The Tune Viking Ship Reconsidered

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The Tune Viking ship has been a riddle for more than 150 years, since being found within a burial in the Oslo fjord area in 1867. It was long thought that the ship’s freeboard was too low for it to have crossed the North Sea. Advances in documentation methods and a detailed study of the preserved parts of the ship have provided new data, and this article outlines a new proposal for how the ship looked when it was built in the early 10th century AD. The Tune ship is reinterpreted as a seagoing vessel, in no way inferior to the Oseberg or Gokstad Viking ships.

Key words: ship archaeology, Tune ship, burial mound, Oseberg, Gokstad, laser scanning, Viking.

In 1867 the Tune ship emerged from the earth of Østfold, making it the first well-preserved Viking ship to be found in the Oslo fjord area. The landowner at Nedre Haugen, Ole Arnesen Haugen, reported the ship discovery at his farm in Rolvsøy (Fig. 1). The ship was named after Tune, a parish in the county of Smaalenen, today in the municipality of Sarpsborg. This article reviews the history of the find, then, based on the author’s doctoral research, presents a reconstruction of the ship and discusses its potential as a seagoing vessel (Paasche, 2010).

The excavation

To present a reconstruction of the Tune ship it is first necessary to discuss some of the events surrounding its discovery and the investigations that took place at that time, as the relatively rough treatment the ship received undoubtedly left its mark. The on-site investigations were conducted by civil engineer B. Chr. Arntzen with the assistance of local workers. Oluf Rygh, at that time director of the Oldsaksamlingen (Antiquities Collections) and a newly appointed professor of history, was notified of the find by post in the autumn of 1867 and given responsibility for the excavation. Alongside the letter was the first sketch of the ship, which included an image of the stern, a section, and some details of one of the frames, the mast partner, and the rudder (Fig. 2). Work was completed in 14 days at the end of September and the beginning of October 1867, with a further eight days spent transporting the ship to Oslo (Arntzen, 1868: 3; Brøgger, 1921: 7). This very short period alone indicates that the ship was not handled with care. Among other indications, there are several marks from the spades used to remove clay from the underside of the ship. The excavation was described by Haakon Schetelig in a publication of 1917, again by Schetelig and Brøgger in 1950,1 and, most vividly, by Marstrander in a book of 1986.

The landowner, Ole Arnesen Haugen, had already begun removing earth from the site in the early 1860s, meaning that the contents of the barrow had been exposed to the air for a substantial period before the ship was discovered and excavated in 1867. This is probably one of the main reasons why the ship’s hull is not preserved above its waterline. The earth beneath the ship was mainly clay, and that above was a mixture of humus and sandy soil. The best-preserved parts of the ship lay in the middle of the grave, where the soil was most dense. The extremities of the ship were located at the edge of the mound where the soil or clay layer was thin; this was probably a major reason for the gradual deterioration of the stems.

Even though parts of the fore and aft of the ship, both stem and stern, were missing, along with most traces of rig and sail, the central parts of the ship survived including ten strakes on each side, the keel in one piece, keelson with the mast step, a mast fish, 13 floor-timbers with ten of them paired with thwarts, knees, and beams. Except for the thwarts made of pine, the rest was entirely made of oak. The hull is a lapstrake construction with clenched nails joining the planks. The keel is T-shaped and has a transition piece in the aft. The rudder was found lying in the aft of the ship. Cleats were used to lash the planks to the floor-timbers, but the upper knees were fastened with treenails going through the hull from the outside.

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To get the ship out of the barrow and down to the local river, the Visterflo, a wooden frame was nailed to the underside of the ship. This wooden frame can be seen in the photographs of the Tune ship taken in the university garden, after the ship had arrived in Christiania (Fig. 3). The ship was pulled down to the river with the help of horses from nearby farms. There it was placed on a barge, floated and towed down to the local town of Fredrikstad, and then taken by boat to the capital. The burial mound must have been clearly visible from the river, the lake, and the surrounding region (Fig. 4). After the Tune ship arrived in Christiana, it was temporarily stored in a shed in the university garden. But later that year, the ship was placed in its own building specially designed by the architect Georg Andreas Bull. This building was torn down in 1911 to make way for the University Aula, and the Tune ship was deposited behind another university building at Fredriks gate 3. It reached its present location at
the Viking Ship Museum at Bygdøy only in 1932 (Figs 5 and 6). Except for treating its exterior with carbolineum (or creosote), turpentine, and linseed oil the ship received no other conservation treatments.

Archaeological context

Viking Age finds from Haugen farm in Tune and nearby areas are described in a number of archaeological texts (Schetelig, 1917a; Brogger; 1921; Johansen, 1986; Johansen, 1994). More recent publications are the first volume of Østfolds Historie, which includes a full description of the Tune ship as well as a comprehensive discussion of Viking Age finds from the area (Norseng and Stylegar, 1999), and Jan Bill’s discussion of the history of the ship find or finds at Rolvsøy (Bill, 2017).

The burial mound at Haugen was approximately 4m high and 80m in diameter (Schetelig, 1917a: 5), making it the second-largest burial mound discovered in Norway to date; only surpassed by Raknehaugen on Romerike (Skre, 1997: 26). The Tune ship sat with its keel at the base of the mound and was oriented almost directly north-south. The remains of a four-sided burial chamber of vertical planks of oak were found in the middle of the barrow. These were set into the clay partially outside the ship’s railing. An example of a similar grave chamber is found in Queen Tyra’s barrow at Jelling in Denmark (Schetelig, 1917a: 6; Krogh, 1993: 93). In Brogger’s reconstruction drawing, the burial chamber is set into the clay around the ship (Brogger, 1921: 12). The inside of the ship’s hull was covered with a thin layer of moss, and there was residue from juniper branches. The rudder was found lying across the ship’s stern, behind the mast. Otherwise, only a few small grave goods are preserved: two glass beads, a piece of carved wood that Schetelig interpreted as part of a saddle, and some simple wooden items. According to the engineer Arntzen, all wooden items were made of oak (Arntzen, 1868: 1). Brogger and Schetelig describe small wooden items, including animal figures, with carved ornamentation in high relief (Schetelig, 1950: 86).

Today, the level of preservation makes it very difficult to recognize these details. There are also records of evidence of iron items too damaged by rust to be saved, including a piece of rolled-up chainmail and a large lump of iron at the southern stem, believed to be the remains of an anchor. Furthermore, excavators discovered the remains of a human skeleton, some preserved remnants of textiles and clothes, and three horse skeletons—one inside and two outside the ship. Additional finds included part of a ski, the remains of a sword, two spearheads, a shield boss, a wooden spade, a wooden lever, and a bung for a barrel (Rygh, 1867: 4; Schetelig, 1917a: 7). Based on the overall composition of the discovery, the ship was dated to the Viking period (Rygh, 1867).

Although there are few published contemporary vessels of approximately the same size as the Tune ship (15–20m), some should be mentioned: for example, the largest of the two Kvalsund boats (18.5m), Skuldelev 1 (16.3m), Skuldelev 5 (17.3m), Åskekær 1, dated AD 977 (15.8m), and Hedeby graveyardship (17–22m) (Lindoe, 1930; Borg, 2000; Crumlin-Pedersen and Olson, 2002). The ship from Kvalsund is 200 years earlier than the Tune ship (AD 690) and was an oared vessel, and the Skuldelev ships are more than a 100 years later. Of course, the Gokstad and Oseberg ships, both burial finds from the same area and the same period, are the most important parallels (Nicolaysen, 1882; Brogger et al., 1917). There are also important iconographic and runic material sources for the earliest Viking ships (Jesch, 2001; Heide, 2014).

Previous reconstructions

The Tune ship was the first reasonably well-preserved Viking ship to be archaeologically excavated, the Borre ship excavation in 1852 having revealed only a few nails from the ship itself. The ship was roughly sketched on site, first probably by the landowner O. Haugen and secondly by B. Chr. Arntzen, the engineer conducting the excavation on site. Later on, E. Skari painted a watercolour of the ship in perspective (Fig. 7) (Haugen, 1867; Arntzen, 1868; Skari, 1869). In Schetelig’s 1917 publication, he included a plan and profile drawing of the ship, as well as cross-sections of the individual frames (Schetelig, 1917a: Chart I-III). The drawing is both a record and reconstruction of the discovery (Fig. 8). The strakes in the hull and internal timbers are also shown on a clear and technically sound ink
Figure 6. The Tune ship find as displayed in the Vikingshipmuseum in Oslo (photo Atle J. Johnsen).

Figure 7. E. Skari, 1869, watercolour painting (Universitetets Oldsaksamling, Museum of Cultural History/University of Oslo).

drawing by Bergen Museum’s artist, M. Abel, that is included in Schetelig’s publication; however, none of these early drawings are truly accurate representations. For instance, in Schetelig’s drawings, a ruler has been used to straighten deformed parts of the hull. It is clear that the frames are straightened, and their positions have been adjusted. Since only those ship parts that survived are shown, Schetelig’s drawings do not qualify as reconstructions. Overall, none of these depictions can be called accurate archaeological drawings, additional documentation of the discovery, or reconstruction proposals, but rather something in between all three.

Ship engineer Fredrik Johannessen came up with a proposal for the ship’s appearance in the late 1920s (Johannessen, unpublished). Johannessen’s drawing were modified by Arne Emil Christensen in connection with an exhibition at the Viking Ship Museum in 1980 (Fig. 9). Werner Dammann later produced several ideas about the ship’s design, but he was also unable to solve the riddle or find evidence that could support a reconstruction of the ship’s main features (Dammann, 1997). Seán McGrail briefly mentions that he considered it likely that the Tune ship would originally have had more than ten strakes; however, he does not pursue this idea any further as he is merely questioning the ship’s stability when heeled under sail (McGrail, 2001: 216). It is odd that the Tune ship challenge hadn’t been thoroughly worked on prior to the project reported here.
Figure 8. The Tune ship, Shetelig i Norske Oldfann II, 1917 (Universitetets Oldsaksamling, Museum of Cultural History/University of Oslo).

Schetelig’s drawings of the Tune ship from 1917 were based on manual measurements of the original parts; but these measurements have been fared, and, through extensive use of a ruler, idealized and adapted in many ways. Regular strake lines and a high degree of symmetry on each side of the keel show that the ruler often took over from reality. The measurements from the drafting film, which can be seen today at the Museum of Cultural History in Oslo (Archive number C23838), do not always agree with those of the final drawing. The plan and layout were drawn with a ruler so that the frames were placed at right angles to the keel.

Figure 9. Front profile of the Tuneship. Drawing by Frederik Johannessen and Arne Emil Christensen (Paasche, 2010: 78).
The shape of the ship was based on the shape of the hull below the waterline and the ship’s width at the beams. The problem with this method is that some of the frames are very deformed, allowing for several different interpretations. Cumulatively, small adjustments of the floor-timbers, based on matching visible features on the frames and planking, indicate a different strake placement, and therefore ship shape. Furthermore, as Schetelig used the ship’s curves to extend the lines of the preserved strakes, neither the actual shape of the strakes nor the extension of the individual strakes is correct.

Methodology and new drawings of the ship

While working on the Tune ship a Cyra laser scanner was used for data collection creating a 3D point cloud (Fig. 10). Both the plank runs and the thickness of the strakes are clearly visible in the scans of the ship, as well as the placement of nails and joints between the various planks in the strakes. Additional drafting was carried out using CAD software, with all plotted coordinates from the laser scan transferred to AutoCAD. In order to get a correct representation of individual parts of the ship, the perspective and the section were selected in the point cloud and then lines were drawn from point to point to create an accurate drawing. The final plans were drawn by hand using three projections on the drawing board. Attempts to create a plan of the floor-timbers and strakes showed that it was possible to draw most of the sections at 1:1 based on the scan. Three different projections were drawn: the plan, sections, and longitudinal profile (Fig. 11).

Plan and profile

The plan is based on reconstructed sections at each frame station, along with a layout of the digital scan of the ship in plan and elevation. The dimensions of the strakes and keel were transferred to the plan. Here the internal strake runs are used, and the drawing is an orthographic projection of the placement of the strakes within the plan. Scarf joints are drawn where they can be detected on the original ship and transferred to the plan from the digital drawing. In the part of the ship that is not preserved, none have been inserted. The ship was reconstructed without ceiling so that its hull shape and lines can be clearly seen. The profile (longitudinal section) has been developed using the same methods as the plan. Here it is the outboard strake runs that are the starting point for the lines. For the rudder, Schetelig’s drawing from 1917 has been used.

There is no simple solution for creating a drawing of the Tune ship. In architectural documentation of a ships’ hull, it is normally sufficient to mirror one side of the keel against the other following the measurement of one side of the ship. Since ship hulls are not always symmetrical, accurate archaeological documentation requires the two sides of the ship to be measured. A good example on the Tune ship is that the ninth strake amidships on the starboard side is 0.05m wider than its equivalent strake on the port side. The construction of the Tune ship shows that the use of materials was
Figure 11. Plan drawing, longitudinal section, and cross section of the Tune ship (Paasche, 2010: 171: fig. 50).
The shape of the keel not only provides information about the ship’s construction, but also its design. The Oseberg and Gokstad ships have relatively flat mid sections then rise slowly towards the stems. A more curved keel raises the stems and increases the width of the ship’s mid section. The shape and curve are controlled through the process of laying and fairing the planks. Studies of the lap angles and the correct placement of the strakes have provided valuable information about the original design of the keel. As mentioned, the keel of the Tune ship was hewn from a piece of solid oak. The T-shape of the keel determines the placement of the first strake, which in turn determines the shape of the entire side of the ship. The keel changes from a T-shape to a rabbet at the lot, the transition piece between the keel and the stem and sternpost.

Today, the keel of the Tune ship hangs down somewhat towards the stern (Fig. 12). This does not seem to be its original shape, but a result of pressure in the burial mound, and probably insufficient support while the ship has been exhibited, as well. The unusual curve in the middle of the keel also shows that it has sagged slightly. This problem has been compounded by the weight of the mast partner and the keelson, which had probably already begun to overburden the keel within the burial mound. In the reconstruction presented here, the curvature of the middle of the keel is maintained but the sagging towards the stern, which is deemed post depositional, has been straightened out.

Stems were undoubtedly curved in the Viking Age. Straight stems were rare in the early Middle Ages and have not been found in any Viking ship excavations. The shape of the stems in this reconstruction are primarily based on the angle of the stern between the keel and the lot, as well as the lines of the strakes drawn from preserved parts of the hull. The proposed stems can be compared to two Viking Age finds from Western Norway: a stem fragment discovered at Nordre Raudeberg in Vågsøy in Sogn and Fjordane (Christensen, 1963: 97) (Fig. 13), seems to fit with the design of the Tune ship; and the lot from Raudeberg, which is almost identical to the preserved lot in the stern of the Tune ship (Paasche, 2010: 152–153). Furthermore, the find from Raudeberg can be matched with a stem from Sunnanå in Vikedal, Ryfylke (Helliesen, 1903; Paasche, 2010: 153) (Fig. 14). The mouldings, nail attachments, width, thickness, length, and overall shape and size all fit almost exactly the Tune ship. The Sunnanå stem was chosen as a starting point for this reconstruction. The characteristic bend in the stem profile on Sunnanå is also found on the Gokstad ship, as well as a boat find from Haukenes Huftern in Hordaland (Nicolaysen, 1882: Chart II; Johannessen and Schetelig 1929: 42–53). We therefore have an apparently contemporary match that fits the shape and design of the Tune ship. Although we have found very few Viking Age ships with preserved stems, and it is therefore difficult to be definitive, the Tune ship has been reconstructed with a curved stem, albeit

**Figure 12.** The keel of the Tune ship hangs down somewhat towards the stern, laser scan (Paasche, 2010: 150, fig. 41).
Figure 13. Stem fragments from Nordre Raudeberg in Vågsøy in Sogn and Fjordane (unpublished drawing A.E. Christensen).

Figure 14. Stem from Sunnanå in Vikedal, Ryfylke (Christensen, 1963: 97).

not as curved as that found on the Oseberg ship, which matches other ships built in the late 9th or early 10th century. The stern of the Tune ship starts with a steady curve of the lot. In addition to the Oseberg stem and stern, comparison can be made with the preserved part of the stern on the Gokstad ship and the smoothly rounded stem from the Skuldelev 3 in Denmark (Nicolaysen, 1882: Chart I; Schetelig, 1917b: 339; Crumlin-Pedersen and Olsen, 2002: 202).

A fragment of tapestry also from the farm Nedre Haugen depicting the stem of a ship is another important source used in this reconstruction (Fig. 15). The tapestry fragment was discovered during the excavation of another Viking Age site on the farm (Brøgger, 1921: 28; Johansen, 1986: 147–153). It provides us with a contemporary image of a Viking vessel, and researchers such as Erling Johansen fancy that it may even depict the burial of the Tune ship itself (Johansen, 1986: 150). The placement of the strakes towards the stem and the characteristic break in the rabbet shown in the tapestry are also found on the Tune ship.

The stem and stern design chosen for the Tune ship reconstruction also fits with the neighbouring preserved beams and ribs fore and aft.

**Design of ribs, beams, and knees**

Close study of the hull shows that several of the floor-timbers have spread and no longer have their original shape or position (Fig. 16). The main reason for this is probably the weight of the mound that once covered the ship has caused cracks across the grain of the wood. The knees on top of the beams originally had a sharper angle than is currently seen; cracks along their upper sides show they have changed shape and spread out (Fig. 17). Brøgger and Shetelig believed that the knees were ‘almost completely preserved’ and that there was no evidence of top frames for attaching more planks above (Brøgger and Shetelig, 1950: 172). This led Rygh, Schetelig, and later Brøgger and Shetelig, to conclude that the Tune ship had a peculiarly low freeboard (Rygh, 1872: 2; Schetelig, 1917a: 112; Brøgger and Shetelig, 1950: 173). With the exception of Dammann’s suggestions in *Das Logbuch* (1997: 92), this view, which is brought into question by a close inspection of the knees, has hindered new attempts to reconstruct the ship.

Careful inspection of the upper ends of the knees on top of the beams shows that the original ends are not preserved (Fig. 18). They have all decayed due to exposure to oxygen and drying out. The knees are sharpened and broken as a result of this decomposition process, rather than having their original ends. The upper ends of the knees are rather short, this shows that they probably extended further. Their shape, along with unfinished remnants of embellishments (decorative lines), indicates that the knees used to be higher, giving room for two more strakes (Fig. 19). As far as we can see, the knees have treenails all the way up to the end, which suggests that they once went higher, probably up to the rail. Even though there are examples such as Hedeby wreck 3 or Skuldelev wreck 6 (Crumlin-Pedersen, 1997: 248, Crumlin-Pedersen and Olsen, 2002: 288), where treenails are used to fasten the very top of the frames, holes placed towards the end of a timber would have weakened it, possibly causing fractures or cracks. Today, traditional boatbuilders on the Norwegian coast avoid finishing the ends of the knees on top of the beams with treenails. Both the Gokstad ship and the small boats from the same site use clenched nails to attach the ends of the knees to the planking (Nicolaysen, 1882: Chart I; Christensen, 1976: 275–278). The upper nail holes seen on the Tune ship knees indicate that the knees once rose to a greater height along the side of the ship than they now do, which would have allowed for more strakes and therefore a higher freeboard.
It is also important to question Schetelig’s measurement of the angle between the beams and the side of the hull (Fig. 19). Schetelig used his measurement of this angle as the basis for calculating an average shape of the knees in his reconstruction of the Tune ship. Moreover, the original angle was probably altered when the ship was compressed within the burial mound. A more closed angle of the knee would mean that the ship’s side would be straighter and, therefore, that the freeboard would have been somewhat greater as well. The ship would then probably also have been able to ride larger waves more securely, since the danger of the bow wave turning in midship is less when the ship’s side is higher as waves that don’t go beneath the hull will creep up the sides of the ship. The ninth strake in Schetelig’s drawing of the cross section has a sharp curve. In this way Schetelig enabled the strakes to stand more upright towards the sheerstrake. There is no evidence of this hollow shape in the Tune ship. It appears that, to solve the problem created by a ship with a low freeboard and only ten strakes on each side, this shape was hypothesized by Schetelig.

Figure 15. A tapestry from a grave mound at Nedre Haugen (drawing Tone Strenger. Universitetets Oldsaksamling, Museum of Cultural History/University of Oslo).

Figure 16. Several of the floor-timbers have an uneven and crooked shape (photo by author).
Recent inspection has shown the presence of treenail holes in the surviving top strakes throughout the hull. This indicates that top frames were put inside the hull as support for the additional strakes (Fig. 20). Treenail holes have been noted every third room from the mast both fore and aft, and it is conjectured that they were placed every third room throughout the length of the ship. Although the top frames overlap and are positioned alongside the standing knees, they are not fastened directly to them. Based on the pattern of treenail holes and examples from other ship finds,
the top frames are not of a regular shape (Nicolaysen, 1882: Chart I and II; Christensen and Leiro, 1976: 17; Crumlin-Pedersen, 1997: 88–90).

Number of strakes

Before we can determine the total number of strakes and the ship’s length it is important to consider the condition of the wood. The excavation process, being nailed to a frame for transportation, the transportation itself, and temporary storage by the university took a toll on the fragile ship. But the speed of this process also had benefits. As the entire operation took only 14 days, it reduced the risk of the Tune ship rapidly drying out. The fact that the ship was left outside and housed in a temporary shed for some time means that it was kept in a humid environment during the first few years after its excavation. This has probably helped to limit post excavation deformation of the wood.

A detailed review of the materials used in the construction of the ship shows that all the planks are hewn from radially cleft oak. The exception is the megínhufr, which is thicker and made from cleft quarter logs. It is generally known by traditional boatbuilders that the strong medullary rays in oak make it necessary for thin strakes to be radially cleft to avoid cracks (Finderup, 2017: 201). On the other hand, the megínhufr is thicker and can therefore be partly cut across the medullary rays. The evenness of the material indicates that it is the portion of the tree trunk under the crown that has primarily been used (Finderup, 2017: 43). It is also easiest to make planks from this part of the trunk.

Based on general experience, we know the shape of wooden objects changes over time. Drying out or undergoing fluctuations in temperature and humidity can affect wood, and knowledge of these factors is extremely important in this reconstruction project. Establishing how much the Tune ship has shrunk in relation to its size at the time it was found, and, possibly, when it was in use, has been crucial during this process. Oak can shrink lengthwise, according to Kollmann, by 0.1–0.2% (Kollmann, 1951: 387). For planks up to 8–10m long we can, according to tests done on oak from the Tune ship, count on 0.2–0.3% shrinkage (Paasche, 2010: 137). The longest plank on the Tune ship is 8m long; shrinkage of 0.2% would then amount to a maximum of 16mm lengthwise. For most of the strakes, shrinkage will have been even less. An average plank length of approximately 4m would give a maximum shrinkage of approximately 8mm. The shape might also have been changed by decomposition, but the fact is that in the reconstruction of the ship the planking is quite easily fitted together. This shows that shrinkage and decomposition are minimal.

Dammann was the first to propose the Tune ship had a greater freeboard in his article Das Tuneschiff ein Stiefkind der Schiffarchäologie (1997), believing that the ship must have had more strakes in order to function properly. He illustrated his hypothesis by adding people to an illustration of the ship, which clarified the mismatch between the ship’s freeboard and its crew (Dammann, 1997: 90). Dammann also presented a long discussion about the location and angle of the oars. Furthermore, he suggested that the hrodarhufr, the Old Norse name for a strake with oar-ports, were higher than previously assumed (Dammann, 1997: 90). Dammann never examined the original material, and he was therefore unable to find sufficient archaeological or ship-specific evidence to propose new drawings. He accepted Schetelig’s rendition of the frames and hull design below the waterline, and he ended up with a hull shape that is not particularly believable. Dammann’s reconstruction of the Tune ship is a copy of the drawings by Schetelig, Johannessen, and Christensen, with the addition of two strakes (Dammann, 1997). Nevertheless, Dammann must be recognized for his suggestion that the ship would have had 12 strakes from the keel up to the sheerstrake.

How many strakes did the Tune ship have? Higher standing knees on top of the beam would allow for more strakes in addition to the ten that have survived, and top frames would also likely allow for one or two additional strakes. The new reconstruction plan shows how the top frames were placed beside the knee, and not as a part of the main floor-timber-beam-knee unit. There is no
sign of oar-ports or attachments in the ten strakes that were recovered. Still the oars, and not least the location of the hrodarhufr, must also be considered. Based on the Oseberg and Gokstad ships, in this reconstruction they have been placed in a somewhat thicker 11th strake giving a vertical distance of 0.38m between the beam and the middle of the oar-ports, which corresponds to the Oseberg and Gokstad ships. Depending on the waterline and displacement, this would provide a good position for using the oars with oarsmen sitting on chests similar to the 0.31m-high chest from the Oseberg find (Grieg, 1917: 121). It is clearly possible to use chests as rowing benches, though we do not have proof that this occurred on the Tune ship. The length of the oars varied according to the location of the rudder within the ship, and this would also determine the angle at which the oars entered the water. The oars at the ends of the ship would probably have been somewhat longer than the ones in the middle (Christensen pers. com.).

There are factors that would have limited the possible height of the side. Perhaps most importantly, the height would have been determined by the size of the sail, as this type of square-sailed ship with a shallow keel and flat bottom is very exposed to the wind. Wind puts a ship at risk of drifting or taking in water, and, in a worst-case scenario, can cause it to capsize. Considering these risks, the sides of the Tune ship are quite low, whether it had 11 or 12 strakes notwithstanding. Just as important as the raking height is the positioning of the strakes towards the stems and the form of the stems themselves. That the Tune ship is a very flat-bottomed vessel, with a relatively low freeboard, indicates that its stems were not as high as, for example, those of the Oseberg ship (Schetelig, 1917b; Brogger and Shetelig, 1950; Paasche et al., 2007).

This reconstruction of the Tune ship has 12 strakes. This is primarily based on physical evidence found in the original material. Since the knee on top of the beam supports the 11th strake, a top frame would only be necessary if there was a 12th strake. The question is then whether only having top frames for every third knee would provide enough support for two upper strakes. In my opinion, it would hold: the 12th strake is not weight-bearing and therefore less vulnerable to being damaged at sea; it was not necessary to fasten the standing rigging to the upper strake—this would probably have required either knees all the way to the top or top frames for each frame. If there also was a top frame in the fore ship, there would have been five frames as support for the 12th strake alongside each side of the ship, in addition to its being attached to the stem. Following the example provided by the Gokstad ship (Nicolaysen, 1882: 58), a gunwale has also been inserted in this reconstruction from bow to stern that provides additional support for the upper strake.

It is unknown whether the Tune ship had oar-ports or keiper, the common Old Norse term for oarlocks. The length to beam ratio of the hull shows that the Tune ship was primarily built for sailing rather than for rowing. Since it is faster to ready the oars with keiper on the top of the sheerstrake, they can be easier to use, but they quickly get in the way when working with a sail and running rigging. A sheerstrake with oar-ports beneath also gives the rowers better protection against wind and weather. A rower must sit above the oar to achieve the correct angle between the oar and water’s surface, regardless of whether using a keip or an oar-port. It is tempting to choose oar-ports since both the Oseberg and Gokstad ships are equipped in this way; however, as the Klåstad ship was equipped with keiper (Christensen and Leiro, 1976: 17), it is not possible to give a definitive answer to the question. It may be that factors such as tradition, taste, and comfort are as relevant as a functional explanation.

Length of the ship

In 1887, Oluf Rygh wrote the following about the length of the Tune ship: ‘The length of its keel is 43 feet, while the length from bow to stern, which can no longer be determined with certainty, is assumed to have been at least 70 feet’ (Rygh, 1877: 152–153). He was working in Old Norse feet, equating to 0.314m, so this gives a keel of 13.49m and an estimated hull length of at least 21.97m. These statements are obviously debatable. The shape and thickness of the keel towards the stems is an important factor to consider when calculating the full length of the ship. The surface of the keel has been preserved 0.08m ahead of floor-timber 5F. Here the keel is 0.16m deep and 0.045m wide. The same keel measurements are again found 0.08m aft of the equivalent floor-timber in the stern (5A). As far as we can follow the shape of the keel forward in the ship, it has the same design in relation to the distance to the ship’s centre in the longitudinal direction as in the stern.

If we look at the tapering of the keel to the fore of the ship and compare it with the shape of the keel towards the stern where the original length is still preserved, it seems that the fore-keel extended 2.05m beyond floor-timber 5F. If this is correct, and since we can see that the end of the timber is missing, we should add 0.10m to the current length of the keel, resulting in a total length of 13.6m. Oscar Montelius, who saw the ship being excavated, thought the keel might have been around 14m long (Montelius, 1884: 174), but he does not explain precisely how he arrived at this figure. According to these calculations, the keel was 13.6m long, which, together with the choice of shape and curvature, gives a total ship length of 18.67m and a maximum beam of 4.22m. Rygh also arrived at a keel length of 43ft, that is 13.49m (Rygh, 1877: 152–153), only 0.11m shorter than this estimated length based on an assumption of symmetry of the keel relative to its centre. On the other hand, he gave a total length of 70ft, or nearly 22m, which seems far too long and does not fit with the keel length he proposed.
Location of the mast

The position of the mast is important for the balance of a ship. There are many elements at play here: hull shape below the waterline, ballast, weight, and trim. The goal is to have a ship that is so well-balanced it is not necessary to use the rudder. Small adjustments would still be needed to keep a vessel steady, but many experiments sailing with replicas over the years have shown that with the right adjustments a ship should not easily fall off or go too fast into the wind. A ship can also be trimmed by moving the centre of the sail, but it is the position of the mast within the ship that is essential for the sail to use the wind’s power efficiently. In all known traditional Nordic boats, the mast is located where the ship is at its widest, which normally provides optimal conditions for the distribution of forces and the location of the rig in the ship.

The Tune ship’s mast step has been preserved, so we know where the mast was located. However, we are uncertain if the step is in the middle of the ship, as the bow has rotted away. Therefore, the mast location does not indicate the ship’s length. The question can be looked at another way: the results from studies of the length of the keel, the transverse sections, the shape of the hull, and the lines of the strakes at the stems can be used to help determine the ship’s length, and thus determine the position of the mast. In this reconstruction, the mast is 0.43m aft of the ship’s centre. As far as I know there are no other examples of masts placed aft of centre in the Nordic clinker tradition in the prehistoric periods. The distance of 0.43m is not great and, considering the Tune ship’s flat bottom with much bearing in the aft of the ship and the possibility to tilt the mast a few degrees, this could have worked quite well.

According to an oral tradition still alive on the west coast of Norway today, the mast’s length should be equal to the circumference of a circle with the diameter equal to the ship’s widest point (Andersen and Andersen, 1989: 53–82; Eldjarn and Godal, 1990: 258). If this rule is applied to the Tune ship, its mast would have been just under 10m high.

Hull design

The length of the Tune ship shows that it once had room for 12 full rowing stations, thus accommodating 12 oarsmen on each side. The ship was primarily a sailing vessel, as indicated by the mast step and fish, but could, based on the tradition and the Oseberg and Gokstad ships, also be rowed. The transverse sections are simply structured with floor-timbers, beams, knees, and top frames. The ship’s preserved parts show that the hull above the waterline is slightly wider in the front. The beams are also widest in the bow. This shows that most of the weight was carried by the front of the ship. Seen from above, the ship has a slightly teardrop shape, which makes for a more manoeuvrable bow.

The shape of the hull below the waterline originally sharpened from frame 4F towards the bow. Similarly, in the stern the hull becomes significantly sharper from frame 5A. The Oseberg and Gokstad ships are generally symmetrical fore and aft, and although there are few parallels to build on, there is reason to believe that the bow of the Tune ship would have had approximately the same design as the stern. It is proposed that the mast is located somewhat behind the middle of the Tune ship, and the bow and stern would have had largely the same shape; however, the hull below the waterline is not completely symmetrical fore and aft. Unlike other ships from the early Iron Age and Viking Age, the Tune ship sides are quite even on the entrance. This provides a good entrance without the ship being too sharp, which could have led to the bow pressing down. A well-rounded hull below the waterline would have made it go through the water easily, and, along with its flat mid section, would have given the ship a good bearing at sea. The upper strakes are angled outwards to ensure that water would have been cast away from the ship.

The transition between the lower and upper hull is the angle between the seventh and eighth strakes. At transverse section 6A the shape is somewhat different than that of the Oseberg and Gokstad ships, where the strakes rise more steeply and evenly (Nicolaysen, 1982: Chart II; Schetelig, 1917b: Chart XXI). Looking at transverse section 6A of the Tune ship we find an unusual feature (Fig. 21): the crossbeam gives the width against the seventh strake, that is below meginluf. The fact that the keel changes from T-shaped to having a rabbet at the lot, the transition to the stem, helps to create a flat hull below the waterline towards the stem. The distinct sharpening towards the stem begins at the lot. The use of the Oseberg and Gokstad ships as models for the shape of the Tune ship’s hull below the waterline is not necessarily appropriate. These ships were each designed differently, and their forms are not identical. The original material shows that the strakes of the Tune ship are the most open of these three ships, giving it the flattest bottom, so other solutions are required to make the stern fit together. If the Tune ship had the same sharp end as the Gokstad ship, it may have made its stern too heavy. The Geitbåt from Nordmøre can be used as an ethnographic parallel to this solution in the stern (Godal, 2014). This larger boat has a characteristic angle low down at the waterline, which gives a good bearing aft. So more recent boat traditions show us that there are several solutions. Traditional boatbuilder Harald Dalland suggested that the explanation for the Tune ship’s somewhat unusual stern is likely to be found by looking at the ship as a whole: ‘the bow must carry the stern’ (Dalland, pers. comm.). With an even and not too sharp transition towards the underwater hull, the ship will get good lift without being dragged down. Furthermore, the ship will have a good bearing towards the stern. Looking at the ship as a single entity can thus provide an
explanation for the unusual transition between the hull below and above the waterline in the stern.

The question is then whether the hull is significantly weakened by a meginhufr that rises above the waterline and is no longer in the curve between the quick- and dead-works. Dalland emphasized how the meginhufr should stiffen the mid ship and not the stern (Dalland, pers. comm.) to give more life to the hull, suggesting: ‘It is desirable for the boat to wag its tail a little’. Even though there is a sharp angle to the strake under the meginhufr, this does not necessarily produce a weak point as there is a lot of timber in this area: ribs, beams, and knees are at their thickest at this point, thus spreading the forces. This type of design is also known from other ship finds, such as the Rong find from Herdla (Færøyvik, 1947: 12–15). In addition, it should be emphasized that it is the stern areas that are exposed to heavy seas. For the stern, good bearing and ship would probably have been more important factors than direct strength against external pressure. The details of the hull in the stern can probably only be clarified once a small-scale model of the ship has been built, which has not yet been completed. Transverse section 6A may appear extreme, since there are no parallels, however it is a faithful representation of the archaeological material once the post depositional deformations are corrected.

### Sail and rig

Sailing vessels from the Viking Age all seem to be designed to tack, which is reflected in the choice of rigging, rudder, and hull shape that can stand up to strong winds and heavy waves. The Tune ship’s form probably gave it good balance in a tailwind. At the same time, the characteristics necessary to achieve sailing ability limit the ship’s design. In earlier interpretations of the ship, the low freeboard and the powerful mast partner were a poor fit. And if the stems of the Tune ship are raised too high, strong winds will get hold of the hull when tacking.

The width of the sail is directly linked to the design of the hull. The Tune ship’s optimal sail width correlates with the hull’s geometric lateral centre and effective sailing centres. A sail that is too wide will make the ship fall off the wind when it is crossed. This relationship can only be demonstrated by experimenting with a full-scale copy of the sail. The height of the sail is related to its desired characteristics. Generally speaking, a high sail gives a ship better crossing ability, that is, it will be able to withstand larger waves at sea. The Tune ship has already been illustrated with a full rig, but this depiction is based on drawings from previous reconstructions of the Oseberg and Gokstad ships’ rigs (Andersen and Andersen, 1989: 247–253), which in turn largely build on the rig from the Nordland boat as it is known from ethnological material (Vinner, 1980; Eldjarn and Godal, 1988). A new reconstruction of the mast and sail on the Tune ship (Fig. 22) is based on both the few archaeological sources we have, the Nordic tradition, but also experimental data first and foremost from the former Skibsarkæologiske Laboratorium in Roskilde (Andersen and Andersen, 1989; Vinner, 1980; Andersen and Vinner, 1997: 175–272).

The mast partner and the mast fish are good evidence of the ship carrying a sail. As the top strake on the Tune ship is completely missing, there are no holes for attaching either the tack (forward corner of the sail) or the sheet. The hull’s form, tradition, dating of the ship and not least sailing with replicas undoubtedly indicate square sails and a mast height of at least 10m (Paasche 2010: 162). The mast partner is an element found in the square-rigged ships of the Viking and Medieval periods and is not something we find in more recent wooden boats. Ships of this type can sail with both low and high rigging but cannot keep their speed up if they are under-rigged. Experimental sailings have shown that ships of this type can even cross with full sail in a gale (Vinner,
1980: 267–278; Andersen and Vinner, 1997: 245–271). At sea, maintaining pace and following the waves is important for a safe trip. The size of such a ship's sail can hardly be determined accurately, but based on sailing experiments on similar ships, like Oseberg and Gokstad, it seems possible that the Tune ship had a sail of at most 100m².

The ship's capabilities at sea

Experimental data shows that an open ship with a low freeboard works well since it pushes the bow wave out and underneath the hull, lifting the ship in the water. Examples of this are many: Skuldelev 2, 5, and 6, the Vik boat, and Valsgärde 14. These are all boats that have been tested by experimental sailing replicas (Almgren, 1962; Crumlin-Pedersen and Olsen, 1967, 1969, 2002; Crumlin-Pedersen, 1970; Larsson, 2007). But the low freeboard suggested in early reconstructions of the Tune ship is extreme for such a large ship. Splashing water and surging waves would be problematic and, due to a greater heel, there is significant danger that the ship would take in water directly, which would be disastrous for this kind of vessel. In earlier interpretations, the Tune ship was thought to have only ten strakes; however, this study has shown that the Tune ship likely had 12 strakes on each side as indicated by the knees being incomplete and treenail holes suggesting the position of top timbers. In traditional Norse boatbuilding, such as seen in Oseberg, Geitbåt and Nordlandsbåt, it is common that the hull ‘grows’, meaning that the front of the ship is slightly wider (Christensen, 1979; 29, 97, and 110). This also applies to the Tune ship, albeit not so distinctly that we can say that the ship has a ‘cod’s head and mackerel tail’, it is not truly teardrop shaped. The teardrop shape becomes more common in more specialized vessels from the Middle Ages onwards; examples could be the medieval ship finds from the medieval towns of Oslo (Sorenga), Stockholm (Helgeandsholmen), and others (Paasche and Rytter, 1998; Dahlbäck, 1982). The shape of the Tune ship’s hull is different above and below the waterline. The quick-works are relatively narrow fore, but somewhat wider in the aft. The opposite is true for the dead-works. This probably helps the ship to push water away and provides the necessary lift in the front. A parallel to this is the Oseberg ship that also widens by some centimetres on each side above the waterline in front of the mast (Paasche et al., 2007; Paasche, 2013: 22–23).

Robust frames gave the ship the strength it needed to survive heavy seas, while the system of cleats and lashings has several advantages: by lashing the floor-timbers to cleats, the vessel reduces the number of holes through the bottom, improving water tightness. In addition, it is possible that fewer treenails left protruding on the outside of the hull meant less resistance and a smoother hull and therefore allowed for higher speeds.

The shipbuilders of vessels such as the Tune ship, with its detailed, carefully considered design, solved the problems related to bearing, lift, speed, and balance.
that arise when a ship’s hull meets the sea. The ship’s low mid section and sharp keel would have helped to stabilize it at sea, something very important for a ship of this size that would have carried a powerful rig of mast and sails. The centre of the ship with strong mast attachment in the form of heavy frames and mast knees, keelson, and mast partner is solid evidence that the Tune ship was sailed (Paasche, 2010: 175). The shape of the hull is determined by the curve of the keel, the hull’s length and width, and the shape and placement of the strakes. A smoother transition between bottom and sides, a greater freeboard, and a stronger attachment for mast make the Tune ship more of a sailing vessel than the Oseberg ship, which can be seen as more of a combined rowing-and-sailing vessel.

Overall, there are many factors which speak to the excellent sailing capabilities of the Tune ship (Fig. 22). Carefully considered and probably tried-and-tested details show that the ship was built for ocean voyages. Brøgger and Shetelig describe the Tune ship as ‘quite seaworthy’ and ‘a sharp sailor for tailwind’, despite expressing surprise at the ship’s low freeboard (Brøgger and Shetelig, 1950: 173). This research has shown that, considering its length and width, the Tune ship is very open in the middle, but still far less so than in Schetelig’s reconstruction from 1917. Although this has not yet been assessed through hydrostatic testing or sailing modelling, it is my impression that the extra strakes up to the sheerstrake give the ship a high enough freeboard to protect it from large waves. The combination of a powerful mast mounting and consequently a large rig with a sharp entrance, not to mention very good bearing due to its flat bottom, are clear indications that the Tune ship could have been fast under sail, similar to the replicas of the Gokstad ship that have often achieved a speed of 10 to 12 knots. It is shorter than the Oseberg and Gokstad ships, but, proportionally, it could have been fitted with the same rig. Flat planks along the bottom also provide steadiness in strong, gusting winds: from this perspective, the Tune ship could very well have been a better sailor than the Oseberg ship, and certainly safer. Further work on the ship, possibly in the form of a full-scale replica, will likely show that the Tune ship sailed at least as well as the Gokstad ship.

**Dating and typological features**

By studying remains of carved pieces of what had probably been a saddle and by comparing artefacts from the Tune ship site with bronze ornaments from the Gokstad ship, Schetelig set a date of approximately AD 900 for both (Schetelig 1917a: 9–10). The dating of the vessels to the Norwegian early Iron Age and Viking Age has subsequently been determined through dendrochronological dating. The latest surviving tree ring in the sample taken from the Tune ship burial has been dated to the year AD 892 (Bonde and Christensen, 1993: 157). After being adjusted for missing sapwood and the time between the timber being felled and being used, Nils Bonde dates the construction to between AD 905 and 910 (Bonde and Christensen, 1993: 158). The samples were corrected again in the final analysis, giving a year closer to AD 910 (Bonde, 1994: 140).

Nevertheless, changes in typological features are a very important part of maritime history and can help us to determine ship types and uses. For example, both the shape of the hull and the system for securing the mast changed during the Viking Age and into the Middle Ages. While the scarcity of ship finds from the early Iron Age provides a weak basis for developing a chronological series, we can say with certainty that society’s need for oceangoing vessels changed throughout the Viking Age. Based on what we know about the ships of this period from the written sources the number of ships purely for overseas raids increased from the late 700s onwards (Sawyer, 1985: 104). From the mid 800s, an increase in the transport of goods and/or trade, emigration, and occupation of land abroad created the need for more cargo-efficient ships. Large, specialized warships—the long ships—are first seen in the 900s and made the relocation of larger armies in conjunction with regular warfare possible, including in conflicts on the other side of the North Sea (Crumlin-Pedersen, 2010: 81–83; Ravn, 2016). The growth of cities on a large scale in the early Middle Ages, and hence the need for large-scale shipping, inspired further specialization, visible in larger commercial vessels such as Skuldelev 1 (Englert, 2015). In such a concise historical framework, the Tune ship should be characterized as a relatively well-developed rowing-and-sailing vessel, with good sailing capabilities, undoubtedly a dependable ocean-going vessel. However, it would not have been particularly well suited to carrying cargo. With little load capacity, but still room for many men on deck, the Tune ship was best-suited to the rapid transport of many people and a smaller amount of cargo. As a warship it would have worked well, although it is much smaller than the really big ships we see towards the end of the Viking Age and into the Middle Ages, such as the Skuldelev ships in Roskilde.

Although samples are small, and we do not know if we are seeing development over time or variety in a contemporary assemblage, changes such as a higher freeboard, increased loading capacity, and more powerful mast fastening point to greater technological development of shipbuilding in the 80 years between the construction of the Oseberg ship in AD 820 and the Gokstad and Tune ships around the year AD 900. The practical solution for the mast on the Oseberg ship makes it lighter than the Gokstad and Tune ships. This design, combining agility and strength with light building materials, also makes the Oseberg ship better for rowing. The Gokstad and Tune ships have much sturdier masts than the Oseberg ship. Use of a large sail with a light hull requires an even distribution of forces. The mast fish lies on top of the beams in all three of
these ships, but the keelson runs over several more of the frames in the Gokstad and Tune ships, and they have more robust knees than the Oseberg ship, which are fastened to the mast fish (Nicolaysen, 1882; Schetelig 1917a and b). According to Crumlin-Pedersen, the mast is supported in a much simpler way than the three classic Norwegian ships. Here, an extra stiffening beam has been added in addition to the cross-ship beam, which is pushed down lower into the bottom of the ship. The ship also has robust stringers for longitudinal stiffening and four top timbers each fastened to a knee on each side, all of which are features of shipbuilding technology more closely related to the later Skuldelev ships than the somewhat older Norwegian Viking ships (Sørensen, 2001: 217–223).

The Tune ship helps confirm a distinction between the first sail-powered ships of the late Iron Age and the more sophisticated ones that come along during the transition from the late Iron Age into the early Middle Ages. Again, with such a small sample it is difficult to distinguish change over time from variety within a single assemblage, but with this in mind, there seems to be a conscious development to increase load capacity. Besides combined rowing-and-sailing personnel carriers, pure sailing vessels developed in this later period (Englert, 2015: 58). For example, in all three of the early Norwegian ship finds there is only one beam across the ship at each frame station. By the time we come to Ladby, Åskærr, Hedeby 1, the Skuldelev ships, and Roskilde 6, a double frame system consisting of a biti and thwart has been introduced (Sørensen, 2001: 207 and 276; Borg et al., 2000: 118; Crumlin-Pedersen, 1997: 101; Crumlin-Pedersen and Olsen, 2002: 198; Myrhøj and Gothche, 1997: 7). A higher freeboard and more internal timbers make the ships less suitable for rowing.

This development allows for ships to be built from the 10th and early 11th century, such as Askekærr and Skuldelev 1, which are more cargo-efficient than Oseberg, Gokstad, and Tune that date to the 9th and early 10th century. The hull form of the Tune ship attests such a transition in building techniques. In addition to the simple frame system it has, like the Oseberg and Gokstad ships, a sharper transition or angle between the quick-works and dead-works than later medieval vessels (Nicolaysen, 1882; Brøgger et al., 1917). The Skuldelev ships on their own show the degree of specialization in the 11th century: the large cargo ship Skuldelev 1, the war ships Skuldelev 2 and 5, and the fishing boat Skuldelev 6 (Crumlin-Pedersen and Olsen, 2002). While the design of warships that used a large number of oarsmen in combination with the sail was maintained over time, merchant ships gradually became more reliant on their sailing capacity.

After the Tune ship, the Klåstad ship, dated to the 990s, is next in our chronology of Norwegian ships (Bonde and Christensen, 1993; Hylleberg Eriksen, 1993; Bonde, 1994). This ship is wider than the Oseberg, Gokstad, and Tune ships, and therefore somewhat more cargo-efficient for its size. Particular to this ship are the almost horizontal megshult and, as a consequence, the strong curve in the hull at the waterline. We do not know enough about the Klåstad ship to be able to describe its shape in every detail, but it does have a place in the transition towards the Middle Ages, a period in which we see more technical designs and the specialization of several types of vessels. The remaining question is whether new discoveries will give more variety in the 9th and 10th century, or confirm the image of ‘all-round vessels’ such as the Oseberg, Gokstad, and Tune ships?

### Future research

The number of preserved ships from the late Iron Age period between AD 550 and 1050 is small compared to the significance that ships must have had for settlement along the Nordic coasts. This society did not have road networks or densely populated settlements, so it would have required thousands of boats and ships to function. It is primarily new archaeological findings that can bring answers to the many questions related to ship types and usages from this period. This interpretive reconstruction of the Tune ship provides a new understanding of the archaeological ship material from the late Iron Age, despite this find having been available to researchers for 150 years. Perhaps the most important finding is that, despite its clear resemblance to the Gokstad and Oseberg ships, Tune is in many ways very different. They are all clinker-built, Nordic-type vessels and almost prototypes for what we know as Viking ships, yet there are also significant differences between them. Oseberg is long and narrow with an extremely low freeboard. The Gokstad ship is far more powerful with the keelson spanning four frames, a stronger mast support system and a higher freeboard. Finally, the Tune ship: short, wide, flat-bottomed with good bearing aft, and possibly with the largest sail area in relation to its total size. The three ships give the impression of having been built for slightly different tasks, or perhaps different answers to the same challenge.

With the same basic form, albeit with a somewhat different hull shape and some distinctive technical details, the Tune ship is an equally important historical source as its contemporaries at the Viking Ship Museum in Oslo. This examination of the ship’s construction and technical details enables it to be placed within a broader discussion. Despite strong coastal traditions, research on prehistoric ships and boats has not been prioritized in Norway. In Denmark,
we see a much greater interest and concentrated effort to highlight this important part of our common Nordic history. We cannot forever bask in the glory of great discoveries such as the Gokstad and Oseberg ships. Even though they attract large crowds, archaeological treasures of this stature need to be studied on a purely scientific level. If we are to increase our knowledge of the central role of ships in our prehistory, the subject must receive far more attention as an important research topic.

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Note

1. Schetelig altered his name to ‘Shetelig’ during the Second World War, hence the variation in spelling found in his earlier and later publications.

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