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RESEARCH

The Dungeness Wreck: A Report on a Carvel-Built Tudor Ship from Kent, England

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Abstract
The 2022 discovery of a 16th-century shipwreck at Cemex's Denge Quarry, Kent, offers a significant addition to the limited archaeological corpus of English-built carvel vessels from the Tudor period. This article presents the findings from the recording and assessment of the wreck, drawing primarily on the grey literature report produced as part of the work funded by Historic England, managed by Kent County Council and undertaken by Wessex Archaeology.
The analyses reveal the carvel-built vessel's timber was sourced from South-East England and East Anglia, suggesting a possible construction date as early as the mid-1530 s and significant modification after 1561.
Crucially, the vessel exhibits a pattern of highly distinctive construction features and carpentry details that are remarkably similar to those of the *Gresham Ship* (circa [c.] 1574).
This article argues that these shared characteristics provide compelling evidence for a distinct regional shipbuilding tradition in South-East England, offering a clear counterpoint to other well-known examples of English shipbuilding from the period.

Keywords 16th Century · Carvel · Tudor · English · *Gresham Ship* · England · Early-modern

Introduction

The sixteenth century was a transformative era for English shipbuilding, as clinker-built vessels were gradually giving way to carvel-planked ships (Adams 2013). This technological shift, encouraged by royal policy and shaped by continental influences, laid the foundations for England's emergence as a naval power (Rodger 1999). Archaeological benchmarks such as the *Mary Rose* (sunk 1545) vividly illustrate the challenges and innovations of this period (Marsden 2009). Yet, while these wrecks provide valuable insights, the archaeological evidence for English-built vessels of the Tudor era remains conspicuously scarce.

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This gap was partially addressed by the 2003 discovery of the Princes Channel wreck (or *Gresham Ship*). The well-preserved substantial remains have been published in *The Gresham Ship Project: A 16th-Century Merchantman Wrecked in the Princes Channel, Thames Estuary Volume I: Excavation and Hull Studies* (Auer and Maarleveld 2014). This wreck was initially considered an anomaly in the panorama of English shipbuilding. In the words of the authors, the *Gresham Ship* "does not easily fit into our current picture of Early Modern shipbuilding", and the existing archaeological record for English ships, as a group, "exhibit surprisingly few similarities", making them "the least homogenous" compared to other regions. The authors further suggest that the "so called 'English' method of ship construction could not be strictly defined from the archaeological record, probably because it was not homogeneous, but also because of a lack of archaeological data" (Ditta in Auer and Maarleveld 2014). The *Gresham Ship* exhibited several unique constructional features that challenged the notion of a singular, consistent 'English way' of shipbuilding in the late sixteenth century (Auer and Maarleveld 2014).

In 2022, the Dungeness shipwreck was recovered during aggregate extraction at Cemex's Denge Quarry in Kent. What is remarkable about this wreck is that it shares many of the unique constructional features of the *Gresham Ship*.

Drawing from a grey literature report (Wessex Archaeology 2025), this article presents the Dungeness wreck (also called the Denge Quarry shipwreck) and ultimately aims to reframe an emergency response into a meaningful contribution to the debate on early carvel shipbuilding in England. It details the circumstances of its discovery, the multi-disciplinary methodologies employed for its recording and analysis, and the key findings regarding its dating, origin, and construction.

This discovery is a valuable addition to a limited corpus and, in some ways, puts us in a position to re-evaluate the characteristics that define Tudor shipbuilding in the strategically important South-East region. Furthermore, the comprehensive 3D scan of the timbers creates a rare and precise dataset, offering a significant research opportunity for detailed studies into its design and construction.

In the final part of this article, the author briefly contextualises these findings within the broader discourse on early modern ship design, highlighting some of the wreck's striking resemblances to the Gresham Ship. The author argues that these parallels point to a well-defined but distinct regional shipbuilding tradition of English carvel shipbuilding in the mid-sixteenth century, separate from that of the later *Sea Venture* and the earlier *Mary Rose*.

Site and Historical Context

The Denge Quarry shipwreck was uncovered in April 2022 during dredging operations at Cemex's Denge Quarry in Lydd, Kent (Fig. 1). The discovery was initially reported by quarry staff through the Marine Aggregate Industry Archaeological Protocol. Following a brief site visit, an application for emergency funding was submitted to Historic England, and Kent County Council commissioned Wessex Archaeology to undertake the recording and assessment of the timbers.

The site is a landlocked, water-filled quarry on the Dungeness Foreland, approximately 500 m from the modern shoreline. This quarry, operational since the 1940s, has undergone successive deepening, eventually exposing the remains.

Fig. 1 Site location

Denge Marsh and Denge Nesse are the historical terms for the area. These areas were annexed to the small but important coastal market town of Lydd, which was a member or "limb" of New Romney, one of the five Head Ports of the Cinque Ports confederation. The Ancient Towns of Rye and Winchelsea, situated to the west of Lydd and Dungeness, were also part of the Cinque Ports confederation.

This area, called the Nesse, served as a site for seasonal fishing settlements, known as cabins, which were utilized by the residents of Lydd. Notably, historical records from the fifteenth century from Lydd shed light on the presence of West Country fishermen, referred to as "Westernmen", who frequented the Nesse for fishing and drying their catches (Draper and Meddens 2009).

From the late Hundred Years' War, the Ness functioned as a key lookout point. Official concerns over watch duties and beacons for Denge Marsh were recorded by 1585, with some disputes arising by 1587 until the threat of Spanish invasion in 1599 led to explicit orders for maintaining a continuous watch (Draper 2024).

Dungeness Foreland has long been a notorious hazard to navigation. Most recorded wrecks occurred on its eastern side, where vessels approaching from the north-east, tacking against south-westerly winds to enter the Camber Estuary, often miscalculated the coastline and failed to round the tip. Even those that succeeded remained at risk of being driven onto the southern, leeward shore (Dhoop 2016).

Medieval chronicles, such as "The Chronicle of Battle Abbey", document disputes over wreck ownership. By the fourteenth century, rights to wrecked goods were typically granted to manorial lords or towns like the Cinque Ports, with distribution agreements formalized by the sixteenth century. Piracy and shipwrecking were common, particularly during wartime (Draper 2024).

The wreck's specific archaeological and environmental context remains poorly defined. The geoarchaeological assessment of borehole data provided by the quarry owner indicates that the vessel likely rested on shoreline sands or gravels before being overlain by an advancing shingle barrier, consistent with the AD 1400 coastline (Long et al. 2006; Long et al. 2007). Yet the exceptional preservation of the timbers suggests deposition in a low-energy setting, such as a sheltered creek, rather than a high-energy shingle shore. Furthermore, the reported presence of a large hull fragment approximately 350 m from the main findspot, together with the presence of two timbers from distinct vessels within the assemblage, seems to suggest a more complex depositional environment containing multiple ships. It is therefore likely that further unknown elements of the wreck(s) remain buried within the quarry sediments but were not intercepted by the extraction works. Unfortunately, the accidental nature of the discovery, and the lack of systematic underwater surveys within the quarry leave these questions unresolved.

Methodology

The methodology adopted for the Denge Quarry assemblage reflected the circumstances of its recovery. All timbers were recovered inadvertently during mechanical aggregate extraction rather than through controlled archaeological excavation, and no systematic survey of the quarry could be undertaken. Because the wreck was not excavated in situ but recovered accidentally during commercial dredging, the focus was on creating the most comprehensive possible record of the timbers under emergency conditions (Adams, van Holk, Maarleveld 1990). The strategy combined advanced digital documentation, targeted sampling, and specialist analyses.

High-resolution 3D scanning with an Artec Leo was the primary recording technique, following the methods developed by Van Damme et al. (2020). Each timber was scanned to capture morphology, toolmarks, fastenings, and carpentry features; the resulting models were annotated in Rhino3D by a nautical specialist. The record allowed the creation of accurate scaled drawings (1:10 or 1:20). All the timbers were tagged, photographed, measured, and sketched to build a comprehensive catalogue.

To document large, coherent sections of the hull and internal constructional relationships—otherwise inaccessible –photogrammetry was employed during a sequential dismantling process. This process provided a critical opportunity to document internal relationships specifically because the assemblage was scheduled to be re-submerged within the quarry to ensure its long-term survival under controlled waterlogged conditions. This strategy prioritized long-term preservation over immediate physical accessibility. This pragmatic compromise was driven by the prohibitive cost of conservation and the absence of an established repository—a reflection of the broader structural challenges still faced in the management of large maritime assemblages recovered under emergency conditions.

The Hull and its Components

Description of the Principal Fragments

Over 140 ship timbers were recovered by the dredger. The majority were lifted in four substantial, coherent sections of carvel-planked hull (5004, 5005, 5006, 5007), reportedly lifted together on the same day from a single location (Fig. 2). Numerous smaller, disarticulated, and often damaged timbers were later retrieved during gravel processing, though whether these fragments derived from the same spot or from a wider area is uncertain, as the processed material was not separated by batch. Throughout the text, numbers enclosed in brackets […] indicates the individual timber numbers, which are correspondingly annotated in the figures.

Despite the accidental mode of recovery, the degree of survival is remarkable. If the four large sections are aligned fore-and-aft – without accounting for the missing portions

Fig. 2 Section 5004, is 6.8 × 2.8 m and is the largest portion of hull preserved, from photogrammetry model

– they would extend for over 12 m, likely representing a significant proportion of the vessel's original length.

Bow

Section 5005 is the forward-most preserved portion of the vessel, representing part of the starboard bow at the turn of the stem (Fig. 3). It measures 2.3 × 1.6 m and comprises just eight timbers: four outer planks and four athwartship members. Its bow location is indicated by the hood ends preserved in two planks, the twist of the outer planking, and the pronounced rise and forward sweep of the two crotch timbers [029, 031] (Fig. 4). The planking narrows and thins toward the hood ends to accommodate the curvature of the bow. Hood ends were chamfered to fit into the stem rabbet and secured with square-shanked iron nails, recessed into the planks.

The structure is dominated by two substantial V-shaped crotches spanning the centreline, with truncated port arms but retaining a rectangular recess likely intended for the keel or another centreline timber, and fastened by an iron bolt to the keel or other longitudinal timber. A square limber hole is cut just above this recess, slightly offset to starboard. Two further half-frames abut but are not fastened to the crotches, rising steeply into near-straight profiles. Axed recesses and alignment marks survive on the inboard faces, presumably showing where ceiling planks were seated.

Likely associated with this fragment is a bevelled oak slab [080], 2.67 × 0.39 × 0.15 m, interpreted as an apron which reinforces the junction of stem and keel and provides an indication of the sweep of the profile of the bow. Trapezoidal in section, gently curving in profile, and set with 32 angled treenails, it retains evidence of a scarf at one broken end and a ferrous fastener along its convex face. While this

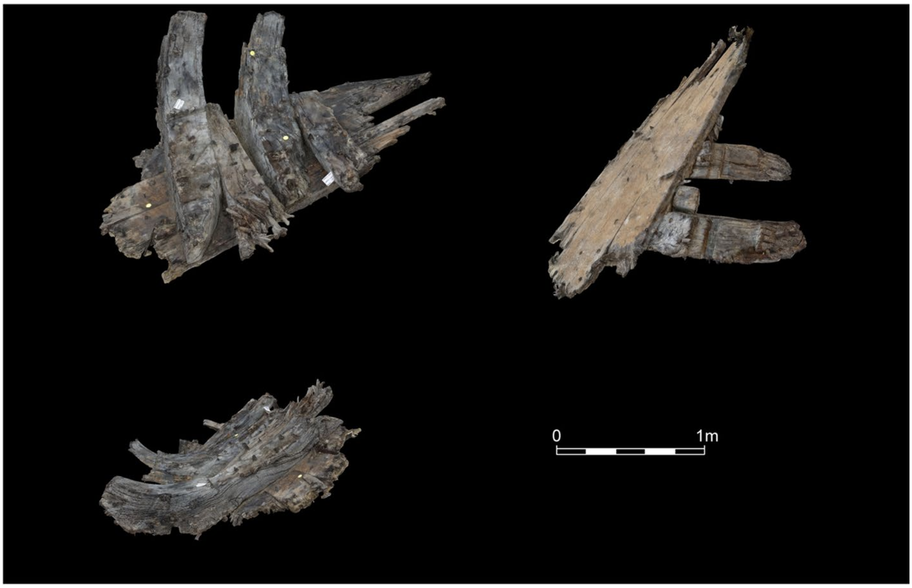

Fig. 3 Section 5005: Top view (top left), bottom view (top right), aft view (bottom left), from photogrammetry model

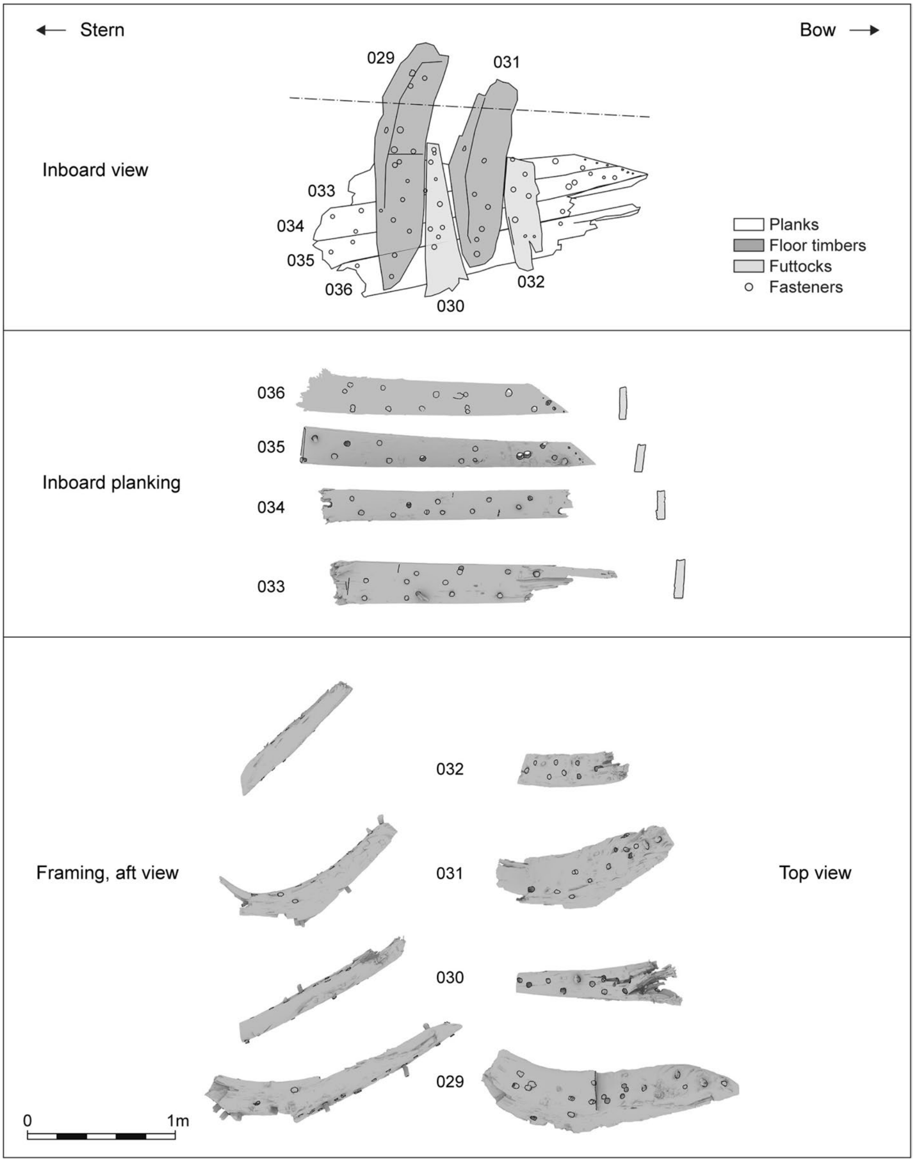

Fig. 4 Section 5005, framing and planking layout

timber could potentially represent another longitudinal component of the stem assembly, its dimensions, fastener depth and patterning, and absence of a rabbet—all mirroring features of the Gresham ship—seem to point toward its identification as the inner stempost or apron.

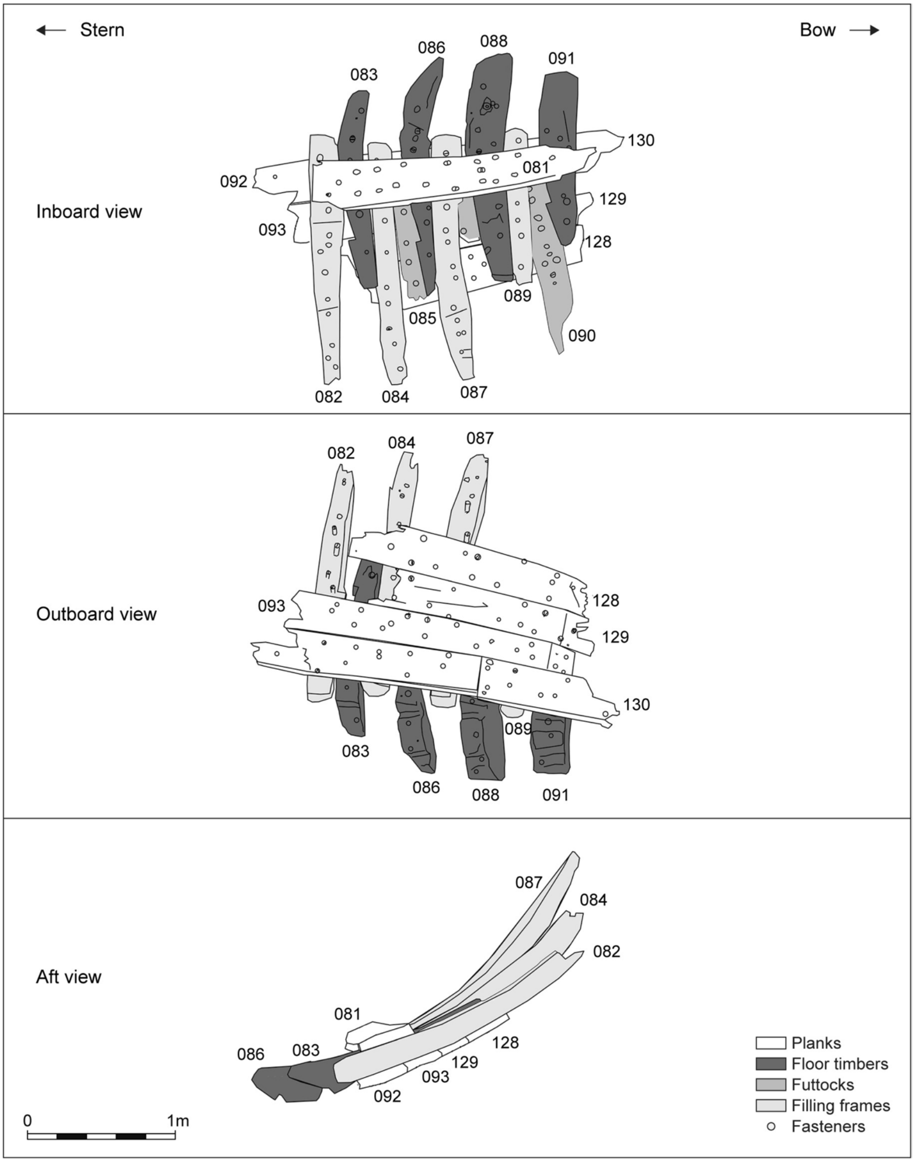

Fig. 5 Section 5006, inboard, outboard and moulded view

Amidship

Section 5006, 2.4 × 2.3 m, derives from the lower starboard hull, presumably just aft of the bow. It comprises four outer strakes and four frame stations (four floors, three futtocks, four filling frames), overlain by a surviving ceiling plank (Fig. 5). The floor timbers, truncated at the centreline, preserve broad feet that narrow markedly toward the bow [086, 088, 091], with triangular limber hole notches and a ferrous bolt fastening at least one floor to the keel.

Futtocks are joined aft to the floors by diagonal hooks each secured with two treenails, with the exception of floor [088]. The narrowing of the floors and the forward lean of the frames are pronounced in this section. The filling frames, one complete [087] at 2.27 m in length, are squared and tightly seated, spanning from the floor arms over the bilge. They strengthen scarf areas and provide shoulders for the futtocks, creating a dense, almost void-free framing system treenailed to the planking.

The outer planking preserves four runs of strakes, all broken amidships. Three scarfs occur in the forward ends of the lowest strakes, all vertical stop-splayed and feathered in the same direction. One is unusually short (180 mm) [093], positioned immediately adjacent to another with minimal shift. The first strake comprises two planks of markedly different width (310 mm and 350 mm), an unusual feature possibly reflecting a stealer, repair, or later modification (Fig. 6).

The largest surviving section, 5004, measures 6.8 × 2.8 m and preserves the lower starboard hull from garboard to bilge (Fig. 7). The profile from the keel to the turn of the bilge is rounded, with flatter floors toward the stern. The keel is absent, and the section is truncated amidship in correspondence to where it would have been.

This section suffered most from recovery damage: both ends are freshly broken, planking bent upward by the excavator, and bucket teeth marks cut across ceiling surfaces. Nonetheless, it preserves 57 timbers: six strakes of outer planking, 12 frame stations, and four ceiling planks. Eleven frame stations retain paired floors and futtocks, mostly joined by dovetail mortices fastened with two lateral treenails. The probable master frame [051, 078] marks a change in framing pattern, with symmetry centred in the room just forward of it. Filler frames, several complete, span the vessel's full breadth, tightly seated in the spaces between the floors.

The six outer strakes, composed of two or three planks each, include four planks preserved full-length. The width of the planking is rather regular, and the layout of the planking has a scarf pattern that aligns them every four strakes with an exception aft. The planks are joined with splayed vertical scarfs that all feather in the same direction and secured with treenails and iron nails. Thick ceiling planks are assembled with stop-splayed scarfs, secured by treenails. The pronounced sny of the bottom planking suggests maximum beam lay close to the midship point of this section, in a position consistent with the master frame.

Stern

Section 5007, 1.66 × 1.12 m, represents the lower part of the sternpost assembly. Probably part of a modified stern, it includes elements of the sternpost, a probable fragment of keel, extended deadwood, and the first three strakes of outer planking that clad an inner, less thick layer of planking. This section seems to indicate that the stern was modified, possibly extended aft.

Considerations and Other Timbers

The possibility that the large articulated sections originated from more than one vessel has been dismissed, given the absence of duplicated elements and the consistent use of materials, dimensions, and workmanship, as well as the reported single location of discovery. Dendrochronological results also support this interpretation.

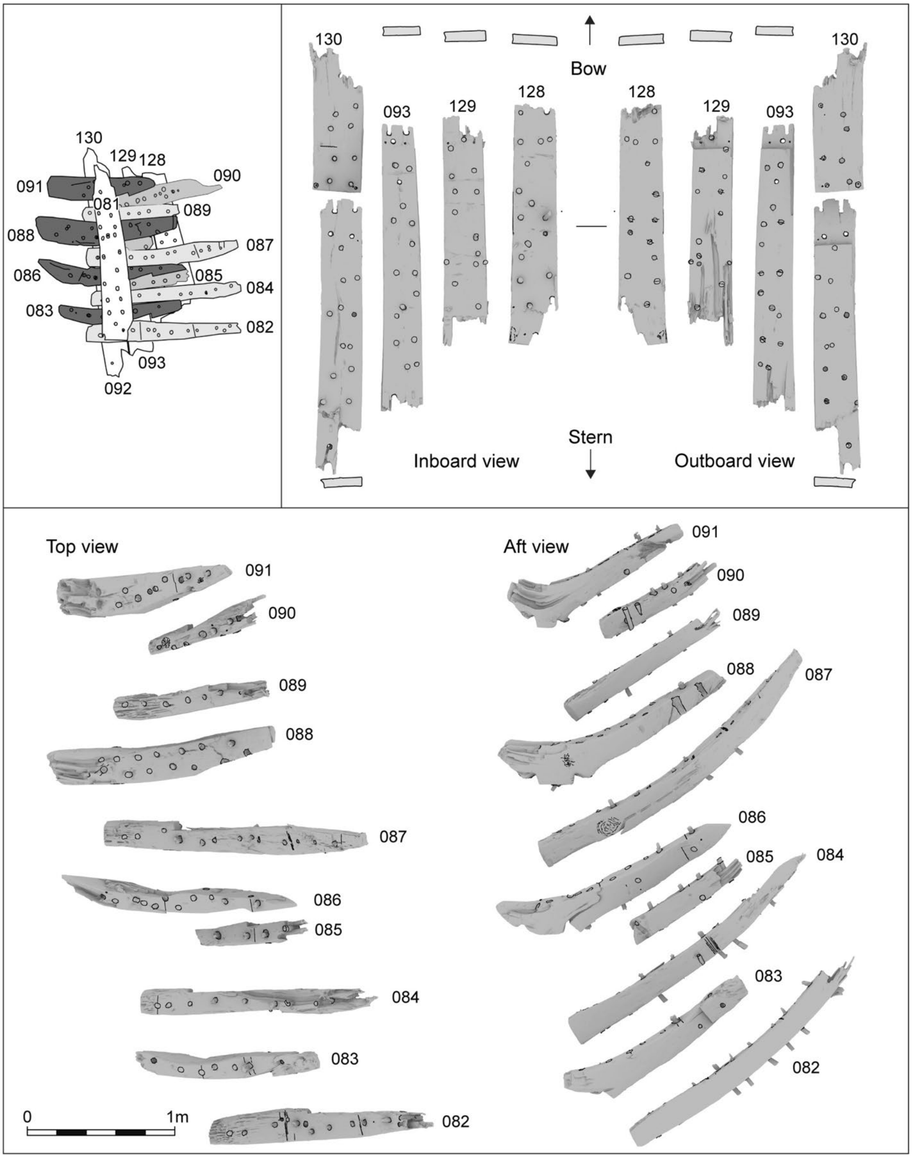

Fig. 6 Section 5006, framing and planking layout

Within the disarticulated timbers and smaller units, most were identified as either frames or planks. A complete oak floor [028], 2.55 m wide with a central limber hole, is notable for its flat profile and fastening pattern, which differs from the floors of the main wreck. Together with similar fragments [026, 027], it may derive from another carvel-built craft, perhaps a large boat or small ship. Timber [022], 2.8 m long with joggles characteristic of clinker floors, appears even less consistent with the main assemblage, possibly representing an earlier, smaller clinker-built vessel.

Fig. 7 Section 5004, top view showing the different disassembly phases, from photogrammetry model

Construction Components

Wood

The construction predominantly used oak, with elm selected for specific planking. The shipbuilders made extensive use of compass timbers for curved elements like floor timbers, crotches, futtocks, and filler frames, many of which were of substantial dimensions [029, 088]. While the oak quality appears very good, the conversion process showed some carelessness, with several floor timbers and futtocks left with sapwood and bark on the surface [076]. Some timbers also contained several knots, which were occasionally drilled out and plugged to prevent rot. In contrast, the filling frames were more uniformly made, typically halved and quartered to regular dimensions (sided dimension ranging from 150 to 240 mm, moulded c. 170 mm) with less branching, suggesting a more consistent selection process for these components.

Elm was used for several outer planks along the hull in Section 5004 [067, 097, 112], and also at the stern, 5007, in both the inner and outer layers of planking [102, 103, 121].

Fasteners

The majority of fasteners were treenails made of cleft oak heartwood, shaved into approximately 16-sided cylinders that were well-rounded with no noticeable flats. Shipbuilders drove treenails for almost all fastenings, with the majority passing through the full thickness of the outer planking, frames, and ceiling planks, although some were cut flush on the frames and did not penetrate the ceiling. The average diameter was between 25 and 35 mm, and it is estimated that over 350 treenails were used to fasten the outer planks of the largest hull Section (5004). In a few instances, a new treenail was bored through an existing one.

The positions for augering holes were often marked on the inboard faces of the frames with a depression made by three or four chisel cuts. This practice likely helped to start the auger and may have served as a guide for less experienced shipwrights. Evidence of mistakes includes several marked positions that were never drilled and a few treenail holes that were started but not completed. Although some intercutting is expected, the treenails were at times distributed in a seemingly random or chaotic pattern, with several driven closely together or doubling over each other.

The builders expanded the inboard ends of the treenail holes, probably with a gouge or by rocking the auger, to create a larger head for wedging. Some treenails were driven at an angle, resulting in an elliptical head. The outboard ends were often scored with two quick blows to form a “V”, “II”, or “X” shape. Wedges were driven into both ends and caulked with hemp fibre.

In addition to treenails, various wooden plugs were employed. These included short, truncated conical bungs (115 mm (mm) long, 35 mm diameter) and shorter, four-sided conical wooden nails (115 mm long, 15–20 mm side) at scarf ends [098]. Blind treenails or plugs of varying diameters compensated for knots [113]. Small triangular wooden pieces (32 mm by 15 mm by 5 mm) were inserted to fill holes left by temporary squared-shaft iron nails on the undersides of the frames.

Iron bolts (25–35 mm diameter, c. 315–380 mm long) fastened larger structural components, such as frames to the keel [088, 091], and reinforced the connection between the keel and sternpost [104]. Significant corrosion makes discerning the head shape difficult, but one example appears round and clenched over a round rove. Square-shafted nails (5–8 mm side) were used to fasten hood-ends and scarf joints between planks and appear in association with the garboards [101, 105] and some repairs. These nails were countersunk, leaving a quasi-square impression approximately 20 mm in diameter.

Waterproofing

The seams of the outer planks were waterproofed with animal hair (calves or cattle) and tar. Builders combed the fibres into tufts, dipped them in an organic binder of pine tar and probably pine resin, and then pressed three strands into a shallow V-shaped groove (10–15 mm deep) cut along the lower edge of each plank. The strands were sometimes twisted or simply pushed together. The bevel angle of the groove changed depending on the plank's position and was realigned at scarves. After laying the material, the builders likely clamped and wedged the planks to draw the edges together, enclosing and flattening the tarred hair within and sometimes squeezing the excess inboard. The precision of alignment and tightness of the seams indicates confident craftsmanship.

At the bow, scarfs and landings were bedded using the same material shaped into an irregular mass of felted bands. The same bedding was applied amply at the stern, for example in the sandwich between the two layers of planks and between the first layer and the post.

A protective layer of dark brown-yellow resinous material, consisting of pitch mixed with pine resin, was generously applied to the hull's interior and exterior surfaces. On certain well-preserved outer planks, traces of a grey surface coating speckled with white were detected, though it is unclear whether it is a surface treatment or result of seabed contaminants.

Although not strictly waterproofing, half-frame [032] has remnants of rabbit skin glue on its inboard fore edge. As no joints or repairs are present, this may be evidence of temporary fastening or timber repurposing.

Keel

Only a single fragmentary piece of the keel at the stern survives [104]. This oak timber is naturally curved, straight in the fore part and curving upward aft beyond the sternpost. It is sub-rectangular in section, with a sided dimension of 120 mm tapering to 80 mm forward across a scarf, and a maximum moulded dimension of 300 mm aft. The forward end has a possible scarf, broken at the lower edge, which fastened the timber to the vertical post [109]. A small shoulder cut on the upper surface likely helped position the vertical post and strengthen the joint. A large vertical iron bolt attached the aft section of the keel to the skeg [117], a fragmented wedge-like timber that notches against its underside. A water stopper runs horizontally between the two. There is no rabbet at the extremity of the keel; the garboards [101, 105] lie flush against its port and starboard faces.

Apron

The apron [080] is a large, curved slab of oak shaped from a half-log section, measuring 2670 mm in length, 390 mm in width, and 150 mm in thickness (Fig. 8). It is trapezoidal in section, with sides flaring out to a maximum of c. 60 degrees to the horizontal, and widens in thickness as it curves upwards, matching the stem's inner curve. One end is broken while the other has a straight cut. A total of 32 treenails are driven at an angle on its sides (15 starboard, 16 port), many of which are not through or are cut flush on the inner hollowed face. The convex outboard face has the remains of

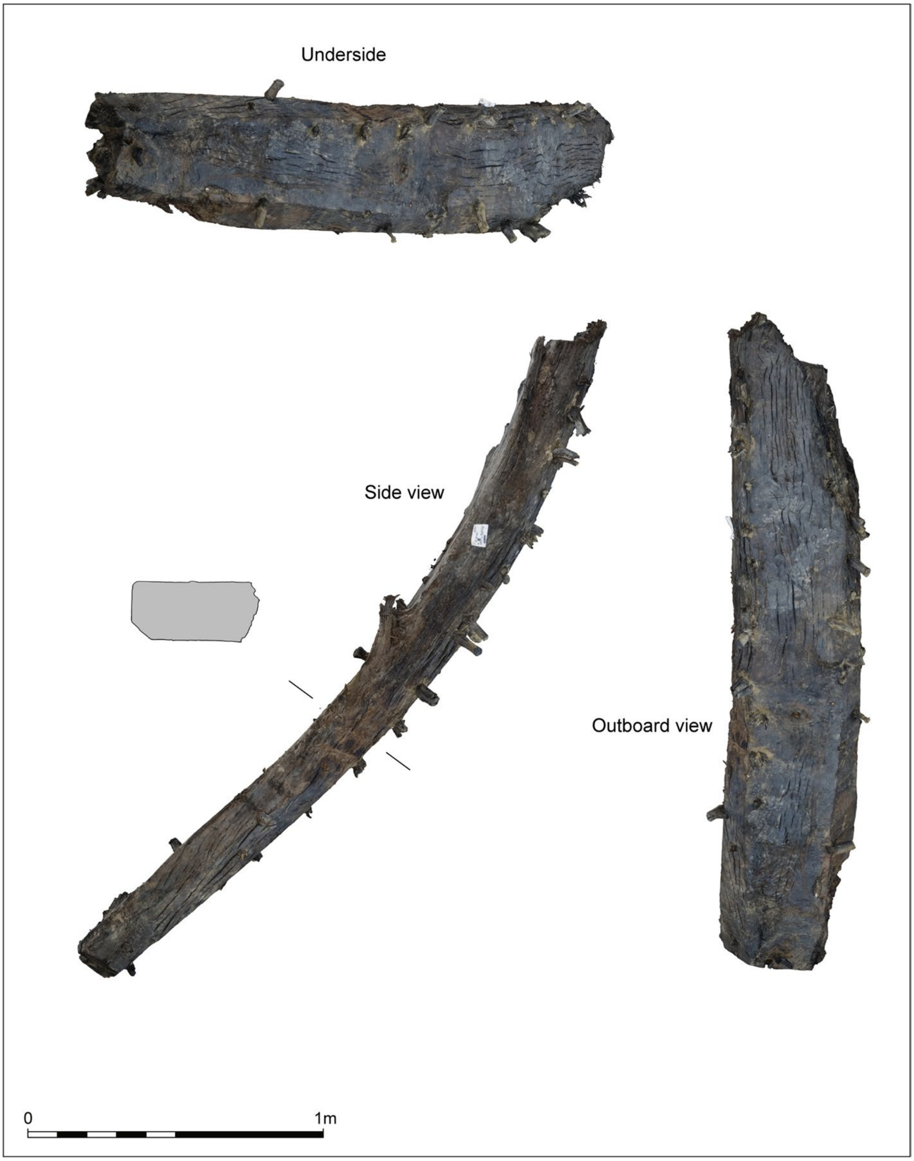

Fig. 8 Timber [080], apron

one central bolt and one at the bottom. Multiple treenails for the hull planking remain intact, protruding up to 70–80 mm from the apron's sides. Two parallel lines carved horizontally across the inboard face probably indicate the location of transversal elements such as rising frames or crotches.

Outer planking

The outer planking is primarily oak, with a limited use of elm. Sawyers tangentially converted the planks from heartwood using pit-saws, leaving bold saw marks, and then dubbed them with an adze. Evidence of charring on some planks [096] indicates they were bent using an open fire. The wood chosen showed few obvious weaknesses, with generally no sapwood left and relatively rare knots.

The few surviving complete planks vary in length from 2.9 m to 5.1 m. Thickness ranges between c. 70 mm at the stern and amidships to c. 50 mm at the bow. Width varies along the plank length between 230 and 480 mm, generally tapering towards the bow. With the exception of plank [130] in the first strake of Section (5006), the strakes are composed of planks with consistent dimensions and regular transitions.

Builders assembled the strakes carvel-fashion, fastening them to the frames with treenails (Fig. 9). V-shaped recesses were carved into the lower edges of all outer hull planks and the upper edges were square.

Every preserved scarf is a vertical splayed scarf, typical of northern European lapstrake construction but unusual in carvel shipbuilding. The scarfs are all aligned in the same direction, with feathered edges terminating in either a flat or a lipped end. The toolmarks indicate that,after the ends of the scarfs were scribed, hollowed with adzes [096] and luted with animal hair and tar. The joints are secured with treenails, usually a minimum of two, as well as square-shafted iron nails, generally arranged in a line of three near the edge. The scarf length ranges between 395 and 580 mm. While generally staggered, the shift is sometimes rather limited, with scarfs in neighbouring strakes as close as 0.7 m apart.

The first three strakes [129, 093, 130] in Section 5006 are an exception, with scarfs placed side-to-side and of shorter length. The presence of a plank of two different widths in the first strake may indicate a repair or modification. The lower edge of one of the two is square, unlike the grooved edge of the preceding one, to which it is fastened with an extra nail.

At the bow, builders chamfered the hood ends into a landing c. 100 mm wide, which tapered onto and was fastened to the stempost with three nails after bedding with waterproofing material was generously applied.

At the stern, the garboards and adjacent strakes turn vertically. A layer of thinner original planking (maximum 35 mm thick) [120, 121] is rabbeted and fayed into the sternpost, covered by a doubling layer of thicker planks (maximum 70 mm thick) [103, 102] which extend past the rabbet line.

The garboard strakes at the stern are made of two short, fragmented oak planks (380–400 mm wide, 50–60 mm thick) on either side of the sternpost. They are sub-rectangular in section, with the lower outer edge bevelled to fit smoothly against the keel.

Overall, the outside of the hull seems well faired, without observable kinks and too many flats that could have resulted from sawing conversion.

The Framing System

The framing system consisted of floor timbers, futtocks, and filling timbers, fashioned primarily from a mixture of whole curved oak logs hewn to shape with an axe and smoothed with an adze, or pit-sawn into halves or quarters (Fig. 10). The shipbuilders

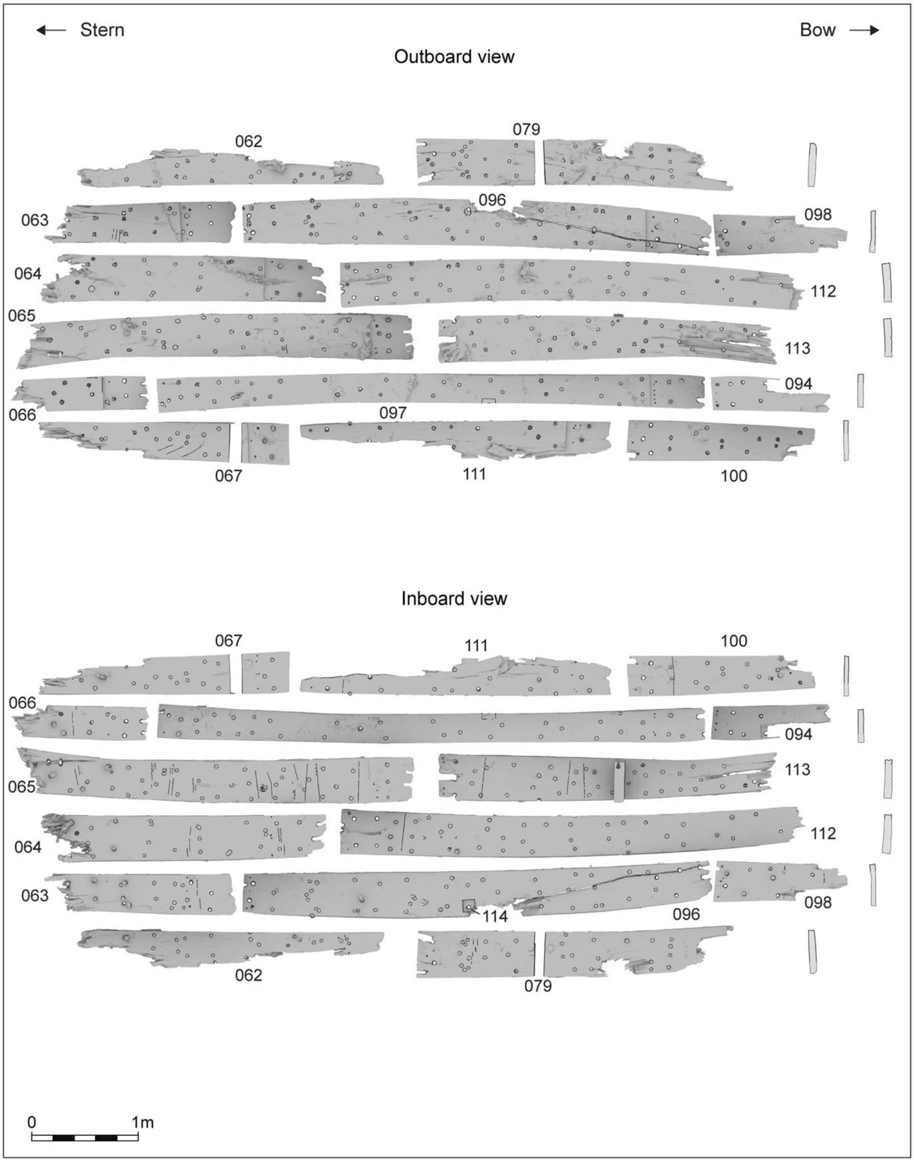

Fig. 9 Section 5004, planking layout

fastened all components through to the planking and ceiling strakes using treenails, with a minority (four or five per timber) not penetrating the ceiling planks.

The lower hull exhibited a dense but irregular framing pattern, with floor timbers securely joined side-by-side to the first futtocks, forming a continuous timber band with the filling frames fitted in between the frame stations.

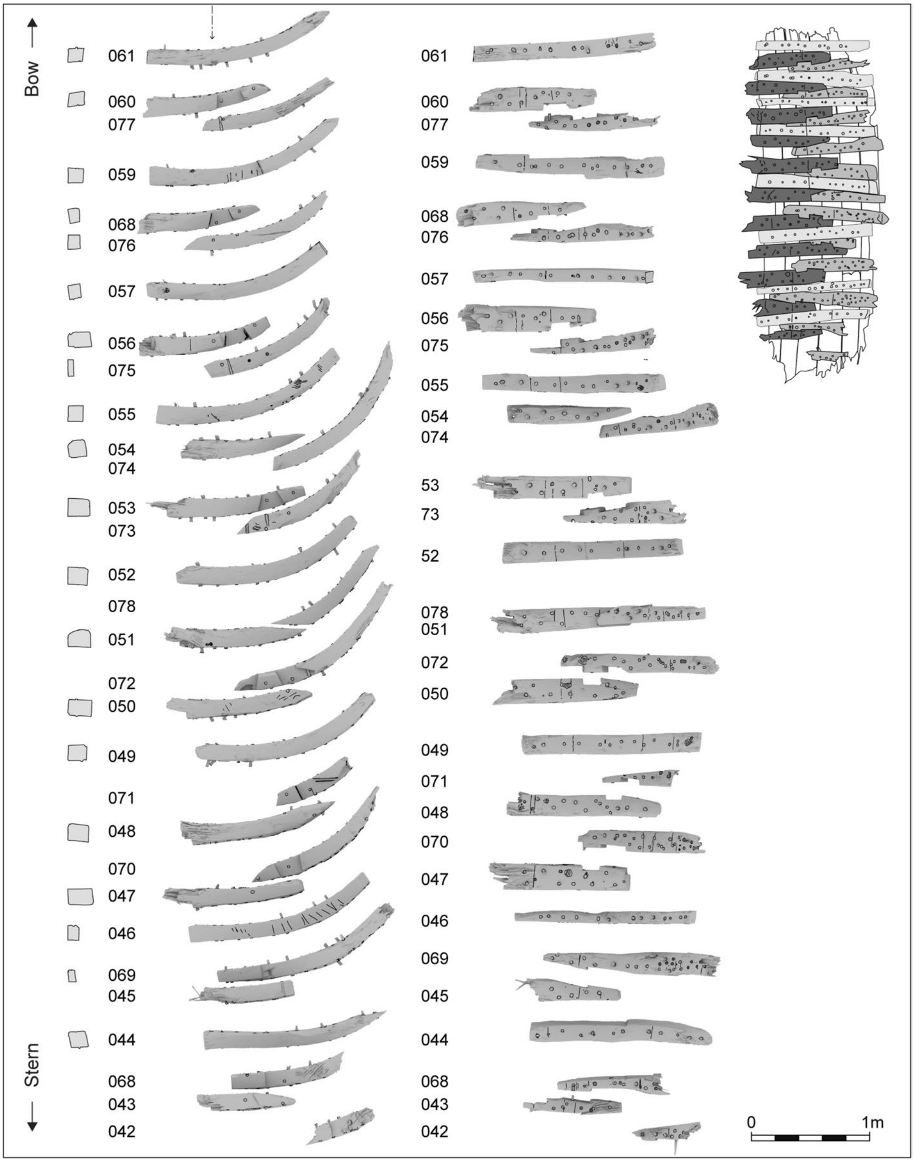

Fig. 10 Section 5004, moulded view from aft and top view of framing

The overlap is not necessarily at the same height in each frame but the filling timbers reinforce the joint spanning the length of the floor flat, but without crossing the keel, and the entire bilge arc.

Builders interconnected the floor timbers and futtocks using a variety of joints, primarily single or double trapezoidal dovetail mortises (long base of 300 mm), some hooked diagonal locks [047], or, in one case, a simple butt joint [054–074]. In the vast majority of cases, two lateral treenails secured the connection, often with one driven through the mortise and a second at the heel of the futtock. They drove these treenails from either the fore or aft direction, often at an angle, and in a handful of cases left them blind [047]. No ferrous fasteners were used for these connections. Dovetail joints were most common in Section 5004 and hook scarfs predominant forward in Section 5006.

The floor of the probable master frame [051] is joined to its futtock [078] with a simple flat diagonal scarf 400 mm long, secured with at least two treenails driven vertically through, unlike the lateral joints seen elsewhere.

The spacing between the floor timbers is fairly regular (400 mm to 530 mm between centres), and the pattern of floor-futtock-filling timber repeats regularly across the hull, except around the master frame. Aft of the master frame, the futtock is fastened to the fore face of the floor, while forward of it, the futtock is fastened to the aft face.

The filling frames were added afterwards and dry-fitted as tightly as possible in between, fastened only vertically to the planking and not to other framing components fore and aft.

Builders likely pre-assembled the frames before erection or built them in a strict sequence, as evidenced by the narrow spaces between frames and the sharp angles of some lateral treenails. The fact that some of these lateral treenails are cut by vertical treenails driven from the outer planking further confirms that the planks were added after the futtocks were fastened to the floors.

Evidence of temporary square-shafted iron nails (3–5 mm sided) on the undersides of the floor timbers and futtocks likely relates to securing plank ends or facilitating placement during construction. The absence of these nails on the filling frames, which were seated after the bottom was planked, is consistent with their later installation. Similar impressions were also found on the upper face of the frames, although more sparingly.

Rather than exhibiting a smooth curve, some of the outboard faces of the lower hull framing present slight angular kinks or flats. Builders dubbed these so the sawn hull planks could fit tightly against the frames' curves. Where extra thickness was needed, they drove wedge-shaped oak filling pieces underneath the frames [088]. This process is reminiscent of later medieval clinker shipbuilding in which the outer faces of the frames were cut to fit the outer planking of the hull. The filler frames show fewer such kinks, as builders instead adzed the inner faces of the outer planking to fit them within the hull.

Floors

The floor timbers were made from large oaks, shaped with a saw and axe and dubbed with an adze. Their scantlings are reasonably regular (250–300 mm sided, 190–230 mm moulded), with a rectangular or sub-rectangular section and slightly rounded edges, generally tapering outboard. The length is variable, but the wrongheads were typically cut between the third and fourth strake, resulting in an overlap with the futtock of up to 920 mm. The floor of the possible master frame [051] measures 190 mm moulded, 250 mm sided, and 1.60 m long. The preserved partial length of the longest floor amidships is 1.78 m.

The floors are relatively flat amidships, with the flat extending outboard with little deadrise to approximately 900 mm from the presumed centreline. Towards the bow, they become more angled and develop a substantial foot [086, 088, 091], increasing the moulded dimension at the centreline from 200 to 280 mm. These forward floors are fastened to the keel with a centreline bolt whilst only very few are fastened this way in the sections amidships. The two crotches [029, 031] at the bow are large natural curved timbers that form a pocket biting onto the keel or another longitudinal timber.

The floors have either a single square limber hole sawn into the underside to a depth of 50 mm and 50 mm wide, or two triangular notches cut to a depth of up to 90 mm at the transition between the foot and the arm.

Futtocks

The first futtocks are generally compass timbers converted in the same way as the floors. They often retain sapwood and bark [076] and are not regularly sided, as the natural shape of the wood is accommodated [072].

Almost all are incomplete, with only the lower ends preserved, cut off square or at an angle. An exception is the futtock of the master frame [078], which survives entirely. It is 1.45 m long, with a maximum sided dimension of 210 mm and moulded of 180 mm, gently tapering outboard. With a rectangular section, its heel is scarfed to the floor timber and its head is diagonally cut, with the inboard slope fastened to the outer hull with a treenail.

Amidships, the futtocks define a rounded bilge, which in some cases [070, 074] appears almost as a segment of a circle, while forward they are almost straight. The longest preserved futtock spans from below the joint with the floor timbers (between the first and second strake) up to at least the sixth or seventh strake, with a maximum preserved length of 2.1 m. The maximum sided dimension varies between 186 and 270 mm, and the maximum moulded between 160 and 180 mm.

Filling Timbers

The 12 surviving filler timbers are naturally grown curved oak timbers, made regular from halved and quartered logs and dubbed with axes. Several were left with sapwood and bark and have clusters of small knots. Nonetheless, they appear regularly shaped and distributed.

Typically, the lower end is vertically cut, starting just after the centreline, and they span all six surviving strakes of outer planking, ending on the last strake where their heads align approximately two strakes above the floor wrongheads. The longest filling frames are around 2.1 m long. Their siding is governed by the space between frame pairs, ranging from 150 mm sided by 170 mm moulded to 240 mm sided by 170 mm moulded for the largest filler frame [052] next to the master frame station.

These timbers were not attached to the main framing assembly but were tightly inserted between the joined pairs of floor timbers and first futtocks, reinforcing the turn of the bilge and the joint area. Even when joggled onto the floors or futtocks, they were never secured to them.

The treenails fastening the filler frames to the planking are more carefully and methodically driven than those in the main frames, showing a similar number of fasteners (around 12) per timber, typically one to three treenails per strake along a single line. In a few cases, the auger was misplaced and the hole restarted nearby.

Interestingly, before fitting the filling frames, builders scraped and smoothed the interior of the outer planking, faying the surfaces to ensure a tight fit. This process removed the tar coating that served as a bedding underneath the other frames, which was not reapplied afterward.

Although this might appear a poor practice in terms of durability, it probably also saved money on the purchase of imported pine tar, and for those funding the work, this deficiency would have been concealed once the filler frames were added, therefore possibly raising questions about the presence of malpractices, socio-economic pressures or even corruption in the shipyard.

Ceiling Planking

Three adjacent strakes of inner planking were preserved on the starboard side. The absence of treenail stubs further inboard suggests no additional strakes existed toward the centreline.

The thick ceiling planks were shaped like the outer hull planks, tangentially converted with a pit-saw and devoid of bark or sapwood. Builders bent at least two [037, 040] with charring, as evidenced by traces of burning on their undersides.

Two planks are virtually complete: the longest measures 6.20 m long by 380 mm wide, while the other is shorter but reaches 460 mm in width. They are approximately 50-60 mm thick. Builders fastened them to the hull with treenails; up to 50 treenails were used on the longer planks, each made flush on the upper face and the majority wedged.

The planks have a gentle camber and sheer, suggesting they were purposefully prepared with a longitudinal curve to accommodate the hull's shape efficiently, saving material and cost. Builders joined the strakes lengthwise using simple vertical scarfs similar to the outer planking. The key difference is that the feathered edges of a ceiling plank scarf point in opposite directions – one toward fore and the other toward aft. The scarfs were c. 400 mm long and secured with a few treenails.

The ceiling planks extended to the bow, and their positions were marked on the upper surfaces of the frames and crotches with recesses or scribed lines.

The Sternpost Assembly

The sternpost assembly features a rabbeted sternpost with an extended aft deadwood [109], a fragment of keel [104], and a skeg [117]. The larger vertical and longitudinal components are oak, while the outer cladding [103, 102] and the thinner planking within the rabbet [120, 121] are elm, excluding the oak garboards [101, 105] (Fig. 11).

The entire structure is secured by more than 20 treenails, each 30–35 mm in diameter, driven through it, while the connection with the keel is secured vertically with iron bolts.

The main component of the assembly is a large, finely tapered vertical oak timber piece [109], with a trapezoidal cross-section that narrows upward and tapers aft. The forward face measures 132 mm sided at the outer heel above the horizontal score for the outer planking. The port and starboard faces are a maximum of 1085 mm high vertically and extend to a maximum of 645 mm fore-and-aft. This substantial element is made of two timbers, the sternpost and extended deadwood, which are presumably joined with a lap joint bedded with waterproofing compound, visible through an angled seam just forward of the rabbet.

The aft part of the post is mostly missing, damaged during recovery. However, fasteners indicate that at least one other vertical timber extended it further aft. The top part of the assembly is broken and eroded. Deeply incised, roughly driven axe marks along the aft upper edge may hint that the timber was reused or salvaged.

The bottom of the assembly has a tapering rebate to seat onto an unusually curved longitudinal timber interpreted as the aftermost heel of the keel [104]. The lower aft face of the post locks into a small step on the upward face of the keel, just forward of the rebate, for additional adhesion.

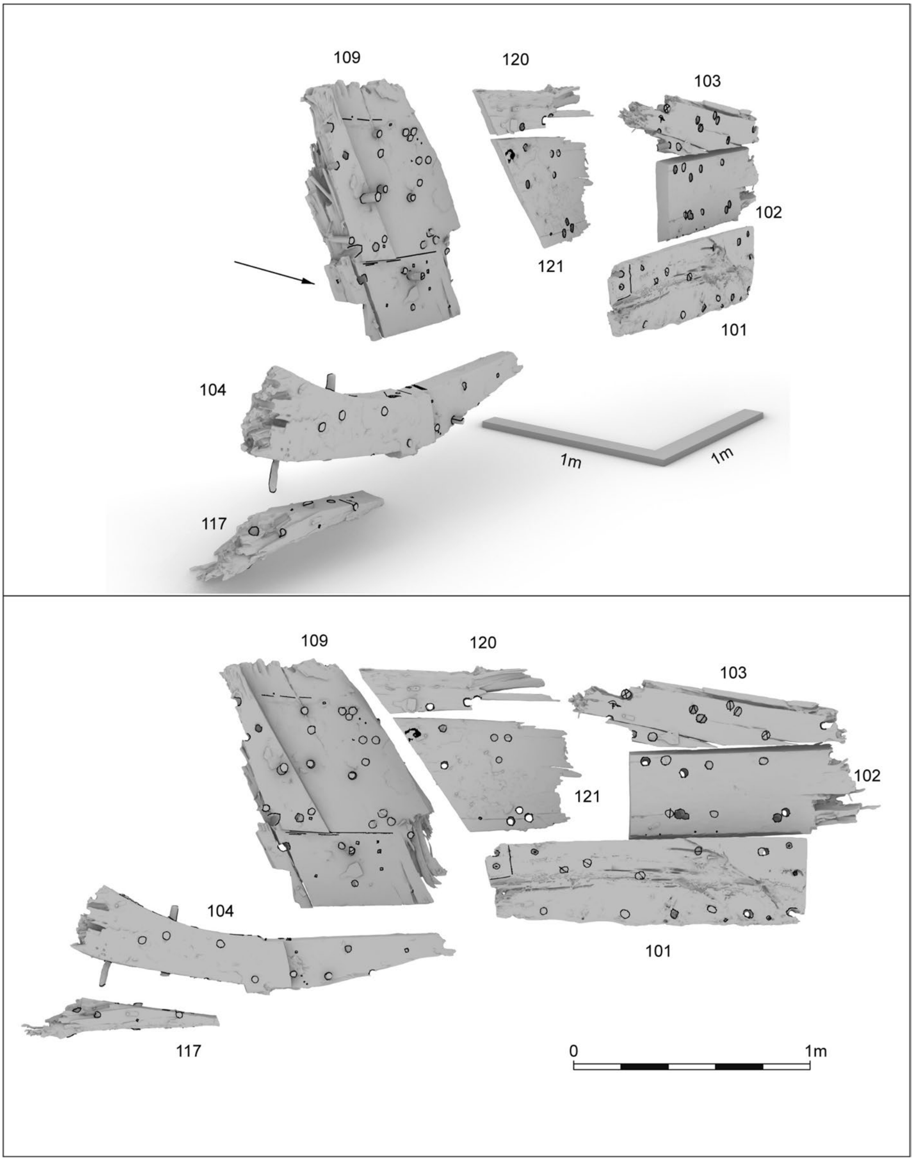

Fig. 11 Sternpost assembly, exploded side and axonometric view of Section 5007

The assembly is raked aft at approximately 64 degrees from the horizontal and provides a rabbet on both sides for the original planking. The rabbet is straight, increasing in depth from 20 mm to 35 mm along the post's height.

The post is double planked. Thin planking [120, 121] (maximum 35 mm thickness, 470 mm width) that fits in the rabbet is nailed and tarred with setworks on both sides. These thin inner planks are clad by the thicker outer planks (maximum thickness 70 mm, width 360 mm) that flow, together with the garboard, beyond the rabbet line, presumably to the sternpost's aftermost face.

The post is scored to accept the garboards, creating a flush siding, and they continue after the aft face of the sternpost instead of terminating with hood ends in the rabbet. They are fastened to the keel with evenly spaced square-shaft iron nails (160-300 mm apart) and treenails in an alternating pattern along the lower edge. Thin wooden shims [119] were packed between the garboard and the post to fill the gaps in between them and improve the fit.

The underside of the keel timber is scarfed and bolted to a reinforcing skeg [117] that seamlessly extends its base, shaped to accommodate the upward curve of the keel aft of the post. The keel and skeg are covered in tar and hair to bed the garboards. A faint square impression on the upper aft corner of plank [101] suggests an iron strap may have reinforced the connection between the keel and stern.

Toolmarks and Intentional Marks

Observed toolmarks include the characteristic lines of pit-saws on several planks and frame sides. For example, on filler frame [046], clear pit-saw marks lead to a triangular split-off section at the end of the saw cut, where wedges split the last section of unsawn timber.

Slightly curved adze blades, up to 80 mm wide, were used for smoothing plank surfaces. These toolmark could be consistent with the light 'stirrup adzes' used by early English carvel shipwrights and of ancient Mediterranean design, which are distinct from heavier shipwright adzes used in the seventeenth century England. Axe hewing is evident on select framing elements, with axe stop marks up to 100 mm wide driven against the grain [052].

Builders used small blades like chisels or gauges to mark treenail positions on the frames [087], aiding the auger tip. The concave wall of some incomplete blind treenail holes may suggest the use of a spoon auger.

Very few intentional marks were identified. Aside from the lines roughly hacked into the upper faces of the frames to indicate the position of the ceiling planks, a series of arrow-like figures cut with a race knife were observed on the aft moulded face of filler frame [046], possibly serving as shipwrights' or sawyers' marks. Additional examples may include a Roman numeral "IX" incised with a race knife on plank [039], as well as four parallel horizontal indentations on the side face of a futtock. On the planking, dovetail-shaped incisions were made across the grain at the ends of cracks, to prevent their further propagation.

Repairs

The low number of minor repairs indicates the use of good planking stock and confident assembly. To address larger knots, shakes, and splits, shipbuilders cut out a rectangular portion of the affected wood and replaced it with a small wooden patch. These patches extended through either the full or partial thickness of the plank and were fastened with iron nails.

Two small square Dutchmen (75 mm by 89 mm and possibly 44 mm by 55 mm), penetrating the entire thickness of the timber, were graved into the upper face of ceiling plank [038] and fixed with iron nails. The grain of these Dutchmen was oriented at a 90-degree angle to that of the plank. The possibility that the mortises they cover were for light stanchions or other supports cannot be excluded.

The outer planking shows few repairs, and their tightness suggests the planks were seasoned or semi-seasoned when dressed.

Most graving pieces were simple inserts, fixed with nails and treenails to repair knots or damage in outer planks. A more intricate repair involved two overlapping patches in which a small outer graving piece was fitted into a hole cut through the plank's full thickness. It was nailed to a larger, recessed inboard patch. Ample matted tar and animal hair was placed into the recesses and on the patches as the area was water exposed.

Builders also used thin, carved 'shims' beneath joining surfaces where a perfect fit was not achieved, providing slight adjustments. These are generally made of elm, and some are very thin, tapering fragments.

Possible Building Concept and Sequence

The sequence of building the hull is likely to have used pre-assembled frames that were composed of floors and first futtocks, pre-joined with lateral mortices and secured with two oak treenails. This applied to all the inspected frames with the exception of the master frame which is has a different type of joint and the two crotches at the bow as these are not fastened to the futtocks.

The narrow space between the frames and consequent lack of room to drive the treenails in the fore-aft direction, shows that floor timbers and futtocks were likely to have been assembled before being erected or at least built in a strict sequence (Fig. 12). This seems to be confirmed by the sharp angle with which some of the lateral treenails are driven. In addition to that, the fact that some of the treenails that secure the floors to the futtocks are cut by treenails driven from the outer planking would further corroborate that at least some of the planks were added only at a second stage when the futtocks were already fastened (for example a lateral treenail driven with a sharp angle between [043] and [068] was cut by a vertical treenail drive from the plank [066]).

Considering the cultural context in which the ship was built it is possible that the master frame and possibly the adjacent frame were erected first to control the shape of the hull, followed by several other construction frames which were raised and attached to the keel, at least some with a ferrous bolt. The frame's shapes seem to have been predetermined with reasonable, but not perfect, accuracy as some later trimming and addition of wedges demonstrate.

After the outer sided faces of the pre-erected frames were adzed to the desired shape and shored into position, some of the outer planking could have been put in place. The spiled planks were probably offered up, clamped tight, close scribed to their neighbours and then unclamped. Now the joint could be made and the plank could be trimmed for a perfect fit. The lower edge of each plank was hollowed out in order to make space for the waterproofing material. During the final hanging process, three strands of rolled and tarred animal hair were laid between strake planks and the planks were fastened with treenails, which were caulked on the outside and secured with wedges on the inside. Joints and hood ends were additionally secured with countersunk iron nails. The planking could have been assembled from stern towards bow with the upper square edge possibly offered for clamping, hammering or shoring.

Prior to hanging, smaller defects in the planks were addressed. Some of the graving pieces and patches are located in areas which would have been inaccessible after hanging.

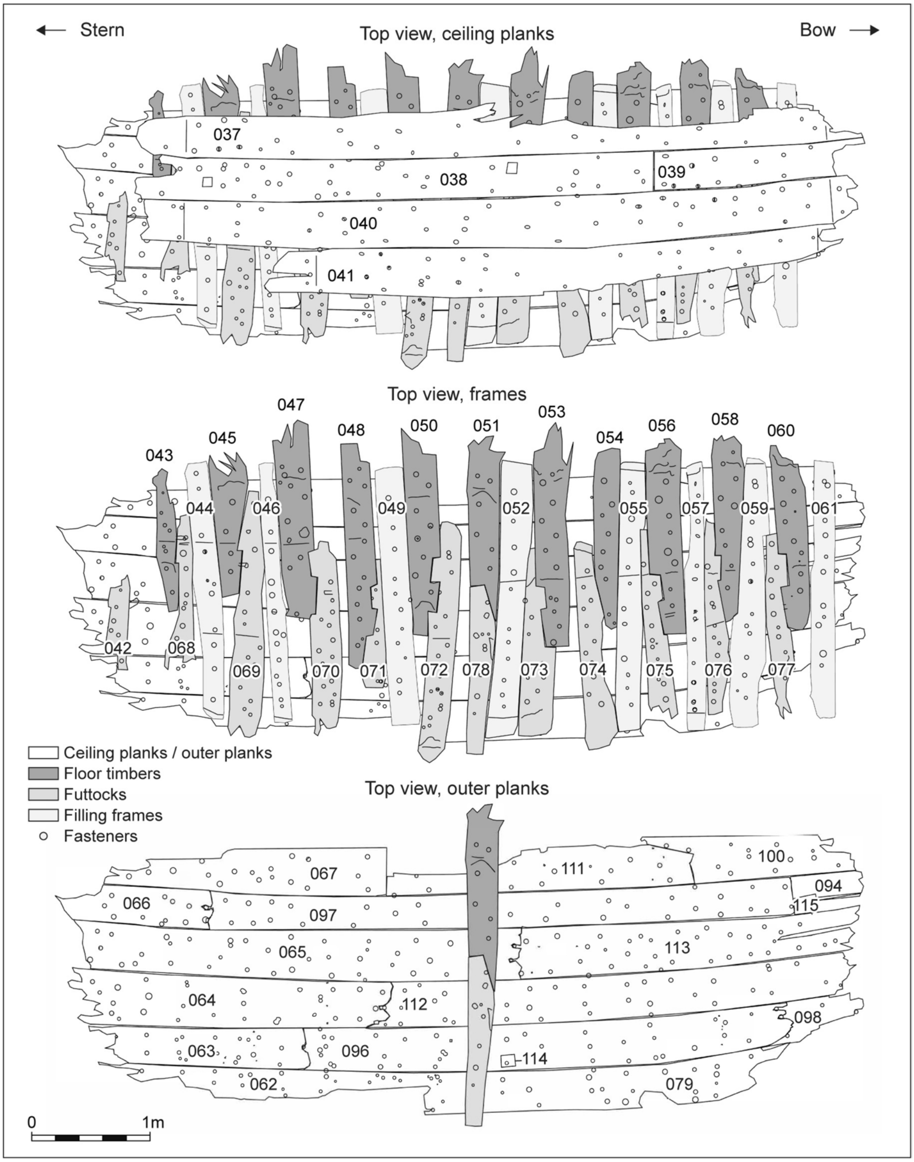

Fig. 12 Plans of Ceiling, Frames, and Outer Planking for Section 5004

At some point later, once the outer planking was already in place, the extra filler frame timbers were fitted between the main frames and sometimes the planking was smoothed to ease their final fitting, removing the tar coat which was not replaced. The roughly hacked line on the inboard face of the outer planking might have been part of this process. The heels of the filling frames do not extend across the keel, and it is hard to establish exactly whether they were fitted during the initial construction of the ship or at a later stage as the dendrochronological analyses seem to indicate. The presence of the impressions of the nails used for the scarfs of the outer planking on the floors and futtocks, and not on the filler pieces, seem to provide a strong argument to further support this sequence.

At some point, presumably after fastening the filler pieces, the top of the frames would have been trimmed, and parts of the sides of a few of the linking treenails are revealed as a consequence. The ceiling plank positions were then marked with lines on top of all frames and fastened through.

Overall, the impression is that the vessel aligns with a frame-led approach although, given that so much attention was given to the structure of the planking, one might question to what extent this is influenced by the longitudinal lines of the planking and whether a more stepwise sequence could be formulated for this wreck.

Date and Place of Construction

Dendrochronological analysis was carried out on 50 samples (43 oak, 7 elm) (Arnold, et al. 2025). Of these, 31 timbers were successfully dated, including two oak and three elm by oxygen isotope methods. The results reveal two main felling groups: an earlier cluster from the mid-1530 s to mid-1540 s, and a later group from 1556–81. A filler frame from Section 5004 [061] preserved bark edge, providing a precise felling date of spring 1561. Two additional timbers fall between these ranges and may be associated with either group or represent a smaller, intermediate felling (Fig. 13).

The earlier dates are mostly from floors and futtocks, while the later ones correspond to filler frames, inserted once the hull was already taking shape.

Overall, the Denge Quarry wreck appears to represent a relatively early English carvel-built vessel (Adams 2013). The majority of dated timbers point towards an initial construction in the mid-1530 s to 1540 s at the earliest, while later felling dates, including a filler frame felled in spring 1561, could reflect repairs or modifications undertaken some decades after the original build. As noted with other ship finds of the wider period (Auer 2014; Bruseth 2017; Watkins 1994), the possibility of timber stockpiling complicates the picture, and construction may instead have taken place somewhat later, in the 1560 s–70 s, using timbers from prior stock, and with the filler frames sourced shortly afterwards the initial framing of the vessel.

If this was the case long-term storage of oak with sapwood would have required immersion in ponds of salt or brackish water, since sapwood left above ground in southern England is highly susceptible to insect attack within just a few years. This method of preservation is both archaeologically and historically documented from the late fifteenth century onwards in southeast England and is also attested in northern Europe (Goodburn 2002, 122).

The vessel was almost certainly built in England, with the oak timbers predominantly sourced from the east and south-east region. The substantial, curved oak logs used for framing provide strong indicators of its geographical origin. Analyses indicate a diversity of woodland sources rather than a single source. Most oak derives from woodlands near the vessel's eventual location, notably Kent, London, and Essex, while some of the filling timbers also match sources in the Midlands. This may reflect the procurement practices of shipbuilding centres in eastern and south-eastern England, supplemented in part by timbers

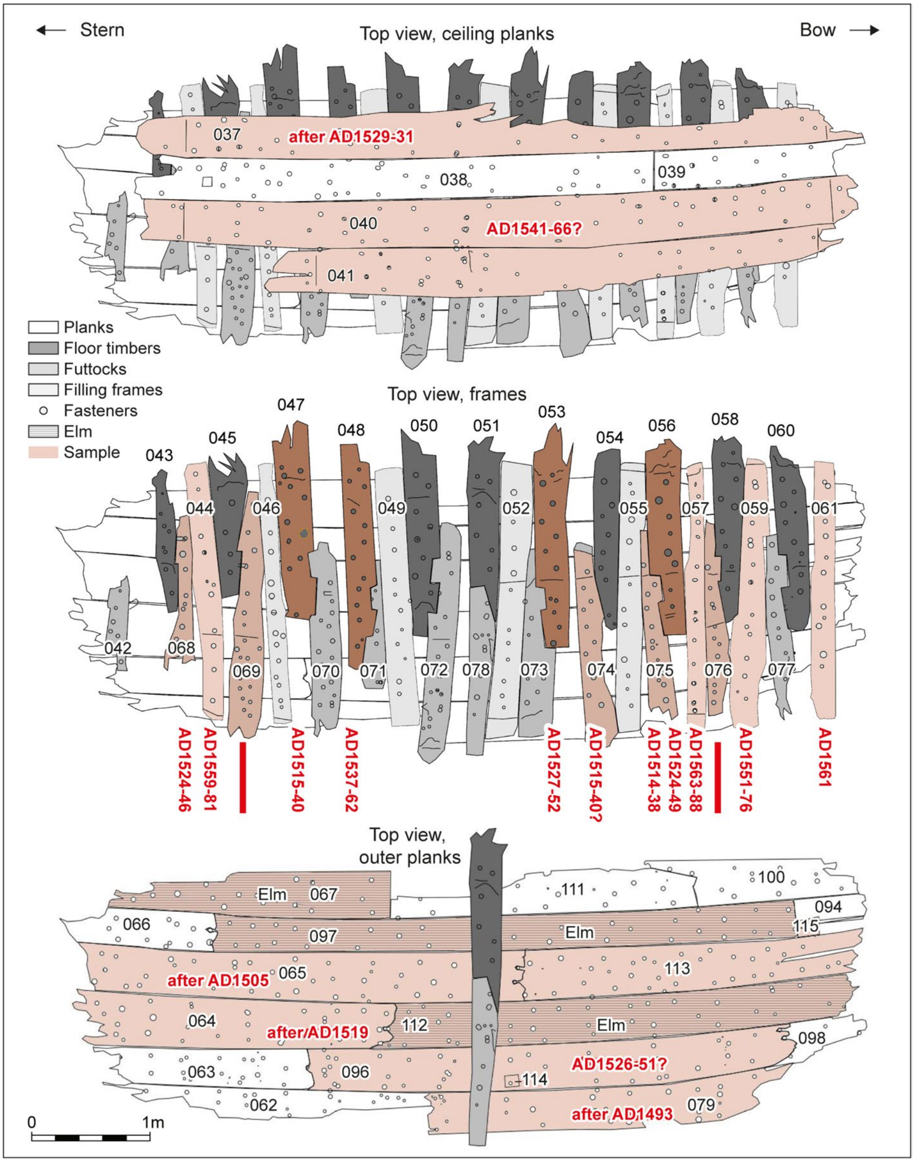

Fig. 13 Plans of Ceiling, Frames, and Outer Planking for Section 5004 annotated with the results from dendrochronological analyses

from more distant regions, indicating a distribution strategy that was regionally focused but occasionally extended beyond the immediate local sources.

Speculatively, if the vessel was built in the area around the Thames Estuary, as a large number of the vessels of the period were (Lambert & Baker 2018), it would have been lost or left to decay in an area close to where it was built and perhaps near its home port.

Hull Modifications

There is some evidence which seems to point to a substantial reshaping of the stern, indicating that the vessel might have been significantly modified from its original build. This modification involved the addition of an unusually curved keel section [104], connected to a further vertical post aft, which would have extended the vessel's length by approximately 1.5 to 2 m. It is likely that the original layer of planks was reworked during this process to widen the sternpost, thereby allowing the new thicker outer hull planks to be fitted over the original post assembly.

Further evidence for this alteration is found on the undamaged aft heel of the sternpost, which exhibits a subtle concave impression tentatively identified as a possible groove for a pintle. This interpretation is supported by associated faint iron staining and a possible diagonal line of nails on the port face, which could suggest the presence of pre-existing metal fittings.

The practice of lengthening ships in this period, particularly English vessels, is well-documented. Sir Henry Manwaring, in his *The Sea-man's Dictionary* (1623) (Perrin 1922), written while he was Lieutenant of Dover Castle, explains that ships with steering difficulties were often either lengthened aft or had a false post added.

These stern modifications may be part of wider changes to the hull. This hypothesis is consistent with other potential construction anomalies observed elsewhere, including gaps in the original framing pattern amidships and the use of an atypically wide board [130] and the unusually close proximity of the scarf joints in the outer planking within Section 5006.

The dendrochronological data provides a potential temporal context for these alterations, though a detailed analysis of the fasteners and assembly sequence is needed to confirm it. The filler timbers associated with a second phase of felling (post-1561) present two primary interpretations: their inclusion as part of the original build—possibly reflecting a variation during construction—which would date the ship to after 1561, or their installation during a major later modification.

Service History

Quantifying the vessel's operational lifespan is challenging.

The outer planking exhibits localized wear and bioturbation, but this damage is not extensive. Notably, teredo worm damage is virtually inexistent. This does not necessarily indicate a lack of seagoing activity as little is known about teredo's origins, spread, and infestation of early modern ships in Northern European waters but it may suggest the vessel did not frequently voyage to warmer, tropical seas where infestation was more common (Palma and Santhakumaran 2014).

The tightness of the original seams and the limited number of repairs collectively suggest the hull had not undergone extensive wear. This evidence might support the hypothesis that the vessel was lost after a relatively short service life, possibly not long after the late 1560 s or 1570 s.

The vessel's use can be dated from a single ceramic shard to the latter half of the sixteenth century; this fragment, from a Raeren stoneware mug, also provides a tenuous indication of contact with the continent (Gaimster 1997; Hurst et al. 1986). The very limited assemblage recovered from the bilge, lodged between the frames, also includes a shoe welt with parallels on the *Mary Rose* (Evans 2005), a near-complete wooden dish, and a small fragment of animal bone.

Direct evidence for the vessel's cargo or whether it was armed is absent. Instead, environmental analysis of sediments collected under the ceilings and associated archaeobotanical remains provides a tentative, though sparse, picture of possible trade activities. From this perspective the analyses suggest potential involvement in both local and foreign trade.

Evidence for domestic or coastal trade includes traces of cereals, walnuts, hazelnuts, and herbs, likely sourced from southern England. Plant remains such as cereal straw, chaff, and bracken are abundant and parallel their use on contemporary vessels like the *Newport Medieval Ship* and *Mary Rose* as dunnage, packaging, or bedding (Carruthers 2013).

Evidence for foreign trade is very limited yet potentially significant as a single pomegranate seed and minor remains of figs were found within the bilge sediments. Pomegranates were occasionally imported from Spain (Gras 1918; Soden 2024) and are rare in northern European archaeobotanical assemblages, though noted on the *Newport Medieval Ship* (Carruthers 2013). Figs and currants from Spain were also prized imports in England (Stone 1949; Soden 2024). These goods may have arrived via major entrepôts like Antwerp, a key hub for English coastal trade in the mid-sixteenth century (Stone 1949) but also could simply reflect food waste or sewage. The absence of exotic spices that are well-known to have been regularly imported into England throughout the fifteenth and sixteenth centuries is notable. Some fruits, such as plums and walnuts, could also have been sourced from established orchards in southern England (Barnes and Williamson 2022; Mate 2006).

Finally, a rounded granite boulder (390 mm by 300 mm by 250 mm) – reportedly recovered alongside similar stones from the same wreck site, though its connection with the remains is not confirmed – was identified as Cornubian Batholith granite, typical of southwest England, with the closest matches from the Isles of Scilly or Brittany. If the boulders were part of the wreck, either as cargo or ballast, it could suggest contact with southwest England or northwest France.

Circumstances of Loss

The cause of the vessel's loss remains undetermined. Examination of the recovered hull sections reveals no conclusive evidence of significant unseaworthiness or catastrophic damage to the outer hull. However, the inability to investigate the remains of the site *in-situ* limits a comprehensive understanding of the loss event.

The site's reported location and geomorphological context suggest deposition on a shingle beach front. One plausible deposition sequence involves the vessel sinking, either accidentally during a storm or being deliberately abandoned, followed by the gradual collapse of the starboard side over time. Subsequent sedimentary processes, including the progression of the shingle beach, would have led to its final burial.

The scarcity of associated finds suggests either abandonment—leaving the hull to decay as a hulk—or systematic salvage. The hacked upper extremity of the sternpost, which may indicate post-depositional removal of timber for firewood or other purposes, could be consistent with either scenario. Unfortunately, the evidence is currently insufficient for firm conclusions, as the possibility of additional archaeological material on the lakebed cannot be excluded.

The possibility that the ship was plundered finds some support in the historical context of Dungeness, an area known for wrecking activities. For instance, in 1589, the Treasurer of Aalborg went ashore at Dungeness and was reportedly plundered by locals who, "under colour to yield assistance fell a-spoiling and hewing the ship" (Acts of the Privy Council 1589–90). The wreck's proximity to 16th-century fishing cabins depicted on contemporary charts further lends credence to the possibility of accidental or deliberate grounding, followed by salvage efforts soon after the loss.

Discussion

Defining a Regional Signature

One significant outcome of this discovery is the emergence of a clear pattern of shared constructional features linking the Dungeness and Gresham wrecks. The *Gresham Ship* is a small to medium-sized armed merchant vessel built shortly after 1574, probably in East England and discovered in the Thames Estuary (Auer and Firth 2007; Auer et al. 2014). This vessel is comprehensively discussed in the British Archaeological Reports (BAR) monograph *The Gresham Ship Project: A 16th-Century Merchantman Wrecked in the Princes Channel, Thames Estuary. Volume I: Excavation and Hull Studies* (BAR 602) (Auer et al. 2014).

While this paper does not aim to provide detailed comparative analyses between the two, some general conclusions may nevertheless be drawn.

Their close alignment in date, origin, material procurement, design, and construction seem to suggest a shared shipbuilding culture in south-east England. The two vessels bracket the mid- to late-sixteenth century – a crucial, transitional period following the *Mary Rose* that captures evolving practices in English shipyards (Adams 2013).

It remains unresolved whether these commonalities represent the output of a single yard, the influence of a particular master shipwright, or the emergence of a coherent regional tradition. Nevertheless, the evidence raises critical questions about the transmission of technical knowledge in early modern English shipbuilding.

Collectively, the wrecks confirm that 16th-century development was not monolithically dictated by the Royal Dockyards but involved distinct regional practices within a wider context of experimentation (Friel 1995).

The *Gresham Ship* was therefore not an isolated anomaly but part of a discrete tradition that did not merely adopt foreign carvel methods, at this point already mediated through some sort of English tradition. Instead, it resorted to creative, pragmatic solutions by adapting and developing (new) techniques from the more established traditional and local shipyard practices.

Based on the evidence from these two wrecks, the defining signatures of this carvel building tradition can be proposed as follows:

1. Vertical scarfs of the outer planks: These scarfs, reminiscent of clinker construction, are unusual in traditionally carvel-built vessels. Apart from the *Gresham Ship*, only a few other carvel vessels display this deviation, but these were generally plank-oriented and are not directly comparable (Cattrysse 2013). Notably, vessels such as the Mary Rose

and Sea Venture do not feature vertical outer plank scarfs, relying instead on butted, caulked ends set on frames (Adams 2013). In the wider Thames region, similar scarfing is observed in 16th-century flat-bottomed Thames barges (sometimes called "western barges") and in older medieval clinker barges of the lower Thames and River Lea, known as 'showts' (Goodburn 2016). The presence of vertical scarfs in the outer planking may therefore indicate the input of shipwrights experienced in clinker construction.

2. "Bird-mouth" or V-shaped seams in the outer planking and setwork: Instead of driving caulking into an open seam, strands of tarred animal hair were laid into a carefully cut V-shaped groove along the lower edge of each plank. This distinctive method of sealing and shaping the seams of the outer planks is documented only for these two wrecks and for which no direct parallel could be found. The practice has broad analogies to the process of luting in clinker construction or to the "setwork" historically recorded in the Thames region and archaeologically attested in the bottoms of local barges of the 16th–18th centuries (Goodburn 2009). These similarities could suggest that this is a solution independently developed from local maritime carpentry and not an imported continental practice. Nonetheless the competency of realisation might indicate a local functional solution rather than a one-off practice. While the precise origin and motivation for adopting this V-shaped seam remains uncertain, it appears to reflect broader experimental responses across north-western Europe to the problem of waterproofing carvel hulls (Adams 2013; Belasus 2019). Beyond its sealing function, the method may also have further implication for the construction process and hull design, forcing builders to follow particular planking order and potentially encouraging a more mixed and longitudinally controlled construction sequence.

Further practices, potentially shared across a wider group of contemporary wrecks broadly characterised as English, also characterize this tradition. These include:

3. Use of filler frames: The fitting of filler frames within a framing system featuring frames where floor timbers and first futtocks are joined with interlocking joints and specifically dovetail mortises. Although this general approach is derived from the Ibero-Atlantic tradition (Loewen 2001), and was implemented in England with a primary reliance on wooden treenails for fastening, the specific defining feature can be found in the systematic addition of filler frames, forming a solid band that sweeps across the turn of the bilge. The analyses of the two wrecks seem to suggest that filler frames were primarily intended as structural reinforcement and fitted after the primary framing was erected and therefore did not have an active role in defining the hull's shape. The extent to which these filler frames are a characteristic of a regional practice is not overly clear and the presence of filler frames in the *Mary Rose* (Marsden 2009) might suggest that this could have been a geographically wider approach and possibly a long-established method for reinforcing carvel-built hulls.
4. Bow construction: Along similar lines is another feature of note which is the bow construction, as both the *Gresham Ship* and the Dungeness wreck display a very similar arrangement with a substantial apron and breasthooks, which it has been suggested is comparable to that seen on the *Mary Rose* (Auer et al. 2014).
5. Use and conversion of material: Whilst certain construction features of the Dungeness and Gresham ships fall within broader English and Atlantic practices – for example, the predominant use of oak, hulls fastened primarily with oakum-driven treenails, and the selective use of elm for specific elements such as planking (Auer 2014; Adams

2013; Marsden 1996) – other aspects, including the choice and conversion of timbers and evidence for the possible reuse of stockpiled material may be ascribed to specific practices in the procurement and use of resources. These could be characteristic of the procurement processes and availability of material of specific shipyards, but this is a topic that requires further research.
6. Modifications of the hull shape: Both vessels were likely built following a concept of a pre-determined design, possibly mediated from some sort of English tradition, and yet they exhibit evidence of reshaping during or after construction. This reflects a broader trend in 16th-century (and later) North-Western European carvel shipbuilding (Lemée 2006; Marsden 2009), which was, according to historical sources, particularly widespread in England (Wagstaffe 2010). It has been suggested that, in the case of the *Gresham ship*, this adjustment of less than perfect hull shapes may stem from the growing divide between ship designers and builders, and from the attempt to apply theoretical paradigms to an established practice (Ditta 2014). In this context, the South-East of England during the second half of the 16th Century appears to have established itself as a hub of innovation, as indicated by the two wrecks and documentary sources (Madox 1976, 114; Barker 1986).

Conclusion: Hybridization and Influences

The mix of carpentry solutions of the Dungeness and *Gresham* ships are probably the manifestation of several overlapping factors. Knowledge transfer from the Royal Dockyards likely created an environment of cross-pollination, where the emerging distinction between designing and building suggests a growing specialisation that allowed theoretical knowledge to be tested in local yards. These new approaches to shipbuilding coexisted with, and drew upon, the local knowledge and skills embedded in the established practices of pre-existing shipbuilding traditions.

From the reign of Henry VIII onwards, foreign shipwrights and craftsmen were employed across the royal dockyards, facilitating the transfer of new technologies and methods into regional shipbuilding (Marsden 2009; Lemée 2006, 67–68). The heart of English shipbuilding in this period was the Thames and Medway (Rodger 1999, 312), with London at its centre. This concentration created an environment that emerged as a hub for technical experimentation and development, even amidst the religious turmoil and frequent conflicts with other European powers that characterised the century. An example of this interplay is the Venetian shipwright Augustino Levello. who is recorded within the payroll for the Royal Dockyard at Deptford between 1543 and 1578, in a period that overlapped with Matthew Baker, who had himself travelled to the Mediterranean in the previous years (Barker 1986; Loewen 2001; Marsden 2009). On the other hand, the secrecy of the trade and apprenticeship system likely facilitated the direct transmission of knowledge, allowing distinctive practices to endure across decades.

Despite—and perhaps even because of—these exchanges and the new theoretical approaches, the evidence indicates that carvel shipbuilding in 16th-century England was far from standardized (Auer et al. 2014). Surviving wrecks of English-built ships display only partial consistency, though it remains unclear to what extent this reflects gaps in the archaeological record or genuine diversity.

The discovery of the Dungeness wreck represents a valuable addition to the current archaeological record of 16th-century English-built wrecks.

Taken together, the Dungeness and Gresham ships gives us a better understanding on how (regional) shipyards were negotiating the technological shift from traditional clinker to carvel construction, while at the same time bridging the gap between architectural concepts and construction practices that might reflect the contemporary theoretical approaches presented in Matthew Baker's manuscript (Barker 1986, Auer et al. 2014, Adams 2013). In this sense, the Dungeness wreck not only complements the *Gresham Ship* but also broadens the basis for identifying these trends before the consolidation of a more standardised English naval practice.

The Dungeness and Gresham ships now stand as archaeological benchmarks for what appears to be a regional interpretation of early carvel shipbuilding. Together, they shift the *Gresham Ship* from an apparent outlier to a key reference point. They reflect a period of intense experimentation, where global influences were filtered through local expertise, resulting in vessels that appear to be both innovative and deeply rooted in their regional context.

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Declarations

Conflict of interest The authors declare no competing interests.

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