Visualising the 'Big Ship'; The reconstruction of a 12th-century cargo vessel found in the harbour of Wismar

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Abstract: At the ISBSA 15 in Marseille, the authors presented the preliminary results from the excavation of a Medieval cargo vessel in the port of Wismar (Germany), built from oak and pine sourced from western Sweden in the period AD 1184-1190. Since then, the full documentation of the wreck has been completed, and the timbers are currently undergoing conservation treatment. As the next step, a minimum reconstruction of the hull form was carried out to analyse the ship's design and construction. This paper discusses the methodology used for the archaeological reconstruction and presents the results of the hull analysis. Finally, the Wismar ship is compared with contemporary ship finds intending to explore its place in the development of the sailing cargo vessel in the 12th and 13th centuries.

Keywords: Nordic Clinker shipbuilding, Early Medieval shipbuilding, Reconstruction, Baltic, Wismar

1. Introduction

This paper aims to present the minimum hypothetical reconstruction of the hull of the 'big ship' of Wismar, which was carried out to understand the displacement and provide a basis for comparing hulls with other contemporary vessels. Although the authors have already presented the site and the wreck's construction features at ISBSA15 held in Marseille in 2018, and a more extensive article is forthcoming, a brief re-introduction of the hull is in order.

The Wismar wreck or 'big ship' of Wismar was one of three medieval shipwrecks found during construction work for the extension of the Wismar Seaport, one of the Hanseatic cities on the German Baltic coast. The wreck was excavated by archaeologists from the State Service for Culture and Monuments in Mecklenburg Western Pomerania in November and December 2017, and fully recorded in early 2018.

The 19.8 m long and 5.3 m wide preserved remains of a clinker-built vessel were deeply buried in soft sediment with a 20 to 25-degree list port side (Fig. 1). Altogether 17 strakes of outer planking were preserved *in situ* on the port side, and four strakes survived on the starboard side. Neither keel nor posts were found. Inside the wreck, 28 frame stations were preserved with their associated timbers. Apart from the intact keelson, stringers and part of the aft deck construction could be recorded.

The ship was built from oak and pine sourced from western Sweden and dated to AD 1184−1190 (Daly 2018). With riveted outer planking, in-laid caulking made of animal hair and the presence of *biti* and *biti*-knees, the wreck belongs to the Nordic clinker shipbuilding tradition of the early medieval period (Crumlin- Pedersen 2004; Bill 2009). Moreover, the construction shows striking similarities with several large 12th-century cargo vessels found in Northern Germany and Scandinavia.

2. Reconstruction methodology

2.1. From wreck to a working model

Following the excavation, the ship timbers were recorded by a team of four archaeologists over 37 days in January and February 2018, using the 3D annotated scans method (Van Damme *et al.* 2020). The timbers were cleaned, sampled and subsequently scanned with an Artec EVA structured light scanner. The resulting textured 3D models were imported into Rhinoceros 3D, where they could be annotated. A written description and photographs of details were then added in order to compile the final catalogue entry for each timber.

The final output consisted of the annotated models, a 2D timber catalogue and 3D prints of all timbers on a scale of 1:20. The 3D-printed timbers were assembled into a so-called working model (Fig. 2), which primarily helped identify the position of the many dislocated timbers found in the site's surroundings. Moreover, as the model was assembled, it helped to understand the construction sequence of the vessel.

The model also became the basis for the proposed minimum reconstruction. Initially, the final working model was mounted over a frame that reflected the keelson's curvature, as the keel was absent as discussed below.

Prior to the placement on the frame, the model showed a pronounced longitudinal twist caused by the absence of the keel, endposts, and starboard side. Once mounted on the frame, with the floor timber aligned to follow the keel line, most of the twisting was removed but not completely eliminated. It should be noted that the final scale model represents a somewhat unique object. It is neither the original as-built version of the vessel nor its shape at the time of sinking, or even the wreck as found. Instead, the model represents an 'adjusted' post-deposition shape state, thus retaining some of the deformations in its shape due to its incompleteness and deposition circumstances.

Fig. 1 3D model of the fully excavated wreck on the seabed showing what remains of the vessel. Landesamt für Kultur und Denkmalpflege Mecklenburg-Vorpommern, Landesarchäologie (author: M. Ditta)

Fig. 2 The working model of the wreck on top of the excavation siteplan. Landesamt für Kulturund Denkmalpflege Mecklenburg-Vorpommern, Landesarchäologie (author: J. Auer)

2.2 From 'adjusted' model to minimum reconstruction

The 'adjusted' model was scanned again, first with an Artec EVA scanner to capture the overall shape and later with the Artec Space Spider to integrate the minute details not visible with the EVA. The resulting combined scans were processed into a meshed model and used as a starting point for the reconstruction. The 3D-printed model has a standard accuracy for the 3D printing technology employed (Selective Laser Sintering) of +/- 0.3 mm for 100 mm, while the Artec EVA has an accuracy of 0.1 mm and a resolution of 0.2 mm. Thus, after scaling the model by a factor of 20, the model's accuracy can be estimated at around +/- 1cm. The minimum reconstruction of the hull form was carried out in Rhino 6, where the meshed and texturised model was imported and scaled by a factor of 20.

The concept of minimum hypothetical reconstruction has been widely discussed and re-defined over the years. In this paper, we adopted the definition put forward by Tanner (2020: 237):

- A watertight envelope capable of floating and representing the vessel in a form capable of its intended function;
- A reconstruction that does not violate any of the archaeological evidence;
- Missing elements are replaced and/or repaired using contemporary comparative evidence.
- Basic hydrostatic calculations to provide an impression of the vessel's potential capabilities.

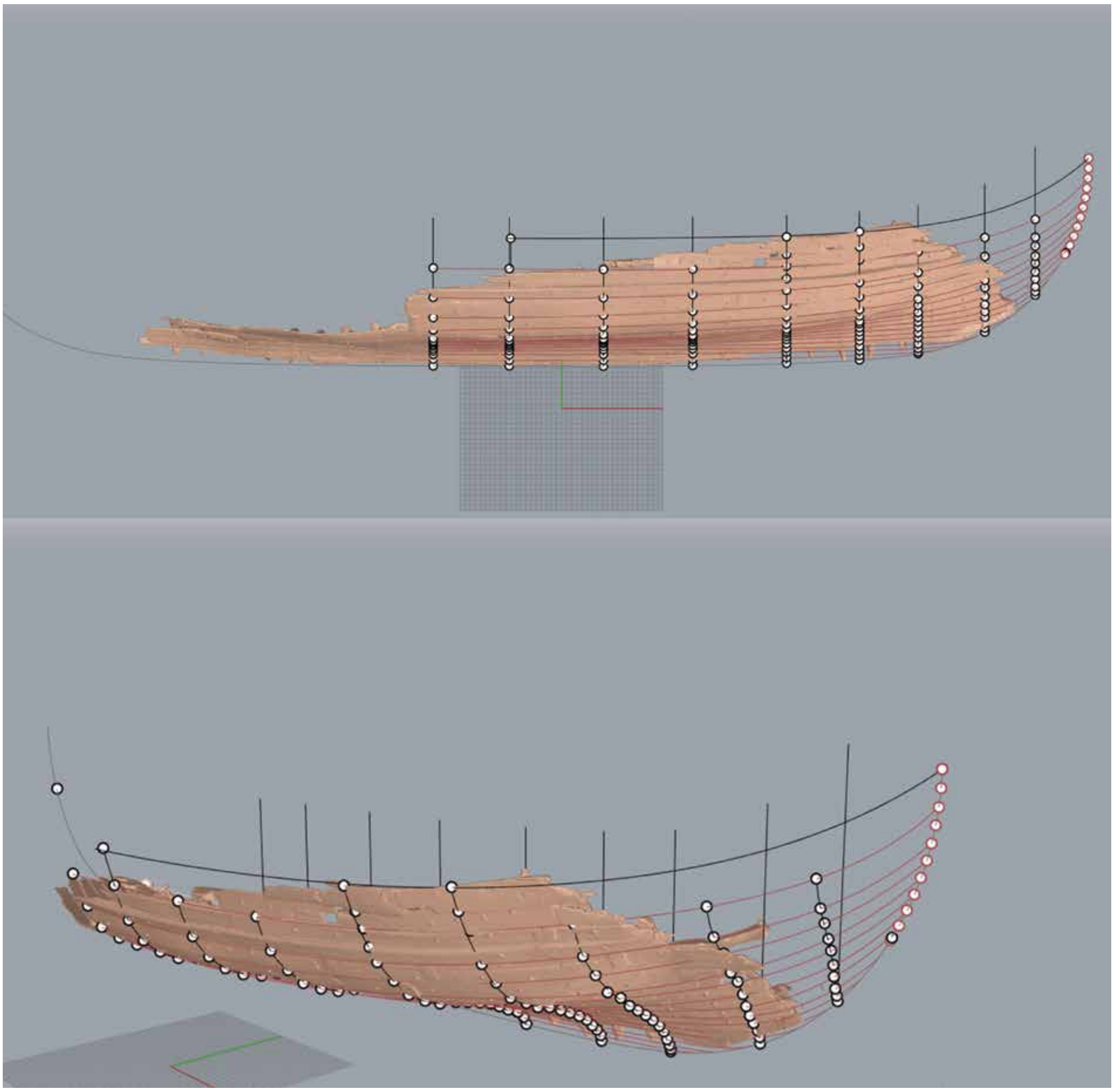

Fig. 3 Snapshot from a reconstruction step. The outer strake lines interpolated through points extracted from arbitrary stations (author: M. Ditta)

As already mentioned, the original scale model still had twists and distortions due to incomplete framing and the asymmetric quantity of materials recovered. These distortions can be categorised as global (Tanner 2020: 239–244), while more localised distortions were also present due to damaged and deformed planking. The correction of global distortions such as twisting and bending were possible using native Rhino commands. The main aim was to reconstruct a watertight envelope for analysis, which entailed creating a conventional lines plan for the exterior of the hull using the outer edge of the strakes. A series of arbitrary stations were created to correct locally deformed areas, and points were extracted for each edge of the outer strakes (Fig. 3). Consequently, the exterior strake lines were interpolated through these points and extended to the reconstructed endposts. Finally, the interpolated lines were faired and lofted, resulting in a watertight hull shell ready for basic hydrostatic calculations (Fig. 4).

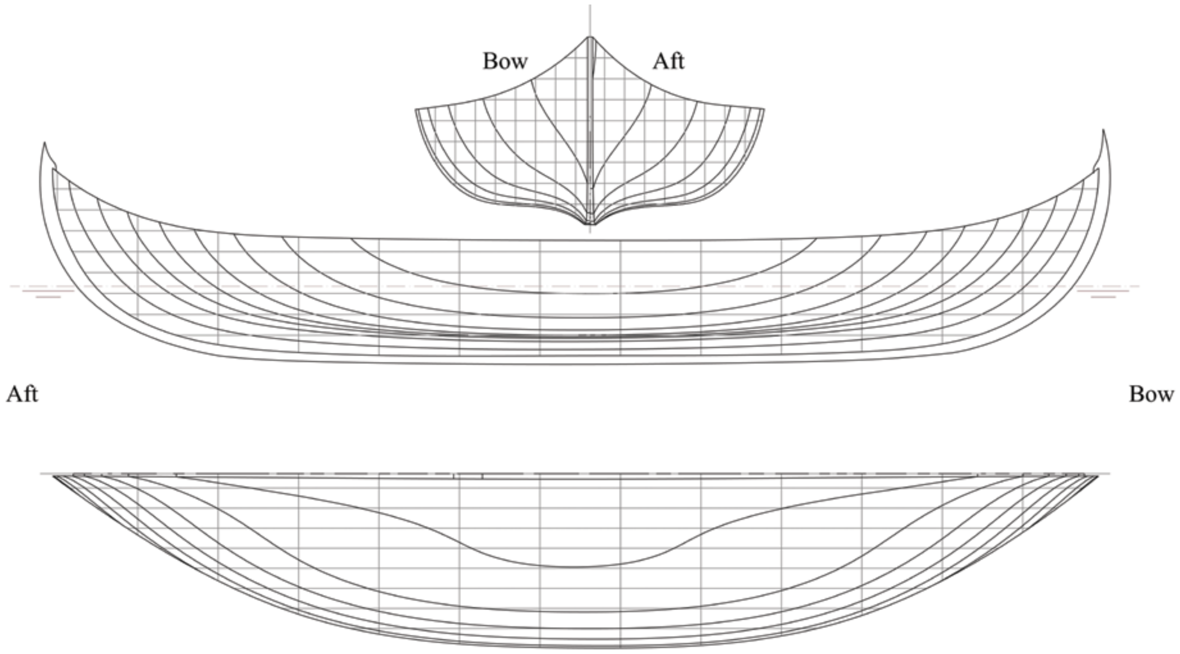

Fig. 4 The lines plan for the minimum hypothetical hull`s reconstruction of the 'big ship' of Wismar is not to scale (author: M. Ditta).

The overall length is estimated based on the symmetry of the internal structural elements. The regular spacing between frames and the symmetrical breaks aft and fore the keelson imply an overall symmetrical arrangement. Therefore, the shapes of the keel and endposts had to be reconstructed based on indirect and comparative evidence. The keel was reconstructed with a moderate rocker, assumed by the shape of the 10-meter-long keelson. This massive timber is believed to have undergone relatively minor deformations and thus corresponds to the original curvature of the keel. A similar characteristic is also seen in the closely comparable Lynæs I ship (Englert 2015: 168–169). The upper moulded dimensions of the keel and thus the rabbet line for the garboard strake have been estimated based on the foot of the floor timbers, while the sided dimensions are based on the surviving keel of Lynæs, which is relatively shallow with 17 cm at midship. As typical for vessels built in the Nordic clinker tradition of the early medieval period, the Wismar ship was double-ended with round extremities. Both endposts were reconstructed symmetrically and based on the shape of the sternpost. The curvature is visible in the surviving wings (a specifically shaped wooden plank between the actual planking and the endposts) and the hood ends of the stern planking. Perhaps coincidentally, the radius of the sternpost appears to be 1/6 of the length between posts.

The sheer-line follows the run of the 17th strake, the last strake, as indicated by the preserved in-wale.

3. What did the ship look like?

Before examining the details of the hull properties, a so-called 'visual' reconstruction is proposed here (Fig. 5) and discussed. This reconstruction aims to give an impression of the ship structures and arrangement resulting from the minimum hull shape reconstruction, the interpretation of the archaeological remains, and comparative sites.

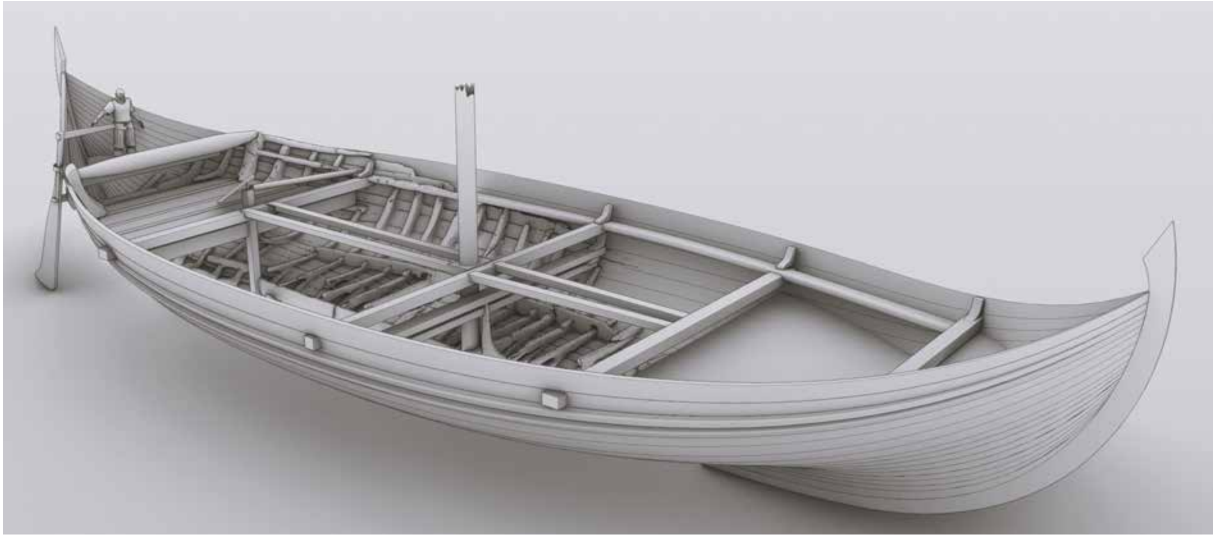

Fig. 5 Visual reconstruction of the vessel based on the working model and available archaeological evidence (author: M. Ditta)

Fore and aft open decks: The deck construction of the vessel can be traced on the port side aft. Here, a preserved beam shelf and some oak standing knees provided the substructure for a half-deck. Moreover, the preserved structure indicates the existence of another, higher deck further aft, which might have been the helmsman's position. Although not preserved, a similar arrangement is expected for the vessel's fore section. Moreover, a hole on the port-side in-wale on the aft deck suggests the presence of a thole pin, which would allow rowing for manoeuvring in and out of sheltered and shallow areas.

Still, on the aft deck, a massive knee from limewood (*Tilia* sp.) probably served as a bearing for a windlass that extended across the entire width of the vessel. While this type of windlass bearing finds a comparison in the much smaller Elling Å ship (1163) (Bill 1997), a corresponding windlass for this type of arrangement was found in connection with the 'Big Ship of Bergen' dated AD 1187/88 (Christensen 1985: 180).

Through-beams: A 22 cm × 22 cm rectangular opening in the 16th strake at the aft deck's forward end indicates the presence of a through-beam. The beam would have notched under the upper stringer, which is confirmed by a recess in the timber. Further notches in this upper stringer imply the existence of at least three of such through-beams. Through-beams are known from the Bryggen excavations (Christensen 1985: 66), and at least two of these beams could be linked to the find context of the 'Big Ship of Bergen'. The largest beam found in Bergen had a square section of 20 cm × 20 cm. Moreover, the seal of the city of Winchelsea in England from the 13th century depicts a ship with striking similarities to the Wismar ship: A single-masted clinker-built vessel with a large windlass on the aft deck (Fig. 6) and three through-beams at the aft, amidship and fore of the vessel.

Fig. 6 Second seal of the corporation of Winchelsea from the early reign of Edward I 1272–1307 (SEC0025), National Maritime Museum, Greenwich, London

Another noteworthy feature is a smaller opening measuring 10 cm × 16 cm above the upper stringer and just aft of the through-beam. Its position above the deck and at the end of the keelson suggests that it served as a scupper-hole. A similar solution can be seen in the Kalmar V, a small merchant ship from the early 16th century. A hollowed-out beam, at the aft end of the keelson above the deck, led the bilge water to a circular scupper-hole in the ship's side. The gutter beam was associated with a primitive bilge pump (Åkerlund 1951: 74). The Wismar ship was probably equipped with a similar pump arrangement, as the position of the lowest two stringers in continuation of the keelson allows free access to the lowest point in the ship between the 22nd and 23rd frame stations.

Based on the curvature of the sternpost, it can be assumed that the ship was equipped with a quater rudder, as stern rudders are generally associated with straight sternposts. As seen in the Kalmar I wreck (Åkerlund 1951: 32), similar longitudinal beams may have ran between the through-beams. A preserved mast partner would have fit in such an arrangement and provided extra reinforcement to the mast. Moreover, a mast horn was fitted fore of the mast step, possibly to counter-act the pressure of the mast against the transverse structures.

4.Talking numbers

The minimum reconstruction resulted in a hull with a Length Overall (LOA) of 23.3 m, a maximum breadth of 7.6 m and a depth amidship of 2.7 m. In order to calculate the hull displacement at full load, the draft was established according to the Icelandic Grågås codex freeboard law. The codex is a collection of laws recorded as early as AD 1117 and used until the AD 1280s. The law states that the minimum freeboard of a cargo ship should be 2/5 of the depth of hull amidships (Morken 1980: 178). In the case of the Wismar ship, the resulting waterline is at 1.61 m and, perhaps not coincidentally, it corresponds with the lower edge of the first wale. The resulting displacement of the hull at the full-load waterline is ca. 89.5 t.

The length-to-beam ratio is 1:3, quite indicative of the cargo-carrying nature of the vessel. While the slightly hollow waterlines and the low Block Coefficient value (0.4) indicate good speed potential, the prismatic coefficient (0.6) might indicate a slightly higher resistance.

McGrail (1987: 195–198) suggested the use of simple form coefficients as a method of determining relative assessments of the capabilities of a boat. However, coefficients are relative values that tell little about a vessel's real-world operations and behaviour (Tanner 2020: 315). That is what we hope to investigate at a later stage with the seakeeping and stability analysis.

5. A brief comparative analysis

Although a detailed list and analysis of comparable vessels have been published elsewhere (Auer, Ditta 2023), a brief comparative analysis of the most closely related vessels is presented here. In terms of construction features, the Lynæs 1 wreck from AD 1140 (Englert 2015: 164) stands out as a very close comparison to the Wismar ship. The similarities range from the general layout of the vessel and the presence of carved planks with a characteristic cross-section (wales) and a w-shaped floor timber to the arrangement of the *biti* system. The remarkable correlation in the provenance of the oak timbers used for construction is another point both wrecks have in common (Daly 2018). While through-beams were not preserved in the Lynæs 1 wreck, these could have been present. However, considering the age difference of 40 to 50 years between the two ships, the features could also represent later phenomena. A marked difference between the two ship finds is the consistent use of pine for all long and straight elements in the Wismar ship. However, despite this difference, Lynæs 1 still looks like a direct predecessor of the Wismar ship.

The 'Big ship of Bergen' (Christensen 1985) should also be discussed here. The 'Big ship of Bergen' not only dates to the same period as the Wismar ship, but the few preserved elements of this vessel also show striking similarities. From the shape of the keelson to the presence of mast *bitar*, through-beams, and the construction of the windlass, the Bergen ship is a larger version of the Wismar ship. However, all preserved structural elements from the Bergen wreck are made of pine.

The Lynæs I wreck is reconstructed with an LOA of ca 25 meters and a maximum breadth of 6.5 m. The ship, significantly more slender than the Wismar ship, has an estimated total displacement of 75 t and a cargo capacity of 56 t, approximately 75% of its total displacement. While a thorough analysis of the bare hull's weight is pending, preliminary calculations based on a similar estimation approach (75% of the total displacement) suggest a cargo capacity of around or over 67 t for the Wismar ship. This estimation considers the remaining bare hull weight of 21.5 t, which is presumed to be about 25% of the total hull, leading to an estimated full load displacement of 89 t.

Although not fully reconstructed, the Bergen ship is estimated to have an LOA of 27–30 m and a maximum breadth of ca 9 m. According to Christensen (2002), the ship had a cargo capacity of 120 t or ca 60 lasts and was meant for bulky but light cargo, like stockfish or timber.

Generally, a trend is noticeable in the L/B ratio, considering other vessels too. Ships predating the Wismar ships have a much higher ratio, a trend already underlined by Crumlin-Pedersen and Bill regarding size and cargo capacity. The Lynæs ship has an L/B ratio of 3.8 against the 3 of the Wismar ship and possibly also the Bergen ship, while the latest comparable vessel from 1265, the Falsterbro ship (Bill 1997), has a ratio of 2.4. Clearly, the trend relates to the increasing specialisation of ships for cargo transportation.

6. Conclusion and outlook

As suggested by Christensen (2002) and Englert (2015), ships such as Lysnæs, Wismar and Bergen are well above what an ordinary *farmann* (a Scandinavian peasant trader) could afford to build, equip and maintain. The high-quality material used in the construction and the sheer amount of raw material needed indicate that these ships were commissioned and owned by someone high up on the social ladder, such as high clergy, magnates, or even kings. Interestingly, late 12th-century to 14th-century sources like the Icelandic Annales and English toll roll often mention the so-called *Buzer* (Christiansen 2002; Simiek 1979)**,** a name used to define cargo ships stemming from Scandinavia. Their names suggest their ownerships, like the *Qgvaldsnesbuza* from the royal seat of Avaldsnes in Norway (Mundal 2017: 44) or the *Lýsbúza* from the monastery Lysa in Norway (Simek 1979: 28). Thus, it is not difficult to imagine that ships like the ones from Wismar and Bergen were built to partake in the Atlantic trade. For example, the stockfish trade from Bergen was sufficiently developed even before 1200 to make it profitable and necessary to build such large ships (Christiansen 2002: 92). At the same time, the Danish dominance in the Baltic was reaching a peak over the areas around Lübeck and Wismar, providing new trade possibilities for professional merchants.

One thing is clear, Scandinavian shipbuilders from around the mid-1100s were able to build surprisingly large ships. Perhaps the pressure on shipbuilders to provide larger ships enticed the introduction of new construction features to reinforce the hull, such as through-beams (Bill 2002: 112) which are documented at least from the end of the 1100s. The size of Scandinavian-built ships continued to rise steadily until changes in the economy and societal organisation brought the trend to a close. When Hanseatic dominance reached its peak, it was their exceptional organisation of trade and a monopoly on essential goods, such as grain and salt, that gave German merchants an advantage rather than their cogs.

Further analysis of the reconstructed hull of the 'Big Ship' of Wismar is planned, including stability analysis and a tank test. First, we would like to estimate the vessel's cargo capacity accurately and appraise its sailing capabilities over different weather conditions. The aim is to understand if the Wismar ship was built for long Atlantic voyages and how it would have performed at sea.

References

Åkerlund, H. 1951. *Fartygsfynden i den forna hamnen i Kalmar*. Uppsala, Almqvist & Wiksells.

Auer, J., Ditta, M. 2023. The Wismar ship: The construction of a large clinker-built merchant vessel from the 12th Century. *International Journal of Nautical Archaeology* 52(2): 287–316

Bill, J. 1997. *Small Scale Seafaring*, unpublished PhD dissertation. Copenhagen, University of Copenhagen, Institute of Archaeology and Ethnology.

Bill, J. 2002. The Cargo Vessels. In L. Berggren *et al.* (eds), *Cogs, Cargoes, and Commerce: Maritime Bulk Trade in Northern Europe, 1150-1400.* Toronto, Pontifical Institute of Mediaeval Studies: 92–112.

Bill, J. 2009. From Nordic to North European. Application of multiple correspondence analysis in the study of changes in Danish shipbuilding A.D. 900-1600. In R. Bockius (ed.), *Between the Seas. Transfer and Exchange in Nautical Technology*. Mainz, Verlag des Römisch-Germanisches Zentralmuseum: 429–438.

Christensen, A. E. 1985. Boat finds from Bryggen. In A. E Herteig (ed.), *The Bryggen Papers.* Main Series. Oslo, Universitetsforlaget AS: 47–278.

Christensen, A. E. 2002. The "Big Ship" of Bryggen in Bergen: What can it tell us?. *Deutsches Schiffahrtsarchiv* 25: 87–95.

Crumlin-Pedersen, O. 2004. Nordic clinker construction. In F. M. Hocker, C. A. Ward (eds), *The philosophy of shipbuilding: conceptual approaches to the study of wooden ships*. College Station (TX), Texas A&M University: 37–63.

Daly, A. 2018. *Dendrochronological analysis of timbers from a shipwreck found at Wismar Wendorf*. Fpl32. dendro.dk report 2018: 32. Copenhagen.

Englert, A. 2015. *Large cargo ships in Danish waters 1000-1250: evidence of specialised merchant seafaring prior to the Hanseatic Period.* Roskilde, Viking Ship Museum.

Morken, R. 1980. *Langskip, Knarr Og Kogge*. Bergen, Wilhelmsen.

Tanner, P. T. 2020. *The reconstruction and analysis of archaeological boats and ships*, unpublished PhD dissertation. Southampton, University of Southampton.

Mundal, E. 2017. Avaldsnes and Kormt in Old Norse Written Sources. In D. Skre (ed.), *Avaldsnes – a Sea-Kings' Manor in First-Millennium Western Scandinavia*. Berlin, Boston, De Gruyter: 35–52.

Simek, R. 1979. Old Norse Ship Names and Ship Terms. *Northern Studies* 13: 26–36.

Van Damme, T., Auer, J., Ditta, M., Grabowski, M., Couwenberg, M. 2020. The 3D annotated scans method: a new approach to ship timber recording. *Heritage Science* 8: 75. https://doi.org/10.1186/s40494-020-00417-9