript{150} Smolarek (supra n. 14) 251. Lienau (supra n. 7) 14: "Die Befestigung der Planken am Steven ist, wie an den Kielenden, durch eiserne Nägel erfolgt, ..." It seems that by "Planken" he meant the end of the wings which were already attached to the end of the planks, since ". . . die Lochstellen im Steven deutlich an den Überresten von Rost auffindbar waren."
avoid splitting. But not all treenails were wedged. For example, the fourth wreck from Ralswiek had every third or fourth treenail wedged. Non-wedged treenails were also observed in the hull remains of the Szczecin and Czarnowsko 1 vessels. Different kinds of woods were used as fastening material. Treenails were carved out of pine for the Orunia vessels, Czarnowsko 1, Szczecin and Ralswiek 4, willow was preferred in the Eckernförder vessel, and juniper for Charbrowo 1.

The Gdańsk-Orunia, Czarnowsko 1, Szczecin, and Ralswiek 4 shipwrecks reveal that softwood was the preferred material for treenails. Gdańsk-Orunia 3, Czarnowsko 1, and the Mechlinek vessel had oak wedges locking the treenails in place. Although the information is insufficient to draw any kind of firm conclusions, the choice of material used for fastening suggests a certain knowledge about the physical properties of wood.

Table 11 shows that, regardless of the different regions in which the shipwrecks were found, the most frequent diameter of treenails is 0.012 m. The only exception is the Mechlinek vessel, which has treenails of 0.014-0.015 m diameter. Diameters range between 0.008 m and 0.015 m. This trend, observed on shipwrecks dated mostly between the 8th-12th centuries, contrasts with Smolarek's observation about the temporal dimension of treenail diameters. He noted that planks found in secondary use in Gdańsk have treenails whose diameter increases as the age

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151 This feature was earlier observed by Smolarek. Also he noted that on finds from Gdańsk area the holes for treenails were not set in a straight line along the edge of the plank. Inspection of other finds, especially those from the Odra system region show that this feature is randomly met; some holes are set in line along the edge of the plank, some from the same line deviate. It seems that this is due to random rather than conscious technical setting. For details see Smolarek (supra n.14) 275.
decreases. The 1.2-1.3 cm diameter observed by him on 12th century material from Gdańsk is a common value for most wrecks like Puck 2 (A. D. 550-8th century), Ląd (9th-11th century), Ralswiek 4 (9th century), etc. which are earlier.

With the exception of the Bażart vessel, the nailing interval does not show too much variation. The largest interval was observed for the Mechlinek boat (0.10-0.12 m) followed by the Ląd vessel. The most common nailing interval stays between 0.07-0.10 m. A notable exception is found in the Ralswiek 1 hull, whose seams were nailed every 0.06 m, an interval which is also seen in the Czarnowsko 2 vessel.

These results are partially confirmed by the plank fragments found in Gdańsk stratigraphically dated between 980-1205. However, the holes in these planks show an interval range from 0.055 m to 0.27 m, which is larger than the 0.06-0.15 m interval of the shipwreck group. On the other hand, the Gdańsk material suggests that the nailing interval increased from 0.055-0.085 m during the 10th-12th centuries to 0.10-0.12 m in the 13th century. While only Kamień Pomorski, Puck 1 and Puck 5 were dated to this later date (and on the basis of no available data), the other shipwrecks dated between the 6th-12th centuries show that their nailing interval is greater (up to 0.12 m) than the

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152 P. Smolarek found that in strata dated to 980-1100 the trenails diameter was 1.1 cm; between 1100-1200 1.2-1.3 cm, and in the 13th century the diameter was 1.4-1.5 cm. Based on this observation, he stated that "[t]renail holes are smaller in planks found in earlier strata than in planks found in later strata." However, in later statements he acknowledges the biases of such a classification: Smolarek (supra n. 14) 273-274.

153 Smolarek (supra n. 14) 262-263, table 12.

154 Supra n. 14, 276.
nailing interval (0.055–0.085 m) of the plank fragments from Gdańsk. Furthermore, the shipwreck data show that the increase in nailing interval has no chronological correlations, although this impression is insufficiently documented because of the small number of catalogued shipwrecks.

From another point of view, the shipwreck data do not suggest that the treenail diameter is a function of the nailing interval. With the exception of the Mechlinek vessel, where indeed the diameter (0.014–0.015 m) can be related to a larger nailing interval (0.10–0.12 m), no other shipwreck shows a relationship between diameter and nailing interval. In most finds, the diameter of treenails stays about the same (0.012 m), while the nailing interval varies between 0.06 and 0.95 m. These results contrast with the interpretation offered by Smolarek.\textsuperscript{155} The available data suggest that the nailing interval varies while the diameter remains constant.

The ratio of nailing interval vs. diameter of treenails shows more variation in the Western group than in the Vistula region: in the former it ranges between 4.6–7.5, while in the latter the variation (excluding the Bagart shipwreck) is 7.0–7.9. With its 8.1 ratio the Ład boat is closer to the Vistula region than to the values obtained for the Western group.

The planks were joined to each other through oblique scarfs fastened with iron rivets (Ralswieck 2 and 4, Bagart,

\textsuperscript{155} Supra n. 14, 277: "Większe rozsunięcie kolków sprzyjało natomiast powiększeniu ich przekroju." However, the material found in Gdańsk does not permit such a clear-cut statement. Several finds indicate that increase in spacing does not necessarily mean treenails with larger diameter. Non-catalogued planks show quite the contrary: at 0.008 m diameter the interval was 0.135–0.152 m, while for a 0.011–0.013-m diameter, the spacing was 0.06–0.12 m. Plank no. 8/1961, dated to the 13th century, shows treenails with a 0.018 m diameter driven at a 0.112-m interval.
Szczecin) or treenails (Eckernförder, Łąd). The scarfs were scattered in order to avoid a vertical alignment of scarfs in the hull planking. The scarf length varies from 0.05-0.10 m (Ralswick 4) to 0.20-0.30 m (Mechlinek). The 3rd starboard strake of the Szczecin vessel shows a scarf with a very weak fastening: only two small iron rivets driven close to the inner edge of the scarf. The fastening of planks to each other suggests two methods of hull planking: the first one is the addition of planks to the hull one by one; the second is the assemblage of the entire strake prior to mounting in the hull. In the first case the rivets protruded through the upper or lower strake as well.\footnote{Smolarek maintained that the scarfs in the strakes were secured with the same treenails used for seam fastening. Although this may be the case for the Gdańsk material, the presence of such non-secured scarfs is rather rare in the shipwreck group. For details see Smolarek (supra n. 14) 277-278.} In the second case the nails are driven in the middle of the plank without touching the seams. The strakes were joined together by overlapping the lower inner edge of the upper strake onto the upper outer edge of the lower strake.

Three wrecks have strakes whose ends were nailed to the adjacent strakes before reaching the posts. These drop strakes were used to give the hull additional breadth. However, the functional role was decided by their placement in the hull. The fifth strake in the Gdańsk-Orunia 3 shipwreck was placed close to the turn of the bilge and this conferred more breadth to the hull bottom. The seventh strake in the Kamień Pomorski shipwreck and the sixth strake of the Łąd shipwreck elevated the middle portion of the sides so that the sheer was flattened.

The overlap of strakes in each hull characterizes that particular hull in terms of the seam width, its structure, and the material used for caulking. The seams played one of
the most important roles in the hull structure. The variation of 0.02 to 0.065 m in the width of the overlap suggests that the land was not of a standard size. The lowest values were observed in the Western group (table 12), specifically in the Ralswiek cluster. Ralswiek 1, with the lowest strake width within the cluster (0.22-0.25 m), has the highest overlap value. Ralswiek 2 and 4 with strake widths of 0.26-0.27 m and 0.30 m respectively have the lowest overlaps from the cluster, and from the entire shipwreck group as well. The highest overlaps were observed in the Vistula and Odra groups.

Table 12. Attributes of seams

<table>
<thead>
<tr>
<th>Ship</th>
<th>Fst</th>
<th>Width(m)</th>
<th>Groove(m)</th>
<th>Luting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>tn</td>
<td>0.045</td>
<td>0.02x0.004</td>
<td>a-hair</td>
</tr>
<tr>
<td>R1</td>
<td>tn</td>
<td>0.03-0.04</td>
<td>yes</td>
<td>a-hair/h</td>
</tr>
<tr>
<td>R2</td>
<td>tn</td>
<td>0.02-0.03</td>
<td>yes</td>
<td>a-hair/h</td>
</tr>
<tr>
<td>R3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>a-hair/h</td>
</tr>
<tr>
<td>R4</td>
<td>tn</td>
<td>0.02-0.03</td>
<td>-</td>
<td>a-hair(w)</td>
</tr>
<tr>
<td>G-01</td>
<td>tn</td>
<td>-</td>
<td>0.035x0.005</td>
<td>moss</td>
</tr>
<tr>
<td>G-02</td>
<td>tn</td>
<td>-</td>
<td>0.03x0.002</td>
<td>moss</td>
</tr>
<tr>
<td>G-03</td>
<td>tn</td>
<td>-</td>
<td>-</td>
<td>moss</td>
</tr>
<tr>
<td>Bg</td>
<td>r</td>
<td>-</td>
<td>-</td>
<td>a-hair</td>
</tr>
<tr>
<td>Fr</td>
<td>r</td>
<td>-</td>
<td>-</td>
<td>a-hair</td>
</tr>
<tr>
<td>P1</td>
<td>r</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>tn</td>
<td>0.05-0.065</td>
<td>-</td>
<td>a-hair</td>
</tr>
<tr>
<td>P3</td>
<td>tn</td>
<td>-</td>
<td>-</td>
<td>moss</td>
</tr>
<tr>
<td>P5</td>
<td>tn</td>
<td>-</td>
<td>-</td>
<td>moss</td>
</tr>
<tr>
<td>Me</td>
<td>tn</td>
<td>-</td>
<td>0.035x0.005</td>
<td>moss</td>
</tr>
<tr>
<td>Ch1</td>
<td>tn</td>
<td>0.04</td>
<td>-</td>
<td>moss?</td>
</tr>
<tr>
<td>Cz1</td>
<td>tn</td>
<td>-</td>
<td>-</td>
<td>moss/hair/t</td>
</tr>
<tr>
<td>Cz2</td>
<td>tn</td>
<td>-</td>
<td>-</td>
<td>moss</td>
</tr>
<tr>
<td>Sz</td>
<td>tn</td>
<td>-</td>
<td>-</td>
<td>moss</td>
</tr>
<tr>
<td>L4d</td>
<td>tn</td>
<td>0.045-0.055</td>
<td>-</td>
<td>moss/a-hair</td>
</tr>
</tbody>
</table>
Table 12. (continued)

<table>
<thead>
<tr>
<th>Ship</th>
<th>Fst</th>
<th>Width (m)</th>
<th>Groove (m)</th>
<th>Luting</th>
</tr>
</thead>
<tbody>
<tr>
<td>KP</td>
<td>tn</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note - Under "Fst" (fastenings used in the seam): tn=treenail, r=rivet. Width - overlap width. Under "Luting": a-hair=animal hair, w=wool, h=human hair, t=textile material.

Comparisons between overlap widths and plank attributes (width and thickness) show no relationship between overlap width and plank width, between overlap width and thickness, and between overlap width and treenail diameter. For example, Ralswiek 2 and 4 with the smallest overlap values fall in the same range of plank widths (0.26-0.30 m) with Puck 2 which has the greatest overlap. Ralswiek 2 and 4 with the same overlap value have different plank thicknesses, 0.012-0.015 m and 0.018-0.026 m, respectively. The diameter of treenails used in the Ralswiek, Puck 2, and Lad wrecks revolves around the 0.012 m value, although there are differences in the overlap widths.

The luting was used for watertightness. Out of 18 wrecks eight had luting of animal hair, and eight or nine? of moss. In five wrecks the luting materials are mixed: animal and human hair (R1, 2, and 3); moss, animal hair, and textile (Cz1); and moss and animal hair (Lad). This can be better understood if we relate the data to the fastening material:

1. treenails and moss (8-9? wrecks)
2. treenails and animal hair (3 wrecks)
3. treenails and mixed luting/caulking (5 wrecks)
4. rivets and animal hair (2 wrecks)
5. rivets and moss (0 wrecks)
6. rivets and mixed caulking (0 wrecks)

There is a seemingly stronger relation between moss and treenails than between any other combination of luting material and fasteners.

From a geographic point of view, it seems that the moss-treenails combination is preponderent in the Vistula region, while the animal hair-treenails combination is present in the westernmost regions of the Baltic southern shore.\textsuperscript{157}

Moss used for luting belonged to the Sphagnum cuspidatum species (Mechlinek), Drepanoclados sp. (G-01, Ład, Kamień Pomorski, Czarnecko 1), and Hypnum fluitans (Charbrowo 1). Here, it seems that the Drepanoclados sp. was used regardless the region where the ship was found.

4. Floor timbers

The first parts of the internal skeleton to be inserted in the erected planking were the floor timbers which can be classified as follows:

<table>
<thead>
<tr>
<th>Ship</th>
<th>Moulded(m)</th>
<th>Sided(m)</th>
<th>Fit</th>
<th>Diam(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>0.15</td>
<td>0.07/0.10</td>
<td>j/n</td>
<td>0.025</td>
</tr>
<tr>
<td>R1</td>
<td>0.12</td>
<td>0.12</td>
<td>j/n</td>
<td>0.025</td>
</tr>
<tr>
<td>R2</td>
<td>0.12</td>
<td>0.08</td>
<td>j</td>
<td>0.025</td>
</tr>
</tbody>
</table>

\textsuperscript{157} The picture does not change even if we add singular finds like the planks found in secondary use in Wolin. The luting was of moss and the planks were fastened with treenails. See Filipowiak (supra n. 145) 179.
Table 13. (continued)

<table>
<thead>
<tr>
<th>Ship</th>
<th>Moulded(m)</th>
<th>Sided(m)</th>
<th>Fit</th>
<th>Diam(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>-</td>
<td>-</td>
<td>j/n 0.025</td>
<td>0.018</td>
</tr>
<tr>
<td>G-01</td>
<td>0.09/0.05</td>
<td>0.07</td>
<td>j/n 0.026</td>
<td></td>
</tr>
<tr>
<td>G-02</td>
<td>0.13</td>
<td>0.07</td>
<td>j/n 0.018</td>
<td></td>
</tr>
<tr>
<td>G-03</td>
<td>0.12</td>
<td>0.07</td>
<td>j</td>
<td>0.026</td>
</tr>
<tr>
<td>Bg</td>
<td>0.12/0.055</td>
<td>0.055</td>
<td>j</td>
<td></td>
</tr>
<tr>
<td>Fr</td>
<td>0.14</td>
<td>0.17</td>
<td>j</td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>0.075/0.11</td>
<td>0.065/0.07</td>
<td>j/n 0.023</td>
<td>0.028P3</td>
</tr>
<tr>
<td>P5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Me</td>
<td>0.11</td>
<td>0.10</td>
<td>j</td>
<td>0.025</td>
</tr>
<tr>
<td>Ch1</td>
<td>0.16/0.18</td>
<td>0.075</td>
<td>j*/n</td>
<td></td>
</tr>
<tr>
<td>Cz1</td>
<td>0.13/0.15(^{158})</td>
<td>0.07</td>
<td>j*/n</td>
<td></td>
</tr>
<tr>
<td>Sz</td>
<td>-</td>
<td>-</td>
<td>j?</td>
<td></td>
</tr>
<tr>
<td>Lqd</td>
<td>0.09</td>
<td>0.067</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>KP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Note - Under "Fit" (carving of the underside): j=joggled, n=notched. Diam - diameter of treenails used to fasten floor timbers to hull. * denotes that only the aftermost and forwardmost frames were joggled.

As a general principle in wooden hull construction, the principal floor dimensions ought to be related to the ship size: the larger the ship the more robust are the floor timbers within its hull. But a comparison of the principal dimensions of our reconstructed ships with the dimensions of floor timbers seems to suggest quite the opposite: smaller ships seem to have more robust floor timbers than larger ships. This can be seen in the

\(^{158}\) Smolarek, (supra n. 14) 314, gives 0.12-0.15 m moulded and 0.08 m sided.
Czarnowsko 1 compared with Puck 2, the shipwreck from Ląd compared with the shipwreck from Mechlinek, Gdańsk-Orunia 2 compared with Gdańsk-Orunia 1, Charbrowo 1 compared with Czarnowsko 1, and Ralswiek 1 compared with Puck 2. This is also the case with Charbrowo 1 (length: 13.2 m) which has more robust floor timbers compared with ships of similar lengths such as Ralswiek 1 (13-14 m) or with Gdańsk-Orunia 3 (13.30 m).

The floor timbers of the wrecks under discussion are not constant in their principal dimensions. The moulded dimension ranges from 0.075 m to 0.18 m, and the sided dimension from 0.055 m to 0.12 m. In both dimensions the highest value is more than the double the smallest value. This can be regarded as a small difference if principal dimensions of the ships as reconstructed are taken into consideration.159

With the exception of the Frombork find, all wrecks had floors with equal or higher moulded dimension compared with the sided dimension. This conferred more axial stiffness, especially against forces acting at an angle to the hull.

The floor timbers from almost all shipwrecks were joggled to provide maximum support to the strakes in that particular place. The only exceptions seem to be represented by the floor timbers from Charbrowo 1, and Czarnowsko 1, although the method was known by the builder, since the forwardmost and aftermost frames were joggled. The other floor timbers have notches on the underside: in the case of Charbrowo 1 the notches are angular cuts with an opening of under 60 degrees, while Czarnowsko 1 exhibits semicircular notches. These notches weakened the floor, and

159 The ships differ in length as much as 9.11 m, and in breadth by as much as 1 m. For a closer comparison see table 4, p. 71.
perhaps this was the reason why the floor timbers had a higher moulded dimension.\textsuperscript{160}

In almost all cases the floor timbers were fastened to the hull with treenails, one treenail per strake. The only exception is the Ład vessel, where the half-frames were not fastened to each strake. The treenail diameters vary even less than the principal dimensions of floor timbers. In this respect the most homogeneous group seems to be the Western group of shipwrecks.

The treenails were made out of poplar (Ralswiek 4), pine (Gdańsk-Orunia 2, Mechlinek), oak (Bagart, Mechlinek) or other wood. The data is insufficient to assess any kind of correlation between the choice of material and the function these treenails fulfilled.

The floor timbers were inserted in the hull at the following intervals:

Table 14. Floor timber spacing in the hull

<table>
<thead>
<tr>
<th>Ship</th>
<th>Interval(m)</th>
<th>Propulsion</th>
<th>Ship type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>-</td>
<td>r</td>
<td>coastal</td>
<td>-</td>
</tr>
<tr>
<td>R1</td>
<td>0.85-1.10</td>
<td>s</td>
<td>open sea</td>
<td>-</td>
</tr>
<tr>
<td>R2</td>
<td>0.80-1.14</td>
<td>s/r</td>
<td>open sea</td>
<td>w</td>
</tr>
<tr>
<td>R4</td>
<td>1</td>
<td>s/r?</td>
<td>open sea</td>
<td>-</td>
</tr>
<tr>
<td>G-O1</td>
<td>0.88</td>
<td>r</td>
<td>coastal</td>
<td>w</td>
</tr>
<tr>
<td>G-O2</td>
<td>0.75-0.80</td>
<td>r</td>
<td>coastal</td>
<td>tr?</td>
</tr>
<tr>
<td>G-O3</td>
<td>-</td>
<td>r</td>
<td>estuarine</td>
<td>w?</td>
</tr>
</tbody>
</table>

\textsuperscript{160} A comparison of the ships in the 13-meter range reveals that the moulded dimension of Charbrowo 1 and Czarnowsko 1 are unusually high. The floor timbers of Gdańsk-Orunia 3 were 0.12 m moulded, those from Gdańsk-Orunia 1 were 0.05-0.09 m, those from Ralswiek 1 were 0.12 m. The difference in the sided dimension is, with the exception of Ralswiek 1, minimal: 0.07 m for the Gdańsk-Orunia and Czarnowsko 1 shipwrecks and 0.075 m for Charbrowo 1 shipwreck.
Table 14. (continued)

<table>
<thead>
<tr>
<th>Ship</th>
<th>Interval (m)</th>
<th>Propulsion</th>
<th>Ship type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bg</td>
<td>1</td>
<td>s/r</td>
<td>coast/est?</td>
<td>tr</td>
</tr>
<tr>
<td>Fr</td>
<td>1</td>
<td>s/r</td>
<td>coast/est?</td>
<td>w?</td>
</tr>
<tr>
<td>P1</td>
<td>0.50-0.60</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>0.72-0.74</td>
<td>s/r</td>
<td>coast/open sea</td>
<td>w</td>
</tr>
<tr>
<td>P3</td>
<td>0.85-1.35</td>
<td>s?</td>
<td>coast/open sea</td>
<td>-</td>
</tr>
<tr>
<td>P5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Me</td>
<td>0.47-0.80</td>
<td>r</td>
<td>coastal</td>
<td>tr</td>
</tr>
<tr>
<td>Ch1</td>
<td>0.9-1</td>
<td>s/r?</td>
<td>inland/coastal</td>
<td>tr</td>
</tr>
<tr>
<td>Cz1</td>
<td>-</td>
<td>s/r</td>
<td>inland/coastal</td>
<td>tr</td>
</tr>
<tr>
<td>Cz2</td>
<td>0.70-1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sz</td>
<td>?</td>
<td>p</td>
<td>inland/est</td>
<td>t/f</td>
</tr>
<tr>
<td>Lad</td>
<td>0.40-0.46</td>
<td>r/p?</td>
<td>inland/est</td>
<td>tr</td>
</tr>
<tr>
<td>KP</td>
<td>-</td>
<td>s/r?</td>
<td>inland/est</td>
<td>tr</td>
</tr>
</tbody>
</table>

Note - All interval measurements are considered to be taken from side to side. Under "Propulsion": s=sailed, r=rowed, s/r=mixed, p=paddled, r/p=paddled/rowed. Under "Ship type": coast/est=coastal and/or estuarine, inland/est=inland and/or estuarine. Under "Function": w=warship, tr=trader, t/f=transport/fishing.

In general terms, early medieval vessels from the Baltic area seem to have the frame spacing related to the method of propulsion, the function, and the type of ship. We will mention here only some of the technical correlations which help in establishing the type, the function, and the method of propulsion of vessels from the southern shipwreck group.

The method of propulsion had an effect on frame spacing due to the fact that thwarts above frames could serve as rowers' benches. In such cases the space between frames had to be ergonomically optimized for the work of one oarsman on either side of the vessel. The data from the
table show that the spacing varies from 0.72 m to 1.14 m in vessels with mixed propulsion, while in vessels propelled only by oars the interval varies between 0.75-0.88 m. This seems to indicate less variation of frame spacing in vessels with rowing propulsion compared with vessels propelled by sail and oars.

The second relationship, between function and frame spacing, presents more difficulties. For example, the frames in the Mechlinek vessel were spaced in the middle body at about 0.40 m intervals in order to confer maximum transverse strength in the hull, which seems a strong argument for considering this vessel in the trader category. This is also suggested by the L:B ratio (3.77) of the reconstructed ship, the lowest from the entire shipwreck group. However, the absence of independent, additional evidence restrains us from any firm conclusion. A similar case is presented by the Lad vessel, where the frame interval, ranging between 0.40 m and 0.46 m, seems to indicate that the vessel was built for transport of heavy cargo. Fortunately enough, its function as a trader or as a transport ship is much more clearly defined by the finding of building material inside the wreck.\footnote{Zeylandowa (supra n. 127) 169-170 concluded that the finding of sandstone and clay-slab fragments inside the wreck indicates that the vessel, in its last voyage, transported building material used in the construction of the church located within the walled perimeter of the fortress.}

The other vessels do not show such a clear relation between function and frame spacing. Bagart and Charbrowo 1, both considered to fall into the trader category, have frame intervals of 1 m and 0.9-1 m, respectively. Although it is premature to draw any conclusion, especially when the ship typology is heavily influenced by the way the vessel was reconstructed, the dichotomy seems to point to a
certain intraclasse differentiation.

The spacing of frames in the hull seems to be influenced by the ship type, which is tentatively established according to the technical qualities of the vessel, its place of discovery, and the investigator's opinion. Thus, if 0.80-1.14 m is the interval between frames in open sea vessels a similar range (0.75-1 m) was observed in coastal vessels, and in coastal/inland vessels (0.9-1 m). The overlap of ranges suggests that the open sea, coastal, and coastal/inland environments did not require a clear differentiation in the frame spacing or that the differentiation was acceptable within an all-encompassing range.

The construction of floor timbers was either simple or composite. In the first case, floors were simply carved out of a naturally-curved timber. In the second case at least one of the floor's arms was a separate piece of wood carved to fit and fastened onto the straight end of the floor with nails. The scarf joint was either an oblique horizontal cut like in the Mechlinek and Charbrowo 1 vessels, or a joggled horizontal cut like in Czarnowsko 1. The wreck from Szczecin was reconstructed with only one composite long floor; the floor was joined by a horizontal scarf. However, the scarph joint seems to be of a more complex design. In longitudinal profile the joint appears to be

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162 As mentioned in the previous chapter, long floor timbers which extended up to the original or reconstructed sheer strake were found with the shipwrecks from Gdańsk-Grunia 2, Bagart, Frombork, Mechlinek, Charbrowo 1, Czarnowsko 1, Szczecin, and probably Lad. From a technical standpoint these elements can be called ribs. The term was avoided here, because with the exception of the Ralswiek 2 shipwreck no hull was found with an intact plank sequence up to the original sheer strake. As a consequence, these elements could have been floor timbers. For this reason, the term long floor is preferred over rib.

163 In the published material the scarph joint is presented as a simple oblique scarf: Filipowiak (supra n. 31) 31, fig. 2.
straight cut at the upper end and then obliquely driven toward the underside of the floor timber. This kind of joint is so far unique in the group of analyzed shipwrecks.

It seems that the futtock-floor combination was used when the floor had to be extended up to the sheer, but in some instances, as in the Gdańsk-Orunia 2 shipwreck for example, the floor, made out of a single piece of wood, was brought in Lienau’s reconstruction only to the 6th strake, while the 7th strake, the sheer strake, was left uncovered.

The reconstructed frames from the Kamień Pomorski shipwreck show futtocks joined through horizontal scarfs to the floor timbers. Two additional futtocks extended the floor on either side up to the sheer. The Kamień Pomorski wreck is the only shipwreck in the group which shows this kind of double-futtock construction.

The scarf joints between futtock(s) and floor timber were usually secured with nails, treenails in the case of Czarnowsko 1 and Mechlinek shipwrecks. However, in the Ład shipwreck the scarf joints between futtocks and floors were not fastened. Together with the half-frames these are unique elements exhibited by the Ład shipwreck.

Czarnowsko 1 had six long floor timbers which actually consisted of a short floor timber and two futtocks joined together by horizontal joggled scarfs. The horizontal scarf is another indication that the frames were made to resist external forces applied at an angle to the hull. In this manner, maximum resistance to compressive forces was conferred by the whole body of the floor timber, although this type of scarf offered less resistance especially to tensile forces.

5. Beams and bulkheads

Beams are necessary to secure transverse rigidity in
the hull. The finds from the southern shore of the Baltic seem to abide by this principle. The wrecks found in this area do not exhibit traces of partial or complete decking. However, this possibility should not be eliminated, since very few wrecks were sufficiently preserved to permit an accurate reconstruction of the upper hull.

Table 15. Transverse reinforcement of upper hull

<table>
<thead>
<tr>
<th>Ship</th>
<th>Beam</th>
<th>Bulkhead</th>
<th>M/S (m)</th>
<th>Fst</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R2</td>
<td>yes</td>
<td>-</td>
<td>-</td>
<td>tn</td>
<td>6</td>
</tr>
<tr>
<td>R4</td>
<td>yes*</td>
<td>-</td>
<td>-</td>
<td>tn?</td>
<td>6</td>
</tr>
<tr>
<td>G-01</td>
<td>yes</td>
<td>-</td>
<td>0.04/0.08-0.10</td>
<td>tn</td>
<td>5-6</td>
</tr>
<tr>
<td>G-02</td>
<td>yes</td>
<td>-</td>
<td>0.04/0.10</td>
<td>tn</td>
<td>5</td>
</tr>
<tr>
<td>G-03</td>
<td>yes</td>
<td>-</td>
<td>0.06/0.10</td>
<td>tn</td>
<td>5-6</td>
</tr>
<tr>
<td>Bg</td>
<td>yes</td>
<td>yes</td>
<td>0.025-0.08/0.125-0.23</td>
<td>tn</td>
<td>7</td>
</tr>
<tr>
<td>Fr</td>
<td>?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>yes</td>
<td>-</td>
<td>0.03-0.04/0.12-0.18</td>
<td>tn</td>
<td>5</td>
</tr>
<tr>
<td>P3</td>
<td>yes</td>
<td>-</td>
<td>-</td>
<td>tn?</td>
<td>-</td>
</tr>
<tr>
<td>P5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Me</td>
<td>yes*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ch1</td>
<td>?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cz1</td>
<td>?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cz2</td>
<td>yes*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sz</td>
<td>yes</td>
<td>-</td>
<td>-</td>
<td>tn</td>
<td>-</td>
</tr>
<tr>
<td>Lad</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>KP</td>
<td>yes*</td>
<td>-</td>
<td>-</td>
<td>in</td>
<td>-</td>
</tr>
</tbody>
</table>

Note - Under "Beam": * = indirect evidence was found, ?= uncertain, yes=beam found by the excavator. Under "Fastening": tn=treenail, in=iron nail. The M/S - moulded and sided dimensions. Under "Level" the number denotes the strake level at which the beam touches the hull.
Besides the fact that very few wrecks were preserved up to the sheer strake, some hulls were reconstructed without beams at certain frame stations. The presence of bulkheads is also attested. Thus, the spectrum of lateral reinforcement of the hull seems to include at least three different structures: floor combined with beam and knees, single-piece long floor, and bulkheads. The 4:1 ratio between wrecks with beams and wrecks without beams suggests that beams were one of the principal elements of the inner structure of ships found on the southern shore of the Baltic.

Dimensions - As it can be seen in the Vistula group, the beams are not at all square in section. The moulded is always smaller than the sided dimension. This means that the larger dimension is in the longitudinal plane of the ship. This characteristic seems to suggest not only practicality in terms of providing better seating for oarsmen, but also concern for hull resistance to torsional forces. The comparison between moulded and sided dimensions of beams and keels in ships where such measurement were given sets the Gdańsk-Orunia wrecks apart from the other finds. It appears that the shipwrecks from Gdańsk-Orunia have identical or similar keel and beam ratios, while the keel and beam ratios from Bagart and the Puck 2 wrecks differ considerably:

164 Absence of beams in a shipwreck at the time of excavation does not necessarily mean that beams were not included in the construction of that particular ship. In this case, the ratio would be even higher. However, for the sake of clarity, our classification of absence or presence of beams is made on the basis of data provided by the investigator.
Table 16. Comparison of dimensions in keels and beams

<table>
<thead>
<tr>
<th>Ship</th>
<th>Keel(m/s)</th>
<th>Beam(m/s)</th>
<th>Keel-ratio</th>
<th>Beam-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-O 1</td>
<td>0.105/0.135</td>
<td>0.04-0.08</td>
<td>/0.10</td>
<td>0.77</td>
</tr>
<tr>
<td>G-O 2</td>
<td>0.10/0.20</td>
<td>0.04/0.10</td>
<td>0.77</td>
<td>0.50</td>
</tr>
<tr>
<td>G-O 3</td>
<td>0.125/0.22</td>
<td>0.06/0.10</td>
<td>0.56</td>
<td>0.66</td>
</tr>
<tr>
<td>Bg</td>
<td>0.11/0.25</td>
<td>0.025-0.08/0.125-0.23</td>
<td>0.44</td>
<td>0.29</td>
</tr>
<tr>
<td>P 2</td>
<td>0.12/0.21</td>
<td>0.03-0.04/0.12-0.18</td>
<td>0.57</td>
<td>0.23</td>
</tr>
</tbody>
</table>

This similarity or disimilarity points to the constructional features exhibited by wrecks in the Vistula cluster, specifically to the dimensional difference between keel and beams.

From a structural point of view floor timbers can also be introduced in the comparison between keels and beams. However, because they have a higher moulded dimension in almost all cases the reverse ratio (s/m) is used. Thus, the following ratio values were obtained for the wrecks listed above: G-O 1, 0.78; G-O 2, 0.54; G-O 3, 0.58; Bg, 0.46; P 2, 0.64. In each case the ratio is approximately the same as for the keel- and beam-ratio, with the exception mentioned before for the beam-ratio of the Bagart and Puck 2 ships.

Shape - In accordance with the principal dimensions of beams, the shape was that of a rectangular board set horizontally within the hull. The beams found in the hull of Puck 2 had identical shapes but different widths. The largest width was exhibited by the lowermost beam which supported the mast-stump. The beams of all the Gdańsk-
Orunia finds were also rectangular in shape, but dimensional differences between them were less noticeable. The dimensions of the rectangular shape were identical at all cross-sections of the beams found at these sites. This gave each beam the appearance of a straight board.

The beams found in the Bagart shipwreck show several features not encountered in any other shipwrecks from the southern shore of the Baltic. The largest beam was deeper at the ends and wider in the middle.\textsuperscript{165} This resulted in a different repartition of weight within the beam. In the plan view the weight was concentrated in the center of the beam while in the transverse view the weight was equally distributed toward either end. The result was a rectangular-shaped beam which changed its attitude from that of a horizontal setting in the center to that of a vertical setting at the ends.

At Bagart, Conwentz found a board which he believed was used to transform a floor into a veritable bulkhead. The board would have been inserted into a groove carved into the upper surface of a long floor timber. The groove was easily recognized on a floor found at the site, which led Conwentz to envision the first partitioned ship ever to be found on the southern shores of the Baltic. This kind of bulkhead would have strengthened the hull at that particular frame station and would have increased reserve flotation in case of hull damage at sea.

Beam Level - The beams were found at different levels within one and the same hull. According to their level,

\textsuperscript{165} The beam, considered part of the mast-frame by virtue of a hole drilled in its centre, was thicker at both ends according to the measurements given by Conwentz (supra n. 2) 54, fig. 8. In contrast with Conwentz' representation, Reitan, (supra n. 3) 19, fig. 13, presented a mast-frame thicker in the centre than at the ends.
they can be classified as beams\textsuperscript{166} and thwarts. Very few beams were found in situ, i.e. seated onto the ends of a floor timber.

Ralswiek 2 had the beam seated on the end of a floor fragment at the 6th planking strake. Its height above the keel and the fact that the sheer strake was at the 7th strake indicate that the beam was a thwart. The beam fragment found in the first wreck at Gdańsk-Orunia was seated on a stringer fragment which was fastened to the 5th strake. Taking into consideration that the 6th strake was used as support for the thole pins, this beam fragment was originally a thwart. A more problematic interpretation is posed by the beams fragments from the second wreck found at Orunia. The fragments were fastened to the end of a floor fragment which reached the 5th strake. This low position in the hull was somehow compensated in Lienau's reconstruction by the presence of oarports carved into the 7th strake. On the basis of this relationship, the beam fragments may be interpreted as preserved parts of thwarts. The third wreck from Orunia exhibited naturally-curved beams close to its ends. The beam found at frame station no. 2 rested on the upper ends of the floor at the level of the 5th planking strake. Because the 6th strake was considered by Lienau to be the sheer strake, the identical beam at frame station 12 fulfilled the role of a thwart. A similar construction was observed in the hull of the Szczecin shipwreck. The naturally-curved end of the beam fragment was seated on the end of the floor at the 4th strake level. However, its role as a thwart is still a matter of debate.

The clearest picture was offered by Puck 2, where

\textsuperscript{166} The lowermost level of beams in ships found in Scandinavia are usually called \textit{biti}, -\textit{er} (ON. \textit{biti}), and they usually rest on top of the floor ends.
beams were found in situ on the tip of the floors. Since the beams reached up to the 4th strake in a hull made of at least 7 planking strakes on either side, the obvious conclusion is that these were not thwarts.

Fastening - The beams mentioned above were fastened with treenails of different diameters to vertical knees which provided support for the side-planking. In the case of Gdańsk-Orunia 2 and 3, at least one of the tips of the thwarts was also nailed to the planking. The use of iron nails for fastening beams/thwarts to knees was recorded only in the Kamień Pomorski shipwreck. No fastenings were observed between beams/thwarts and floor timbers, or between beams/thwarts and stringers.

6. Knees

As strengtheners, knees are usually used to reinforce those angular joints within a hull which are potentially weak. It appears that for the shipwrecks under discussion the joint between a beam/thwart and the hull itself was considered a weak spot, because all knees found in their original positions were fastened onto the end(s) of a beam/thwart. In this location the knee acted as the joint between the beam and the hull. They were set in an upright position right above the floor timber. The visible result of this kind of construction was that the knee became a "natural" extension of that floor. Unfortunately, in shipwrecks found on the southern shores of the Baltic, few knees were found in their original position within the hull. The most common case was the finding of knees separated from the hull remains; in some cases they were

167 This observation is also supported by the material excavated in Gdańsk. See Smolarek (supra n. 14) 301-303.
fastened to the beam/thwart.

Table 17. Knee position and fastening in the hull

<table>
<thead>
<tr>
<th>Shipwreck</th>
<th>Type Position</th>
<th>H-fst</th>
<th>V-fst</th>
<th>A-fst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R 2</td>
<td>s v/f</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>R 4</td>
<td>s v/f</td>
<td>2</td>
<td>2?</td>
<td>0</td>
</tr>
<tr>
<td>G-O 1</td>
<td>s v/f</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>G-O 2</td>
<td>s v/f</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>G-O 3*</td>
<td>s v/f</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>a v/f</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Bg</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fr</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>s v/f</td>
<td>2-4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>P3</td>
<td>s? v/f</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>P5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Me</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chl</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cz1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cz2</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sz</td>
<td>a v/f</td>
<td>4?</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Lad</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>KP**</td>
<td>s v/f</td>
<td>2-3</td>
<td>1-2</td>
<td>0</td>
</tr>
</tbody>
</table>

Note - Under "Type": s=symmetrical - with 2 knees per each beam, a=asymmetrical - one knee and a naturally curved beam. Under "Position": v=vertical part of frame, h-fst=horizontal fastening, v-fst=vertical fastening, a-fst=apex fastening. ? denotes probable, * denotes loose knee fragment found only, ** denotes data taken from reconstruction.

The technical monotony of the data apparently indicates that knees were used exclusively to strengthen the beam/thwart joint and the upper hull strake(s). Thus, the
knees were placed at frame stations.

More treenails/iron nails were used to fasten the knee to the beam/thwart than to fasten the knee to the hull planks. This was due to the necessity of rigidity in the beam/thwart, and also because knees could have been fastened to beams before their insertion in the hull.168 Rigidity of upper hull was enhanced by the treenails being obliquely driven at the apex of knees.

The arms of most midship knees169 seem to be unequal. The arm parallel with the beam/thwart appears longer than the vertical arm. Also, knees with arms of equal size occur, as in the case of Gdaňsk-Orunia 2 and Ralswiek 4 or the isolated beam knees found in Gdaňsk.170

7. Stringers

Stringers are normally used to strengthen the hull longitudinally. In the case of the shell-based construction of small open vessels, the stringer plays a secondary role, because the overlapped edges of planks furnish the necessary longitudinal strength in the hull. In places where the overlap is absent (the upper edge of the sheer strake for example), the stringer becomes the main reinforcing element. The data show that stringers were used to reinforce the sheer strake. By virtue of its position in the hull, the sheer strake was not only vulnerable to external and internal forces, but was also used as a

168 This is obviously the case when naturally-curved beams/thwarts were inserted in the hull.

169 As in the case of Gdaňsk-Orunia 3, the knees in the middle body seem to have unequal arms, while the knees found at the ends seem to have equal-sized arms. On the other hand, the Puck 2 vessel seems to have had one knee with equal arms in the middle body, in the after part, one knee with equal arms.

170 Catalog nos. 1952/764 and 1952/765. Smolarek (supra n. 14) 302, fig. 77.
support for the oar system.

Table 18. Stringer attributes and location

<table>
<thead>
<tr>
<th>Shipwreck</th>
<th>Position</th>
<th>D(m/s)</th>
<th>Length</th>
<th>Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R2</td>
<td>s/i</td>
<td>0.059/</td>
<td>0.049</td>
<td>?</td>
</tr>
<tr>
<td>R4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>G-01</td>
<td>5 s/i</td>
<td>0.035/</td>
<td>0.06</td>
<td>A2-F12</td>
</tr>
<tr>
<td>G-02</td>
<td>s/o</td>
<td>0.10/0.04</td>
<td>Lship</td>
<td>oak</td>
</tr>
<tr>
<td>G-03</td>
<td>s/o?</td>
<td>0.025</td>
<td>Lship</td>
<td>oak</td>
</tr>
<tr>
<td>Bg</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fr</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>5 s/i</td>
<td>0.065/</td>
<td>0.11</td>
<td>A3-F13</td>
</tr>
<tr>
<td></td>
<td>6 s/i</td>
<td>0.135/</td>
<td>0.045</td>
<td>A3-F13</td>
</tr>
<tr>
<td>P3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Me</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ch1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cz1</td>
<td>-</td>
<td>-</td>
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<td>Cz2</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Sz</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lad</td>
<td>5 s/i</td>
<td>0.06/</td>
<td>0.073?</td>
<td>birch</td>
</tr>
<tr>
<td></td>
<td>s/o</td>
<td>0.088-0.091/</td>
<td>0.053</td>
<td>Lship?</td>
</tr>
<tr>
<td>KP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note - Under "Position": s=sheer strake/i=inside the hull, o=outside. Under "D" (dimensions given in meters): m/s=moulded/sided. Under "Length" (denotes length of stringer taken from reconstruction): Lship=stringer runs for the entire length of vessel.
This reinforcing element was attached either inside or outside the upper edge of the sheer strake. Inside the hull the inwale was used to support thole-pins as in the case of Gdańsk-Orunia 1. The first wreck from Orunia and the second wreck from Puck show that stringers were also used in the coherent structure inside the hull. Their principal role was to reinforce longitudinally the sides of the hull. The stringers found in the Gdańsk-Orunia 1 and Puck 2 hulls (on top of floor heads) supported also the thwarts. This was necessary to disperse load concentration in frames. In addition, Puck 2 had a second stringer notched over the lower knees. This feature was also encountered in the Ład vessel, where a stringer was notched over the floor

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171 The position of the sheer-strake stringer in Lienau’s reconstruction of the Gdańsk-Orunia 3 shipwreck is doubtful. While the fragments found at the site seem to be remnants of a sheer-strake stringer, its position within the hull is far from being certain. Besides the fact that the fragments were found in a detached state, the plan view drawing of the hull remains shows thole-pin blocks inside the hull, while in the section view a stringer is shown fastened on the outside of the sheer strake: Lienau (supra n. 7) fig. 25.

172 A certain constructional trend seems to appear. Gdańsk-Orunia 2 and Ład, both classified as traders, had their stringers fastened outside the sheer strake. On the other hand, warships like Kalswiek 2 and the other two wrecks from Orunia had their stringers fastened inside the sheer strake. This constructional dichotomy seems to be related to the role of the stringer within the hull. Inside the hull, it provided support for the oar system, thole-pins in the case of the two Orunia wrecks and oarports in the case of Kalswiek 2. In traders, the oar system was restricted to the fore-and-aft quarters, since the space in the middle body was used as cargo area. Hence, the stringer was attached to the outer side of the sheer strake. In this manner the stringer not only reinforced the strake, but also it provided additional protection against mechanical forces. In the case of the Ład vessel, the stringer provided support for the crooked elements bent over the sheer strake.
timbers.\textsuperscript{173} The stringers were inserted in both hulls at the level of the 5th planking strake in order to supplement the strength of the hull planking at the turn of the bilge.

From another point of view, the dimensions of stringers were dictated by their position in the hull. Inwales or rubbing strakes were wider, while the side/bilge stringers were thicker.

The length of stringers is hypothetical since only partial remnants were found in a poor state of preservation. In general, the ship reconstructions show inwales or rubbing strakes from stern to stem, while stringers run almost for the entire length of the middle body. As for the choice of wood for these elements, it seems that oak received a strong competition from other woods such as birch and poplar.

8. Mast and its support system

The system of propulsion used in these vessels can be classified into three major groups: sailing propulsion, rowing propulsion, and mixed propulsion, which is a combination of the first two. Sailing propulsion was ascertained in wrecks where fragments of mast-steps were found, and also by indirect evidence. Unfortunately no mast or mast fragments have yet been found. Comparative historical and ethnographic data indicate that rowing ought to be considered a probable method of propulsion for those vessels where no trace of sailing propulsion could be

\textsuperscript{173} A floor timber was notched to receive the stringer. For details see Smolarek (supra n. 127) 175, fig. 7. Another similarity between the two stringers is the material from which they were made: birch (Betula sp.). This is a lighter wood which is about 30% stronger in bending than oak. For details see A Handbook of Hardwoods, Forest Products Research (London 1956) 48.
The documented artifacts indicate that the propulsion system used by each vessel was as follows:

<table>
<thead>
<tr>
<th>Shipwreck</th>
<th>Sailing</th>
<th>Rowing</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R2</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>R4</td>
<td>-</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>G-01</td>
<td>?</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>G-02</td>
<td>-</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>G-03</td>
<td>-</td>
<td>yes?</td>
<td>-</td>
</tr>
<tr>
<td>Bg</td>
<td>yes</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Fr</td>
<td>yes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>yes</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>P3</td>
<td>?</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Me</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ch1</td>
<td>yes?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Cz1</td>
<td>yes</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Cz2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sz</td>
<td>-</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>Lød</td>
<td>-</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>KP</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note - ? denotes possible, yes? denotes most probable.

The table shows that roughly half of all wrecks found on the southern shore of the Baltic yielded sufficient information about their propulsion. The mast support system used by vessels propelled by sail can be summarized as

174 The statement is not exclusive; sailing should be regarded as a possible alternative.
follows:

Table 20. Mast support system

<table>
<thead>
<tr>
<th>Shipwreck</th>
<th>Mast-step</th>
<th>Mast-partner</th>
<th>Mast-beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2</td>
<td>trans</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Bg</td>
<td>trans</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Fr</td>
<td>trans</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>P2</td>
<td>long</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Chi</td>
<td>trans?</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Czi</td>
<td>trans</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>


The evidence suggests that all wrecks propelled by sail were one-masted, with the mast set about midway in the length of the ship. In all cases except one, the mast was supported transversely. The floor was either the step for the mast, as in the Bagart and Frombork shipwrecks (fig. 15), or the lateral support of a separate mast-step timber as found in Ralswiek 2, Charbrowo 1, and Czarnowsko 1. In the second case, the mast-step was an additional wooden element either nailed (Ralswiek 2) or lashed (Charbrowo 1 and Czarnowsko 1) to the side of the floor timber.¹⁷⁵

¹⁷⁵ The mast-step found in the first wreck from Charbrowo raised difficulties in interpretation. Lemcke maintained that the rectangular, shallow mortise cut into the upper surface of the main floor should be regarded as the mast-step of the ship. Lienau, (supra n. 7) 34, states: "Die Lage des Mastloches im Spant ist insofern etwas ungewöhnlich, als sonst derartige Mastlöcher quadratisch ausgeführt werden, so daß es zweifelhaft ist, ob es sich überhaupt um ein Loch für den Mastfuß handelt, oder ob das Loch und das vorgefundene Querstück nicht einem anderen Zwecke dienen." Lienau rightly pointed out that the above-mentioned mortise carved into the centre of the main floor could not fulfill the role of a mast-step because of its shallowness and its shape. On the other hand, Smolarek, (supra n. 14) 343-344, fig. 94, found in the storerooms of the National Museum in Szczecin an elliptically shaped timber with a square hole in its centre. He interpreted the cuts visible on both ends as wear
Fig. 15. Bagart and Frombork mast-floors
In the Bagart and Frombork shipwrecks, the mast was seated into the floor timber, while in the other finds, the mast rested directly on the keel. Keels which supported the mast directly did not have larger dimensions than keels over which floors were used as mast-steps. On the contrary, the dimensions of keels from both groups seem not only similar, but even larger in the group with floor timbers used as mast-steps. Apparently, the kind of bottom support employed was not affected by the dimensions of the keel.

The nailing of the additional mast-step element gave firm support for the mast-heel, while lashing resulted in mobility at the foot of the mast. The lashing permitted the removal of the wooden piece, while the nailed support was permanent. This detail suggests that the small wooden mast-step could have been attached to the main floor of any ship. That means that ships propelled initially by oars could have been transformed into sailing vessels without any structural change and without any difficulty.\textsuperscript{176}

marks left by the rope which lashed the timber to the main floor. His conclusion was that this was the mast-step of the Charbrowo shipwreck, and that Lemcke wrongfully asserted that it was used only as reinforcement of the main floor. While Smolarek's interpretation seems very plausible, it is surprising that Lienau did not mention anything about the strange elliptical fragment in his publication. However, in his sketch of the Charbrowo shipwreck, published initially by Lemcke, a board is lashed to the side of the mainfloor in three places. This would correspond with the wear marks found by Smolarek on his elliptical timber. But the sketch shows also that the board did not have any square hole in the middle. While this can be explained by a supposed pre-excavation disturbance of the timber or by the fact that Lienau did not have all the necessary information, it does not provide a satisfactory answer to the problem. For the moment, it seems that Smolarek's finding is most likely to answer the problem of the mast-step of the Charbrowo shipwreck, inasmuch as the reconstruction given by Froznak (supra n. 117) 253, fig. 11 does not bring any new solutions. On the contrary, his reconstruction has the mast-step on the wrong side of the main floor. His reconstruction attempts were published unaltered by Eilmer (supra n. 91) figs. 65, 98 and 73, 102.

\textsuperscript{176} The capability of sailing is determined by hull form and proportion. Based on the fact that all the vessels had T-shaped keels and flat floor timbers, their design is that of narrow flat-floored and soft-bilged hulls. The difference, then, between sailed and oared vessels is almost nonexistent in terms of hull shape. This observation seems to support the idea of a mobile mast-step which could have been attached in
The mast was supported further up at the beam/thwart level. It went either through a hole drilled in the centre of the thwart (Ralswick 2, Bagart), or it rested in a semicircular cut carved into the after edge of the crossbeam (Puck 2). The mast received in this manner a second support point close to its base.

The mast-step found in the Puck 2 wreck is unique among the early medieval mast-step timbers from the southern Baltic region; it rested over four floor timbers and was carved in three places underneath to decrease its weight. The carving also allowed space for the free movement of bilge water. At about the midpoint in its length a square mortise served as a mast-socket. A naturally curved stump was left as forward support for the mast. The stump was supported at its base by the beam which had in this place a semicircular cut. The stump filled in the void left by the absence of a thwart, i.e., the stump fulfilled the role the thwart had in the transverse support system. In this manner the mast was supported at its foot and also along its first 0.80 m of height. The idea of two points of support remained, only the manner of reinforcement changed from transverse to vertical.

9. Rigging and sail

The information about sail and rigging in early medieval ships found on the southern coast of the Baltic is very scarce, one reason being the perishable nature of these kinds of artifacts. Artifacts possibly related to sailing are few: a woolen piece of cloth found at Frombork, interpreted by Heydeck as remains of the caulking material; three poles, an iron ring and several "long square nails" any hull no matter if it was previously rowed or not.
found at Bagart; the willow loop fastened inside the hull of Ralswiek 4; the holes drilled in the sheer strake of Ralswiek 2, and the treenail driven into the bilge stringer of Puck 2.

The last feature can be associated with the rigging of Puck 2. Unfortunately, Stepień did not offer further details on this or on any other special feature of the shipwreck. A similar interpretation can be accepted for the two holes drilled in the sheer strake of Ralswiek 2 at one side of the mast-floor. As mentioned before, these holes were 0.02 m in diameter and were 0.09 m apart.

The willow loop fastened close to the keel on the starboard strakes of Ralswiek 4 raises even more difficulties in interpretation. Its position in the hull suggests that it may have served as a fastener for running rigging like halliards for example. In this case the mast would have been stepped at the missing frame no. 5.

The poles found at Bagart raised another difficult question. Conwentz presented several explanations, none of them satisfactory. The use of poles as wehden would explain their asymmetry but not their notching at the thickest end. The notched end seems to suggest that the poles had a specific function within the Bagart vessel, and that their role was to affix the thicker end in a certain designated place. In other words, the poles could easily be seen as southern Baltic prototypes of a tackle spar used in windward sailing.

177 He wrote that the poles may have been used as rigid mooring for the ship anchored near shore or as vertical parts of navigation buoys. Feddersen suggested that they were part of a support system for a tent destined to cover the midship area: Conwentz (supra n. 2) 55. Feddersen's explanation was entirely accepted by Reitan (supra n. 3) 20, 22, fig. 16 who reconstructed the midships area covered by a tent. See also my fig. 5, p. 31.

178 Buoys used by fishermen in Kiel.
The woolen cloth fragment also poses some questions. The idea of a caulking material is not better than that of remnants of a sailing cloth. Wool and flax are known to be used as materials in sailmaking in Northern Europe.

10. Oar power

Although direct evidence for rowing, such as oars or thole-pins, was very scarce in any of the shipwrecks, some constructional details suggest that oar power was used for propulsion. A good example seems to be the first wreck found at Orunia, where enough of the stringer and the sheer strake were left for a reconstruction of the oar propulsion system. The vertical, square mortises cut in the sheer strake stringer measured 0.048 by 0.02 m and served in all probability as thole-pin slots. A shallow semicircular groove 0.025 m deep and 0.16 m long was carved on the after side of the thole-pin slot. These grooves were cut into the upper surface of the stringer and the sheer strake and were used as oar supports. Each triangular thole-pin had a hole in the centre for the insertion of a thole bight.

Isolated finds, such as the thole-pin from Puck Bay, indicate not only the kind of propulsion but also the type of oar support and its position within the hull.

A number of oars were found as isolated finds in Gdańsk in strata dated between the 10th-13th century. On the basis of blade shape, four types were identified:

179 The vertical holes and the semicircular grooves were recorded in two places along the gunwale stringer and the sheer strake. Their sequence is consonant with the run of the sheer strake and also with the position of the planking scarfs. Based on these arguments Lienau's reconstruction of the oar support system seems most possible.

180 Litwin (supra n. 67) 144, fig. 10.

181 Smolarek (supra n. 14) 334-335.
trapezoidal, rectangular, long ellipsoidal, and short ellipsoidal. The blade cross-section also is different: the first three types had straight blade cross-sections, while the last type displayed a curved cross-section. Also, the blades of the first three types differ from the last type through the presence of a blade reinforcement. This was done by leaving the centre of blade thicker than the rest of it. In this manner the reinforcement not only strengthened the blade, but also enhanced its balance.

A difference exists between oars as regarding the transition between the blade and the loom. The trapezoidal type is the only one which shows an abrupt transition between the blade and the loom.182

11. Steering system

Only two wrecks can be associated with artifacts related to steering. At Frombork a wooden fragment was interpreted by Heydeck as part of an engraved rudder,183 while at Szczecin an oar was found with the shipwreck remains. The oar had a short loom and a rectangular-shaped blade. The diameter of the loom reached its maximum close to the blade. This made the centre of weight to be located close to the blade. Filipowiak interpreted the find as an

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182 The straight-cut side of the blade meets the loom in a 90-degree angle. This kind of joint was not only weak from a structural point of view, but also reduced the active surface of the blade.

A well-preserved boss was found in Gdańsk. Smolarek interpreted it as part of the support system for a quarter-rudder. The boss had an elongated, elliptical shape. Approximately in its center, the boss had a naturally-grown rounded stump with a hole running down its center. The hole, which passed all the way through to the other side, was used for the withy which fastened the rudder to the boss. Two larger holes were used to fasten the boss to the hull. Besides these, there were two smaller holes along one of the edges. Their function remains unclear, but it is possible that they were used in conjunction with the fastening of the boss to the side of the hull. The artifact from Gdańsk indicates that the quarter-rudder was known in the southern area of the Baltic.

184 Filipowiak (supra n. 122) 86, fig. 5.
CHAPTER IV

SCANDINAVIAN PARALLELS

Several sites in Scandinavia (fig. 16) have yielded sufficient information which can be used as a comparative basis for the material found in the southern Baltic region.

1. Keels

T-shaped keels were documented at several sites in Scandinavia. Of two shipwrecks at Fjørtoft, Norway, the larger exhibits a T-shaped keel similar to those excavated on the southern shore of the Baltic, but the hull shows a slight deadrise angle amidships. The hull of the smaller vessel, an eptirbatr, was rounded amidships, perhaps a shape dictated by the vessel's function as a service boat or as a ferry. The scarf used to join the keel-plank to the sternpost and stem in the smaller boat was of the same vertical flat type as recorded in shipwrecks from the Southern Baltic region.\(^{185}\)

The dimensions of a T-shaped keel found at Mork resemble closely the dimensions recorded for the Ralswiek 2 and Bagart keels, although the height of the keel from Mork

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\(^{185}\) The upper face of the keel of the larger vessel was flat, although it could have been rounded originally. It was 0.10 m moulded beneath the flanges and 0.12 m sided. The second boat was built like a prám in the middle body, but the hooping ends of the strakes were fastened to the posts. A false keel was fastened with five trenails to the bottom plank, and with one nail to each of the posts. The site was dated by H. Shetelig, B. Farøyvik, and P. Fett, "Fjørtoftåtane," Bergens Museums Årbok 3 (1943) 24, between the 5th and the 8th century A.D., but B. Myhre "Ny datering av våre eldste båter," Arkeologiske Meddelelser fra Historisk Museum (1980) 27-30 obtained through C14 analysis the dates of A.D. 830 and 860 +/- 90.
Fig. 16. Scandinavian parallels
might have been originally somewhat greater.\footnote{186}

Other finds do not exhibit the same degree of similarity. The keel fragment found at Gredstedbro was rabbeted,\footnote{187} and its T-shaped cross-section resembles more the keel cross-section of Skuldelev 6 than those from the Southern Baltic group.\footnote{188} The horizontal scarf present at one end of the keel fragment is paralleled only by the scarf joint between the keel and the sternpost of the Lad shipwreck.\footnote{189}

The larger ship from Kvalsund (620-760) was built on a T-shaped keel with a maximum of 0.20 m sided.\footnote{190} The keel ends were scarfed horizontally for the joint with the stem.

\footnote{186} H. Shetelig and F. Johannessen, "Kvalsundfundet og andre norske myrfund av farteier," \textit{Borgens Museums Skrifter} 2/2 (1929) 46-47; Ellmers (supra n. 91) 184, 336; the keel fragment was reused in the foundation of a building. It measured 0.24 m sided, a value close to those recorded for the keel from Ralswick 2 (0.24 m) and Bagart (0.25 m). The keel from Mork had a web of 0.045 m moulded and 0.10 m sided. The low value of the moulded dimension suggests either use-wear during its life span as a keel or remodelling for its secondary use. In view of its flatness, Ellmers suggested a date before the end of the 8th century, while Shetelig and Johannessen concluded that the finds from Mork can be chronologically paralleled with the Kvalsund ship remains.


\footnote{188} Cruulín-Pedersen (supra n. 187) 262-267 noted that the angle between the flat top of the keel and the bearding line was 24 degrees, which left an angle of 132 degrees between garboards. The presence of a horizontal scarf at one end of the keel together with the C14 dating led him to place the Gredstedbro find before the end of the 8th century.

\footnote{189} A horizontal scarf joint between keel and sternpost or stem was used in the Ockelbo boat. The keel was 0.17 m sided and had a T-shaped cross-section. For details see Humbla and von Post (supra n. 17) 34, fig. 15.

\footnote{190} Although a low deadrise of the bottom planking leaves the impression of a rounded hull, the cross-section of the larger ship from Kvalsund resembles more the Nydam and the Hjortspring hulls than those found on the southern shore of the Baltic. The curve of the bottom planking and the flare of the upper hull contribute substantially to the spoon-like shape seen in the Hjortspring and in the Nydam vessels. For details of the reconstruction, see Shetelig and Johannessen (supra n. 186) 62-63, fig. 37, pl. 2.
and the sternpost. Although this type of scarf joint was present in the Lad shipwreck, the similarity is not complete. The scarf joint from Lad is flat, while the scarf joint from Kvalsund is jogged at the outer end.

The recently excavated boat from Gislinge exhibits a keel with a clear T-shape in the middle body.\(^{191}\) The flange meets the web at a 90-degree angle, a feature recorded in almost all keels from the southern Baltic region. The keel was moulded 0.08 m and sided 0.20 m. These values are comparable with the keel dimensions of the Lad boat.

Variants of the T-shaped keel are also seen in the finds from Bårset (Pre-Viking or Early Viking Age),\(^{192}\) Oseberg (about 820),\(^{193}\) Gokstad (895-900),\(^{194}\) Klåstad (9th-10th c.)\(^{195}\) Äskekär (840),\(^{196}\) Galtabäck (1100-1300),\(^{197}\) and

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\(^{191}\) The very-well-preserved boat fragments were typologically dated to the end of the Viking Age. For details see M. Gethche, "A Viking boat from Gislinge Lømmedjord," *Maritime Archaeology Newsletter from Roskilde* 1 (1993) 10-11.

\(^{192}\) G. Gjessing, "Båtfunnene fra Bårset og Øksnes," *Tromsø Museums Årskrifter* 58 (1941).


\(^{195}\) A. E. Christensen and G. Leiro, "Klåstadskipet," *Vestfoldminne* (1976) 8 gave for the vessel a median date of 800 + 80 A.D. obtained through C14 analysis. However, O. H. Eriksen, "Dendrokronologisk undersøgelse af skibsvrag fra Klåstad, Norge," *Nationalmuseets Naturvidenskabelige Undersøgelser* 21 (1993) obtained through dendrochronological analysis a date of 990 A.D.

\(^{196}\) P. Humbla and H. Thomasson, "Äskekärredhåten," *Göteborgs och Bohuslänns Föreningens Tidskrift* (1934) 12: "The keel's cross-section was T-shaped amidships, more like the keel of the Gokstad ship than the keels of the Galtabäck and Oseberg vessels.

\(^{197}\) Humbla and von Post (supra n. 17).
Lynes (1150). With the exception of the Årby (800-900) keel-plank, all keels exhibit a lower dimension of the flanges compared with that of the web. In the Southern Baltic region the relation is totally reversed, the flanges extended more than the web.

One of the principal features of a T-shaped keel is represented by the angle of the bearding line. With the exception of the Årby keel-plank and the Galtabäck keel, the underside of flanges in all of the above mentioned shipwrecks form an obtuse angle with the web. This resulted in a visible deadrise angle of the garboards which in turn conferred sharpness to the bottom of the hull.

On the other hand, almost all T-shaped keels from the Southern Baltic region exhibit a right angle at the flange. For this reason the garboards, and the whole bottom planking, have very little or no deadrise at all. However, this T-shaped keel variant, so common in the southern Baltic region, is also seen in the ship from Ladby (900-950) and in later finds from Falsterbo (1100-1250).

198 Crumlin-Pedersen (supra n. 18) 52-53.


201 Humbla and von Post (supra n. 17) 34: "The Falsterbo boat, investigated by me in 1933, had a keel [...] like one of the Danzig-Ohra vessels, no. 1, while no. 2, and 3 seems of an older type.;" H. Åkerlund, "Skeppsfyndet vid Falsterbo 1932," Sjöhistorisk Årsbok (1931-52) 97, fig. 3, 94: "The keel consists of two parts, from which the forward part, the longest, is 8.0 m long, while the after part is about 2 m. The parts were fastened together through a vertical scarf, secured with eight spikes. The keel was about 0.15 m moulded."
Kalmar 1 (1200–1250),\textsuperscript{202} and Sjøvollen (1210+/–80).\textsuperscript{203}

2. Stem and sternpost

The best parallels for stems and/or sternposts of the curved/stepped category are to be found in later finds such as the vessels from Skuldelev.\textsuperscript{204} The sternpost of Skuldelev 1 shows elements common to both the sternpost of Gdańsk-Orunia 1 and the stem of Gdańsk-Orunia 2. The common feature of the sternposts from Gdańsk-Orunia 1 and Skuldelev 1 is the presence of wings as an intermediary element between the post and the strake ends. Wings are also present in the Gokstad ship.\textsuperscript{205} According to P. Humbla, the "intermediary pieces" of Gdańsk-Orunia 1 were used to ease the tension in the halsar, i. e. at the hood ends of strakes where the stem and the sternpost curvature rises vertically.\textsuperscript{206} From a technical point of view, the wings from Gdańsk-Orunia 1 resembles more the hlutar seen in the Gokstad ship than the wings of Skuldelev 1. The sternpost of Skuldelev 1 was reconstructed with a V-shaped uppermost section carved out of a single piece of wood. The inner

\textsuperscript{202} H. Åkerlund, "Fartygsfynden i den forna hamnen i Kalmar," Kulturhistoriska undersökningar vid Kalmar slott I (Uppsala, Sweden 1951) 27–51.


\textsuperscript{205} W. Dammann, "Das Gokstadschiff," Das Logbuch (1983) pl. 1a, 10: "Die Plankenenden "halsar" liefen in die Sponung der hlutar ein."

\textsuperscript{206} Humbla and von Post (supra n. 17) 43: "Med andra ord, nåten äro markerade på dessa mellanstycken, och denna markering fortsätter in på den breda stäven, så att den jämna kurvan, som borde bildas av bordsbelaarnas fals, löper ut mot stamspetsen."
edges of this section were stepped for the joint with the uppermost six strakes of the hull. In the Gdańsk-Orunia 1 shipwreck, the uppermost section of the sternpost received four "intermediary pieces", which were nailed to the sternpost, two on either side. This is also seen in the Gokstad ship with the difference that the lower wing was carved to receive more hood ends than the upper wing. Similarities can also be seen in the Oseberg ship,\textsuperscript{207} where planks were brought up to the stem through intermediary pieces, and also in the fragmentary finds from Falsterbo.\textsuperscript{208}

Like the Gdańsk-Orunia 2 stem, the Skuldelev 1 sternpost has a composite structure, made out of three elements. However, the scarfs used to join the elements in the two vessels differ. The Gdańsk-Orunia 2 elements were joined through vertical flat scarfs, while the two lowermost elements of the Skuldelev 1 sternpost are joined through a joggled vertical scarf.

Another common feature for the Skuldelev 1 sternpost and Gdańsk-Orunia 2 stem is the step carved into the inner face of the lowermost element. Nevertheless, the Skuldelev 1 sternpost has two steps carved into its lowermost element, a feature encountered in the Gdańsk 2 post, but not in the Gdańsk-Orunia 2 stem.

The sternpost and the stem found at Rimbareid have the same number of steps carved into their inner edges as does the sternpost of Gdańsk-Orunia 1.\textsuperscript{209} Also, Smolarek found

\textsuperscript{207} Sjøvold (supra n. 193) 16-17, 22.

\textsuperscript{208} Åkerlund (supra n. 201) 96: "Av de tre nedersta bordgångarna äro borden närmast förståven bevarade, och dessa bord ha nått fram till stäven, medan vid följande två bordgånger ...finnas ett par korta bordbitar, som utgjort mellanstycken mellan stäven och borden. fig. 4 och 5."

\textsuperscript{209} Farøyvik and Fett (supra n. 185) fig. 6e.
that the Rimbareid shipwreck exhibits the same type of jogged scarf joint between the keel and the posts as does the keel scarf of Czarnowsko 2.\textsuperscript{210}

The Gdańsk 2 post has four clefts carved into its inner face, a feature encountered in neither the Skuldelev 1 sternpost nor the stem and the sternpost from Gdańsk-Orunia 1 and 2.\textsuperscript{211}

Some details of the Gdańsk-Orunia 2 stem can be seen in finds from Haukenes and Hatlestrand.\textsuperscript{212} A step situated in the upper half of the Haukenes posts seems to suggest that the upper ending of the Gdańsk-Orunia 2 stem was actually a step shrunken to the extreme. With its two steps cut into its inner face the post from Hatlestrand resembles most the Gdańsk 2 post, although the inner face of the post does not have clefts.

The second category of posts, those that are raked and rabbeted, also has parallels in Scandinavia. One of the earliest parallels is offered by the stem found with the oak vessel from Nydam, which resembles the large rake of the Gdańsk-Orunia 3 stem. The second common feature is the presence of a rabbet carved on either side of the stem. Although both stems seem to have a triangular shape in cross-section, the Nydam stem has a cleft carved into its inner face. This gives a somewhat V-shape form in the lower part of the stem.

The appearance of the Ralswick 2 stem resembles the

\textsuperscript{210} Smolarek (supra n. 14) 239.

\textsuperscript{211} Olsen and Crumlin-Pedersen (supra n. 204) 165: "Danzig-Ohra (in Polish: Orunia 1 (10)), was the same in shape but without the cleft in the inner edge. The lower part of the stern in Skuldelev 1 is likewise without a cleft..."

\textsuperscript{212} Færoyvik and Fett (supra n. 185) figs. 6 a, b, c, and d.
post recovered from Valkijärvi. Both finds show a moderate rake and a rabbet carved into either side. The Valkijärvi post was scarfed horizontally at the lower end for the joint with the keel-plank, while the Ralswieck 2 stem was fastened to the keel through a vertical flat scarf. In both cases treenails were used to fasten the scarfs. Nevertheless, the stem from Ralswieck seems to have a more complicated design. According to Herfert, small triangular "intermediary pieces" connected the strakes to the stem. If "intermediary pieces" mentioned by Herfert were wings, then the closest parallel for Ralswieck 2 stem can be found in the Skuldelev 3 stem.

The design asserted by Herfert for the stem of Ralswieck 2 can also be seen in the stem of Puck 3. Without wings, this stem is identical with the Gdanski-Orunia 3 stem. However, the addition of boards with a stepped inner face transformed its appearance into that of a multisteped V-shaped stem. In this case the stem from Puck mostly resembles the stem from Skuldelev 3. Since the Puck vessel seems to have at least 8 strakes on either side of the keel, its stem could have been larger than the stem of the Skuldelev 3, which was carved to receive a total of 7

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strokes on either side. Through the addition of wings, the stem from Puck 3 seems to incorporate diagnostic features common to two distinct categories of posts. In this respect, the Puck 3 stem can be considered to represent yet another category of southern Baltic stems and sternposts.

Another notable feature is the presence of holes in stems and/or sternposts. The stem of Skuldelev 3 has a hole of 0.04 m in diameter drilled close to the outer edge of its uppermost section. The location of the hole in the stem of Skuldelev 3 resembles the position of a hole found at the sheer-stroke level in the Gdańsk-Orunia 2 stem. The Puck 3 stem has a rectangular hole forward of the garboard step. The purpose of this hole situated below the waterline is uncertain.

3. Planking

A selective sample of the hull planking from Scandinavian vessels is given below for comparison with the hull planking from shipwrecks found on the Southern Baltic region.

Table 21. Hull and hull planking in Scandinavian vessels

<table>
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<th>Ship</th>
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<th>H(m)</th>
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<td>1.20</td>
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<td>.028-.065</td>
</tr>
<tr>
<td>Skuldelev3</td>
<td>13.50</td>
<td>3.20</td>
<td>1.40</td>
<td>.27-.42</td>
<td>.025-.035</td>
</tr>
<tr>
<td>Skuldelev5</td>
<td>18.00</td>
<td>2.60</td>
<td>1.10</td>
<td>.25-.38</td>
<td>.020-.040</td>
</tr>
<tr>
<td>Skuldelev6</td>
<td>12.00</td>
<td>2.3-2.5</td>
<td>0.9-1.2</td>
<td>.25-.40</td>
<td>.022-.028</td>
</tr>
</tbody>
</table>
Table 21. (continued)

<table>
<thead>
<tr>
<th>Ship</th>
<th>L(m)</th>
<th>B(m)</th>
<th>H(m)</th>
<th>W(m)</th>
<th>T(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falsterbo</td>
<td>13.50</td>
<td>4.50</td>
<td>2.55</td>
<td>-</td>
<td>0.025-0.030</td>
</tr>
</tbody>
</table>


Comparisons between the plank dimensions listed above and those given in table 10, chapter III, reveals that Nydam (oak), Gokstad, Skuldelev 2, and Hedeby 1 exhibit dimensions comparable with those of the planking of the Southern Baltic group. However, these vessels are the only ships from the selected sample whose principal dimensions are far greater than the range of values of reconstructed ships from the southern Baltic region (Loa: 8.25-17.36m, B: 2.10-3.40m, H: 0.66-1.10m). The rest of the vessels, whose range of values (Loa: 9.56-18.00m, B: 1.50-3.20m, H: 0.63-1.40m) is similar to that obtained for the Southern Baltic group, have larger dimensions of their planking: plank width in Scandinavian vessels ranges between 0.21 m and 0.50 m compared to 0.14-0.30 m range from the Southern Baltic group, and plank thickness ranges between 0.02 m and 0.065 m compared to 0.01-0.03 m range recorded in the Southern Baltic group. This indicates that hulls of Scandinavian provenience tend to have wider and thicker planks, a tendency which does not seem related to

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215 Falsterbo and Skuldelev 1, whose breadth and height differ considerably, are not taken into consideration.

216 For further comparison see the range of values given in table 4, chapter III.
the ship size.

Another characteristic of Scandinavian hull construction was the meginhufr, set at the transition between the live work and the sides of the vessel. It was either L-shaped (Oseberg), Z- or S-shaped (Klåstad, Åskekärr), or just thicker than the other planks in the hull (Gokstad, Tune). This feature is absent in the shipwrecks from the southern Baltic region, although some constructional details may suggest a closer comparison. The thwarts found at Bagart had at both ends a recess carved on the underside. Since the recess is longer than the heads of the corresponding floor timber, Reitan concluded that the ends of the thwarts rested on a thicker plank similar in shape with the meginhufr found at Oseberg. This interpretation weakens due to several technical details. The sheer st rake, the heaviest st rake in Reitan’s reconstruction, is supported only by the thicker ends of five thwarts to which it was fastened with trennails. This transverse support seems insufficient inasmuch as the sheer st rake provided the support for the oars of the vessel.

On the other hand, the thick planking st rake from the Bagart vessel does not fulfill the role of its so-called counterpart found in the Oseberg ship. The Oseberg ship had a sharp hull form, and the meginhufr was located about the waterline of the vessel. Fastened only to adjacent

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217 Reitan (supra n. 3) 19: "Übereinstimmend mit den Abmessungen des Hauptspanes und der andern Spanen war die Oberkante der sechsten Planke nicht 3/4 Zoll dick, wie die andern Planken, sondern etwa 2 Zoll dick, was auf eine Ausbildung der Beergölzer wie beim Osebergschiff schließen lässt."

218 Experimental tests carried out with the Oseberg ship replica, the Eddas/Oseberg, proved that the meginhufr was located at the waterline of the vessel leaving only two strakes above the water. The low freeboard and other technical factors caused the Eddas/Oseberg to sink on a trial sailing in 1988. For details see J. Godal, "Viking ship is reconstructed and tested," Dy-Foren (1989-1990) 22-25; Godal, "Vikingskip til bunns," SM 8 (1988) 34-36; also M. Carver, "On-and off-the Edda," in O. Olsen, J.
strakes, the *meginhuftr* facilitated the transition between the bottom and the sides of the hull. The thick planking strake from Bagart does not fulfill this kind of function. The shape of the midship floor timber indicates a rounded hull with a smooth transition at the turn of the bilge. In this hull shape the thick planking strake would be situated above the waterline of the vessel, a location which departs from the model suggested by the Scandinavian vessels.

The hull of the Puck 2 vessel had the widest strake, the fourth strake, situated at the turn of the bilge. This suggests that the idea of a strong plank situated at the turn of the bilge might have been known on the southern shore of the Baltic. Nevertheless, the fourth strake was of the same thickness as the other strakes in the hull.

Table 22. Fastening in Scandinavian hulls

<table>
<thead>
<tr>
<th>Ship/Site</th>
<th>F</th>
<th>D(cm)</th>
<th>I(cm)</th>
<th>L(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nydam (oak)</td>
<td>r</td>
<td>-</td>
<td>14-15</td>
<td>7-9</td>
</tr>
<tr>
<td>Kvalsund2</td>
<td>r</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gokstad</td>
<td>r</td>
<td>-</td>
<td>18.5</td>
<td>-</td>
</tr>
<tr>
<td>Gokstad3</td>
<td>r</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skuldelev1</td>
<td>r*</td>
<td>-</td>
<td>16-20</td>
<td>3.5-4.5</td>
</tr>
<tr>
<td>Skuldelev2</td>
<td>r</td>
<td>-</td>
<td>12-15</td>
<td>2.5-3</td>
</tr>
<tr>
<td>Skuldelev3</td>
<td>r</td>
<td>0.7-0.9</td>
<td>12-20</td>
<td>3-4</td>
</tr>
<tr>
<td>Skuldelev5</td>
<td>r*</td>
<td>-</td>
<td>15-20</td>
<td>3-6</td>
</tr>
<tr>
<td>Skuldelev6</td>
<td>r</td>
<td>-</td>
<td>15-20</td>
<td>3-4</td>
</tr>
<tr>
<td>Falsterbo</td>
<td>r*</td>
<td>0.6-0.7</td>
<td>17-20</td>
<td>-</td>
</tr>
</tbody>
</table>

Note - Under "F" (fastening type): r=rivets, r*=rivets and some treenails. D = diameter of rivets. I = interval of nailing. L = land width.

Skamby Madsen, and F. Rieck eds., *Shipshape - Essays for Ole Crumlin-Pedersen on the occasion of his 60th anniversary, February 24th 1995* (Roskilde, Denmark 1995) 305-312.
This dispels its likeness with that of a true Scandinavian meghufr.

The nailing interval in the hull planking is wider in Scandinavian hulls than in those of the Southern Baltic group. As mentioned before, the strakes of Scandinavian shipwrecks were clinker, a feature encountered in the Southern Baltic group only in the finds from Bagart, Frombork, and Puck 1. This strengthens the idea of a relationship between fastening material and nailing interval, i.e. rivets tend to be more widely spaced than treenails. The material used for fastening also influences the diameter of the nails. Rivets tend to have a diameter less than one centimeter, while treenail diameter usually varies between 0.01 m and 0.015 m.

On the other hand, comparison of strake overlap in both groups (table 12, chapter III, for the Southern Baltic group) indicates a surprising similarity. The range of values of the Southern Baltic group (0.02-0.065 m) is similar with that from the above mentioned sample of Scandinavian vessels (0.025-0.09 m). This suggests that the type of fastening material does not affect the width of seams.

Another apparent distinction between the two groups is related to the ratio between thickness and width of overlap. The overlap width in the Scandinavian group is either greater or smaller than double plank thickness. In the Southern Baltic group the overlap width is almost double the thickness,219 which again strengthens the idea of

\[\text{Overlap/thickness average ratios (cm) for shipwrecks from the southern Baltic region:} \]
Eck (2.25), R1 (1.90), R2 (2.22), F2 (3.24), Ch1 (2.10), Lad (2.52).

Overlap/thickness average ratios for Scandinavian shipwrecks are:
Nydam (3.40), Skuldelev 1 (0.86), Skuldelev 2 (1.1), Skuldelev 3 (1.16), Skuldelev 5 (1.5), Skuldelev 6 (1.4).
commonality between shipwrecks from the Southern Baltic region.

On the other hand, several finds from Scandinavia indicate closer similarities with finds excavated on the Southern shore of the Baltic. Excavation of the Bulverket lacustrine settlement, located in the middle of the marshy area of Tingstäde, Gotland, brought to light remains of two wooden boats and several other, ship-related fragments. The remains found at Bulverket included plank fragments, knee fragments, floor timbers, and a beam thought to be part of a rudder frame. The plank fragments indicated that strakes were overlapped and fastened with tree-nails. This method of fastening was found in 17 shipwrecks and ship-related fragments from the southern shore of the Baltic. In addition, the dimensions of the largest plank fragment reached a maximum of 0.26 m in width.

220 Conducted by A. Zetterling, the excavations between 1921 and 1936 revealed the existence of a lacustrine settlement located approximately in the middle of the marshes of Tingstäde. The investigations revealed that the settlement was originally a fortified marae with an area of about 26,900 sq. m. built entirely of wood. The 29 ship fragments were recovered from the shallow lake, conserved, and stored until 1976 in the National Museum of History. In 1977 the fragments were donated to the National Maritime Museum. However, a certain confusion exists about crossdating. The C 14 analysis indicated 1180-1215 A.D. for the boats and 1035 A.D. for the settlement. The solution proposed was to consider the boats as old as the settlement since they should have been in use during its existence. B. Varenlius, "Bulverketbåten - ett gammalt fynd i ny belysning," Statens Sjöhistoriska Museum 1 1 (1979) 11: "Denna C14-datering förorsakar kronologiska problem. Själva Bulverket är ju C14-daterat till ca AD 1035 och båten bör ju rimligtvis ha använts av dess innevånare." The early date is also suggested by the technical details of these boat remains. C. O. Cederlund, "Bulverketbåten - en modell för dokumentation av båt- och fartygsämnings," Formvänden 75 (1980) 30: "De antar, med hänvisning till båtträdets konstruktiva karaktär, att det snarare bör hemma i tidig medeltid, än 1200-tal som C14-dateringarna angav."

221 Varenlius ( supra n. 220) 20: "Vad styrningen beträffar har en styrkåra varit anbringad på styrbordssidan och fått i bite 12 medelst en vidja eller dylikt i de hål som är borrade genom bitet (Pl. 4)."

222 Supra n. 220, 19: "De bordplankor som har del av ursprungliga kanter kvar (nr 21, 22, 26) indikerar att borden förbundits med varandra medelst klinknaglar av trä, (Pl 6 och 7)."
and 0.025 in thickness. These values are comparable to those obtained for the plank fragments from Baqart, Gdańsk-Orunia 2 and 3, Ralswiek 1 and Ralswiek 2 (table 10, chapter III).

Archaeological excavations carried out since 1982 at Fribredre Å on the Falster island have revealed the existence of a shipyard dated between 1000 and 1200. A large number of worn ship parts, unused treenails, chips and ship-related waste material found at the site indicate that the shipyard was engaged in ship repairs and replacement of ship parts.

Several technical details of the recovered shipbuilding material resemble characteristics seen in shipwrecks from the southern shore of the Baltic. The most striking example is that the planks recovered at Fribredre were fastened with wedged treenails instead of iron rivets. In some of the planks, the treenails were driven about 0.065–0.09 m apart. This nailing interval is within the range of 0.07–0.10 m observed in the Southern Baltic shipwreck group (table 10, chapter III). Furthermore, the nailing interval from Fribredre is similar to that of Ralswiek 2 (0.07–0.09m) and 4 (0.06–0.08m). The lowest spacing of 0.065 m is common to both the Fribredre planks and the first wreck found at Charbrowo.

The luting in the strakes from Fribredre consisted of

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224 Supra n. 223, 18, fig. 10.
a mixture of wool and moss. This mixture of luting materials was also found in between the strakes of the Łąd shipwreck and the Czarnowsko 1 shipwreck.

Several treenail heads from Fribødre were carved at the joint between the head and the shaft, a feature which enhanced the distinction between the two parts. Treenails used to fasten floor timbers to the planks in the Gdańsk-Orunia 1 shipwreck and the treenails from Gdańsk do not share this characteristic. No visible distinction can be seen between the head and the shaft, except that the shaft tapers slightly toward the head of treenails.

The use of treenails for fastening strakes was recorded also in wrecks and/or singular plank fragments of Scandinavian provenience. This is seen in the extended logboat from Mosjö, where the upper strake was fastened to the hollowed trunk with treenails. The shipwreck from Bårset, dated with approximation to the early Viking Age, had an upper strake partially lashed and partially fastened with treenails to the next strake. A recently excavated shipwreck from Lapuri exhibited rivets and treenails driven alternatively in the same seam.

225 Supra n. 223, 19, n. 11.
226 Liennau (supra n. 7) fig. 14, pl. 5.
227 Smolarek (supra n. 14) 273, fig. 67.
228 Ellmers (supra n. 91) 117, 320: "Datiert hat man das Boot bisher wegen seiner großen Tiefenlage in die Bronze- oder sogar Steinzeit."
229 Gjesing (supra n. 192) 30: "Ovargangen har dels vært sydd, dels någnet med furusagler..."
Isolated finds such as the undated plank fragments from Andenes,\textsuperscript{231} the pre-Viking plank fragments from Mork, and the single plank fragment from Eketorp\textsuperscript{232} were also fastened with treenails. The planks reused for the coffins found in the cemetery excavated at Lund were fastened to each other with treenails.\textsuperscript{233}

A situation similar to that from Fribröldre was encountered more than a century ago at Paviken where numerous ship fragments including plank fragments were fastened with treenails.\textsuperscript{234}

Several finds suggest that treenails were used also in clinker hulls. Treenails were used to fasten strakes in Skuldelev 1,\textsuperscript{235} Skuldelev 5,\textsuperscript{236} Haithabu 2,\textsuperscript{237} and Falsterbo.\textsuperscript{238}

\textsuperscript{231} Ellmers (supra n. 91) 148, 329.

\textsuperscript{232} Westerdahl (supra n. 21) 27, fig. 11. A C14 date of 634 +/- 95 obtained for the artifact cannot be crossdated with finds from the same cultural context.

\textsuperscript{233} Supra n. 21, 18.

\textsuperscript{234} H. Munthe, "Om gamla tillägsplatser för Parkoster på Gotland," GotlandsArkiv (1947) 51: "Och nåra utloppet har [P. A. Säve] i ett åkerdike påträffats "krumt skeppsvirke, varjehanda timmer, plankor, bordläggning på klink m. m., uti hvilket intet järn fanns men bultar av blott trä, allt av furu." Ellmers (supra n. 91, 129, 323) considers the expression "krumt skeppsvirke" an indication of a local boatbuilding, while Westerdahl (supra n. 21, 32) gives credibility to Säve's information. However, the use of treenails in different joints points to shipwrecks fastened in a similar manner as those found on the Southern Baltic region. Furthermore, the use of pine treenails is paralleled in the Raiswieik 4, Szczecin, Czarnowsko 1 and Gdańsk-Orunia shipwrecks, where pine treenails were used for fastening the hull planking.

\textsuperscript{235} The 12th strake was fastened with rivets and treenails to adjacent strakes.

\textsuperscript{236} The entire midship section had strakes fastened with rivets, spikes, and treenails. It seems that treenails were also used at the sheer strake.

Another defining element attributed to vessels built in Scandinavia is the use of luting material of animal origin. Other luting materials used in vessels found in Scandinavia were wool (Oseberg), woolen material soaked in pitch (Falsterbo, Nydam), and animal hair together with textile (?) material (Åskeskärr, Kalmar 1). A notable exception is found in the oak shipwreck from Visby, where a mixing of wool, moss, and tar was used for luting. The wreck was approximatively dated between the 12th and the 14th century.

The luting materials from Scandinavian finds can be paralleled with about half of the known shipwrecks found on the southern Baltic region. These are the shipwrecks from the Western group, the Bagart, Frombork and Puck 2 shipwrecks from the Vistula group, the Czarnowasko 1 shipwreck from the Baltic group, and the Lad shipwreck from the Odra system. In all of these shipwrecks, animal hair was used as luting/caulking material. However, clear similarities with the Scandinavian group can be found only in the Eckernförde and Frombork (cattle hair), Puck 2 (animal hair), and Ralswiek 4 (wool) vessels. In all other


238 Åkerlund (supra n. 201) 96: "En del bord hade "pinnats" samman med små träagnaglar och i något ser man både trä och järnnaglar i samma nat." 239 Skuldelev 3 and Skuldelev 5, Sjøvollen, Haithabu, Gokstad 1.

240 Ellmers (supra n. 91) 131, 323-324.
vessels the mixture used for luting, including animal- and human-hair mixture from the first three vessels from Ralswiek, does not have parallels in the Scandinavian group. The mixture of moss and animal hair used in the Låd and the Czarnowsko 1 shipwrecks is comparable with the Visby shipwreck and with Middle Age and Late Middle Age finds from Scandinavia. However, the tripartite mixture of moss-animal hair-textile from Czarnowsko 1 has not as yet been recorded in Scandinavian finds.

4. The coherent skeleton

The Bulverket finds also yielded information about timbers used inside the hull. A U-shaped wooden artifact was interpreted by Varenius as a frame used in an extended logboat. The frame strengthened the hull of the dugout in the same manner as the frames of the logboat from Sierzchów, or the frame found in the dugout recovered from the Gotland Deep. The other fragments were remains

He based his argument on the shape of the artifact and on the fact that it had never been notched on the underside. Furthermore, two notches, one on either arm, were carved close to the upper end of the frame. This feature together with the location of the three existing holes (one in the middle, and two at the extreme ends of arms) suggested him that this was a frame fastened to a hull that was not of lapstrake construction. Since the possibility of a carvel-built hull was excluded the alternative was that the frame was fastened to a hollowed trunk. Under these circumstances the notches indicated the addition of another strake overlapped over the sides of the dugout.

M. Prosnak, "Statek jednopienny z Sierzchowa, Pow. Łowicz," Wiadomości Archeologiczne 34 (1969) 204-210. The frames had a more open curvature to fit the hollowed trunk of an extended logboat made of oak.

Smolarek (supra n. 120) 6. The dugout, without having parallels on the southern Baltic shore, is unique in the Museum's collection because of its outer protuberance which may be interpreted either as a leeboard or as a stavskågg. Humbis and von Post (supra n. 17, 16, fig. 5b) interpreted the after protuberance seen in a dugout from Västergotland as a means of joining two dugouts side by side. The depiction of a boat with such a protuberance was found in Gissleårde, Bohuslän: E. Nylén, "Gutarnas farkoster," in I. Jansson ed., Gutar och vikingar (Stockholm 1983) 123: "...finns dessa detaljrika hållristningar av sköpp och strax intill en ristningar av ett svärd. Det märkliga med dessa bilder är att de skiljer
of one or more plank-boats. A treenail hole was found drilled at the apex of a knee. The location and the angle of drilling is similar with those seen in the main-frames of the Gdańsk-Orunia 2 and 3 shipwrecks.

A naturally curved timber was easily recognized as the remain of an aftermost or forwardmost floor timber. Its underside was juggled to fit the run of the planks. The central notch carved on the underside finds a good parallel in the notch carved in the aftermost preserved frame of Czarnowsko 1.

A floor fragment recovered at Fribrødre was juggled on the underside. Unlike the Bulverket find, this floor timber did not have a central notch. Instead, notches were carved at each step. The flatness of its central underside and the slight deadrise angle suggest that the floor was inserted over a T-shaped keel. Its shape has parallels only in the Western group of shipwrecks, namely the Eckernförder shipwreck and the first wreck from Ralswiek. The absence of holes on both sides of the central part indicates that the floor was not fastened to garboards. This feature was recorded in the Eckernförder wreck, the Ralswiek 4 vessel, for certain frames of the Kamień Pomorski wreck, but also in Skuldelev 1, 2, 3, and 6. Other ship parts, such as a rudder-frame, a forwardmost frame, and several knee fragments find their best parallel in Scandinavian finds

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244 Værenius (supra n. 220) 22, fig. 10; pl. 2; pl. 10.
245 Skamby Madsen and Crumlin-Pedersen (supra n. 20) 18, fig. 10.
246 Olsen and Crumlin-Pedersen (supra n. 204).
like the Gokstad vessel\textsuperscript{247} or Skuldelev 1.\textsuperscript{248}

Excavations at Fotevik have yielded data about five sunken vessels used as submerged navigational obstacles.\textsuperscript{249} The reconstruction of the midship section of Fotevik 1 shows similarities with finds from both Scandinavian and Southern Baltic groups of shipwrecks. Ingelman-Sundberg noted the similar design of bite knees used in Fotevik 1 and Skuldelev 5.\textsuperscript{250} Besides this, the general construction of the internal skeleton at the midship station is similar with that used in southern Baltic shipwrecks. The heads of the floor touch the stringer which supports the beams used as thwarts. On top of the thwarts standing knees and a stringer(?) support the sheer strake. This constructional sequence is similar with that of Gdańsk-Orunia 1, but the cross-section of Fotevik 1 is sharper than that of the hull of Gdańsk-Orunia 1.

5. Propulsion systems. Steering

The remains of the Gislinge boat offer several interesting details about its inner skeleton. The reconstruction of the midship section shows a rounded hull

\textsuperscript{247} Danman (supra n. 205) pl. 7g.

\textsuperscript{248} Skambø Madsen (supra n. 20) 18, fig. 10g, 10e.

\textsuperscript{249} In August 1981 a blockage of five ships was discovered at 1-2 m depth in the Fotevikene fjord. The first wreck, with a reconstructed length of about 12 m, was dated by Crumlin-Pedersen to 1000-1100. The C14 analysis of knee samples gave a date of 1060 +/- 65. The second wreck, thought to be the remnant of an open boat, was dated to 1000. For details see B. Hard, "Fotevikene - handelsplats eller ledningshamn?," Utst�llningskatalog - Institute of Archaeology - University of Lund Report Series 16 (1983) 3-28; also G. Crumlin-Pedersen, "De marinarkeologiske undersøgelser 1981 og 1982," Pupps FORNIS - Arkeologiska undersökningar kring Fotevikene, Skåne 1981-1983 (Lund, Sweden 1984) 7-68.

similar with those seen in shipwrecks found on the southern Baltic region. This impression is strengthened by the simplicity of the frame system composed of a floor timber and a thwart with naturally-curved ends. The thwart receives underneath support from a stanchion inserted in the floor timber. The heads of the thwart support the inwale, which is used as an oar support. A square mortise was carved into the center of the upper face of a floor timber situated forward of the midship section. The floor timber seems to have functioned as a transverse mast-step, a feature similar with that found in the Southern Baltic region.

The largest floor timber found at Bulverket offered several important details. Its underside was joggled to fit the planking of the lower hull. The deadrise angle of the underside carving of the floor timber and the distance between notches indicate that the hull must have been built on a T-shaped keel 0.22-24 m sided at its widest point. This value is close to the median value of 0.215 m obtained for the shipwreck group from the southern shore of the Baltic Sea. The shape of this floor recalls to mind the main floor timbers of Gdańsk-Orunia 1, Charbrowo 1, and Czarnowsko 1 shipwrecks.

The Bulverket floor timber had also a mortise carved into its upper surface. A circular, shallow hole was carved on either side of the mortise. The sequence hole-mortise-

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251 Varenius (supra n. 220) 22, fig. 10; pl. 2; pl. 9.

252 Supra n. 220, 19: "Våghålen på bottenstockarnas undersidor anger dock att den haft en största bredd av 22 cm. Det bredaste måttet återfinns på bottenstock 4. Bredden kan antyda att kölen varit T-formad i tvärsnitt." The drawing of the floor showed that a distance of 0.24 m existed between the ends of the two central notches. The rounded shape of notches suggests that these fulfilled the role of limber holes. The new element introduced by this floor is the small notch/limber hole located above the center of the keel.
hole suggested that the floor was used as a mast-step. The foot of the mast was probably inserted into the mortise, while stanchions were set into the side-holes. This arrangement is identical with the transverse mast-support system recorded in almost all wrecks found on the southern shore of the Baltic. It mostly resembles the mast support system used in the Frombork and Bagart vessels. The only difference is that in these vessels the stanchions were set close to the mast-step, while in the Bulverket floor the holes for the stanchions are set above the garboards.

A similar sequence of holes was found in a beam. Made out of a naturally-curved timber, the beam was curved at one end as a knee. The other knee was fastened with treenails to the straight end of the beam just as is seen in the ship fragments found in Gdańsk. In plan view the beam had an elliptical shape. Its approximate dimensions in the center were 0.05 m moulded and 0.22 m sided. The straight end of the beam and the apex of the curved end were hollowed enough to straddle the heads of the floor timber. This feature can be seen in the shipbuilding remains excavated in Gdańsk, specifically the knee found in strata dating from the 10th to the 13th century.

The central hole, drilled through the beam, was slightly larger in diameter than the mortise carved in the mast-floor. The other two holes on the other side were situated at the same distance as those observed in the upper surface of the mast-floor. The final reconstruction situated the beam on top of the mast-floor. In view of this arrangement, the beam fulfilled not only the role of a

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253 Supra n. 220, pl. 4.
254 Smoliarek (supra n. 14) 302, figs. 77a and 77b.
255 Supra n. 14, 303, fig. 77g.
thwart, but also that of a mast-partner. This kind of frame construction is present in the Szczecin vessel and in Gdańsk-Orunia 3, with the exception that the frame was placed toward the end of the hull in these ships and not amidships.

The only longitudinal mast-step timber found until now in the southern Baltic region is from the Puck 2 shipwreck (fig 7). From a structural point of view, the best parallels can be found in the mast-step timbers from Skuldelev 3, Skuldelev 5 and the Lapuri vessels. This type of mast-step timber exhibits a square mast-step located behind a naturally-grown stump which supports the mast forward. This feature is common to all the just-mentioned mast-step timbers with the possible exception of the Lapuri mast-step timber. The stump was supported by a beam set forward of the stump either at its base (Puck 2) or at its upper end (Skuldelev 3). The mast-step timber was notched on the underside to fit over three (Skuldelev 3), four (Puck 2), or five (Skuldelev 5) floor timbers. The underside was either carved between notches for floors (Puck 2, partially Lapuri) or left in contact with the keel over its entire surface (Skuldelev 3 and 5). In view of these technical similarities, the mast-step timber from Puck 2 can be regarded as a constructional element with clear Scandinavian parallels.

Another artifact with parallels on both sides of the Baltic is a very-well-preserved parrel from Gdańsk. However, the similarity is not complete. The Fribrødre parrel\textsuperscript{256} exhibits rounded ends and circular holes. The parrel found in Gdańsk has tapered ends with angular

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\textsuperscript{256} Skamby Madsen (supra n. 20) 21, fig. 14.
notches carved on its outer side.\textsuperscript{257} The parrels from Oseberg and Sigtuna have straight-cut ends and triangular holes.\textsuperscript{258}

Oar power was one of the principal means of propulsion used in ships from both Scandinavia and the southern Baltic region. Nevertheless, oar power was used according to the ship type and functionality. In general, ships used as ferries, be it for war purposes or just for regular traffic, were propelled mainly by oars. Oar power was used also on ships like Skuldelev 1 and 3 where sailing was the major mean of propulsion.

Table 23. Oar support systems

<table>
<thead>
<tr>
<th>Ship/Site</th>
<th>Oarports</th>
<th>Thole-pins</th>
<th>Propulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halsnøy</td>
<td></td>
<td>longitudinal</td>
<td>r</td>
</tr>
<tr>
<td>Nydam</td>
<td></td>
<td>longitudinal</td>
<td>r</td>
</tr>
<tr>
<td>Kvalsund</td>
<td></td>
<td>longitudinal</td>
<td>r</td>
</tr>
<tr>
<td>Gokstad</td>
<td>slit(1)</td>
<td>longitudinal</td>
<td>r/s</td>
</tr>
<tr>
<td>Oseberg</td>
<td>slit(2)</td>
<td>longitudinal</td>
<td>r/s</td>
</tr>
<tr>
<td>Fjæroftl</td>
<td></td>
<td>longitudinal</td>
<td>r</td>
</tr>
<tr>
<td>Bårset</td>
<td>slit(1)</td>
<td>longitudinal</td>
<td>r</td>
</tr>
<tr>
<td>R2</td>
<td>slit(1)</td>
<td>vertical</td>
<td>r/s</td>
</tr>
<tr>
<td>G-01</td>
<td></td>
<td>vertical</td>
<td>r</td>
</tr>
<tr>
<td>G-02</td>
<td>oval?</td>
<td>vertical?</td>
<td>r</td>
</tr>
<tr>
<td>G-03</td>
<td></td>
<td></td>
<td>r/s?</td>
</tr>
<tr>
<td>Gniezno</td>
<td>round</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Puck*</td>
<td></td>
<td>longitudinal</td>
<td>-</td>
</tr>
</tbody>
</table>

Note - Under "Oarports": slit(1)=number of slits, oval or round=shape of oarport. Thole-Pins - position relative to the sheer strake. Under "Propulsion": r=rowed, r/s=rowed/sailed. * denotes isolated find.

\textsuperscript{257} Smolarek (supra n. 14) 349, fig. 98.

\textsuperscript{258} Dammann (supra n. 205) pl. 11e, 11f; Ellmers (supra n. 91) 321, fig. 192a, 192b.
As can be seen in the above table, oar support systems found in both Scandinavia and the southern Baltic region differ not so much in principle as it does in technical details. Regardless of the region in which a ship was found, a relation seems to be established between propulsion and type of oar support system. Thus, thole-pin support systems is found only in ships with oar propulsion, while ships with mixed propulsion have oar-holes.

Although this dichotomy has already been noted,\(^{259}\) the new aspect to be stressed here is that it applies to both ships from Scandinavia and from the Southern Baltic region. The only exception is Gdańsk-Orunia 2, which has a rather doubtfull reconstruction of its sheer strake, and the isolated thole-pin carved from a naturally-curved timber from Puck.

Another similarity is presented by the Ralswiek 2 - Oseberg parallel. Both ships had oars inserted through notched oarports (ON. hábora) carved into the rowing strake (ON. roðrarhúfr).

There are also differences. In Scandinavian rowing vessels the thole-pins are fastened parallel with the inwale. The finds from Gdańsk-Orunia suggest that a vertical alignment was adopted for thole-pins inserted through the inwale.

It is difficult to assess the originality and/or the commonality of steering systems of both groups, mainly because steering apparatus is very poorly represented in the Southern Baltic group. The only parallel that can be drawn is between the boss from Gdańsk and those found on the Scandinavian territory. The base of the boss from Gdańsk has an elongated shape while the shaft is

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\(^{259}\) Smolarek (supra n. 14) 340.
cylindrical and distinct from the rest of the body. This is different from Gokstad, where the boss is round and has a knob-like appearance. In both cases the boss was fastened to the hull. The Gokstad boss was fastened to the hull and the rudder frame. It is very possible that the boss from Gdańsk was fastened to the side of the hull only.
CHAPTER V

HISTORICAL SOURCES

The lack of information about Slavic seafaring and shipbuilding in the written sources of the second half of the first Christian millennium seems to be endorsed by the lack of archaeological evidence for Slavic seagoing vessels for the period between the end of the Migration period (500 A.D.) and the 7th-8th century. 260

Information about Slavic nautical enterprises, ship types, harbours and ports, naval battles, etc., appears only in late historical documents written between the 10th and the 13th c. These originate mainly from Scandinavian and German sources which, owing the military conflicts of that time, biased the factual content through subjective interpretation.

The maritime trade between the 7th and the 10th c. was of vital importance for those Slavic trading centres located on the Baltic islands, which developed from the very beginning a strong shipbuilding tradition (fig. 17). Helmold wrote that,

"Sunt et insulae Balthici maris, quae incoluntur

260 The lack of evidence refers to keeled vessels; for this period only simple craft have been discovered. In 1991 the Central Maritime Museum in Gdańsk (Poland) had in custody 22 logboats; several of them displayed certain interesting features. For example, the dugout from Ulanów (L-5.40 m; B-0.65 m; H-0.25 m) has the shape of a tree trunk in the midship section and the sides are slightly flared. The C14 obtained for it was 650 A.D. +/- 50.

The dugout from Nowa Cerkiew with its huge dimensions (L-10.30 m; B-1.15 m; H-0.92 m) has a high-pointed bow and no transverse reinforcement. The size of this craft indicates its possible employment not only on inland waterways but also in estuarine and coastal navigation. The craft was dated by C14 analysis at 880 A.D. +/- 40."
Fig. 17. The Baltic Slavs
Among these Slavic vikings, the Rani/Rugiani were the most powerful. On the island of Rügen, they founded Arkona and Ralswiek, two important transit stations on the East-West trade route which made also the connection between the European mainland, Skåne and the Danish archipelago.

The active maritime trade which connected these coastal emporia was carried on ships of different types and sizes, but because of the nature of commerce in this period, the functionality of a ship was often dual, especially in the case of small size ships of the *skūta* type.

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263 H. Falk, "Altamdisches Seewesen," *Wörter und Sachen* 4 (1912) 93-97. Both types are between 4 and 15 thwarts in length, which is a fairly large variation in size. This variation was used to adapt the *skūta*/*karf* to specific purposes related to function and geoclimatic conditions. However, a *skūta*/*skūta* of 5 thwarts seems to have had the same basic qualities as one of 15 thwarts. It was used mainly for coastal navigation, but was also used in crossing the Baltic. Its lightness made it suitable for inland navigation and portage over large tracts of land. Its nautical qualities (speed, stability, seaworthiness, manoeuvrability, shallow draught, cargo capacity, etc.) qualified this type for warfare and piracy but also for 'light' commerce. Typical examples of this kind are: Bulverket (Gotland) - 5 thwarts, Ralswiek 2 (Rügen) - 7 thwarts, Puck 2
This technical elusiveness biases the interpretation of ship types which is further complicated by the lack of detailed written information earlier than the 10th century. This situation is somehow alleviated by the sporadic information contained in late (11th-13th century) Scandinavian and German sources.

In his Gesta Hammaburgensis Ecclesiae Pontificum, Adam of Bremen usually refers to ships with the general term of navis without any further specification. However, in describing the connections between Funen, Sjælland and the Jutland peninsula, he mentions that "[m]are natura tempestuosum duplicique plenum periculo, ut, etiam si ventum habeas prosperum, vix effugas manus pyratarum."264

This passage indicates that both the victims and the pirates relied on wind for the accomplishment of their purposes, and only a ship equipped with mast, sail, and rigging could have been so dependent on the wind patterns in the Danish archipelago. Adam of Bremen mentions the "sinum Sclavanicum" south of Funen and Sjælland. This suggests that control and/or the intense maritime traffic in the Kiel Bay was heavily influenced by the Slavs. This impression is apparently confirmed in a short passage from Knýtlingasaga which specifies that during the reign of Waldemar I (1157-1182) 600 Slavic ships were wrecked by bad

(Gdańsk Bay) - 12 thwart.


265 Supra n. 264, 233.
weather at Joluholm. This information is also given by Saxo Grammaticus, who mentioned that 1500 ships were wrecked.

A more important route apparently controlled by the Slavs was the shipping lane which started in the 'sinus Slavonicum', passed Stargard/Aldenburg, Reric, Jumne/Wolin, and then continued along the Pomeranian coast to Gdańsk and Truso, until it reached the Kurlandian coastline. From there ships bound for Novgorod followed the coast up north until they entered the Gulf of Finland. According to Adam of Bremen, from Jumne/Wolin "...vela tendens XIII die ascendes ad Ostrogard Ruzziae." This information lets us assume that in a normal dagr a ship could have covered circa 54 nautical miles at an average speed of 4.5 – 5.4 knots, speed not unthinkable for merchant ships of that period.

The Slavs, however, did not sail only on coastal waterways or in estuarine waters. Helmod, quoting an earlier information provided by Adam of Bremen, wrote that

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266 "Ex Historia Regum Danorum Dicta Knýtlingasaga," Monumenta Germaniae Historica (cited hereafter as MGH) XXIX (Hannover, Germany 1892) 307: "En at samr kevdi for us 600 Vínda skip við Joluholma."


268 Adam of Bremen (supra n. 264) 80.

269 This estimate should be considered against such specific factors as the wind direction and speed, hull shape, steering device, ballast, rigging and sail shape: M. Vinner, "Recording the trial run," in O. Crumlin-Pedersen and M. Vinner eds., Sailing into the Past. Proceedings of the International Seminar on Replicas of Ancient and Medieval Vessels, Roskilde 1984 (Roskilde, Denmark 1986) 224; for example, in the preliminary trials with Skuldelev 3 replica, the "Roar" (L - 14 m.; B - 3.3 m., D -1.4 m., sail area - 46 sqm.) achieved 8.6 kn. while "...running under double-risked sail in a true wind of 32 kn. In a true wind speed of 12 kn the boat-speed on the tack would be 4.0 kn ..."
the great emporium at Birka hosted ".. omnes Danorum, Norveorum itemque Slavorum ac Semborum naves allique Scithiae populi pro diversis commerciorum necessitatibus sollemnis convenire solent."\(^\text{270}\)

The author conveys the remark that people listed by him frequented the Birka market on a regular basis, hence their presence should be considered a proof of Birka's commercial fame. However, the sequence in the enumeration itself suggests that the Danes and the Norwegians were the most numerous, while the Slavs and the Sembians were a minority.\(^\text{271}\) But even if Helmold did not specify what type of naves they used to cross the Baltic, it is important to realize that the Slavs came to trade at Birka in their own ships.\(^\text{272}\)

Nevertheless, most of the accounts about Slavic ships come from passages related to warfare, since the attention of medieval writers was drawn more often upon the military and political situation than upon economic aspects of that time. Adam of Bremen wrote that during the reign of Magnus the Good (1042-1047) "..verum Sclavis terribilis, qui post mortem Chnud Daniam infestabant. Ratibor dux Sclavorum

\(^{270}\) Helmold (supra n. 261) 20. Adam of Bremen (supra n. 264) 58: "Ad quam stationem, quia tutissima est in maritimis Suevianae regionibus, solent omnes Danorum vel Nortmannorum itemque Sclavorum ac Semborum naves allique Scithiae populi pro diversis commerciorum necessitatibus sollemnis convenire."

\(^{271}\) The word itemque can be translated either as 'and also' or 'and even'; the latter would suggest that the Slav merchants were seen much more rarely in Birka than the text states. However, this observation affects only the frequency and not the fact that the Slavs traded with success in the Scandinavian markets.

interfectus est a Danis."273 In spite of Magnus' successes at Wolin and Lyrskovshede,274 the situation in the Danish archipelago was so distresfull that "Sveno... Bina castra, alterum in Fionia, in Sialandia alterum, propter fretum molitur, quae piratis timori, incolis vero receptui forest. Sed a Scavia utrumque convulsum proditum."275

It was in this period that barrages of sunken ships were laid at navigational passages in order to make them impassable for the Slavic ships.276 The pressure mounted by the raids of the Slavs reached its climax during the second half of the 11th and the first half of the 12th century. In this period Roskilde was sacked,277 and Konungahella was conquered and burned to the ground. These raids were

273 Adam of Bremen (supra n. 264) 137.

274 "Ex Historia Magni Boni Regis," MGH XXIX (1892) 396-397: "Siōan sigldi hann meō flotann yfir til Vinõlandz ok kom meō herinn utan at Jomi; gekk Magnus konungr þar a land ok herjaði, bredi þædi bygðir ok menn, garði hann Vinõnikinn bernað ok vann mærg staurvikki; "Ex Catalogis Regum Danorum," MGH XXIX, 169: "Magnus rex Scavos fines suos invadentes ad ulciscendum Radeburg principem eorum, qui a Danis occasu erat, in campestribus Heideba 15 milia paganorum occidit;" J. C. H. R. Steenstrup, Venderne og de Danske før Valdemar den Store (Kjøbenhavn 1900) 67-72; the victory at Lyrskovshede put an end to a Wendish punitive expedition which sacked southern Jutland and reached the outskirts of Ribe (cf. Adam of Bremen, supra n. 264, 137). Although Steenstrup thought the Wends broke through the Danevirke, there is a strong possibility they reached Jutland by sea.

275 "Ex Saxonis Gestis Danorum," MGH XXIX (1892) 69-90.

276 Barrages from Skuldelev (950-1050) and Fotevik (second half of the 11th-first half of the 12th century).

accomplished by Slavs in vessels of the **herskip** category,\(^{278}\) sometimes referred to in Helmold's *Cronica Slavorum* as **nares predonum.**\(^{279}\)

A more detailed depiction of ships from this category is given in Snorri Sturlusson's *Heimskringlasaga* where the well-known Wendish siege of Konungahella is described in detail. Thus, on August the 9th, 1135, "[o]n the day before Saint Lawrence Mass, when high mass was being read, Rétibur, the king of the Wends, arrived at Konungahella with five hundred and fifty [660] Wendish swift sailing vessels, and on every boat there were forty-four men and two horses."\(^{280}\)

The term ON. **snækja**/**snækkjur**/Pol. **sneka** was applied to fast sailing ships with a length above 20 thwarts.\(^{281}\) They were used in warfare for different purposes like scouting,

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\(^{278}\) As Slavic terminology for ship categories remains to be clarified, the Scandinavian categories of **herskip** and **kaupskip** can offer sufficient parallelism for their Slavic counterparts.

\(^{279}\) Helmold (supra n. 261) 201, 215.

\(^{280}\) Snorri Sturluson, *Heimskringla* - History of the Kings of Norway, transl. by Lee M. Hollander (Austin, TX 1964) 725-726; "Ex Svorronia Historia Regum Norwegiensium Dicta Heimskringla," *MGH* XXIX (1892) 345: "Lafranz vökudag, ða er talat yar fra hamessu, kom Rétibur Vinðakonungr til Konungahelli, ok hafði halft setta hundrað Vinða*-snækkjur, en a hverri snækkju voru menn 40 ok 4 menn ok 2 hestar...”

\(^{281}\) Falk (supra n. 263) 102-104; 103: 

"[d]åb in der anord. Literatur **snækkja** die stehende Bezeichnung der wendischen Schiffe ist, vergl. Fms. II, 299. 308. 327, III, 4.32, VII, 188..." Rikke Malmros, "Leding og Skjaldekvad," *Årbøger for Nordisk Oldkyndighed og Historie* 1985 (1986) 102-103: "[o]det **snækkja** har en betydelig udbredelse i den sene vikingetids Nordeuropa...[s]om oversættelse af det latinske **rostrata nautical**, skibe med snabel -krigsskibe...[a]**snækkja** har givet været en udbredt krigsskibebetegnelse i skandinavisk prosa..." Although Malmros' critical approach of 13th-century ship terminology is perfectly justified, the use of ON. **snækkja** to describe Racibór's vessels seems to be consonant with its function as a warship, and also with the fact that each vessel had on board 44 men which is conducive to the idea of a 20-thwart ship. In this case, Snorri's narration seems to reflect an oral tradition built upon eye-witness accounts of a siege less than a hundred years old.
transport, naval engagement, and raiding. In this case the ships were used mainly for transport of land troops and horses, although before landing in Konungahella, the Slavs engaged in a naval battle with the crews of the 9 merchant ships moored in the harbour.\textsuperscript{282} The number of 44 men was written as 40 and 4 which suggests not only functional differentiation between crew members, but also that Racibor’s \textit{snekkjur} had as many as 20 thwarts without counting the space allotted for horses and the fore and aft quarters. This unique account, in which Slavic ships are mentioned in connection with horse transport across the Baltic, indicates that the size of the Slavic warships was comparable with that of similar Scandinavian vessels, and that they can be classified into the \textit{herskip} category, which relied on mixed propulsion. The royal ship may be interpreted as somewhat larger than the other \textit{snekkjur}/\textit{sneki} in the fleet since "[t]he king had the priests put out in the ship’s boat and Andreas carried the Cross in his bosom. The heathens led the boat along the ship, around the bow, and back along the other side to the afterdeck, then with forks pushed it toward the landing stages."\textsuperscript{283}

This passage recalls how Racibor, who previously took captive Andreas and the other clerics aboard his ship,

\textsuperscript{282} "Ex Snorronis," MGH XXIX, 346: "\textit{Austrfararekip} 9 flutu i anni fyri bryggjum, er kaupmenna attu. Vinór lögdu þar fyrst at ok borðuz við kaupmennina." The text is exact in describing the merchant ships with the term \textit{austrfararekip}, because this name was given to a vessel used on the Baltic trade, including ships bound for Russia. Excavated in Roskilde fjord, Skuldelev 3 is considered of what would be the remains of a Baltic merchant dated toward the end of the Viking period in Scandinavia (950-1050).

\textsuperscript{283} "Ex Snorronis," MGH XXIX, 348-349: "Konungr let skjota a skipbatinn kennimönnum ok bar Andreas krossinn i faðmi ser. Þær leiddu batinn fram með endilöngu skipinu ok fram fyri barðit ok sptr með þóru borði til lytingar, skutu síðan við forkum ok hrundu batinum inn at bryggjunum."
released them in a small dinghy which was the ship's service boat. The small craft was lowered from one side of the ship, then pulled around the bow and along the other side until it reached the afterdeck (ON. lypting/-ar). This is a unique reference which suggests that Slavic sneki/snekkjur belonging to the high rank nobility were partially decked. The difference in size between the Slavic flag-ship and the rest of the fleet is also evidenced by the fact that it carried an ON. yfirbáttr, a service boat, on board.284

The term snekkjur is used in the Ingasaga,285 and also in the Knytlingasaga where Egil's naval encounter with a Slavic host is vividly described. The fate of the battle was decided when "[o]n board of the ship near Egil's ship was the Wendish leader; and when the battle was so violent that men could not see each other Egil boarded the Wendish snekkjuna, and inflicted a mortally wound to the leader, then he returned to his ship."286

This laconic fragment is representative of how battles were fought on the sea. The long-range engagement ended as a land battle in the confined space of a ship, where the goal was to clear the enemy deck through close combat. The side which lost its leader during the battle was considered defeated. This kind of hand-to-hand battle could have been

284 Falk (supra n. 263) 91.


286 "Ex Historia Regum Danorum," MGH XXIX, 277: "Peir børdust a skipum, ok var þat næst Egils skipi, er a var hofðingi Vinda; ok er orrostan var sem akofust, ok menn botust eigi skilja, hvarir hninga mundu, þa hljop Egill af skipi sinu ok upp a Vinda snekkjuna, ok hjo til hofðingians ok veitti honum bana sar, ok þegar hljop Egill ò fugr aput a sitta skip..."
fought only between "compatible" ships, i.e. between ships with decks and freeboards at approximately the same level. Although the text is unclear on how Egil boarded the ship of the Slavic dux, the vessels seem to be of analogous design.

An almost identical scene is depicted by another passage in which Saxo related the sea battle of Esbernus and Wethemannus with the Slavic raiders Mirocus and Strumicus:

"Per idem tempus Esbernus et Wethemannus, opportunas patriae excubias multi navigationis impendio prosecuti sedulumque piraticae opus ingressi, in septem piraticos myoparones quator incidere navigiis. Tunc Mirocus, pugil spectatae audaciae, fortitudinis suae motum intra propriae navis spacia continere non passus, Wethemanni se appetentis navigium virtutis fiducia solitarius insilit; cedentibusque per ignaviam remigibus, neminem in eo preter Wethemannum rebellem habuit. Quos Esbernus, rate preteriensis, risu prosequi contentus fuit neque aut hostem laedere aut civem iuvare sustinuit, ne pluribus adversum unum opem tulisse videretur. Progressus itaque Strunicum athletam insignis fortitudinis capit. Sed nec prius Mirocus, ut pedem referret, urgeri poterat, quam alius navigii supervenientis viribus arceretur." 287

The same tactics of close combat and boarding the enemy ship can be perceived from this passage. The action of Mirocus, the intervention of Esbernus, and the capture of Strunicus are all indicative of the heavy fighting occurred in the Western Baltic region during Waldemar's reign. In describing the ships of the combatants, Saxo noted that the Slavs had seven myoparones while the Danes had only four

287 "Ex Saxonis," MGH XXIX, 144.
The text further informs us that Wethemannus' ship was rowed, which suggests that the Danish squadron was composed of warships propelled solely by oars, while the Slavic ships had a mixed propulsion. By virtue of their closeness, these naval encounters tested the skills and the ingenuity of those involved in the fighting.

In 1171, when the Danes controlled the Western Baltic, the battered Slavic ships still found resources for naval skirmishes in which their bravery was commended by the Danes. Although Saxo's Danorum Regum Heroumque Historia, which is one of the major sources of information about Slavic ships and seafaring, was biased by an ardent desire to glorify the deeds of the Danes, the text contains several important details about the "enemy ships". Thus, he recounts how Absalon and Nicolaus ambushed a Slavic ship:

"Qui cum Absalonis navigationem suam superare conspicerent, callidum fugae commentum amplexi, submisso velo, contrariam vento navigationem remigio molientur. Id attentantibus Nicolaus rate obvius fuit. Quam adversa navigatione petentes mira gubernatoris solertis sefellere. Nam cum ad eius pene contactum pervenisset, obliguato remigio in illud navigii sui latus, quod ab hostibus aversum erat pariter concurrere iussi reliqui se erigentis oppositu perinde ac muro hostilia quibus incessebantur, iacula vitavere."\(^{289}\)

\(^{288}\) Myoparœ, onis was the Latin term used to define a small vessel with a mixed propulsion. On the mosaics of the Late Roman period, the myoparœ is shown as a one-masted ship with a square rig and oars affixed at the sheer strake on both sides of the vessel. Thus, the term describes perfectly the image of a 12th-Century Baltic ship from the barekip category. On the same mosaics the ratia was shown as a vessel propelled solely by oars. For details see L. Casson, Ships and Seamanship in the Ancient World (Princeton, NJ 1971) 137.

\(^{289}\) "Ex Saxonia," MGH XXIX, 144; Christiansen (supra n. 267) 544-545: "And when the enemy noticed that Absalon was overhauling them, they decided to escape by a trick; they lowered their sail, and began to row..."
The text offers us several important details. The position of the two vessels in the first sequence of the chase, when Absalon was sailing after the Slavic ship, suggests that they were sailing in close haul. Then, on account of superior Danish velocity, the Slavs changed the course, lowered the sail, and started to row into a headwind. The Slavs took this decision, because they realized that Absalon’s ship was based primarily on wind propulsion, while their vessel was propelled by oars and sail. The third observation is related to the second sequence of the chase, when Nicolaus’ ship, with rowing/sailing propulsion, appeared in front of the Slavic vessel. The dangerous manoeuvre then made by the Slavic skipper reveals not only his skill as helmsman, but also suggests that the ship had a shallow draught and a rounded hull which permitted the heeling angle mentioned in the text.

But the Slavs were not involved only in insignificant

290 The chase could not have happened with the wind abaft or abeam. In both cases the Slavs would have eased Absalon's task by allowing him to come at close quarters in no time. The only sound situation seems to be when the two vessels were tacking in a headwind.

291 "Ex Saxonis," MGH XXIX, 144: "Sed Absalon velo, Nicolaus remigio piratas petebat."

292 Such a manoeuvre imposes great stress on the rudder's fastening rope and especially on the hull. The rapid turn made in order to avoid collision with Nicolaus’ vessel heeled the Slavic ship toward the enemy. In that instance, the skipper realized the danger of being exposed to the Danish arrows and slingshots and ordered the crew to move toward the other side. This situation caused the centre of gravity of the vessel to shift from the centre line toward the side of the vessel. In this manner the skipper compensated for the heeling angle and also had changed the outward heel to an inward heel. The movement protected the crew from the volley of arrows and seems to have allowed for minimum losses in speed. The discipline of the crew and the skill and ingenuity of the helmsman are per se arguments for a strong maritime tradition among the Slavs.
skirmishes and/or expeditions of plunder. Thus, the anti-Slavic war from 1147 had seen movements of fleets from both sides. To counteract the actions of the army led by Adolf II and Heinrich the Lion in the Wagrian territory, the Obodritian duke Niclot (1127-1160) deployed his forces by sea to the mouth of the Travee river, and from there upstream to Old Lübeck.\(^{293}\) The account reveals not only the degree of coordination between Obodritian terrestrial and maritime forces, but also that the Slavic ships were sufficiently shallow to navigate on inland waters to transport siege troops to Old Lübeck.\(^{294}\) The burning of merchant vessels - *naves onustae* - in Lübeck is a good indication of the commercial activity the city experienced even in those unsettled times.

In Book XIV, which covers the period between 1134 and 1178, Saxo recounts the Slavic wars before and during the reign of Waldemar I (1157-1182). In the first campaign against the Rugians/Ranians, Waldemar and Absalon landed on the shores of the Zingst peninsula and ravaged the nearby villages while the fleet was engaged by Rugian/Ranian ships which the Danes

".. fugam a remigio mutuantes velorum intensione prosequitur. Sed intervallo precessionis et volucratis navigationis adiutos instando magis quam

\(^{293}\) Helmod (supra n. 261) 119: "Sentiens enim Niclotus irrevocabilem esse iuratae expeditiones profectonem, clam parat navalem exercitum transmissoque freto applicat classem ad ostium Travenae percusserus omnes Wagirensium provinciam, priscum Saxorum exercitus infunderetur sui terminis... descendit navalis Slavorum exercitus per ostium Travenae. Tunc clives Lubicanae urbis audito murmure exercitus inclamaverunt .. Sed populus multa potacio (temulentus) neque strato neque navibus ammoveri potuit, quo usque hostibus circumvallati naves mercibus onustas insaecto igne perdiderunt."

\(^{294}\) Supra n. 261, 70: ".. in urbe Lubeke, ecce improvisus supervenit exercitus Rugianorum sive Ranorum, subvectione per alveum Trabenae urbem navibus circumdederunt."
The intervention of the Rugian fleet forced Waldemar's landed army to withdraw onto their ships. In the ensuing naval fight, the Rugians seem to have adopted hit-and-run tactics, perhaps due to their unpreparedness for the Danish attack, but also because of familiarity with their own native waters. On the other hand, the Danes did not obtain the decisive encounter they hoped for, partly because of the superior velocity demonstrated by the Slavic vessels. While this can be explained by the difference in the ship types of the two warring sides and by the Slavs' knowledge of local waters, it does not elucidate why the Danes chased them by sailing and not by rowing from the outset.

In another passage, Saxo related how, in the 1160 campaign, a Danish expeditionary fleet engaged the Slavs upstream on the Warnow river. The Danes stranded their ships while forcing the entrance into Der Breitling and at that moment "[i]n quos Sclavi navigis suis tang

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295 "Ex Saxonis," MGH XXIX, 102.

296 Helmeld (supra n. 261) 216: "Slavi enim clandestinis incursibus maxime valent. Unde etiam recenti adhuc etate latrocinialis haec consuetudo adeo apud eos invaluit, ut omisso senis agriculturae commodis ad navales excursus expeditas semper intenderit manus, unicam spem at diviciarum summam in navibus habentes sitam." It seems that short, quick, and unexpected raids were the preferred naval tactics, which might explain better why the Rugians avoided a pitched battle with the Danish fleet.

297 Christiansen (supra n. 267) 446-447: "Quos caetera Danorum classis certatim magnis remigii nisibus insecuta/velocitate navigationis aequare non potuit."
propugnaculis utendo superne tela librabant." The stylistic figure of a ship used as siege tower does not necessarily imply that the Slavic vessels were higher than the Danish ships. Previously, Saxo mentioned that the Danes jumped overboard into the shallow water and pushed their ships by grasping the "complexi remorum" with their hands. In this manner, the men in the water were lower than those aboard the approaching vessels. The essential detail revealed in this passage, however, is the technical capability of a Slavic ship to navigate in the shallows. The Danish ships, even the small ones, seemed to be lacking in this respect. This distinction has to be related to the shape of the hull beneath the waterline, and also to the draught and the size of the vessel. The Slavic seagoing ships accustomed to sailing up the Warnow seem to have had a flat-bottomed or a rounded hull.

However, these technical features were reflected negatively in sailing the open sea in bad weather. A Slavic fleet prepared to invade the island of Mön in around 1170-1171 was surprised by a storm at sea, and most of the ships were wrecked:

"...Sclavi, cum remigio adversum undarum saeviciam eluctari nequirent veloque sibi consulere vellent, tempestatis magnitudine eversis navigis, mergebantur...Bina ex iis navigia, remigum virtute a fluctibus defensa..." 300

296 Supra n. 267, 445.

299 Supra n. 267, 445: "..manibusque foros complexi/remorum vices corporum viribus exequentur."

300 "Ex Saxonis," MGH XXIX, 140.
The passage relates how the Slavs tried in vain to escape the storm by rowing, and when they resorted to sails their ships capsized. This detail suggests that these ships were not stable enough to resist strong winds under sail, and perhaps this was the reason they initially tried to escape by rowing. The fact that two of their vessels, propelled by oars, reached Rügen safely seems to support this supposition.

In his recollection of Danish campaigns into Slavia, Saxo uses different terms for the enemy ships. Thus, in an expedition against Arcona and Por - the latter being situated on the mainland opposite the island of Rügen - Absalon's forces observed how the enemy ".. cuidam forte stagno adactos cimbis fuga petere."

Also, in their attempt to reach the island of Grzutow, situated in the middle of the Dziwna, the townsmen from Wolin ".. pretereuntem scaphis incesseret .." In the same passage Saxo used two terms to describe the small rowing craft of the Wolinians, which was probably used for local transport, and estuarine and coastal fishing.

The Rugians/Ranians took part in the campaign on the Dziwna channel as Waldemar's allies, to whom they swore allegiance. In their attempt to cross the shallows, the Danish army had to resign from portage due to the weight of their ships. Among them "Rugianis solis sex puulas rates hac arte educere cõtigit .." The word rates seems to

301 Christiansen (supra n. 267) 477.

302 The channel which separates the island of Wolin from the Pomeranian mainland. The island of Grzyszów is situated in front of the actual town of Kamień Pomorski (Poland).

303 Christiansen (supra n. 267) 521.

304 Supra n. 267, 523.
denote ships which were light enough for portage.

In contrast with the local craft, the vessels used by the Slavs for war purposes were of larger dimensions, and as such they were described as "... novē longas naves a se prospici referēte: piratas esse nō dubitās .."305 The term navis longa is actually the Latin transliteration of the ON. herskip/langskip which was the generic term employed for warships in that period.

Also in Book XVI Saxo recalls the final submission of Pomerania during the first years (1182-1184) of Canute VI and offers some details about Bogusław's fleet before the battle from Greifswald Bay:

"Igitur, Bogiszlavus Rugianā classem appellet ratus a cētum et quinquaginta myoparoni circuiri defyderat reliquam classem veluti in aciem iactis anchoris componit: naves quibus alimenta vehebantur aliquid pyraticis praestantiores inter ipsas et continentē admovit: armate multitudinis speciem vacua lignoru effigie adumbraturus."306

The passage mentions at least two categories of vessels in the Pomeranian fleet. The "naves quibus alimenta vehebantur" were superior to the piratical ships, i. e. there were ships with a more robust construction and a higher freeboard than the myoparoni. Their placement in the second battle line confirms their role as cargo carriers. The ships described as myoparoni seem to represent vessels

305 Supra n. 267, 487; "Ex Historia Regum Danorum," MGH XXIX, 316: "...pa komu par at þeim 9 Vinçaskip ok òll erit stor..."

306 Supra n. 267, 613; "Ex Historia Regum Danorum," MGH XXIX, 319: "Burizleifr hatfōt 5 hundruð skips, ok heīð þa enn Vestrvinda"; "Arnoldi Chronica Slavorum," Monumenta Germaniae Historica Scriptores Rerum Germanicarum in usum scholarum separatam editī 14 (Hannover, Germany 1978) 82-83: "Quodam igitur tempore Buggezlavus princeps sive rex Pomeranorum...[a]scendit igitur ad eum cum sexcentis piratis..."
used in warfare since Saxo mentions them in the same passage as piratical vessels. It seems that Saxo used the Latin term here to emphasize the distinction between the two categories found in Bogusław's fleet. Their placement on the seaward side of the fleet indicates not only that they were ships of the herskip category, but also that Bogusław was aware of the enemy presence in the Rugian waters and that he expected a close combat any time soon. However, this measure of precaution did not prevent the defeat of his fleet and the subsequent submission of Pomerania to the Danish suzerainty.
CHAPTER VI

CONCLUSIONS

A general overview of all historical sources reveals from the beginning a lack of detailed information regarding the maritime history of the Baltic Slavs. The Roman, Byzantine, and Anglo-Saxon sources contain some information about the Southern Baltic region during the Roman Age and Migration period, but none of these sources furnishes details about Slavic seafaring.

Apart from general statements the written sources refrain from any detail regarding Slavic seafaring activities in the period between the 7th and the 10th centuries. This temporal gap in historical sources is particularly unfortunate, because in this period tremendous changes occurred in all maritime societies that inhabited the coasts of the Baltic Sea. During the Vendel period (6th - 8th c.) the Scandinavian society went through a transition process marked by adoption of new solutions to old seafaring and shipbuilding problems. In this period ships started to differentiate, the sail was improved significantly as one of the principal means of propulsion, and steering with a quarter rudder was perfected.

The only sources known to cover in some detail the maritime endeavors of the Baltic Slavs between the 11th and the 12th centuries are mostly Scandinavian and German ones written between the 11th and the 13th century. According to these sources the Slavs inhabited the southern Baltic coast from the Schlei in the west to the Vistula lagoon in the east. Important trading centers such as Stargard/Aldenburg, Liubice/Alt Lübeck, Reric, Wolgast, Arkona, Ralswick,
Jumne/Wolin, Szczecin, Gdańsk, Kołobrzeg, etc. were located in their territory. The prosperity of these centers resulted from an active involvement in the Baltic trade, involvement made possible by seafaring which connected all these centers in a trade network.

By virtue of their geographic position, these centers acted as intermediaries, not only between East and West, but also between Scandinavia and Europe. 307 Starigard, Reric, and Liubice linked Skåne and the Danish islands with the German hinterland; Wolgast, Szczecin and Wolin received goods shipped on the Odra from Bohemia, Silesia, and Małopolska; and Kołobrzeg, Gdańsk, 308 Puck, and Truso linked economically the Vistula basin and its tributaries with trading centers from Eastern Baltic, Russia, and the Byzantine empire. It was through these maritime emporia that Slavic ceramics, a most-sought merchandise, was shipped to Scandinavian markets as early as the 8th century. 309

The existence of these trading centers certifies the

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degree of integration of Wagrians, Obodritians, Veletians, Rugians, Wolinians, and Pomeranians into the Baltic maritime economy. The Rugians, for example, developed a maritime-oriented economy as early as the second half of the 8th century. Historical sources mention that the opening of the Rugian fishing season attracted numerous foreigners in Arkona, because "[c]eterum Rugianorum terra ferax frugum, piscium atque ferarum." The information on seafaring contained in Scandinavian and German sources reveals that by the end of the Early Middle Age, the Baltic Slavs were actively involved in maritime activities such as fishing, commerce, and warfare. Their involvement was made possible by the development of shipbuilding activities, shipyards, and ship-related crafts such as carpentry, sail-making, rope-making, iron casting, etc. The number of new and/or reused shipbuilding materials indicates that Wolin, Szczecin, Puck, and Gdańsk had their own shipyards and/or

310 Zak (supra n. 307) 675-689.


312 The event was also accompanied by a resurgence of viking raids since Abaslon decided to patrol the Rugians waters at that time. For details see "Ex Saxonis," MOS XXIX, 137.

313 Helmold (supra n. 261) 214.

314 J. Herrmann, H. H. Bielfeldt, J. Brankack, W. Coblenz, P. Donat et. al., Die Slawen in Deutschland (Berlin 1972) 191: "Weitere Handelsplätze lagen bei Arkona, wo sich fremde Kaufleute zeitweise zum Heringssmarkt versammelten."

315 Sadowski (supra n. 76) 78: "Besides there was a lot of unplanned or coarsely finished wooden items, shavings and a number of loose boat parts...An alternative explanation would in fact be that it may be the remains of a shipyard."
boatbuilding workshops. The ship remains found at Ralswiek led Herrmann to conclude that a ship-graveyard seems to have existed on the island of Rügen.\textsuperscript{316}

The free development of these market-towns was nurtured not only by economic ties but also by the political situation of the Baltic Slavs. In most cases, these commercial towns were centers of local political power where decisions were made in accordance with the interests of the town council. Other towns, such as Reric, Liubice, or Starigard were also seats of princely power which enhanced their status under the tutelage of the political leader.

The decline of Slavic maritime economy and consequently the decline of seafaring and shipbuilding activities ought to be related to the political situation which occurred in the Wendish lands beginning with the second half of the 12th century. In this period, a marked contrast existed between the feudal organization of German and Scandinavian states on one side and the kinship organization of the Baltic Slavs on the other. As Labuda already suggested, the Baltic Slavs entered the stage of monarchic centralization late in the 11th-12th century.\textsuperscript{317} In the 9th and the 10th century their territorial organization was dependent on traditional kinship where the political leader, Lat. dux, together with the hereditary nobility, exercised the collective responsibility of major political decisions.\textsuperscript{318}

\textsuperscript{316} Herrmann (supra n. 314) 191: "Nahe dabei lag ein "Schiffsfriedhof", auf dem bisher drei Boote ausgegraben worden sind, die ehemals als Hochseeschiffe dienten."

\textsuperscript{317} Smolarek (supra n. 14) 102.

\textsuperscript{318} Herrmann (supra n. 314) 200-218.
In contrast to the Wends, the Scandinavians and especially the Germans formed by the end of the 11th and the beginning of the 12th century strong monarchic entities which perceived the Slavic territory as a fertile ground for political and ecclesiastical expansion. The Baltic Slavs, fragmented in several political and religious centers, failed to successfully counteract the expansionism of their powerful neighbors. As the existence of hereditary priesthood and that of cultic centers at Arkona, Demmin, Riedegost/Rethra, Wolgast, Szczecin, etc., polarized the religious attention of the base population, the reception of Christianity by high-rank nobility did not change the course of the matter.

Nevertheless, the Wendish maritime activity was seemingly at its height during the 11th and the 12th centuries, when written sources detail not only its geographic outreach, but also the ships involved. These ships of the Slavs were called in the literary sources different names according to the narration context, which seems to have taken into account their type and size. A division between ship types seems to have been already present in the 11th and the 12th centuries. These names can be classified in the following categories:

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319 German expansionism supported the formation of the Magdeburg bishopric, which constituted a bridge-head for further territorial gains. The 12th century Danish military expansion produced the first monastic settlements in Pomerania, at Dergun by Demmin (1171?) and Kolbacz near Szczecin (1173). The Polish kingdom under Boleslaw the Wyrmouth (1102-1138) founded the bishopric of Lebus on the Odra (1124) for similar expansionist purposes. However, the violent expansionism prevailed over these pacific ecclesiastical enterprises. An eloquent example is given by the so-called "crusade" in 1147, when coordinated German and Danish armies sacked the Obodritian and the Veletian territories.
Table 24. Ship names from historical sources

<table>
<thead>
<tr>
<th>Warships</th>
<th>Traders</th>
<th>Fishing boats</th>
<th>Smaller craft</th>
</tr>
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<tbody>
<tr>
<td>myoparo</td>
<td>navis onusta</td>
<td>scapha</td>
<td>cimba</td>
</tr>
<tr>
<td>ratis</td>
<td>navis praestantiors</td>
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<td>skipbatinn</td>
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<td>snekkja</td>
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<td>skeiðir³²⁰</td>
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<td>Vinðaskip</td>
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<tr>
<td>stor Vinðaskip</td>
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<td></td>
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<tr>
<td>navis longa</td>
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Furthermore, the contextual meaning of each passage suggests that even an intra-class differentiation had taken place. This can be seen in the warship category where ships can be classified according to their size and method of propulsion.

According to its Latin meaning ratis was used to designate a ship propelled by oars only. All three shipwrecks from Gdańsk-Orunia can be included in this category. The term myoparo was used for a vessel propelled by oars and sail; it can be seen as a typical Slavic raider. It seems that this kind of swift sailing vessel was mentioned by Helmsd under the general term navis praedonum. Navis longae seems to designate vessels used in naval warfare, although according to Scandinavian ship terminology they can be classified as skutur/karfar and snekkjur/skeiðir, respectively. Puck 2 with twelve rooms and Ralswiek 2 with six or seven rooms can be considered in

the myparones/skutur/karfar category. Although not attested archaeologically, ships of larger size seem to have existed, since the written sources mention warships in the sessur category. The size of warship was also dictated by the nature of warfare characteristic to the Baltic realm. The ships which carried horses for the attack on Roskilde or Konungahella were undoubtedly built to correspond to the task.

In general, historical sources agree that Slavic naval warfare embraced either the form of major naval engagements or that of transport of regular armies to enemy territory. Besides regular warfare, there was always the activity of war parties whose main purpose was primarily of an economical nature. It is in this period that the name of viking was used for those Slavs who raided regularly Scandinavia. In Ibn Fadlan's description of Wendland the "... rivers have no names themselves but are each one called vyk, and the peoples of the narrow rivers are called vikings, which means the Northmen warriors who sail their ships up the rivers and attack settlements in such fashion."321

This appellation, generally thought to describe only raiders of Scandinavian origin,322 was applied in equal measure in the 11th and the 12th centuries to the Slavs. In Heimskringlasaga Hakon the Good sailed on the Scanian waters "[t]o fight all vikings, whoever he could find, both

321 M. Crichton, Ecstasy of the Dead—the manuscript of Ibn Fadlan relating his experience with the Northmen in A.D. 922 (New York, NY 1976) 68.

According to Saxo the viking raids of the Slavs were the major cause for the obstruction of fjords and sea inlets with artificial barriers because "Iisdem temporibus, effusis piratae habenis, a Wandalicis finibus Eidoram usque omnes per orientem vici incolis vidui ruraque culturae expertia iacuere. Sialandia ab ortu et meridie marcida situ, vastitate torpebat...Fioniae nihil residuum preter paucos incolas piratica fecerat. Falatria, spazio quam virtute contractor, incolarum fortitudine parvitas dampna pensabat...At Lalandia...pacem tamen pensione petebat...anfractus aequorum, quominus piratas admitterent, prelongis palis ac sudibus obstruebantur."  

Information about ships of the kaupskip category is very scarce for this period. The detail offered by Saxo about Duke Boguslaw's traders seems to suggest that these ships were recognized in that period by their shape and size. The shipwrecks from Kamien Pomorski, Mechinek, Czarnowsko (1), and Charbrowo (1) could be considered as examples of naves onustae, although they could belong to the ratis or myoparo categories as well. This apparent lack of functional detail seems characteristic for that period in which small craft had often a dual role.  

A similar conclusion can be drawn for the shipwreck found in Szczecin, which is thought to represent the

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323 "Ex Snorronis," MGH XXIX, 333: "[o]k drap alla vikinge, hvar sem hann fann, berti Dani ok Viinr..."

324 A well-known artificial obstruction was that built by five sunken ships in the Peberrenden channel near Skuldelev. Artificial barrages were also erected at Jydedybet, Vimmelskaftet, and Vesterrenden. The Skuldelev ships have become a major source of information for shipbuilding in the 11th century, but their role as a barrier against Slavic attacks still remains a matter of research. For details see Olsen and Crumlin-Pedersen (supra n. 204) 91-94.

325 "Ex Saxonis," MGH XXIX, 94.
remains of a vessel used for fishing and/or transport. Its small size and the method of propulsion classifies it in the scapha or cimba category. The presence of fishing artifacts suggest that this boat was, at least for sometime before the wreckage, involved in fishing activities. The Lad shipwreck seems to belong in the same category of vessels as the Szczecin boat. Before wreckage it was apparently used to transport building materials, a fact which does not clarify its original function.\textsuperscript{326} Besides this, the vessel seems to present a combination of maritime and inland shipbuilding traditions. The T-shaped keel, the lapstrake method of hull construction, the use of animal hair as caulking material, and the double-ended shape are characteristic of the shipwreck group located mostly along the Baltic coast. On the other hand, the sharp turn of the bilge and the transverse reinforcement system suggest a close relationship with the medieval prams from Egersund, Falsterbo, Treiden and Elbląg,\textsuperscript{327} and with the modern inland craft of that area.\textsuperscript{328} The reshaping of one of the floor timbers suggests that the vessel was initially built in accordance with the Wendish maritime tradition and afterwards was rebuilt for heavy transport on inland waters. This idea is supported also by the 1.05 m interval at which ribs/long floors were inserted in the hull, an interval which is typical of vessels with oared propulsion.

Historical sources relate also about some of the nautical qualities of these vessels. They were superior to

\textsuperscript{326} Zeylandowa (supra n. 127) 169-170.

\textsuperscript{327} Ellmers (supra n. 91) 104, figs. 77-79.

\textsuperscript{328} J. Litwin, "Współczesne szkutnictwo ludowe nad Warta," Nautologia 1 (1986) 46: "Łódź ta, choć zbudowana na stepce i mająca zakładowe poszycie, jednakowo i znacznie pochylonymi stewartami przypomina może obecnie stosowane łodzie."
Danish warships in velocity under oars, but were seemingly inferior in stability under sail. The dimensions and the construction of transverse mast-steps found in the excavated shipwrecks suggest lightness, which is undesirable in a mast support at work in heavy weather. This might explain the passage in Saxo about the wreckage of a Slavic fleet off the island of Møn, although such evidence is insufficient in itself to characterize the overall performance of the masts and rigging of Slavic ships.

The dimensions of mast-sockets also suggest moderate dimensions for the mast, and implicitly for the sail. The mast-steps from Puck 2, Frombork and Bagart show a more stable structure for the mast support system. However, the last two vessels are thought of as remains of an East Baltic shipbuilding tradition, while the Puck 2 longitudinal mast-step has strong analogies in the Scandinavian shipbuilding.

The ability of Slavic ships to navigate in the shallows, clearly stated by Saxo in his chronicle, allowed them to evade the Danish warships. This suggests that these ships had a shallow draught, a feature which is in accordance with the data obtained from shipwrecks found on the southern shore of the Baltic. These shipwrecks exhibit a flat-bottomed hull shape and very little variation in the height of the T-shaped keel, which made them perfectly adapted to the shallowness of the southern Baltic coast and to navigation in estuaries and on the rivers. As previously mentioned, this hull shape constitutes one of the features characteristic for the group of wrecks from the southern Baltic shore. In this

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329 Lienau (supra n. 7) 14.
respect, they separate themselves from the Scandinavian ships, where the underwater hull has a pronounced wine-glass shape.\textsuperscript{330}

Velocity and draught are influenced also by displacement. In this respect, the superior performance of Slavic vessels was favored by the lightness of their hulls. Archaeological evidence indicates that this was obtained by a simpler skeletal structure and by the use of lighter planks.

Apart from these few details which seem to match the archaeological evidence, historical sources are void of any reference about the method of construction or the choice of wood used in these vessels. The only source of technical knowledge seems to be offered by shipwrecks found on the southern shore of the Baltic Sea. However, ships represent mobile units, and as such they cannot be interpreted a priori as proofs of local shipbuilding unless distinct features indicate their autochthonous provenience.

In this regard, the shipwrecks from the southern shore of the Baltic indicate several details which classifies them as a group despite their different locations. The most common characteristics can be listed as follows:

1. T-shaped keels with minimal variation in the moulded dimension; 90-degree angle between flanges and web; m/s ratio lower than 1; maximum sided in the midship section.

\textsuperscript{330} This statement concerns the "classical model" of Scandinavian vessels as seen in Viking Age shipwrecks and ship remains. The fact that flat-bottomed ships started to appear in southern Sweden and Denmark after 1000 constitutes another matter related to economic factors. Falsterbo, Galtabäck, Kelmarl, Eltang Vig were ships expressly built as cargo carriers. The wine-glass hull form was adapted to the large structure of cargo carriers, and this can be clearly seen in the Skuldelev 1, Lynæs, and Sjøvollen vessels.
2. Vertical flat scarfs between keel and posts.
3. Double-ended hull.
4. Lapstrake construction.
5. Plank thickness between 1.5 cm and 2.5 cm.
6. Wedged treenails 1.2 cm in diameter for fastening strakes to each other.
7. Moss luting in Pomerania proper; animal hair to west of the Odra and east of the Vistula river.
8. Floor timbers not fastened to the keel; underface joggled; having tendency to be naturally-curved timber; fastened to planks with treenails.
10. Use of knees for stiffening joints between beams and upper hull.
11. Use of stringers to reinforce sheer strake.
12. Transverse mast-support system.
13. Oak as preferred material (with several exceptions) for all ship parts.

This summary of the main characteristics of the southern Baltic shipwreck group shows that from a theoretical point of view all timbers from these shipwrecks have Scandinavian parallels. The best example is the combination of floor timber, beam (ON. biti) and knees, which illustrates the basic transverse system used to reinforce Viking Age Scandinavian vessels. However, the similarity stops at this level, because the technical details of each hull member suggest differences in dimension and shape. The main result was that the Slavic and the Scandinavian vessels did not differ in their general appearance, which explains the confusion of the inhabitants of Konungahella in 1134 and of the Pomeranian Duke Bogusław in the naval battle of 1184. The difference
in technical detail is not limited to the individual hull members but also to the construction in general.

One of the major features which characterizes the southern Baltic shipwrecks as a group is the use of treenails instead of rivets to fasten the planking strakes together. This feature, already stressed in the scholarly literature, appears rather awkward in a period when iron was used by the Wends as primary material for tools, weapons, and other domestic items.\(^{331}\) This impression is strengthened by the fact that iron was the principal fastening material in Scandinavian shipbuilding. However, the use of treenails cannot be considered primitive.\(^{332}\) The mechanical strength of a treenail is comparable to that of an iron rivet.\(^{333}\) Furthermore, the treenail is easy to procure in forested areas and does not require specialized tools or workshops for its fabrication. Nor are treenails corroded by the gallic acid in oak planks,\(^{334}\) and this may have been one of the reasons the hull planking of the Southern Baltic shipwrecks was joined together by treenails and not rivets.

The choice of wood used for the treenails points to other interesting details. Willow, used for treenails in the Eckernförder shipwreck, is a light, low density, soft

\(^{331}\) Herrmann (supra n. 314) 84-87.

\(^{332}\) T. Delimat (supra n. 16) 49-50.


\(^{334}\) P. Wagner, "Wood species in Viking Age Shipbuilding," in O. Crumlin-Pedersen and M. Vinner eds., *Sailing into the Past. Proceedings of the International Seminar on Replicas of Ancient and Medieval Vessels, Roskilde 1984* (Roskilde, Denmark 1986) 132: "If I should mention a drawback with oak, it is that gallic acid in the wood corrodes iron nails. I do not know whether this fact may account for the use of treenails instead of iron nails in some cases."
wood with low bending strength which is not resistant to shocks but dries fairly rapidly.\textsuperscript{335} Because of its qualities it did not cause cracks in the seam.\textsuperscript{336} Its property to absorb moisture and to dry fairly rapidly made it suitable as a treenail material. It was also used in Skuldelev 1, 2, 3, and 5 and in Hedebjörn 1, which seems to suggest a certain regional preference.

The use of pine in Gdańsk (now Gdansk), Orunia, Czarnowsko 1, and Szczecin and juniper in the Czarnowsko 1 shipwreck suggests that softwoods were preferred as treenail material in Pomerania. In contrast to willow, pine has a medium movement (3-4.5\%) and is tougher, stiffer, and more resistant.\textsuperscript{337} In laboratory tests pine was comparable to oak in resistance to tensile, compressive, and shearing forces, and even superior in elasticity.\textsuperscript{338} These properties qualify it as a better choice than willow, although it is obvious that each species of wood has its own inherent advantages and disadvantages.\textsuperscript{339}

\begin{tabular}{|c|c|c|c|}
\hline
Wood & Tensile & Compressive & Shear & Elasticity \\
\hline
pine & 33 & 590 & 105 & 140,000.00 \\
oak & 40 & 650 & 110 & 130,000.00 \\
\hline
\end{tabular}

\textsuperscript{335} \textit{Handbook of hardwoods} (supra n. 173) 253.

\textsuperscript{336} Wagner (supra n. 334) 134.

\textsuperscript{337} \textit{A Handbook of Softwoods}, Forest Products Research (London 1957) 42-44.

\textsuperscript{338} Kollmann (supra n. 333) table 5; the following strength values were obtained for \textit{Pinus Sylvestris} and \textit{Quercus sessiliflora} S. (values in kg/cm²):

\textsuperscript{339} It is not known yet whether the choice of treenail material was related to the ship function, inasmuch as the present data is insufficient for such analysis, and the use of treenails from the same species was observed in both warships (Skuldelev 2 and 5) and traders (Skuldelev 1 and 3). However, the Scandinavian example may be biased, since treenails were not the main fastening material used in those ships.
The use of moss has been reiterated in the scholarly literature as the second major characteristic of southern Baltic shipwrecks. In his 10th-century account about the Slavs, Ibn Ja'qūb mentioned that moss was used to fill in the joints of their bathhouses and the seams of their ships.\(^{340}\) The parallel between house construction and shipbuilding can be perceived also in the method of construction; east of the Odra/Oder river houses were built in the wall-first method since the beginning of the Hallstatt period,\(^{341}\) while early medieval vessels were built in the shell-first method. The use of moss as luting material is documented throughout the modern period up to the present time,\(^ {342}\) which gives weight to the idea that the use of moss could have been initially a "technical borrowing" from house building practices.

As previously mentioned, the use of moss seems to dominate only regionally and not over the entire southern Baltic area, animal hair being equally employed in the luting of seams. It is worth mentioning that those southern Baltic shipwrecks in which moss was used for luting were caulked with animal hair in later repairs (Szczecin, Lad), while in the Fotevik 5 vessel, where animal hair was used for luting, repairs were caulked with moss.\(^ {343}\) This exchange


\(^{341}\) T. Chrzanowski and K. Piwok, Drewno w polskiej architekturze i rzeźbie ludowej (Warszawa 1981) 11.

\(^{342}\) K. Waligórska, "Konstrukcja statków piwających po Sanie i Wiśle w XVIII wieku," Kwartalnik Historii i Kultury Materialnej 8/2 (1960) table 3; also Smolarek (supra n. 14) 288.

\(^{343}\) Filipowik (supra n. 122) 93. However, it should be pointed out that there is a marked difference in the species used on the southern shore of the Baltic (Drepanoclados sp.) and the species used in Fotevik 5 (Rhytidialdelphus s. and Thuidium t.). According to Filipowik, Drepanoclados was never used in Scandinavian shipbuilding, although its
suggests that both materials were known for their watertight properties on both sides of the Baltic, and that "a reciprocal exchange of experience and influences has taken place in the area."\(^{344}\)

On the other hand, the shipwrecks from the southern shore of the Baltic show a surprising unity in the choice of construction material. All wrecks were of oak; only a few timbers were made of other species of wood. This homogeneity in the choice of building material suggests not only practical knowledge of wood properties of different species of wood, but also points to a local origin for these shipwrecks. In the early medieval period, the littoral zone of the Southern Baltic, and especially the lagoons formed at the mouth of rivers from this area, were well forested with oak of good quality which provided an excellent material for shipbuilding. Oceanic oak and mixed stands of oak and spruce were also found in Southern Sweden, Gotland, Öland, and Denmark,\(^{345}\) but by the end of the Viking Age, these supplies seem to be almost depleted by the extensive use of wood in shipbuilding and defensive works.\(^{346}\) In this regard, a good comparison is offered by

distribution area includes South Sweden and Denmark.

\(^{344}\) Supra n. 122, 93. The use of human hair in Ralswiek 1, 2, and 3, and Wolin strengthens the idea of experiments with watertight materials. From another point of view, the use of bison hair in the Bagart shipwreck suggests, contrary to Conwentz's opinion, that the vessel was locally built. The European bison, *Bison europaeus*, once distributed over a large area of continental Europe, was limited in 1851 to Lithuania, Moldavia, Wallachia, and Caucasian mountains. Their absence from the arctic and subarctic zones was explained by the fact that grass was not in sufficient supply to support large ruminants. For details see G. Vasey, *Delineations of the ox tribe; or the natural history of bulls, bisons, and buffalos* (London 1851) 40-44.


\(^{346}\) Wagner (supra n. 334) 136.
the parallel between the wood species used in the Skuldelev ships and the shipwrecks from the Southern Baltic shore. According to Wagner, eight species of wood were identified in the construction of the Skuldelev ships,\(^{347}\), while only six wood species were used in the construction of the entire group of shipwrecks (21) from the southern Baltic region. However, this data can be easily misinterpreted. We must take into consideration that Skuldelev 1, 2, and probably 6 were not built in Denmark. This would lower the figure obtained for the Skuldelev group to only four wood species as observed in the locally-built vessels (Skuldelev 3 and 5). However, even this result shows the contrast in wood diversity between the Skuldelev finds and the southern Baltic shipwreck group. This difference seems to strengthen the idea that the shipwrecks from the southern Baltic region were locally built.

The last issue concerning these shipwrecks is their chronological sequence which is far from being established. The following dates were obtain by the use of an array of methods ranging from geological observations through the C14 analysis:

<table>
<thead>
<tr>
<th>Shipwreck</th>
<th>Date</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eck</td>
<td>8th-10th</td>
<td>C14, A</td>
</tr>
<tr>
<td>R1</td>
<td>9th</td>
<td>A</td>
</tr>
<tr>
<td>R2</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>R4</td>
<td>9th</td>
<td>S</td>
</tr>
<tr>
<td>G-01</td>
<td>10th-11th</td>
<td>P, S, T</td>
</tr>
<tr>
<td>G-02</td>
<td>10th-11th</td>
<td>P, S, T</td>
</tr>
</tbody>
</table>

\(^{347}\) Supra n. 334, 131.
Table 25. (continued)

<table>
<thead>
<tr>
<th>Shipwreck</th>
<th>Date</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-O3</td>
<td>10th-11th</td>
<td>P, S, T</td>
</tr>
<tr>
<td>Bg</td>
<td>8th-11th</td>
<td>A</td>
</tr>
<tr>
<td>Fr</td>
<td>6th-7th</td>
<td>T</td>
</tr>
<tr>
<td>P1</td>
<td>1250 +/- 15</td>
<td>C14</td>
</tr>
<tr>
<td>P2</td>
<td>550 A.D.-8th</td>
<td>C14</td>
</tr>
<tr>
<td>P3</td>
<td>8th-13th</td>
<td>A</td>
</tr>
<tr>
<td>P5</td>
<td>9th-10th</td>
<td>C14</td>
</tr>
<tr>
<td>Me</td>
<td>11th-12th</td>
<td>A</td>
</tr>
<tr>
<td>Chl</td>
<td>920-930</td>
<td>C14</td>
</tr>
<tr>
<td>Cz1</td>
<td>11th-12th</td>
<td>A</td>
</tr>
<tr>
<td>Sz</td>
<td>10th</td>
<td>C14</td>
</tr>
<tr>
<td>Ląd</td>
<td>6th-9th</td>
<td>C14</td>
</tr>
<tr>
<td>KP</td>
<td>9th</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>12th-13th</td>
<td>C14</td>
</tr>
</tbody>
</table>


The uncertain dating of some of these wrecks, such as the one found at Frombork, makes it difficult to interpret these finds on a chronological scale, particularly since they represent different types of vessels. The oldest shipwrecks are those found in Szczecin and Eckernförder Bay, followed by a group of eight finds dated in the 9th and the 10th centuries. The last phase of the early medieval period (950-1300) is represented by the Gdańsk-Orunia, Mechlinek, Puck 1 and 5, and Kamień Pomorski shipwrecks. This can be clearly seen by arranging the approximate average of each proposed date in the following chronological sequence:
Table 26. Chronological sequence of shipwrecks

<table>
<thead>
<tr>
<th>A.D.</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Fr?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Eck</td>
<td>R1</td>
<td>R4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>P3</td>
<td>Bg</td>
<td>Cz1</td>
</tr>
<tr>
<td>10</td>
<td>Lad</td>
<td>G-01</td>
<td>G-02</td>
<td>G-03</td>
</tr>
<tr>
<td>11</td>
<td>Me</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>KP</td>
<td>P1</td>
<td>P5</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From a typological point of view these shipwrecks show a slight evolution of their technical features. The rounded hull form of the Szczecin boat becomes more flat-bottomed as seen in the Czarnowsko; the rounded keel-plank from the same vessel seems to have been replaced by a fully developed T-shaped keel. Nevertheless, this comparison is probably biased by the small sample size currently available. The futility of such an analysis is furthered by the fact that these shipwrecks seem to represent different ship types.

In conclusion it can be said that historical sources together with the available archaeological evidence support the idea that on the southern Baltic shores the Slavs initiated, developed, and maintained a strong maritime presence. At the height of their expansionist period, they controlled the western Baltic region, and even colonized
the Danish islands of Falster, and Lolland. The historical depiction of their vessels seems to confirm the archaeological evidence. These ships were flat-bottomed, easy to manoeuvre, and had the advantage of a shallow draught. They were suited for the natural conditions of the southern Baltic region characterized by a low coastline, sandy beaches, shallow estuaries, and marshes. The performance of these vessels constituted a great challenge for the maritime kingdom of Denmark, and it was not until the German expansionism took its toll on the Slavic lands that the Danish leidangr ships could exercise control over the Western Baltic. After the battle of Greifswald Bay, the Slavic maritime puissance ceased to exist. Following the sure but steady rise of a Hanseatic maritime presence in the Baltic, Slavic shipbuilding was restricted for the ensuing centuries only to vessels used for local transport and fishing.

\[348\] This is attested by the Slav nobility attending the Danish court (Pribislav for example) and their Danish fiefs; by the finds from Fribrødre Å; and by toponymy such as Korselitse, Jerlitse, and possibly Fribrødre/Pribrod in Falster, Kramnitse, Binnitse, Tillitse, Kuditse, and Vindeby in Lolland. For details see Steenstrup (supra n. 274) 111-112; also Christiansen (supra n. 267) n. 139, 755.
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APPENDIX

GLOSSARY OF SHIPBUILDING TERMS

The glossary of shipbuilding terms, which illustrates words used in the text, is intended to help in the understanding of basic terms characteristic of Northern European medieval shipbuilding and as such, it should be considered as a supplement to main nautical dictionaries.

**Afterdeck.** Deck situated at the stern of a vessel (ON. *lyping*).

**Amidships.** The longitudinal center of a vessel. See *midship*.

**Back rabbet line (margin line).** The line formed by the inner side of the garboard strake with the keel or the posts.

**Beam.** Transverse timber which touches both sides of the hull. It constitutes the main element of lateral reinforcement in early medieval hulls built in the Baltic region. Depending on its position in the hull, the beam can be a ON. *biti* or a thwart.

**Bearding line.** The line formed by the outer side of the garboard strakes with the keel or the posts.

**Bevel.** Tapered end of a plank obtained by carving in the edge(s) to the desired angle of joint.

**Bilge (turn of).** Denotes the transition from bottom planking to the side planking.

**Bit.** Vertical post situated at the deck level/sheer strake used to fasten mooring cables.

**Blade.** The active part of a quarter-rudder characterized by width and asymmetrical proportions.

**Boss (Wart).** Robust piece of wood designed to hold the
rudder away from the hull. It was drilled in the center for the rudder withy.

**Bow.** The foremost part of a vessel.

**Breast hook.** Curved piece of wood fastened at the ends of a vessel at the sheer strakes and stringers. In Gdansk Orunia 1 it was not fastened to the sternpost.

**Bulkhead.** Vertical partition within a hull. In the case of Bagart it consisted of a large board inserted into a grooved floor timber/rib.

**Caulking.** Material of vegetal or animal provenience inserted in the joints of a preassembled hull to make them watertight. Often it was covered with tar or other resinous substances.

**Centraline.** The theoretical plane which divides a vessel into two symmetrical parts along its longitudinal axis.

**Cleft.** Small shallow notch carved into the inner side of a post.

**Clinker (built).** The method of hull construction characterized by overlapped strakes fastened to each other with rivets. In this case, the term denotes the way of fastening according to ON. hnoðsaumr (riveted seam), hnjoða, hnita (=to hit, to pound).

**Cog.** Northern European merchant vessel developed in the early medieval period and characterized by full body lines; keel-plank; flush-laid bottom planking (Southern Baltic only); clenched lap side planking; moss caulking; raked, partially rabbeted, and straight stem and sternpost.

**Deadrise (angle).** The angle of the bottom planking measured from the horizontal plane which passes through the head of the keel.

**Deck.** Boards laid horizontally below the sheer strake to cover the interior of a vessel. They can be laid in between bitar (Skuldelev 3, Gokstad 1,
Oseberg) or at the upper beam level (Skuldelev 1). Deck space for the helmsman (ON. lyting, -ar) seems to have covered the space after and forward of the rudder frame.

**Dinghy.** Small service boat (ON. skipbátr) which could have been either stored behind the mast (ON. yfirbátr) or towed behind the ship (ON. eptirbátr).

**Double-ended (vessel).** Vessel with similar bow and stern shape.

**Draught.** The depth of hull immersed in the water, sometimes called the live work as opposed to the dead work, which is the hull above the waterline.

**Drop-strakes.** Strake whose ends are nailed to adjacent strakes and not to the stem or sternpost.

**Dugout.** Craft built out of a single trunk of wood. According to the method of construction and the kind of wood employed, the dugouts are classified as hard- and soft-dugouts.

**Flange.** The horizontal part of a T-shaped keel.

**Floor (timber).** Curved transverse timber set on top of the keel with its arms extended toward the turn of the bilge on both sides of the hull. Usually, it was joggled underneath to fit the run of the planks.

**Flush-laid.** Method of hull construction where strakes are laid edge-to-edge. As opposed to carvel-built, the term does not imply any connotation defining the fastening method.

**Frame.** Main transverse reinforcement system composed of one (rib) or several joined elements.

**Futtock.** Short timber used to reinforce the sides of the hull. In Slavic shipbuilding it was generally scarfed onto the heads of the floor timber, the whole assemblage, when preassembled, being known as a made frame.

**Garboard.** First pair of strakes to either side of the keel.
Groove. Shallow longitudinal cove observed in the lands of strakes or in the upper surface of some of the floor timbers found at Bagart.

Half-frame. Timber, used for transverse reinforcement of a hull, which stretches from the keel up to the sheer strake.

Head (of floors, of keel). The uppermost extremities of a floor timber or the point where the flanges meet the web in a keel.

Heel. Temporary inclination of a sailing vessel from the vertical axis in the transverse plane.

Hood end. The end of a strake (ON. hals, -ar) to be fastened either to a post or to a wing.

Inwale. Stringer fastened to the inner side of the sheer strake as seen in Gdańsk-Orunia 1, Puck 2, etc.

Joggle. Stepped carving of a floor timber in order to fit the shape of another element. The vertical difference between the two sides of the same scarf.

Keel. The longitudinal timber placed at the centreline of a hull bottom.

Knee (long, short). A naturally-curved timber used to reinforce the angular joint of two timbers in a hull. A short knee is the knee whose horizontal arm is fastened onto the end of a beam/thwart. A long knee has its horizontal arm extended to the other bord as a beam/thwart.

Land. The area of seam where two strakes overlap.

Lapstrake. Method of hull construction where the seams of the overlapped strakes are secured with a variety of fasteners, such as treenails, treenails and rivets, clenched nails (clenched lap) or iron nails driven through treenails. In Southern Baltic shipbuilding it denotes that method of construction where overlapped strakes are fastened to each other with treenails.

Loom. The part of a rudder or oar which connects the blade
with the tiller or handle. In opposition with the active part, the blade, the loom is considered the passive part of a rudder or of an oar.

Luting. Material of animal or vegetal origin inserted in the joints of a hull before assemblage.

Mast (-step, -foot). Vertical pole set about amidship to support the yard and the sail. The mast-step is the mortise cut either in a timber set longitudinally onto the keel (ON. kerling) or in a floor timber, and its purpose is to receive the heel of the mast. In some of the Slavic vessels, the mast-step was a three-sided notch cut either in a main floor timber or in a separate piece of wood, with the fourth side covered either by another piece of wood or by the floor timber itself. The mast-foot is the length of mast below the lowermost beam.

Middle body. The length of the hull where the planking seams run on almost parallel lines.

Midship. The place of maximum breadth in a hull. In Slavic vessels the maximum breadth seems to coincide with the geometric middle of the hull, although the reconstructions of Bagart and Mechlinek shipwrecks point rather the opposite.

Mortise. Rectangular or square cut of variable depth made to receive another element.

Moulded. The vertical dimension of a timber.

Oarlock. Support for the loom of oar situated either on a separate timber attached at the upper edge of the sheer strake or directly on the sheer strake.

Oarport. Opening in one of the upper strakes of the hull for the oar loom.

Overlap. The method of fastening in which the edge of one element overlays the edge of the other element.

Parrel. Naturally-curved piece of wood (ON. rakki) which serves to fasten the yard to the mast.

Plank. Long wooden board used in the building of the hull
of a vessel. A plank bears a different name, depending on its position in a hull.

Post. Wooden timber fastened at both ends of a keel designed to hold the ends of the planks or the wings of a vessel.

Pram. Term used for flat-bottomed vessels (OSl. pramů, ON. pramr, Pol. prom) used in inland navigation.

Rabbet (line). The longitudinal groove located on the either side of a keel, stem, and sternpost carved for a better seating of the edges of planks. The rabbet line is the place of seating of the lower edge of the garboard.

Rake. The horizontal length corresponding with the inclination of a stem or a sternpost from their vertical position.

Rib. Frame made out of a single piece of wood that runs from one side of a vessel to the other.

Rigging. Generic term used to designate the ropes used to support the mast (fixed rigging) and the ropes used to manoeuvre the sail and the yard (running rigging).

Rivet. Metal fastener composed of a nail whose end is hammered over a rove.

Rove. Metal piece of variable shape perforated in the middle in order to allow the end of the nail to pass through.

Rubbing strake. Wide stringer fastened at the upper outer edge of the sheer strake as seen in the vessels from Gdańsk-Ozunia 2 and 3, Ład, etc.

Rudder (frame). Steering device which has the appearance of an oar with a shorter loom and a longer blade. The rib to which the rudder was fastened is called the rudder frame.

Quarter rudder. Rudder mounted on the side of a vessel close to the stern.

Scarf. Beveled end of a timber ready to join another timber
prepared in a similar way.

**Scuttle.** To sunk a vessel intentionally.

**Seam.** The overlap between strakes where fastenings are driven.

**Service boat.** See Dinghy.

**Sheer (strake).** The uppermost strake in a hull.

**Shell.** The outer lining of a hull; the planking of a hull.

**Sided.** The horizontal dimension of a timber.

**Side-planking.** The planks of the sides of a vessel above the turn of the bilge.

**Skeleton.** All timbers used to reinforce the hull planking from inside.

**Stanchion.** Vertical post used to support a beam inside the hull.

**Starboard.** The right side of a vessel viewed from the stern. In the Baltic shipbuilding it usually denotes the side where the quarter-rudder is attached (ON. *stjórnborði*).

**Stealer.** See Drop-strake.

**Stem.** The post fastened at the forward end of the keel.

**Step(ped).** See Joggle.

**Sternpost.** The post fastened at the after end of the keel.

**Strake.** Planks scarfed to one another to form a continuous line of planking from sternpost to stem.

**Stringer (shelf-).** Timber used to reinforce the hull longitudinally. A shelf-stringer additionally supports transverse elements within a hull.

**Thole-pin.** Wooden pin inserted vertically into the sheer strake or inwale which served as pivot for the oar movements. The detached oarlock from Puck
indicates that thole-pins were also made from a naturally-grown timber.

**Thwart.** Upper beam which served as seat for rowers.

**Treenail.** Cylindrical piece of wood carved with a distinct head and used to fasten parts in a hull.

**Wart.** See **Boss.**

**Web.** The vertical part of a T-shaped keel.

**Wedge.** Tapered piece of wood used to lock a treenail in place.

**Wing(s).** Piece(s) of wood (ON. hlutr, -ar) set between the hood ends of strakes and the post.

**Withy.** Elastic wooden twig used to fasten the quarter rudder to the boss.
VITA

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Born on the 23rd of April, 1964 in Bucharest, Romania.


Between 1983 and 1987 Mr. Indruszewski completed all requirements for both Bachelor of Arts and Master of Arts degrees in History and Philosophy, at the University of Bucharest. He successfully defended his thesis - the first Romanian academic work on the subject of maritime archaeology - in July 1987. During his study years, Mr. Indruszewski participated in underwater surveys in Poland and worked as research assistant at the Institute of Archaeology in Bucharest.

In 1987 Mr. Indruszewski was named in a teaching position at the Liubcova Elementary School.

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In 1990 Mr. and Mrs. Indruszewski left Greece for Phoenix, Arizona. Mr. Indruszewski was hired as custodian at St. Francis Xavier Grammar School in Phoenix.

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