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5.2 Skuldelev 2

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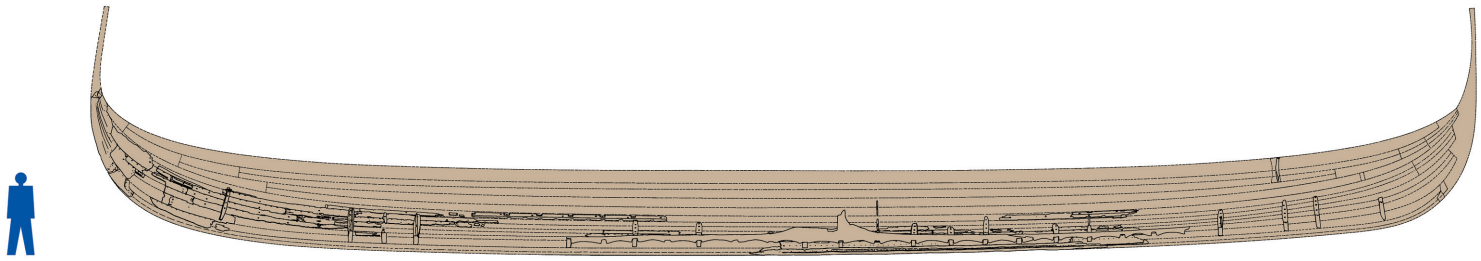
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5.2.1 Excavation

Position in the barrier

The numbering of the wrecks in the barrier followed the sequence of their respective underwater investigation during the initial work in 1957-59, as described in Chapter 2.2. Already in 1957, it was clear that the barrier contained more than one ship, as two individual keels with planking and floor timbers were located at the passage through the barrier established by fishermen, one on top of the other. In 1958, yet another wreck was found further south in the barrier and consequently these ships were numbered 'Wrecks 1, 2 and 3'. At the same time some isolated parts of a ship found to the north of the 'Fishermen's Hole' were thought to be parts of still one more wreck and consequently given the name 'Wreck 4' (Fig. 1). The same year 'Wreck N', a small panel of badly preserved planking with fragments of frames of the same nature as those in 'Wreck 4', was reported by local sand-diggers at a depth of only 0.5 m on a bank ca 300 m southeast of the barrier.

During the 1962 excavation, it became clear that 'Wreck 2' and 'Wreck 4' were parts of the same vessel. This ship, here described under the name Skuldelev 2, was a very long ship which had been placed across the channel with a load of stones, and originally covered practically the full width of the natural passage over its threshold (Fig. 2). The ship was oriented northeast-southwest, with the bow pointing south-west. It was resting on top of Wrecks 1 and 3 and had evidently been positioned there some years after the scuttling of these ships (cf Section 5.2.2 of this chapter). The assumed identity of 'Wreck N' as part of Skuldelev 2 was later confirmed as a result of dendroanalysis.

State of preservation

The position of Skuldelev 2 on top of the pile of stones and ships' timbers of the first phase of the barrier, left the wreck unfavourably exposed. Whereas Skuldelev 1 had settled on the hard, curved but relatively even surface of the moraine ridge, the keel, planking, and frames of Skuldelev 2 were poorly supported and wedged in between the stones of Skuldelev 1, below, and its own load of stones. Parts of the planking and frames of Skuldelev 2 were found broken down and lying vertically over the western edge of Skuldelev 1 (Fig. 3).

Those parts of the ship that were not effectively covered over or pressed down by the stone-load probably partly stuck up out of the water after scuttling. The fact that practically all portions of the ship above the waterline had dis-

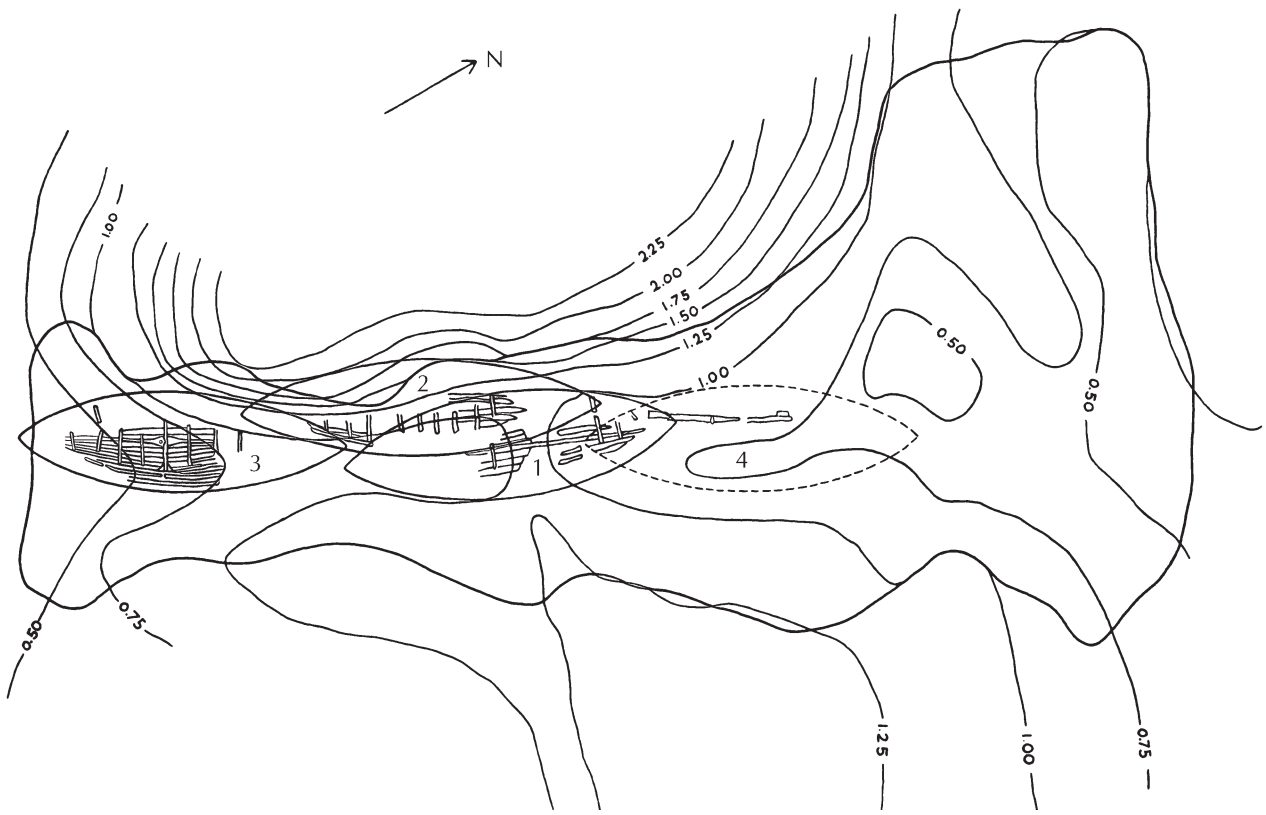


Fig. 1. This plan resulted from the underwater investigations of 1957-58; the ships are marked out as they were located, based on a very conservative estimate of their original size. The contour lines, based on elevation recordings taken on top of the stones in the barrier, clearly show how the narrow passage made by the fishermen through the middle of the barrier affected Wrecks 1, 2, and '4'.

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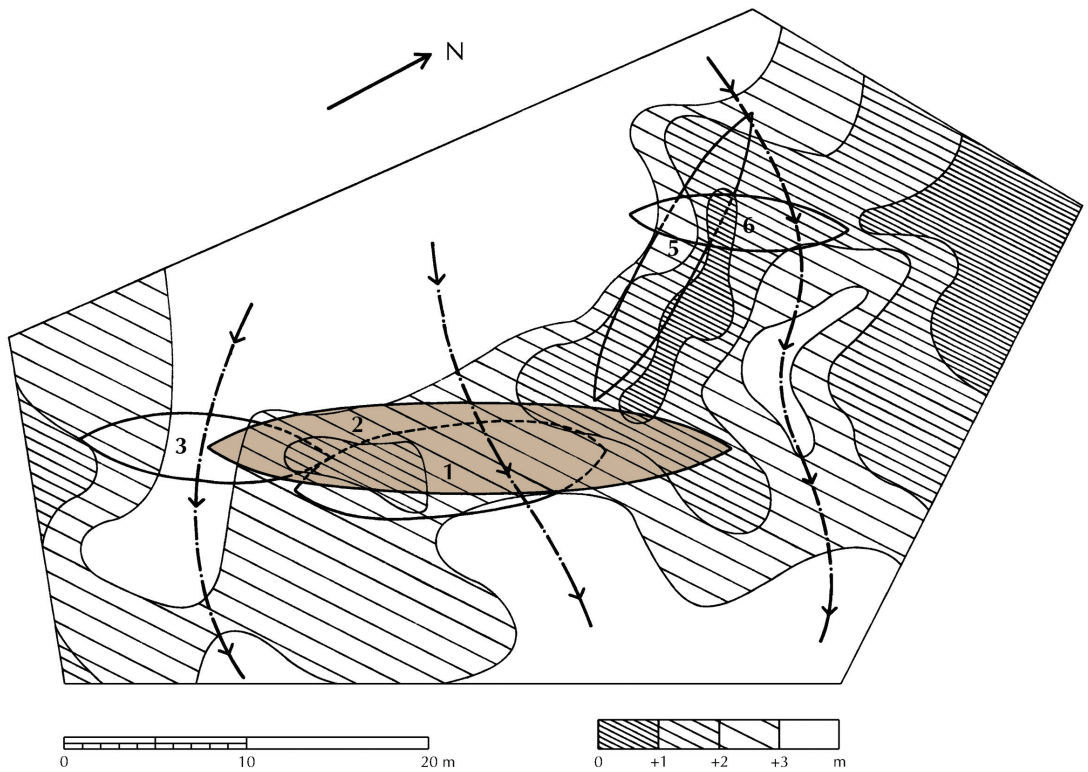


Fig. 2. The position of Skuldelev 2 (in brown) in relation to the natural barrier (the shaded areas) rising as a threshold from the bottom of the Peberrenden *channel (the white area).*

appeared totally at the time of the excavation is a strong indication that these parts were deliberately removed soon after the scuttling. The only elements remaining from the upper part of the ship in the forward and midship sections are a fragment of a strong side timber which had been split along its length, evidently to separate it from the planking, and a few knees. Thus those parts of the ship that were accessible from the surface and not held down by the load of stones may have been cut off for re-use, just as in the case of the top-strakes of Skuldelev 1, discussed above.

Even after having been cut down drastically, probably by the local inhabitants shortly after the second phase of the barrier had been established, the wreck was not left in peace, as demonstrated by the numerous associated parts found scattered within the excavation area. These timbers were primarily found in the deep pit at the western edge of the barrier. The fact that these elements of the ship had not floated away after they had been separated from the ship indicates that, at this stage, the oak-timbers were waterlogged. It is likely that winter ice had packed the channel and thus dislodged the various parts of the wreck. Some of the stones and parts of the ship lying closest to the surface were even frozen into the ice and moved with the ice flakes as the ice broke up and drifted with the wind. This was the case with 'Wreck N', found 300 m away from the barrier.

The fishermen's establishment of a passage for their boats in the 1920s may also have affected this wreck, as the keel and planking of the central part of the wreck is missing in this area (cf Fig. 1). None of the ships' timbers recorded in 1924 by Kai Uldall are from this wreck, however, and the character of the pointed end of the keel of Skuldelev 2 here indicates that it may have jutted out from the protecting stone-heap for a longer period. Consequently, a considerable part of this northern end of the vessel, as well as the southern bow end, may have broken up and been dispersed shortly after deposition.

Excavation and raising

During the 1957 diving campaign, a small portion of the wreck around the keel was uncovered, together with a length of the planks of 'Wreck 4'. A few fragments of the floor timbers, a keelson knee and a length of the first strake on the starboard side of the ship were taken up before the exposed areas were covered over again with stones, sand and seaweed. In 1958 some parts of the floor timbers of 'Wreck 2' were taken up, as well as the few and badly preserved remains of 'Wreck N'.

The two separate parts of the wreck in the barrier were treated as independent units during the 1962 excavation. 'Wreck 4' was excavated during the period 12-20 July (Fig. 4),

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Fig. 3. Skuldelev 2 during excavation in 1962, seen from the west. The keel rides on top of the stones in Skuldelev 1 with the starboard planking pressed down along the side of the ship below.

and photogrammetrically surveyed on 19 July. It was taken up in two days and its fragments numbered from 1501 to 1570. The central part of the ship was excavated between 27 July and 7 August, recorded as 'Wreck 2' with the fragments numbered 501-599, and photogrammetrically surveyed on 9 August (Fig. 5). Lifting of the hull timbers started the next day and was concluded in the course of eight days. In the final phase of the 1962 fieldwork, the slope down to the deep pit west of the barrier was excavated in the period 1-14 October, and this yielded a considerable amount of wreckage, mainly from this ship (Fig. 6), numbered within the sequence of loose finds from P600 to P749 and from 1801 to 1819. Since we had not foreseen that the archaeological activities would continue so far below the water-level, this part of the excavation was quite problematic. Excavation near the cofferdam wall had to be done carefully so as to insure against the wall's collapse and to prevent water from entering the area from below the wall's base.

The keelson, however, lay down the slope with the upper end level with the ships in the barrier and the other end buried deeply in the soft sediments of the pit far below the intended excavation limit. Under emergency conditions the excavation work continued down the slope until the middle part of the keelson was freed. In the process of excavating the keelson further down, the after stem of Skuldelev 2 was found. The deepest part of the keelson was



Fig. 4. Skuldelev 2 ('Wreck 4'). The port side aft after excavation.

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Fig. 5. Skuldelev 2. The northern section of the wreck (lower left) partly exposed on top of the stones and timbers in Skuldelev 1 (upper right). In the foreground the central parts of the floor timbers 2F-4F above the keel and two keelson knees.

not easily accessible, and finally had to be pulled out of the mud so this long length of timber could be transported to the conservation facilities.

The difficult conditions for recording the various scattered parts of the Skuldelev 2 wreck *in situ* in the barrier meant that the overall plan of the wreck had to be pieced together from several localised recordings (Fig. 7) and an compassing photograph could not be taken at any time, except from the air (Fig. 8).



Fig. 6. Skuldelev 2. Dislodged parts on the western slope during excavation.

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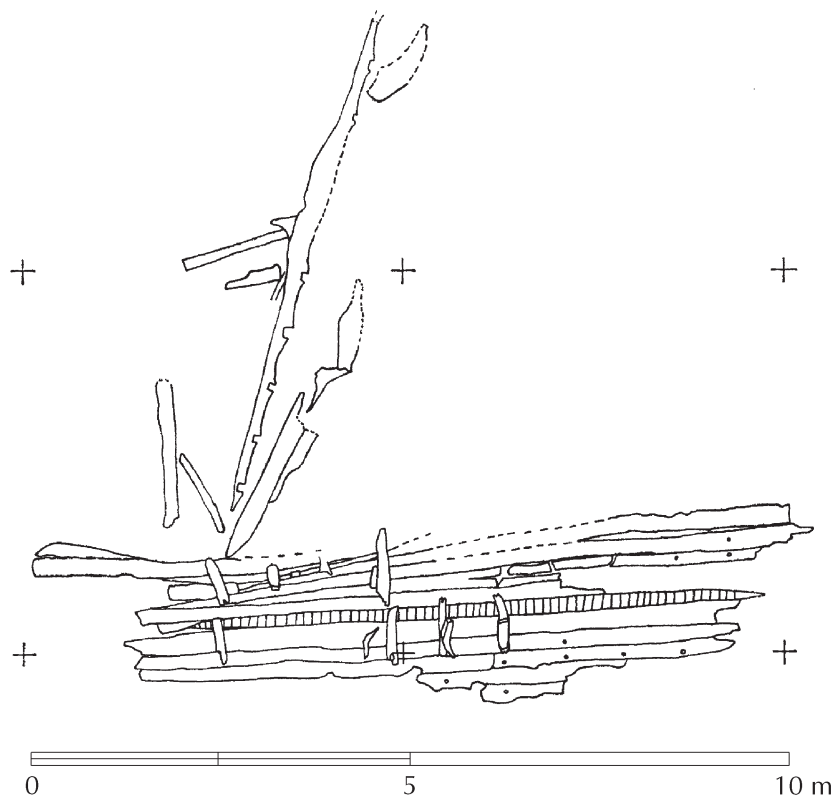


Fig. 7. Skuldelev 2. Plan based on the photogrammetrical survey 1962. Scale 1:100.

5.2.2 Description of the preserved parts of the ship

In contrast to Skuldelev 1, the remains of Skuldelev 2 were scattered all over the excavation area, making it impossible during the excavation stage to apply one and the same normal description system to all the remains. Consequently, each of the coherent sections of the wreck was recorded individually with a description code applied in the field based on an arbitrary base-point in each part of the wreck. It was not until a much later stage, after the detailed recording of the keelson and the keelson knees had taken place and these elements could be related to each other and to the frames found *in situ*, that the original position of the mast in the ship could be established. At this stage, the numbering of the frames was changed in order to follow the system applied as a general standard for all the Skuldelev ships. The description here follows this revised system but the codes used in the field are shown in parentheses on some of the illustrations.

It is necessary in this case to present the analyses that were used to identify the individual elements described below and to establish the general structure of the ship. As a starting point, the two coherent areas of planking ('Wreck 2' and 'Wreck 4'), were taken to be situated at the correct distance in relation to each other. This assumption was supported by the facts that the orientation of the planks matches perfectly from the one area to the other, and that in both cases, the planking was firmly fixed in position by stones.

In both areas of planking, the treenail holes in the strakes mark out the frame stations and provide a clue as to the position of the floor timbers. Some of these elements had been found *in situ* and could thus be immediately placed in their correct positions. Owing to the differences in the spacing of the treenails in the individual timbers, it was possible even to position several parts of the floor timbers that had been found loose.

In this way, the greater part of the floor timbers from the central part of the ship could be placed correctly in relation to the keel and planking. Even two of the keelson knees had been found *in situ* in 1962 on top of their floor timber (cf Fig. 5), and several of the other floor timbers bore traces from the fastenings of the keelson knees, making possible the fitting of most of the loose knees into their original positions.

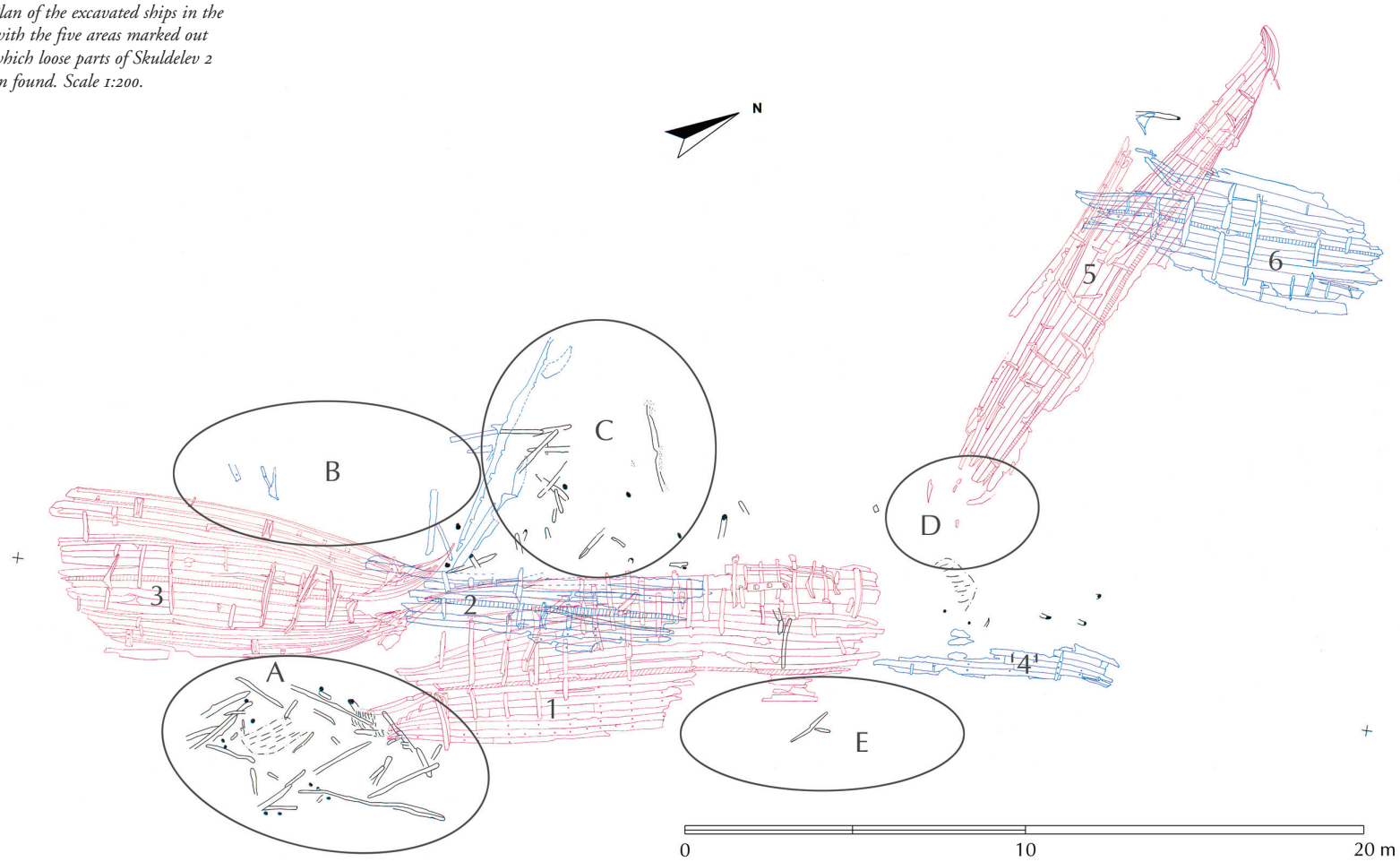
At this stage the keelson could be restored into its original position in relation to the frame stations. Here all the keelson knees fitted correctly and the small variations in the spacing between the floor timbers corresponded with the notches on the underside of the keelson. With the mast-step position used to identify frame 0, the frames were numbered fore and aft, from 10F to 8A. The frame posi-

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Fig. 8. Skuldelev 2. Aerial photograph of the wreck on top of Skuldelev 1.

Fig. 9. Plan of the excavated ships in the barrier with the five areas marked out within which loose parts of Skuldelev 2 have been found. Scale 1:200.



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tions in the planking aft could be numbered 11A to 21A by extrapolation from the end of the keelson.

Now the elements of the structure that had been identified as to their original position in the ship could be studied in relation to the five areas around the wreck from where these and other elements from Skuldelev 2 had come (Fig. 9). This study showed that structural members from the foremost part of the ship (forward of 5F) had been found in the areas A and B on both sides of Skuldelev 3, and only here. This corresponded with the fact that the forward part of Skuldelev 2 had originally been positioned on top of the stones in Skuldelev 3. Evidently, the ship's timbers had been completely removed here, except for a small number of individual elements deposited on the spot without further local scattering.

The loose elements that could be fitted into the middle and after part of the ship all came from area C (the western slope and the deep pit), area D (between Skuldelev 1 and 5) and area E (outside the starboard bow of Skuldelev 1). The after stem was found in area C at the deepest part of the pit, 20 m away from its original position, together with the large keelson and several other elements. Other midship elements had moved to the areas D and E.

This pattern of deposition serves as circumstantial evidence for the sorting out of those elements for which there are no other clues to their original position in the ship. For these, a provenance from the forward part of the ship is suggested for all parts from areas A and B, whereas the elements from areas C, D, and E are likely to have come from amidships or aft.

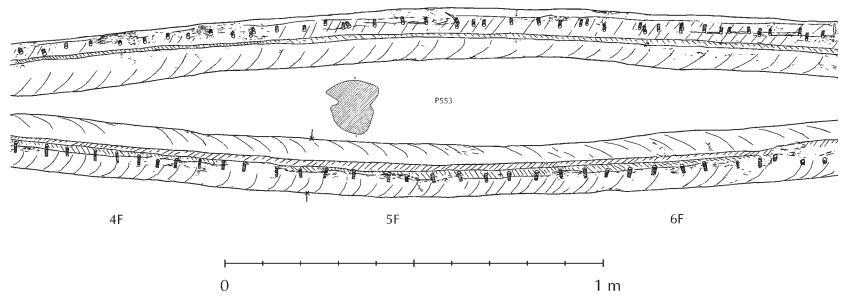


Fig. 10. Skuldelev 2. A section of the keel seen from starboard (above) and port (below). Scale 1:20.

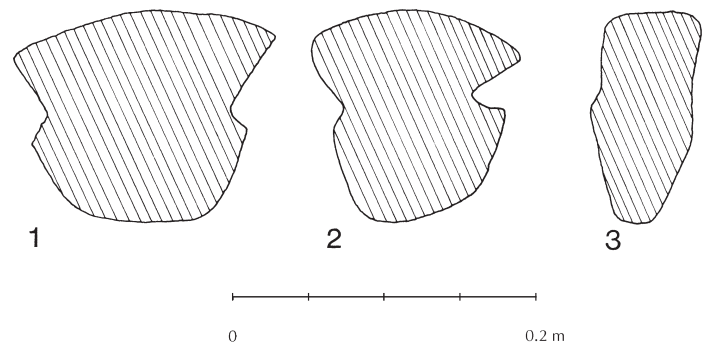


Fig. 11. Skuldelev 2. Cross sections of the keel. Scale 1:5.

The keel

A 7.6 m-long length of the midship part of the keel is preserved. The forward end is broken away between 7F and 8F, and the after end of the preserved part is worn down to a point between 2A and 3A (Fig. 10). The keel is of oak with a curved top surface in cross-section and has pronounced rabbets for the keel strakes (Fig. 11). The maximum width of the keel is 17 cm along the top and 9 cm at the underside, and the height is 14 cm. Originally the keel was slightly deeper, as it clearly shows signs of wear, as do the garboard strakes. Probably the original height was ca 16-17 cm over the midship length.

Two small pieces (M252B and M322, Fig. 12) of a scarf in the forward part of the keel were found in area A. The fragmented state of these pieces indicate that this part of the ship was deliberately taken apart in order for some elements to be salvaged for reuse.

The original complete keel was probably built up of a long central element, of which the now preserved keel is a part, and one or two curved intermediate lengths, or *lot*s, at each end, to build up a gentle curvature from the midship length of the keel to the fore and after stems. The lower end of the composite after stem is 8 cm wide and 12-13 cm high, and has a scarf to the *lot* aft, showing that these parts were assembled in a vertical scarf and secured with four iron rivets. The first strakes, the garboards, were fastened to the keel with iron spikes spaced at intervals of 10-16 cm, but a series of extra spike holes in the rabbet show that the lower part of the first strake had been replaced at some stage during the ship's active period.

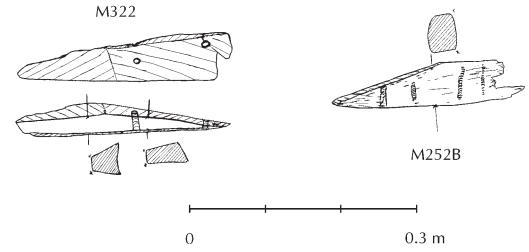


Fig. 12. Skuldelev 2. Fragments of the forward keel scarf found in area A. Scale 1:10

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Fig. 13. Skuldelev 2. The stem aft. Scale 1:20.

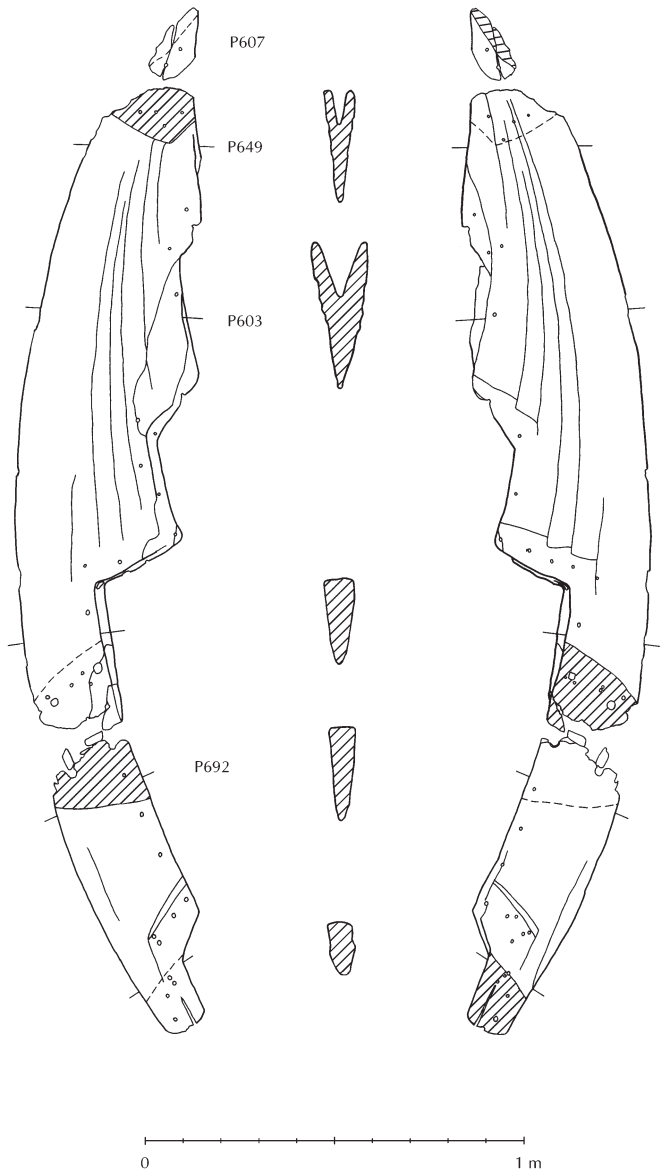




Fig. 14. Skuldelev 2. The stem aft as found in situ*, seen from the starboard side with the port multiple-end planks in position.*

Stems

The after stem (Fig. 13) is a composite structure of oak, originally comprised of three elements. The lower part is 0.80 m long, and has a scarf by which it was attached to the after part of the keel, or *lot*. There is a step for the first strake and a broad scarf to the central part of the stem, fastened with two treenails and a number of spikes or rivets.

The central part of the stem is 1.7 m long, with an open, V-shaped cross-section and sides carved with a continuation of the lines of the planking, similar to the found stems of Skuldelev 3 and 5 (Fig. 14). There are three steps for the multiple hooding end planks, the lower two of which are for the strakes 2B to 6B or 7B, which were found with the stem. The narrow top-most multiple hooding end plank, now lost, would have connected all remaining strakes above the sixth or seventh strake with the stem. This conclusion is based on the fact that the top edge of the stem has no holes for rivets and consequently must be considered as a continuation of the sheerline of the top-strake onto the stem.

At the upper end of the central part of the stem there is a broken scarf with holes for four rivets to fasten the top of the stem. A fragment of this scarf (P607), fixed to a piece of the upper part of the stem, was found near the main element of the stem. These fragments show that the direction of the grain is the same in the central and the upper part of the stem, the inboard edge of the stem formed a gentle

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curve throughout its length, and the inner edge of the stem was 4 cm broad.

No remains were found of the fore stem of Skuldelev 2, but evidence from other ship finds from within the same period and building tradition suggests that it was most likely similar to the stem aft.

Planking

All of the found planking parts of Skuldelev 2 are made from radially-oriented oak planks. The planks are of the same maximum thickness, 25-28 mm in the middle with a slightly oval cross-section, but the first three strakes from the keel are strongly eroded on the outside. In some cases the planks seem to have been intentionally shaped with a curved cross-section, in other cases the planks may have been pressed out of shape once part of the barrier. Most planks have been extensively damaged owing to the factors described above and only two areas of coherent planking were found *in situ*. However, a number of plank fragments were found, some of which could be ascribed to particular strakes on the basis of individual features or even tentatively placed in their probable original position in the ship, as described below.

In the forward and midship areas from 10F to 3A, the greater part of the strakes 3B to 5S were found together with a fragment of 6S and fragments of 4B and 5B. This section was recorded as 'Wreck 2' during the excavation (Fig. 16). These planks were severely damaged owing to their position between the stones in Skuldelev 1 below and those in Skuldelev 2 itself. Initially, as a result of the absence of continuous support for the planks, large portions of the edges of these had broken off and their remaining surfaces subjected to organic decay. However, sand and shells were eventually deposited between the stones, and they protected the planks against further decay. This panel of planking can be studied in context, and it gives a good impression of the bottom planking of the ship at the time it was scuttled, as these planks were found in their correct relative position. The holes for the treenails to the frames furthermore serve as a guide to the interrelationship of these elements in the damaged areas.

From the port side aft, parts of strakes 1B to 7B between frame 11A and 21A were preserved *in situ* ('Wreck 4') (Fig. 17). This part of the planking rested directly on the relatively even sea floor to the north-east of the bow of Skuldelev 1. Consequently these planks are generally preserved in a better condition than those from midships, except for those at the southern end of this section, as the planks were exposed already in 1957, and those areas where a few large stones from the seabed had damaged the planks.

In the after end, these port side planks had been broken off abruptly at frame 21A, as if the after stem and the multiple hooding end planks had been torn away with considerable force. The fact that the after stem was found together with the multiple hooding end planks in area C confirms this impression of violent disruptions to the wreck some time after the scuttling of the ship. This disruption most likely occurred as a result of ice drift in the channel, dis-

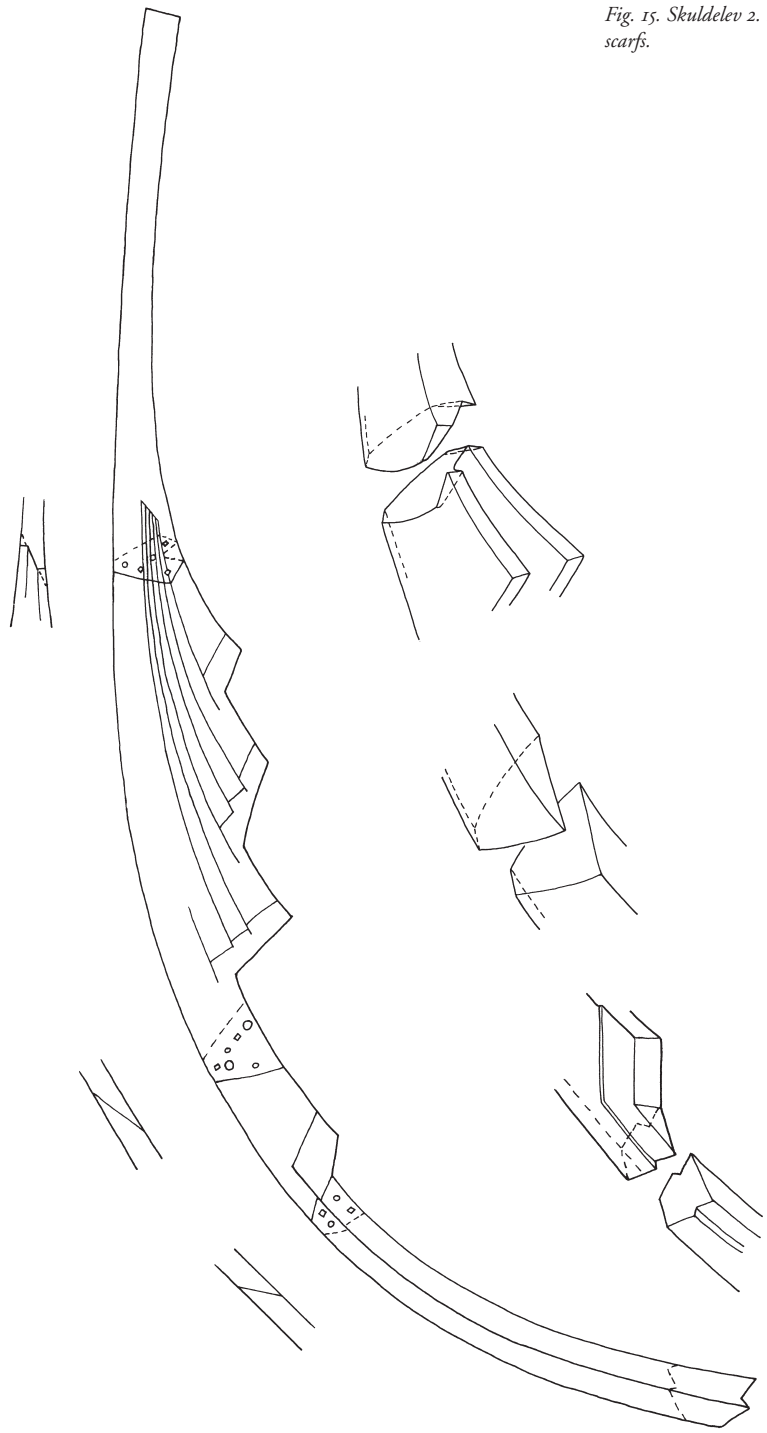


Fig. 15. Skuldelev 2. Details of the stem scarfs.

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Fig. 16. Skuldelev 2. The keel and the coherent part of the planking from 10F to 3A found in situ *and recorded as 'Wreck 2'. Scale 1:80.*

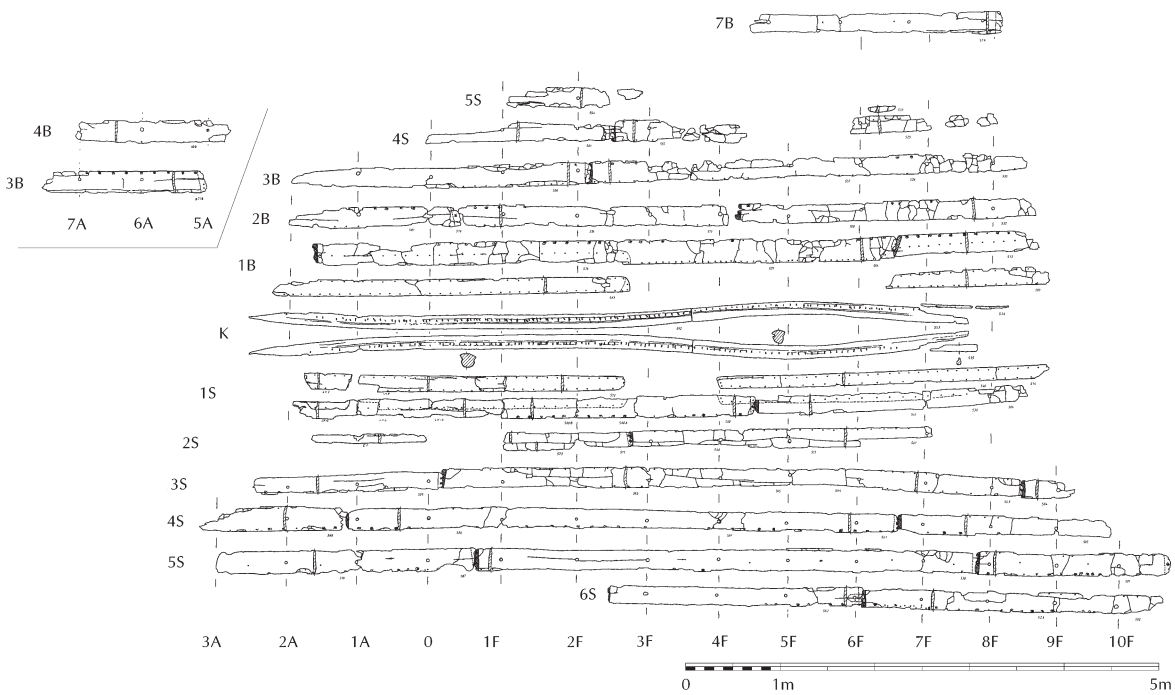
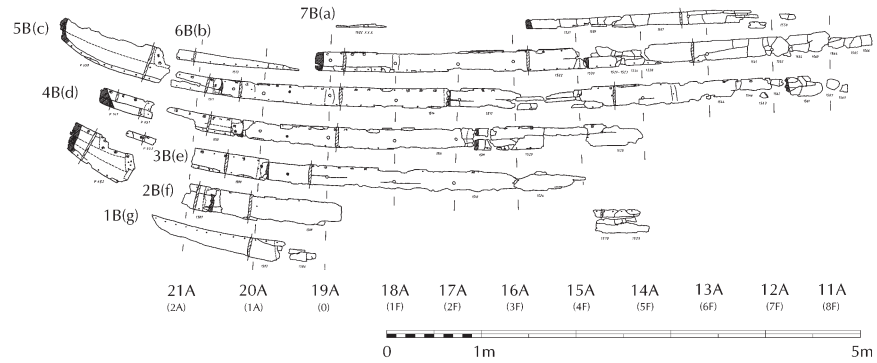


Fig. 17. Skuldelev 2. The planking from port side aft found in situ *and recorded as 'Wreck 4', together with the multiple-end planks or stem-wings found together with the aft-stem. Scale 1:80.*



placing stem, keelson and several other parts of the wreck. The multiple hooding end planks found with the stem are shown in Fig. 17. They take up the ends of the strakes with a triple end plank for 2B-4B (Fig. 18) and a double end plank for 5B-6B which may, however, have been broader to take up strake 7B as well.

In order to identify the fragments of planking found loose (Fig. 19 and Table 1), it is necessary to take into consideration the system of fastenings for the floor timbers and the side timbers, as these fastenings are a clue to the positioning of a plank in the original shell of the hull. A general feature of the floor timbers is that they are fastened with a treenail to each of the second to sixth strakes on each side of the hull. The side timbers are riveted to the fifth strake halfway between the holes for the frames and in some cases also to the sixth strake. A stringer was fastened to the inside of the seventh strake with a treenail between each set of frames, and here the *biti*s and *biti*-knees were riveted through

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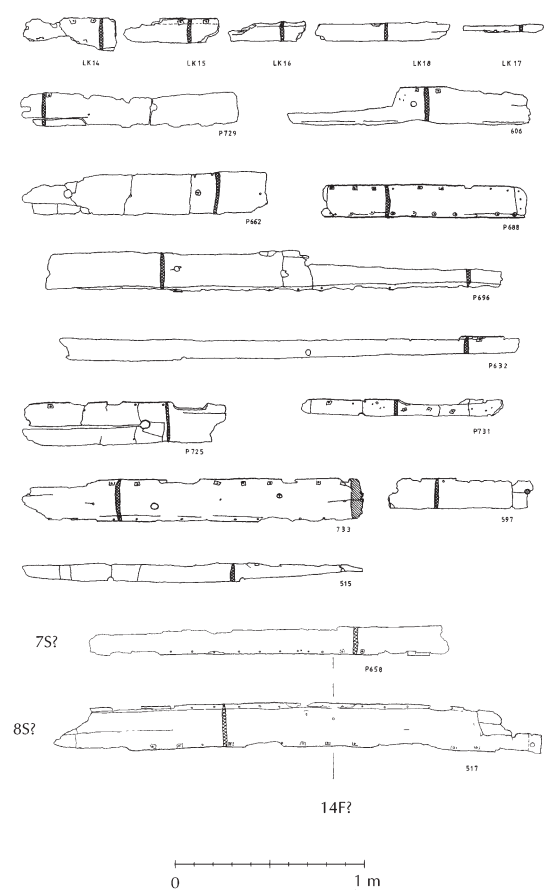


Fig. 18. (Left) Skuldelev 2. Triple-end plank for the strakes 2B, 3B and 4B.

Fig. 19. Skuldelev 2. Planks from the wreck found out of their original context. Scale 1:40.

the stringer and the plank. Therefore, a plank from the seventh strake is characterised by a hole for a rivet at each frame station and a treenail slightly offset from this. It is not clear in detail how the knees, beams, etc., of the upper parts of the hull were fastened and none of the loose fragments of planking displays features that point to an original position above the seventh strake.

Where the planking is best preserved, the fastenings could be studied in detail (Fig. 20). The rivets are spaced on average 11-14 cm apart without any evident pattern in the variations between the strakes or from amidships to aft. The rivets are made from iron nails with round heads and shafts, 6-7 mm$^{\varnothing}$, riveted over rectangular roves, ca 25 x 30 mm. The rivets are placed in the middle of the *land*, the overlap between the edges of the planks. The upper, inner edge of the lower plank is usually decorated with mouldings, 25 mm and 28 mm wide, gouged into the wood with two v-shaped lines, spaced 20 mm and 21 mm apart and with a groove in between.

On the contact surface between the planks there is often, but not always, a shallow groove for a string of wool made with two or three intertwined cords, dipped in tar and inserted prior to the assembly of the planks. This caulking material is described in Chapter 3.2.

There are a number of indications of repairs to the planking, most markedly with the doubling of the garboards port and starboard. These repairs are described below in Section 4 of the present chapter.

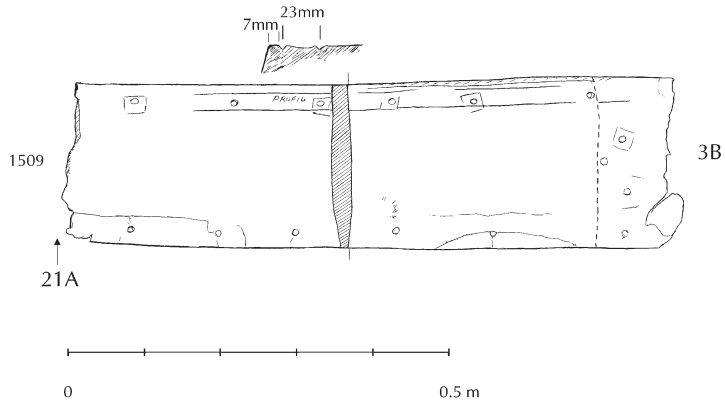


Fig. 20. Skuldelev 2. Strake 3B aft with details of fastenings, decorative moulding and cross-section of the plank. Scale 1:10.

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No.	dendro D2-no.	assoc. with	remarks	found in	original position	strake
345	24			'Wreck N'		
M332				area A	forward	
M333				area A	forward	
M334			2 strakes	area A	forward	
P515				area B	forward	
P517	8	P658	repair plank	area C at 7½ F	amidships	
P597				area B	forward	
P606			with repairs	area C	mid or aft	
P632				area D	mid or aft	
P638			repair plank	area B	forward	1S/1B?
P658		P517	double holes	area C at 7½ F	amidships	
P662	18		strong erosion	area C	mid or aft	
P688				area C	mid or aft	1S/1B?
P696	16		strong erosion	area C	mid or aft	
P725				area C	mid or aft	
P729				area A	forward	
P731			spec. features	area C	mid or aft	
P733	15			area A	forward	

Table 1. Skuldelev 2. Loose finds of planks.

Framing system

The system of internal support for the hull of Skuldelev 2 is based on elements which would ensure the stability of the hull in such a way as not to counteract the controlled flexibility that was evidently an important feature of this shell-based construction.

There is a strict system behind the layout of the framing system (cf Fig. 21), with the floor timbers spanning the lower seven strakes on each side and with an average spacing between the frame stations of 72 cm amidships and 67 cm aft. Halfway between the frame stations, slender side timbers span the fifth, sixth and seventh strakes. On the seventh strake, a stringer is joggled over the tops of the floor timbers and side timbers and it has notches on the upper side to accommodate a *biti*, the lower beam, over each floor timber. The *biti*s are supported from below by slender stanchions at their midpoint and they were originally fastened at each end with a slender knee. Only a few fragmentary parts of the framing system of the upper part of the ship are preserved. In this ship the keelson and its knees no doubt originally served as a longitudinal strengthening element fully integrated in the framing system that also maintained the ship's systematic structure, and is fully detailed below.

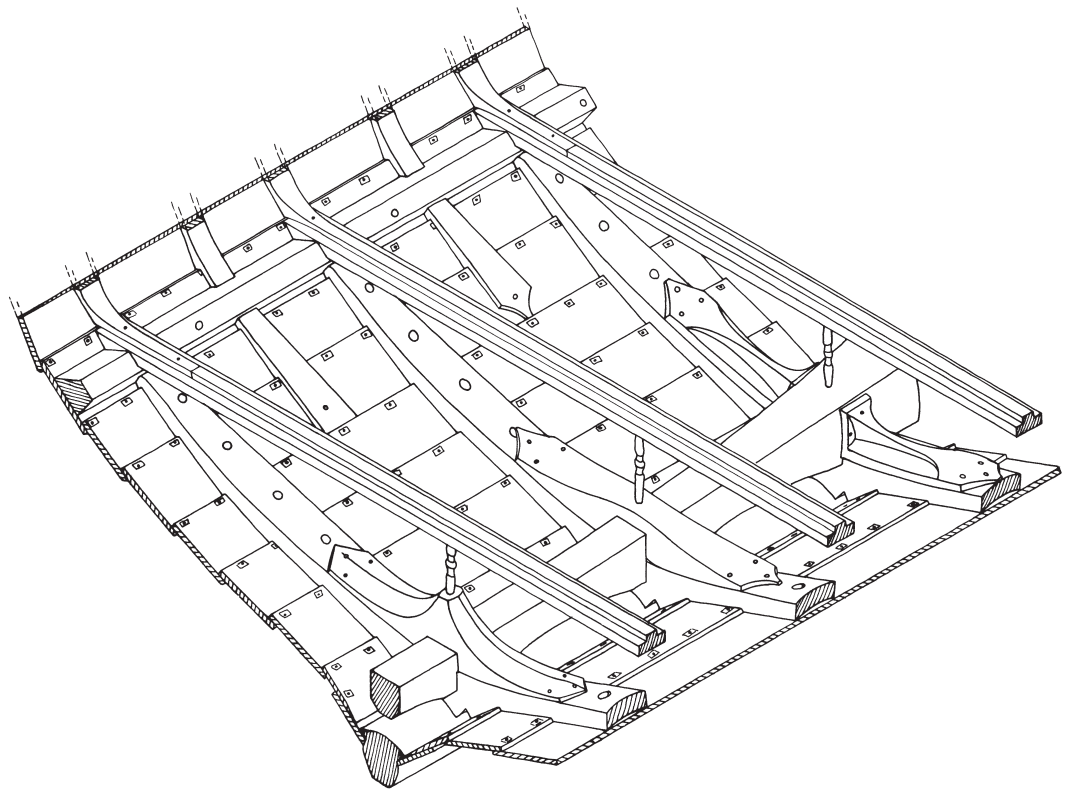


Fig. 21. Skuldelev 2. Reconstruction drawing of bottom section near amidships.

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Floor timbers

Completely or partially preserved floor timbers were recorded from a total of eleven known frame stations amidships and aft (cf Table 2 and Fig. 22). These timbers have been identified as to their positions, even those that were found loose, on the basis of the nail hole patterns.

Some of these floor timbers were taken up during the initial years of diving investigations and recorded at a scale 1:10 or 1:5. Consequently, these early recordings were not always done to the same level of accuracy as those done at full scale after 1962.

The floor timbers are all made from oak crooks, grown to a shape that was as close to the final shape of the element as possible. These were taken either from the trunk and a thick branch or from a curved tree. Each floor timber was very carefully cut to shape with a smooth upper surface with decorative mouldings along the edges and the underside joggled for the keel, with limber holes on either side of the keel, and for the planking. All cross-sections of the floor timbers amidships show a curved upper side and a corresponding hollowing of the underside facing the strakes. The frames are fastened to the second to the sixth strakes with 22-24 mm$^{\varnothing}$ treenails of willow, locked with a conical head on the outside and an oak or pine wedge on the inside.

There are some common characteristics as well as some variations to the shape of the floor timbers. They demonstrate that the ship had a bottom shape with fairly steeply raked garboards and considerable deadrise. Seen from above, the floor timbers in general are broad and flat with a 'butterfly shape' in which the width increases from 9-10 cm over the keel to 12-16 cm at the third and fourth strakes and then decreases to 5-7 cm at the upper end on the seventh strake. Seen from the side, the height of the floor timbers varies from 10-14 cm over the keel to 5-8 cm at the third strake and 1-2 cm at the top ends. In the midship part of the ship, the 'butterfly shape' of the floor timbers with slender 'wings', is very marked, giving the impression that these timbers act more like flexible springs than as rigid reinforcements.

Characteristically, all the floor timbers at amidships are broken at the transition point between the solid part over the keel and the broad and flat arms stretching up to the sixth and seventh strakes. These fractures are a result of the stresses from the load of stones on the ship that also rested on a hard bed of stones after sinking. The stresses broke down the bottom structure along both sides of the keel. Similar effects can be seen at a smaller scale in the floor timbers from the aftermost part of the ship, as described above. In contrast, the floor timbers from the forward part of the ship are almost intact, indicating a different pattern of disintegration.

No.	raised	description	found	garboard angle	frame position
1504	1962	port side	in situ		19A
O111	1957	port top	in situ		14A
O112	1957	mid-part	in situ	(83°)	1A
O113, O114	1957	port fragment	in situ		0
O116 P669 1814	1957 1962 1962	port fragment starb. fragment starb. fragment	in situ area C area D		1F
22 P545 P679 P701	1958 1962 1962	port side mid-part starb. side	in situ in situ area C	87°	2F
O16 P543 P695	1958 1962 1962	port side mid-part starb. side	in situ in situ area C	94°	3F
1815 P542 P550	1962 1962 1962	port side mid-part starb. side	area D in situ in situ	87°	4F
P596 P551	1962 1962	mid-part starb. fragment	area A in situ	86°	5F
32 P524	1958 1962	mid and port starb. side	in situ in situ	83°	6F
P510 P522	1962 1962	mid-part starb. side	in situ in situ	< 90°	7F

Table 2. Skuldelev 2. Floor timbers, elements of known position in the hull.

Table 3. Skuldelev 2. Floor-timbers, elements whose position in the hull is known approximately.

No.	raised	description	found in	centre-hole	garboard angle	frame position
P671	1962	complete	area C	x	67°	ca 15A
P635	1962	broken at port side	area C	x	69°	ca 14A
P684	1962	complete	area C	x	74°	ca 13A
O117	1957	mid-part and port	area E	no	81°	ca 8A
P672	1962	mid-part and port	area C	no	85°	ca 6A
P670	1962	port side	area C			
P720	1962	mid and starb.	area C	no	93°	ca 4A
P584	1962	mid and port	area B	x	72°	ca 11F
P601	1962	port side	area B			
1802	1962	mid and starb.	area A	x	61°	ca 13F
P734	1962	complete	area A	x	56°	ca 14F
M79	1962	mid-part	area A	x	(ca 27°)	ca 16F
1801	1962	starb. top	area A			

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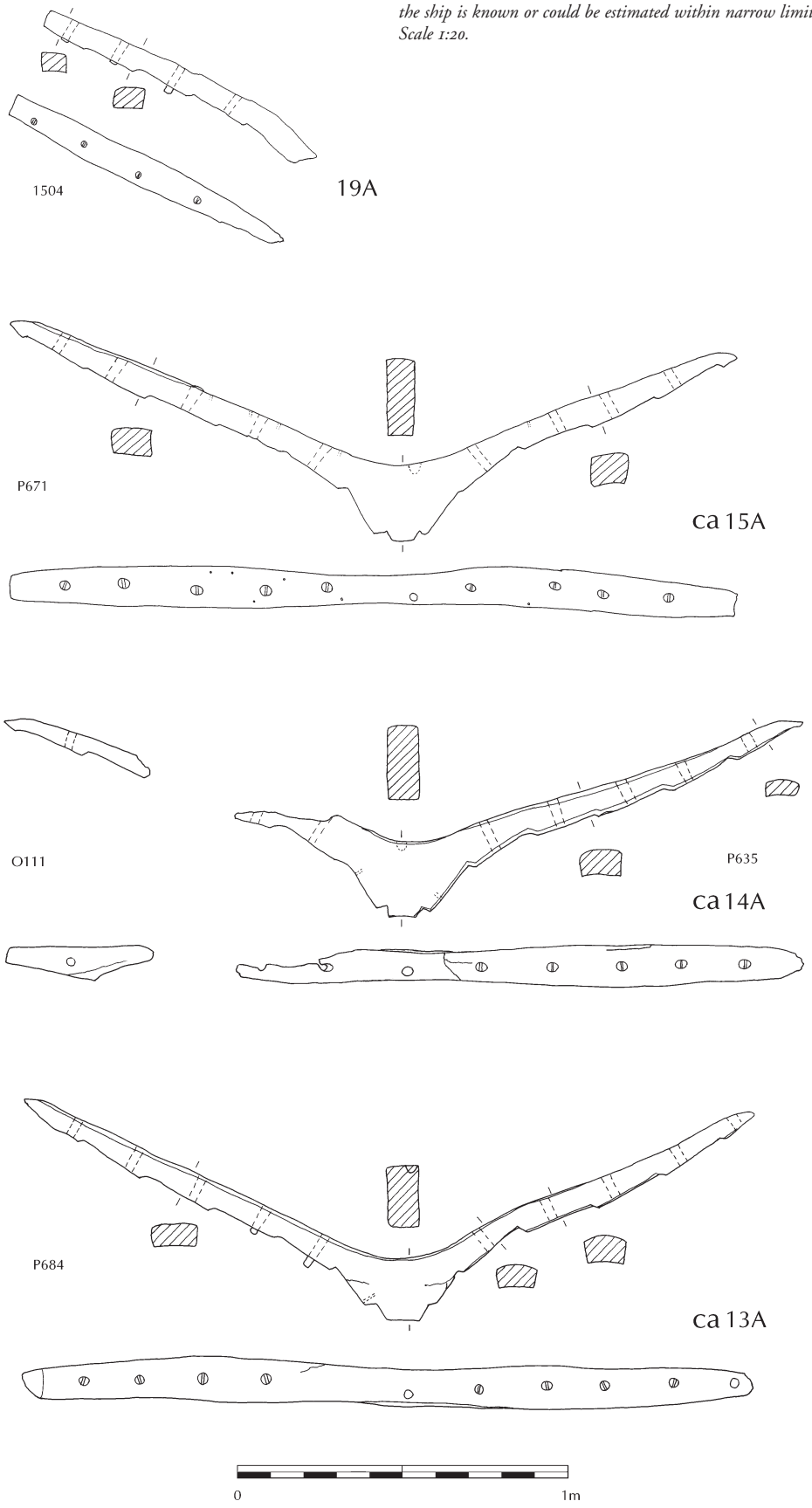


Fig. 22A. Skuldelev 2. Floor-timbers, the position of which in the ship is known or could be estimated within narrow limits. Scale 1:20.

The angle between the first strake on each side of the keel, the garboards, as measured on the floor timbers between the notches for these strakes is around 90° (86°-94° as recorded) in the area between 2F and 5F. Forward and aft in the ship this angle is likely to decrease, as these strakes were originally almost vertical at both ends.

This feature is a clue to the relative positioning of the best-preserved floor timbers found out of context around the wreck and evidently coming from areas in the ship from which little or no planking has been found to indicate their original positions (Fig. 22A-C). Initially, these floor timbers were categorised on the basis of two other criteria: 1) Those from areas A and B (cf Fig. 9) were taken to be from the forward end of the ship, and those from areas C, D and E were attributed to amidships or aft in the ship. 2) Those floor timbers which had not been covered over by the keelson had a shallow hole drilled on the top in the centre-line as a socket for the lower end of a vertical *biti*-stanchion (cf the description below), whereas no such holes were found on the floor timbers from 10F to 8A as these were fitted into the notches of the keelson.

After sorting out the loose floor timbers according to these two criteria, the timbers could finally be placed in a sequence determined by the variation in the angle of the garboards. As the strakes in the original ship would have been given a gentle curve lengthways, the variations in this angle served to indicate the relative position of these frames, and thus this group of floor timbers could be ascribed to the frame positions given in Table 3. The original position of each of these frames is likely to be as stated or within one, or at the most, two stations of this.

Normally, traditional clinker-built ships and boats are constructed with the aim of making the port and starboard sides symmetrical. This is not always possible, owing to such things as the small variations in plank width of the strakes, etc., but such differences are normally faired out during the construction process in such a way that the resulting shape of the hull is practically symmetrical. Deliberate deviations from the longitudinal symmetry, such as the asymmetrical construction of the Venetian gondola to compensate for its one-sided propulsion, are not known from ship finds of the Viking Age or Medieval Period in the north.

Against this background it is remarkable that, while the forward floor timbers are regular and symmetrical within the normal limits, the floor timbers from the after part of Skuldelev 2 display a marked asymmetry in the lower strakes. There is a difference of up to 15° when the port and starboard sides of the strakes are mirrored over the mid-line of the central part of the floor timbers. At a certain stage in the analysis of the ship, this feature was taken as an indication of intentional asymmetry that was meant to provide a

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better flow of water around the rudder at the starboard side aft.[1] Detailed wood-technological studies of the relevant six floor timbers,[2] in combination with the final analysis of the original position and orientation of these floor timbers, have shown, however, that this was not the case, as demonstrated below.

The floor timbers have been cut from oak trees, in five cases at the junction from the trunk with a thick branch and in one case from a curved tree (Fig. 23). In most cases (4 out of 5), the floor timber was distorted or broken on the side which was cut from the branch, the weaker of the two parts of the timber. In Table 4 the deviation angles between port and starboard are given for the strakes 2 and 3, with reference to Fig. 23 for the orientation of the floor timbers in the parent tree.

The figures in Table 4 demonstrate that the angles of the second and third strakes vary from one floor timber to the next when port and starboard sides are compared. In addition, the most marked irregularities seem to occur to port in some cases, to starboard in other cases. The reason for the lack of symmetry in the floor timbers aft is most likely to be found in the stresses and strains exerted on these by the load of stones after scuttling. Amidships the slender floor timbers broke on both sides, whereas those aft were stronger and were able to stand the stress with less breakage but not without permanent distortion. As a contrast, the relatively regular form of the floor timbers from the forward end indicate that this part of the ship was dismantled soon after the scuttling and may not have had much of a stone-load. Thus this analysis does not support the idea that the shipbuilders of Skuldelev 2 deviated from the standard practice, known from other finds, of aiming to build a symmetrical hull.

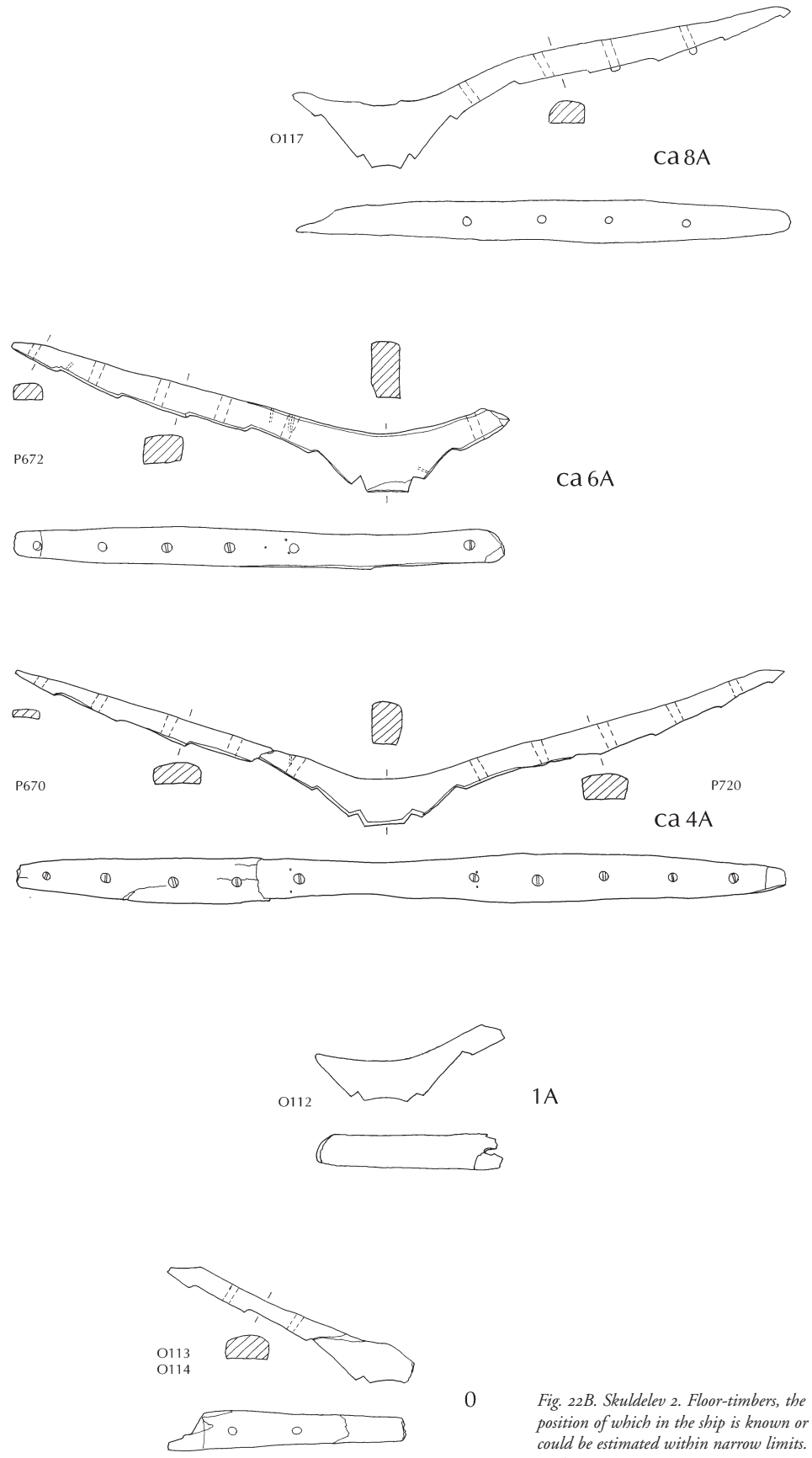
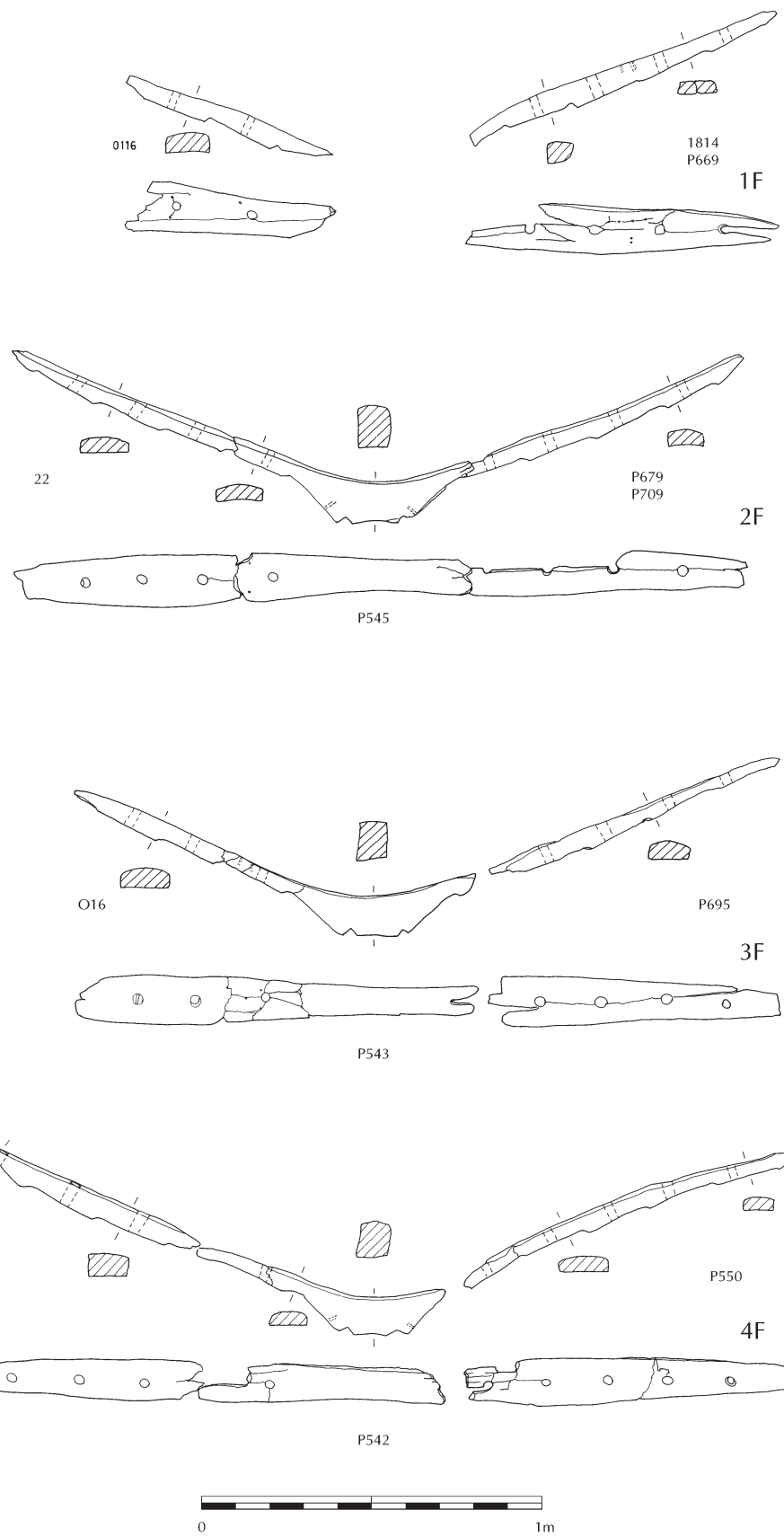


Fig. 22B. Skuldelev 2. Floor-timbers, the position of which in the ship is known or could be estimated within narrow limits. Scale 1:20.

1. Erik Andersen: Betragtninger over Skuldelev 2's bundform. 15/8 1994. NMU archive
2. Claus Malmros: Træteknologisk undersøgelse af seks agter-bundstokke fra Skuldelev vrag 2/4. 19/7 1994. NMU archive

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No.	frame position	parent tree cf Fig. 23	deviation port to starboard for second strake	deviation port to starboard for third strake
P671	ca 15A	A	ca +6°	ca +6°
P635	ca 14A	A	ca 0°	ca +10°
P684	ca 13A	C	ca 0°	ca +7°
O117	ca 8A	A	(ca +15°)	
P672	ca 6A	B	ca 0°	
P720	ca 4A	B	ca -15°	

Table 4. Skuldelev 2. Type of parent tree and angles of distortion for six floor timbers aft.

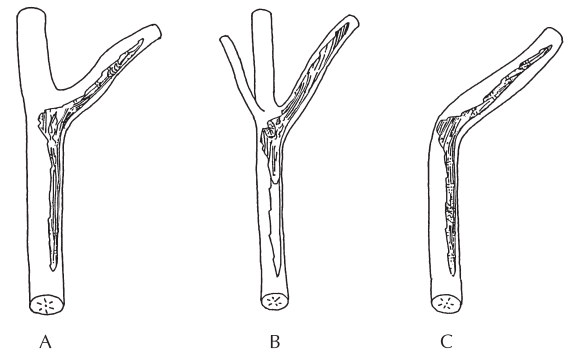


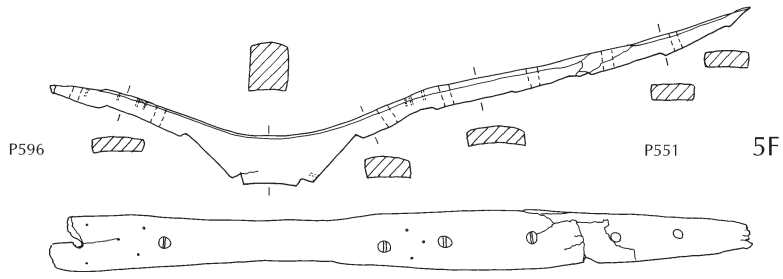
Fig. 23. Skuldelev 2. The position of the floor-timbers aft in the parent trees.

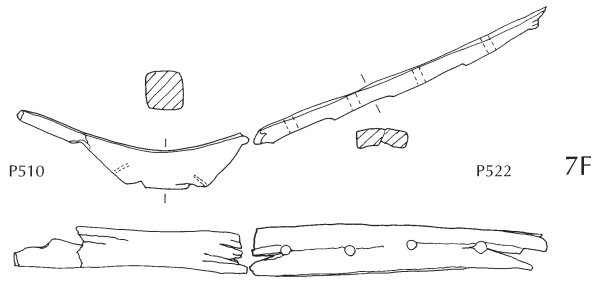
Table 5. Skuldelev 2. Floor timbers, fragments of unknown position in the hull.

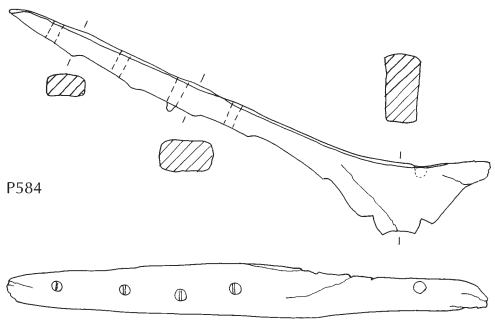
No.	raised	description	found in	original position
O103	1956	top of frame		
345	1958	fragment of frame	'Wreck N'	
O17	1958	side of frame	ca 3A	amidships or aft
O18	1958	top of frame		
O43	1958	side of frame		
366	1958	top of frame	area B	forward end of ship
P520	1962	top of frame	6F-7F, starboard	forward end of ship
P685	1962	side of frame	area C	amidships or aft
1813	1962	top of frame	area D	amidships or aft

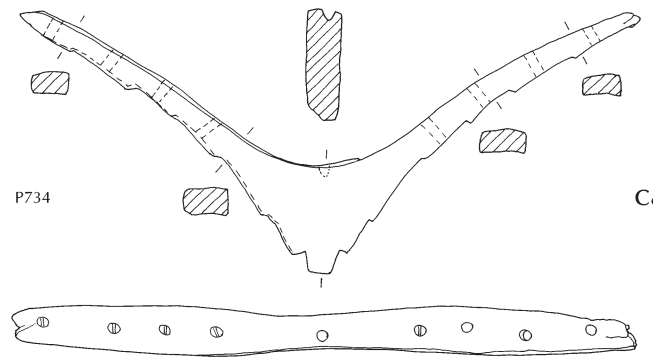
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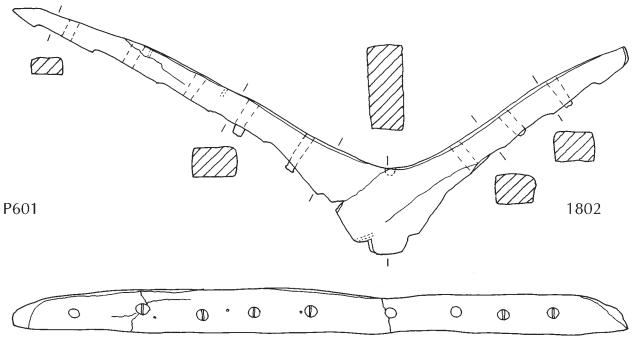
Fig. 22C. Skuldelev 2. Floor-timbers, the position of which in the ship is known or could be estimated within narrow limits. Scale 1:20.

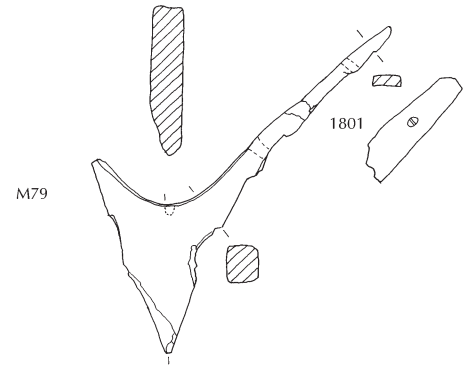














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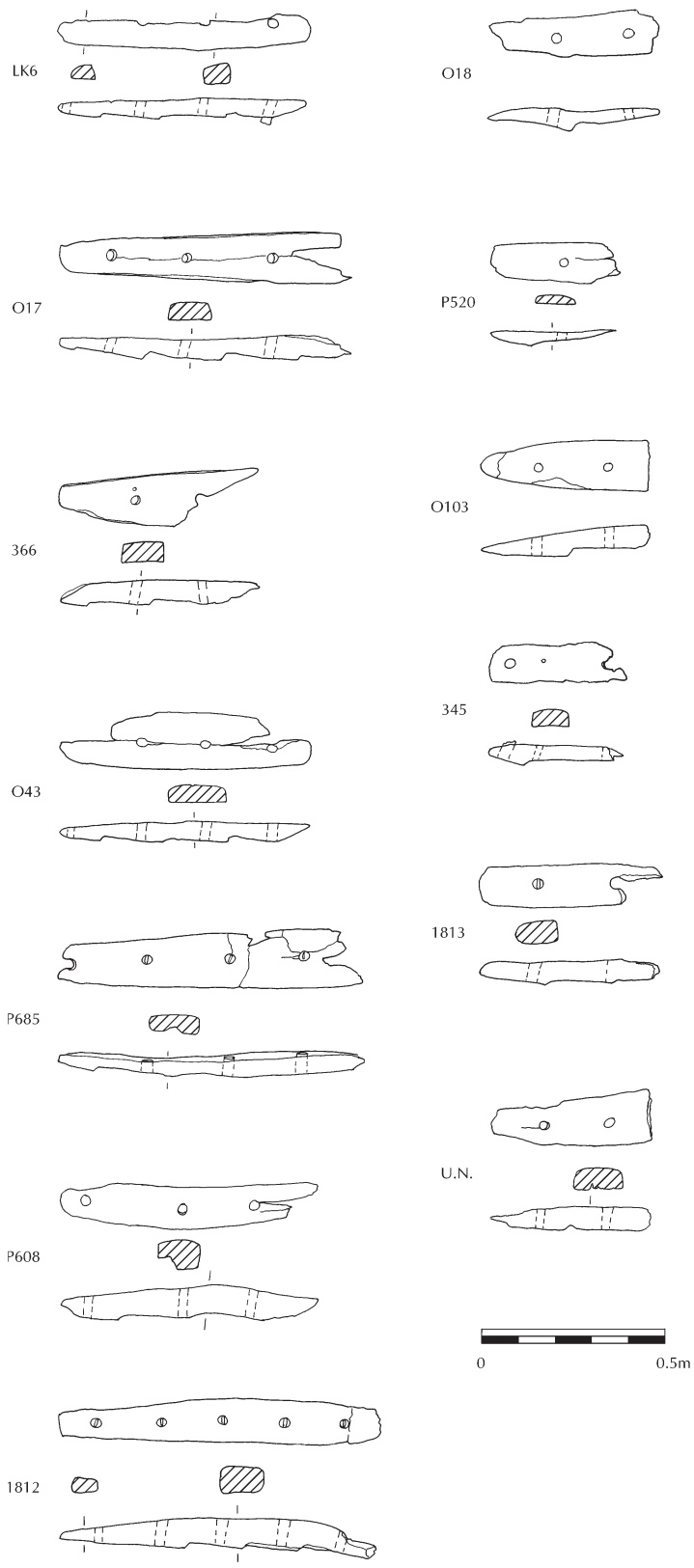


Fig. 24. Skuldelev 2. Fragments of floor-timbers of unknown position in the ship. Scale 1:20.

Once the precise or approximate original position of most of the floor timbers was determined there were still a limited number of floor timber fragments that could not be specifically placed except very generally (Table 5 and Fig. 24). None of these fragments displays characteristics unknown from the floor timbers described above.

Side timbers

The side timbers (Figs 25-26) are the only structural elements in Skuldelev 2 that are not all made of oak, as some of these are of willow. They were originally elegant and slender, and placed equidistant between every frame station, except aft of 15A or 16A. They rest against the upper edge of the fourth strake with a broad, flat end or a nicely pointed shape. Originally, they were fastened to the fifth strake with an iron rivet and continued upwards over the sixth strake and under the stringer on the seventh one, being fastened here with a rivet. In some cases a short scarf for a continuation of the element upwards is found in the sixth strake, secured with a rivet (Fig. 27). None of these slender side timbers is preserved beyond the seventh strake, but the fact that some of them were scarfed at the sixth strake is a strong indication that they originally extended well beyond that strake.

There is a striking contrast between the solid character of the side timbers in Skuldelev 1 and those in Skuldelev 2, which are extremely slender with a thickness of only 1-3 cm in spite of the fact that they are joggled for the clinker planking. Their width varies in a regular pattern, decreasing from 9-13 cm at the lower end, to 5.5-7.5 cm below the stringer on the seventh strake. Along the edges a decorative moulding has been carefully cut, as elsewhere in the ship.

Table 6. Skuldelev 2. Side timbers, fragments of known position in the hull.

No.	wood species	found	strakes	frame position
1526-27, 1531-33		in situ	5B-6B	14½ A
1540-42		in situ	6B	13½ A
1543		in situ	5B-6B	12½ A
1548-52, 1555-56		in situ	5B-7B	11½ A
P743, P746		loose in situ	5S	½A or ½ F
P552		in situ	5S-6S	5½F
P529		in situ	5B	6½F
P521	oak	in situ	5S-6S	7½F
P503		in situ	5S	9½F

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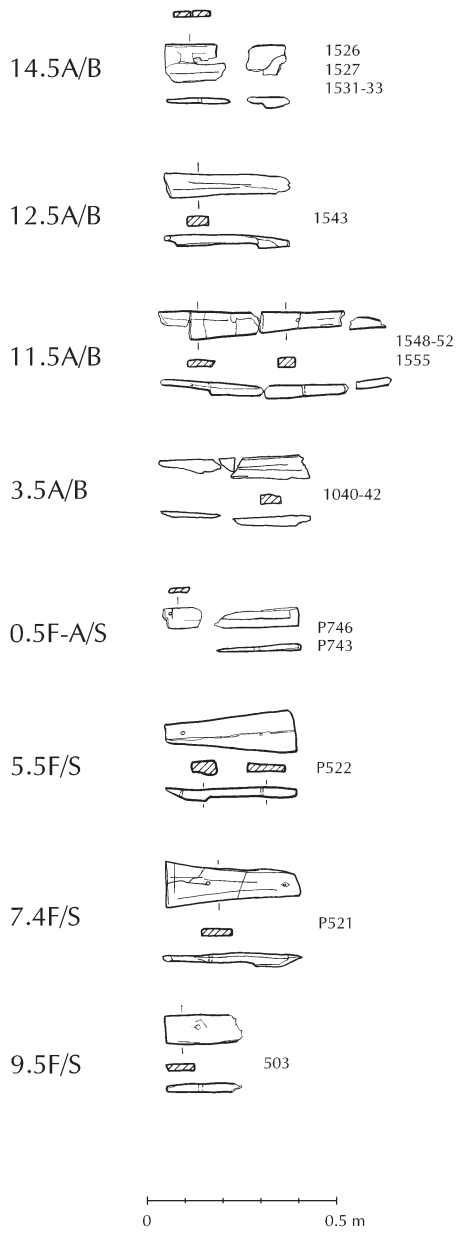


Fig. 25. Skuldelev 2. Fragments of side-timbers found in situ. *Scale 1:20*

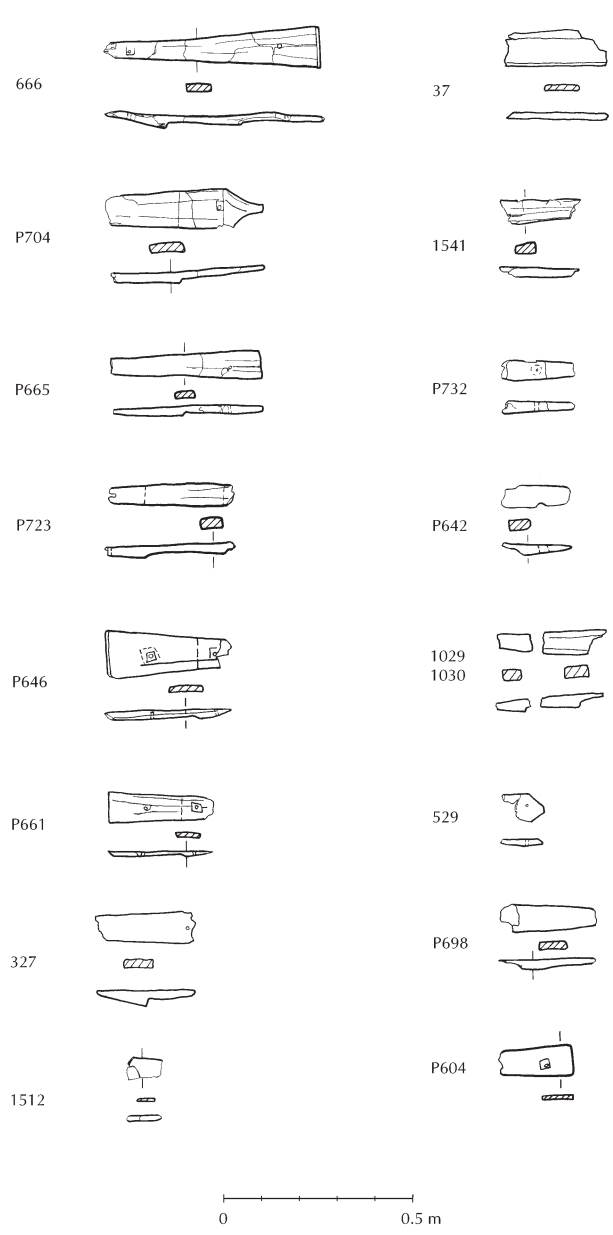


Fig. 26. Skuldelev 2. Side-timbers and fragments of these found loose. Scale 1:20

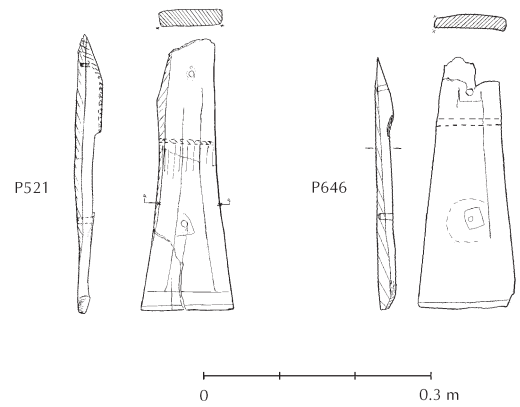


Fig. 27. Skuldelev 2. Lower part of side-timbers P521 and P646 with scarf at the upper end for a continuation. Scale 1:10.

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No.	wood species	found in	original position
327/499	oak	'Wreck N'	
1015	oak	area A	forward
1029		area A	forward
1030		area A	forward
P642		area B	forward
P646		area B	forward
P604		area C	amidships or aft
P661		area C	amidships or aft
P665		area C	amidships or aft
P666	willow	area C	amidships or aft
P698		area C	amidships or aft
P704	willow	area C	amidships or aft
P723		area C	amidships or aft
P732		area C	amidships or aft
1512		in ship at 20½A	aft

Table 7. Skuldelev 2. Side timbers, fragments of unknown position in the hull.

*Biti*s, stringers and knees

Among the loose parts of Skuldelev 2 were two fragmentary lengths of a stringer of oak. This longitudinal strengthening element was originally fastened with treenails to the inside of strake seven. Here the contact face was notched to receive the top ends of the floor timbers, which were fastened neither to the strake nor to the stringer, but wedged in behind the stringer. Notches were also cut in the stringer for the side timbers and the rivets fastening these to strake seven. On top of the stringers notches had been cut for the ends of the *biti*s which were fastened here with a spike (Fig. 28, see also Fig. 21).

The longer stringer fragment, P633, was found in area D and is therefore most likely to be from the midship or after part of the ship. It is 4.10 m long, broken at both ends and has notches for five floor timber tops and *biti*s, and for six side timbers. The average distance between frames here is 68 cm, with variations between 66 cm and 70 cm, but overall corresponding to the average frame distance measured on the planking aft.

The shorter stringer fragment, P 677, is 1.39 m long and has notches for two sets of floor timbers, *biti*s, and side timbers. The distance between frames here is 71 cm, and this fragment is broken at one end and has a hooked scarf at the other end. It was found between areas B and C and is therefore likely to have come from the forward or midship part of the ship. The average frame distance of 72 cm recorded for the planking here is in accordance with that of the fragment. There is a perfect match between P519, a length of the seventh strake port which was found in area C, and this fragment of the stringer.

The precise position of the two lengths of the stringer in relation to the known frame positions can only be loosely determined by comparing the spacing of the notches in the stringers for the upper ends of the floor timbers with the spacing of the notches in the keelson for the lower part of these timbers. These two sets of distances, however, will deviate if the frames are not positioned strictly at right angles to the centreline. In several places the notches for the *biti*-ends are slightly off-set from the notches for the top-ends of the floor timbers. This feature shows that the positions of the *biti*s in some cases were adjusted to compensate for slight irregularities below.

The notches for a *biti* over the floor timbers in each of the two fragments of the stringer are 8-11 cm wide, and they show that such *biti*s were present over the entire midship length of the ship. Most of these are now lost, but among the loose parts of the ship found in area C to the west of Skuldelev 2 are two *biti* fragments from this ship (Fig. 29).

The best preserved of these, P721, is a 1.64 m-long *biti* that served as a deck beam. It is 10-11 cm wide at the ends, 13 cm in the middle, and cut into a ⊥-shaped cross-section to receive the deck boards along both sides. Originally, this

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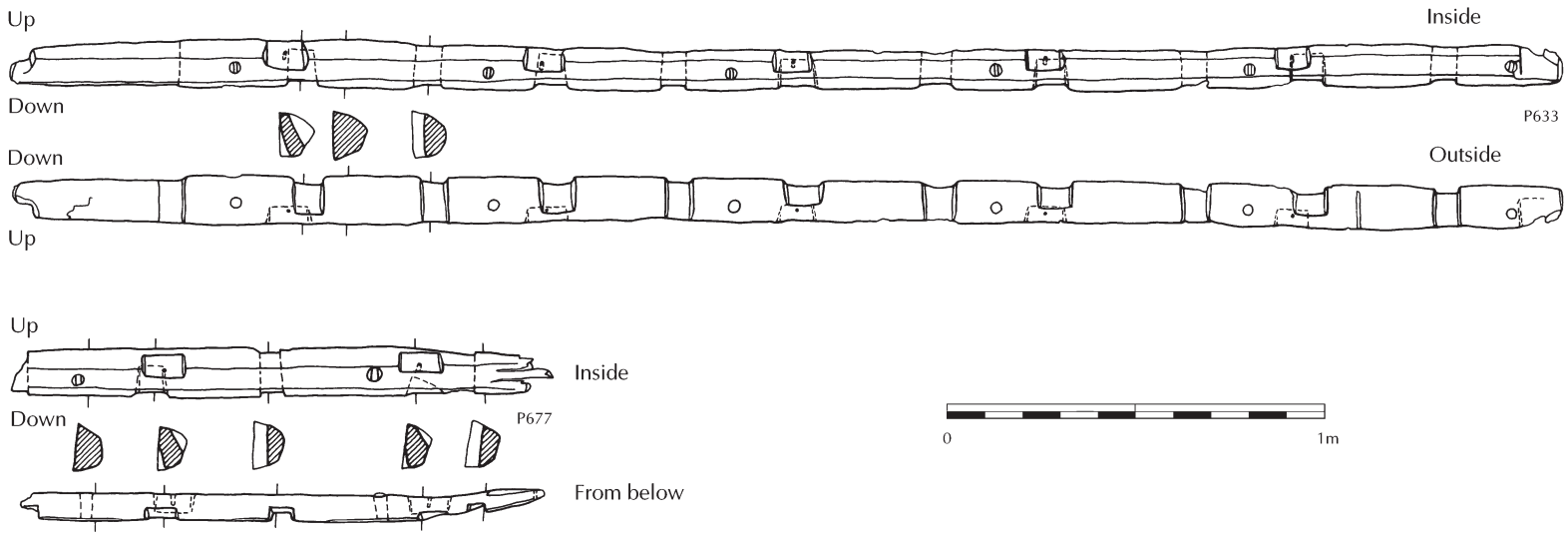


Fig. 28. Skuldelev 2. Two lengths of a stringer, originally mounted on the inside of the seventh strake with notches for the tops of the floor-timbers, the side-timbers and the biti*s. Scale 1:20.*

biti continued at both ends into a *biti*-knee of the same width as the middle ridge of the *biti*. The beam and the knee at one end were cut from the same piece of wood that had grown in the shape needed for its function. However, this knee is now broken off. At the other end, a separate knee, now lost, was originally fastened with two rivets.

The *biti* itself, however, is well preserved with several features of interest. On the underside, the ends are dressed to fit over the broad top of the floor timber below rather than to rest on the longitudinal stringer as described above. This shows that this *biti* was originally mounted near one of the ends of the ship, outside the area amidships where the *biti*s rested on the stringer. The short length of the beam corresponds to the distance between the top ends of the floor timber below. As the *biti* was found in area C it most likely came from the after end of the ship, probably from frame station 19A, where the top of the preserved port side of the floor timber is square, corresponding to the notch on the underside of the *biti*.

The upper side of the *biti* is characterised by a middle ridge and 3-5 cm-wide and 2-3 cm-deep rabbets for the deck planking that was evidently laid out loose, as there are no traces of fastenings for this. Amidships, the ridge has been cut away to provide space for a 28 cm-wide longitudinal element, fastened with various nails and spikes.

On top of the ridge two shallow holes, 2.5 cm in diameter and depth, are spaced 0.7 m apart and symmetrical with the centre of the beam. They served as sockets for stanchions to support another element above the *biti*. A hole through the beam close to the centreline probably served as

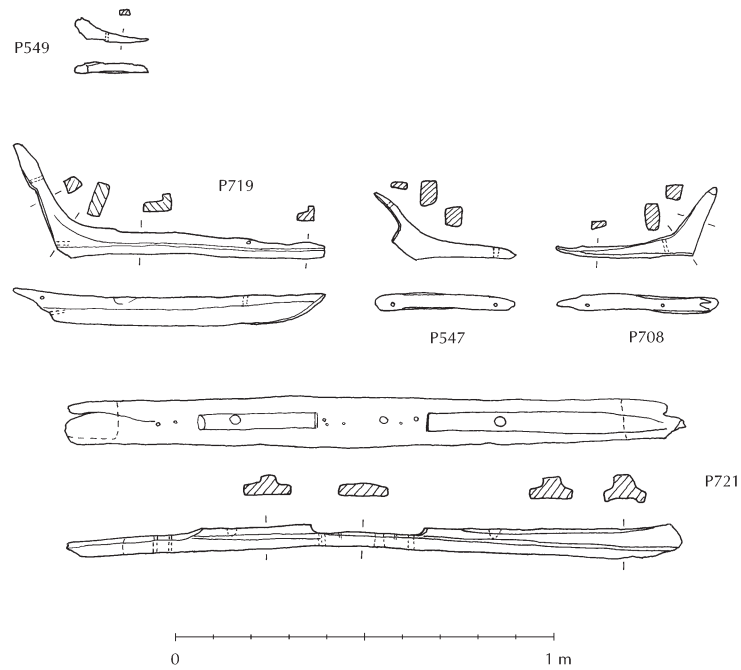


Fig. 29. Skuldelev 2. Biti*s and* biti*-knees. Scale 1:20.*

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Table 8. Skuldelev 2. Biti*s and associated knees.*

No.	angle	element	found	original position
P547	144°	knee with notch	Sk. 2 at ½F, B	amidships
P549	ca 130°	small knee	Sk. 2 at ½F, B	amidships
P708	111°	*biti*-knee	area C	aft
P719	108°	*biti* with knee	area C	aft
P721		*biti*	area C	aft

Table 9. Skuldelev 2. Stanchions for biti*s and beams.*

No.	length	found	original position
P548	180 mm	Sk. 2 at keel, ½F	1F?
P589	170 mm	Sk. 2 at 1½F	1F? or 2F?
P617	(160)/280 mm	area D-E	amidships or aft
P647	350 mm	area C	amidships or aft
P705	350 mm	area C	amidships or aft
1811	180 mm	Sk. 2 at 2A	2A?

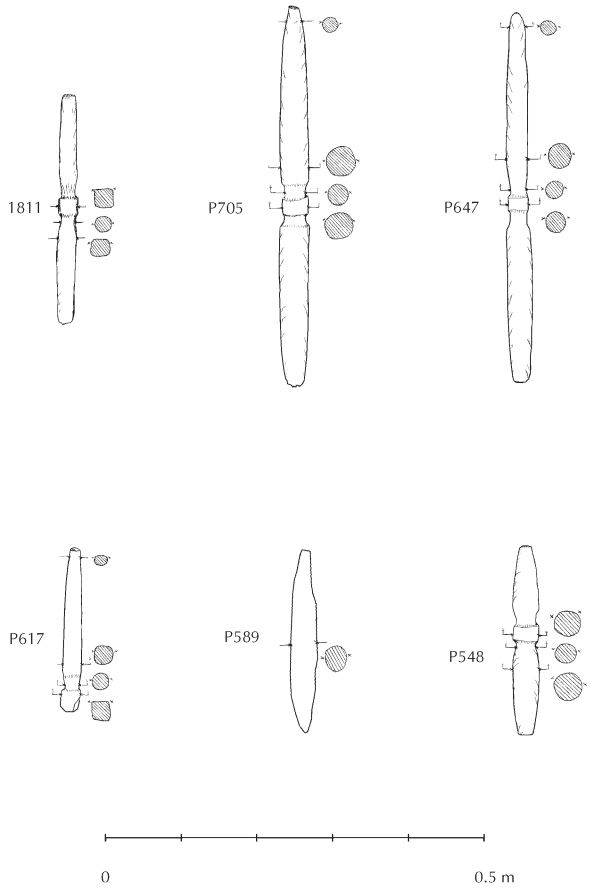


Fig. 30. Skuldelev 2. Stanchions to support biti*s and beams. Scale 1:10.*

socket for a similar stanchion from the underside of the *biti* to the floor timber below, as the central part of all floor timbers outside the keelson have similar holes for stanchions.

The other *biti* fragment, P719, is strongly eroded and only preserved at the side with the knee that was cut out of the same piece of wood. In this case, there is only a rabbet for the deck planking at one side, showing that this beam, found in area C, also came from aft in the ship at a position where the deck ended, but possibly continued at a different level. The knee is joggled for two planks, probably the eighth and ninth strakes, the first one of these at an 108° angle to the beam. A spike and rivet fastened the knee to the planking.

Among the knees found loose in and around Skuldelev 2, there are three which may have served as knees for *biti*s or for upper beams/thwarts in this ship, to judge from their narrow width and overall characteristics (Fig. 29 and Table 8). Two of these knees, P547 and P549, were found amidships, whereas P708 is from area C. In the preserved sections of the hull amidships, the angles between horizontal and the eighth strake is ca 130°-144° for the knees. For knee P708, the angle is 111°, corresponding to the angle of *biti* P719, and so both are from aft in of the ship according to the above-mentioned criteria. The knee P547 is joggled for a stringer. Such a feature does not show up on the other *biti*-knees and it is therefore most likely that P547 had a different function in Skuldelev 2, such as a knee for a thwart above the *biti*.

From the observation of socket holes in the floor timbers, the *biti*s and the keelson chocks, it appears that a considerable number of stanchions were used in the construction of Skuldelev 2. For each 'standard frame', three stanchions were needed, one below the *biti* and two between the *biti* and the beam or thwart above it. Generally the two upper stanchions are of roughly the same length throughout the ship, whereas the length of the lower stanchion depends on the distance between the *biti* and the floor timber or keelson chock below.

In Table 9 and Fig. 30, the six stanchions found in and around Skuldelev 2 are presented. Two of these, P647 and P705, seem to be fully preserved with a length of 35 cm, whereas P548 and 1811 are both 18 cm long. The stanchions are cut with a decorative ring around the middle and slightly tapered ends that fit into the sockets at both ends.

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Upper part of the framing system

The elements thus far described form the bottom part of Skuldelev 2 with its internal strengthening system up to the seventh strake, consisting of floor timbers, *biti*s with knees and rabbets for the deck planks, stringers, and side timbers (cf Fig. 21). There are also indications that suggest there was originally a second layer of slender beams, probably serving as thwarts, positioned over each *biti* and supported by stanchions.

In contrast, practically all parts of the external hull of the ship above the waterline are missing except the after stem and the aftermost section of port planking. The internal strengthening system for the upper part of the ship is represented only by the horizontal knee (no. 1505), found *in situ* between the frame stations 20A and 21A on strake 5B, and a strong frame-member, (side timber no. 1015), that is joggled for planking, and split lengthways. This second element evidently came from the bow region, as it was found in area A (Fig. 31). These two elements provide some important clues as to the character of the sides and the internal structure of the ship above the level of the *biti*s, even if they only represent the two ends of the ship. In the same area, the knee M324 was found, which may belong either to Skuldelev 2 or 3.

The above-mentioned horizontal knee, no. 1505, was fastened with treenails to support a beam or a bulkhead in front of the after stem at 21A, and possibly also had some connection to the side rudder mounting on the starboard side aft. The angle of the knee is ca 90°, indicating that the beam or bulkhead was either curved or mounted at an angle to the centreline of the ship, since the ship's sides aft curve in to meet the stern. The fact that there was a strong beam or bulkhead aft indicates that a similar feature may originally have existed forward as well. Since the horizontal knee ended square and was not continued forward, there is no reason to believe that it was part of a continuous line of knees from aft to fore as in Skuldelev 1.

The strong side timber, no. 1015, is an important clue as to the character of the upper part of the planking of Skuldelev 2. Similar side timbers were also mounted in Skuldelev 3 over the top-strakes, strengthening these and in some cases also serving as a base for rigging cleats (cf Chapter 5.3.2). The fragment from Skuldelev 2 is decorated with a curved moulding along the inner face and joggled for the planking on the outside face. The upper notches have almost the same orientation and they probably represent the two uppermost strakes in the forward part of the ship. From these notches, the measurements of these upper strakes can be determined: The width is 17 cm for the top-strake, which has had a thicker upper part, and 9 cm for the strake below. These strakes were probably almost vertical in their original position and the oarports would probably have been cut in the lower one of these. The notch for the third strake from above is oriented inwards at an angle of 25° to the upper planks. This notch is deeper than normal notches for the planking, and it may have been cut to accommodate a stringer on the inside of this plank. This important element is preserved as a fragment since the original side timber was cleaved lengthways and only one half is preserved.

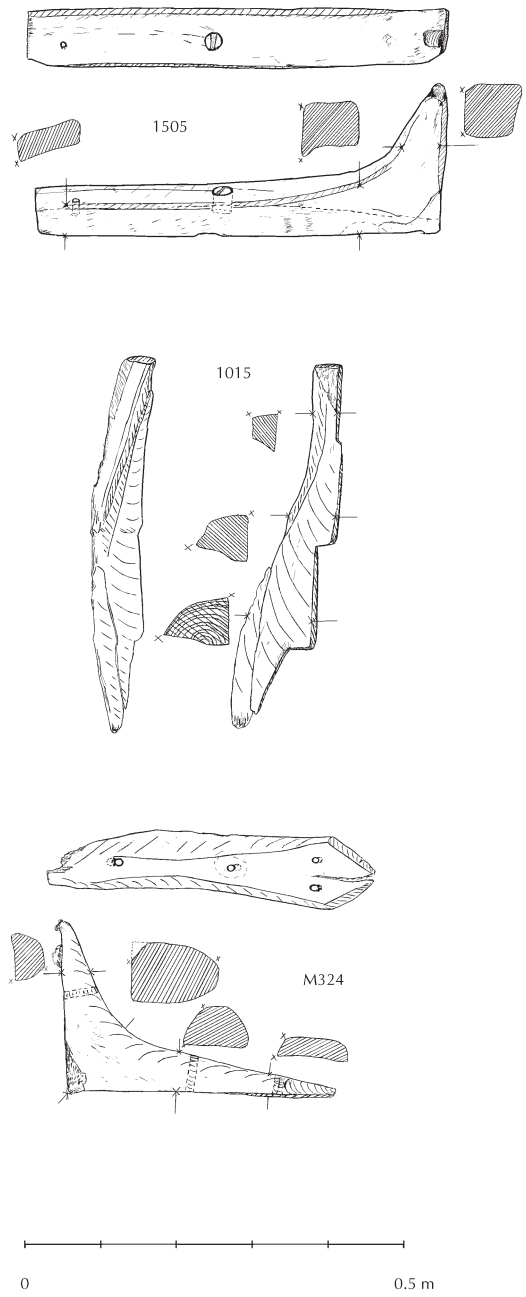


Fig. 31. Skuldelev 2. Horizontal knee (1505) found in situ *aft in the ship, a fragment of a side-timber (1015) with notches for the upper strakes, and a knee (M324), both found in the bow area. Scale 1:10*

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Miscellaneous

There are a few structural elements found in and around Skuldelev 2 which seem to belong to this ship but which have not been mentioned yet as their original function has not been identified. Such is the case with a group of small knees of oak (Fig. 32) that have angles of 75°-98° between the two arms. Two possible functions for these have been considered: They might be horizontal keelson knees, or standing knees to connect the upper beams or thwarts and the side of the ship, probably fixed on a stringer, which would explain their steep angles. The former explanation will be discussed below in relation to the keelson. Their small size and the range of variations in the angle of the knees, however, argue against the possible use of these knees to fasten the thwarts (cf Table 10).

In area C, an 0.89 m long slender beam of oak, P703, which is worn and broken at one end and cut off at the other end was found (Fig. 33). The beam has a ridge running along its length, flanked by a rabbet on both sides and originally pierced by horizontal iron nails spaced 34-38 cm apart. The original function of this element is not known, and it is not certain that it comes from Skuldelev 2.

No.	angle	element	found	original position
66	small knee	89°		
359	small knee	75°		
1501	small knee	ca 98°	Sk. 2 at 12A-20A	aft
1502	small knee	91°	Sk. 2 at 17A	aft
1804	small knee	91°	area A	forward
1810	small knee	ca 97°	Sk. 2 at 2F, B	amidships
4501?	small knee	90°		
P609	small knee	97°	area E	mid or aft
P713	small knee	90°	area C	mid or aft

Table 10. Skuldelev 2. Small knees of unknown function.

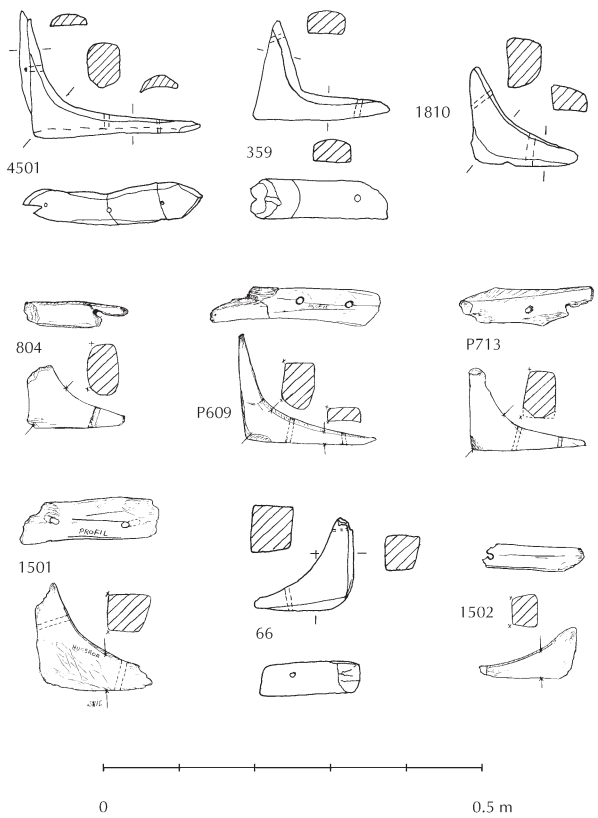


Fig. 32. Skuldelev 2. Small knees of unknown function. Scale 1:10.

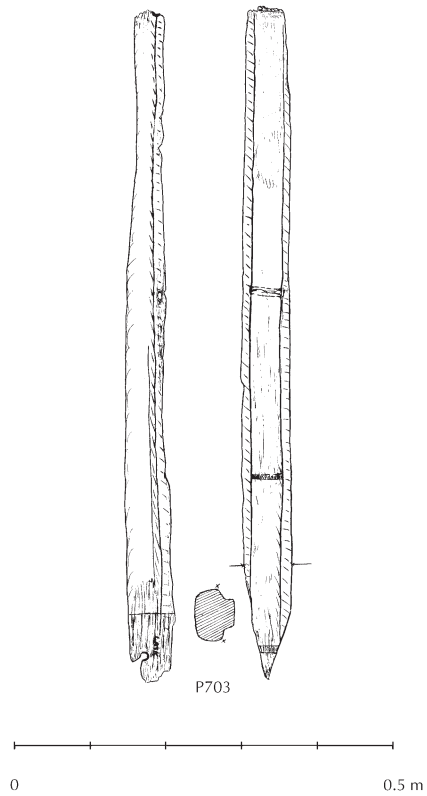


Fig. 33. Beam with rabbets and scarf, found west of Skuldelev 2. Scale 1:10.

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Hull parts related to propulsion and steering

In Skuldelev 2 the keelson is a central element for distributing the stresses and strains from the mast and sail over a large part of the bottom of the ship. At the same time, the keelson considerably reinforced the longitudinal structure of the hull. Other parts of the structure directly related to propulsion or steering of the ship have not been found owing to the ship's fragmentary preservation.

Keelson and keelson knees

As described above, the keelson was found loose, but it was possible to place it in its original position in relation to the frames of 'Wreck 2' by means of the keelson knees and chocks. The standard descriptive system for the frames in the ship could thus be established, starting from frame station '0' at the mast step, and going forward and aft from there. The keelson extends from frame stations 8A to 10F.

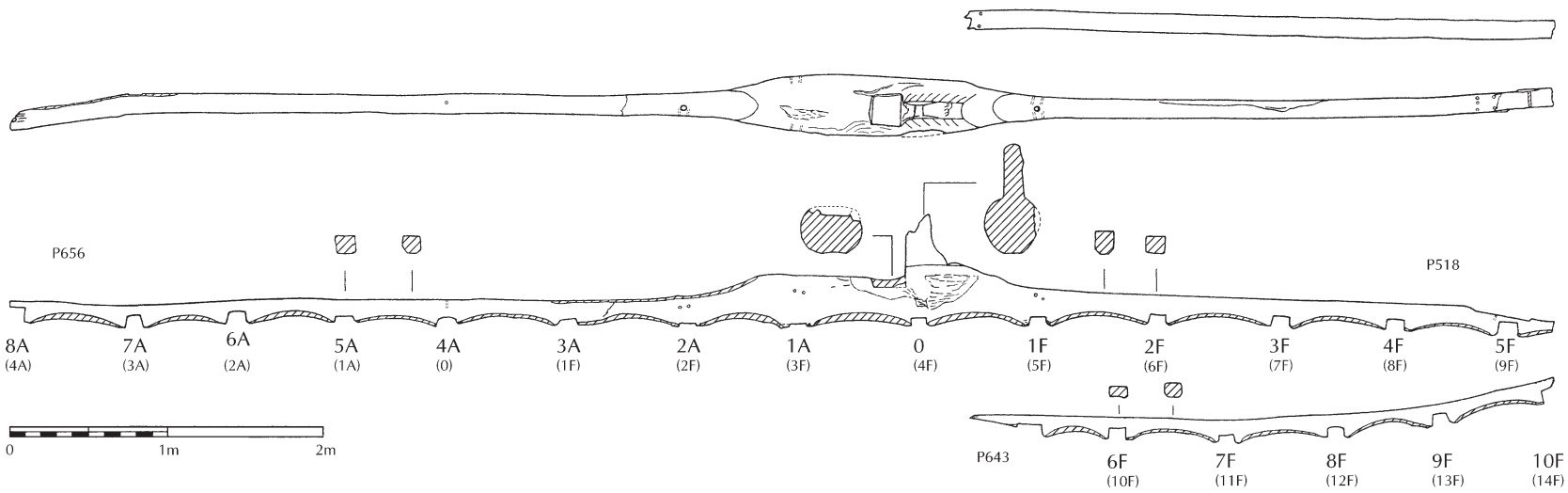
The keelson (Fig. 34) consists of two parts, of which the main element is 9.85 m long. They are joined by a hooked scarf, and so give the keelson a total length of 14.1 m. The keelson is 11 cm wide, except in the area of the mast step, where the width increases to ca 38 cm. The mast step is ca 18 x 18 cm; its present depth is ca 5 cm, and its original depth could not have exceeded 8 cm. Immediately in front of the mast step is a vertical branch of considerable thickness which is broken off at a height of 45 cm above the bottom of the mast step. The keelson did not rest directly on the keel but on top of the floor timbers, and was notched to a depth of 2-8 cm for these on the underside with arches in between these notches. There are no direct fastenings between the keelson and the floor timbers.

The main length of the keelson is straight, except that both ends have been bent sidewards as the keelson settled on the western slope between the areas B and C. The forward length is curved upwards, possibly as a result of pressure in its secondary position under the main keelson.

The keelson was held firmly in position in the ship, partly by its own weight and the notches for the floor timbers, but mainly by the upright branch and a series of elements riding over the keelson or supporting it from the sides around the mast step. These elements (Fig. 35 and Table 11) fall in two groups. At the frames 1F to 2A, one knee from each side supported the keelson. Each of these was shaped to fit the side of the keelson and the top of a floor timber and was fastened with spikes into both parts. The knees on both sides at 1F and 2A have been found and they are very elegantly shaped to combine strength and minimal weight.

Outside the central part of the keelson, the keelson supports are shaped as double-knees or chocks, cut to a roughly triangular shape that bridges over the keelson. They are spiked to the floor timbers on both sides, whereas there are no fastenings directly to the keelson. In one case, P516, the central part of the chock rises up to a peak with a boring for a stanchion for the *biti* above. Similar borings are found on the best preserved of the other chocks and most likely all the double-knees were originally similar chocks. This is supported by the fact that there are borings on top of the keelson for stanchions only at 1F and 2A. At all the other frame stations, except 0 and 1A, these holes were made in the double-knees over the keelson and in the floor timbers fore and aft of the ends of the keelson.

Fig. 34. Skuldelev 2. The keelson.



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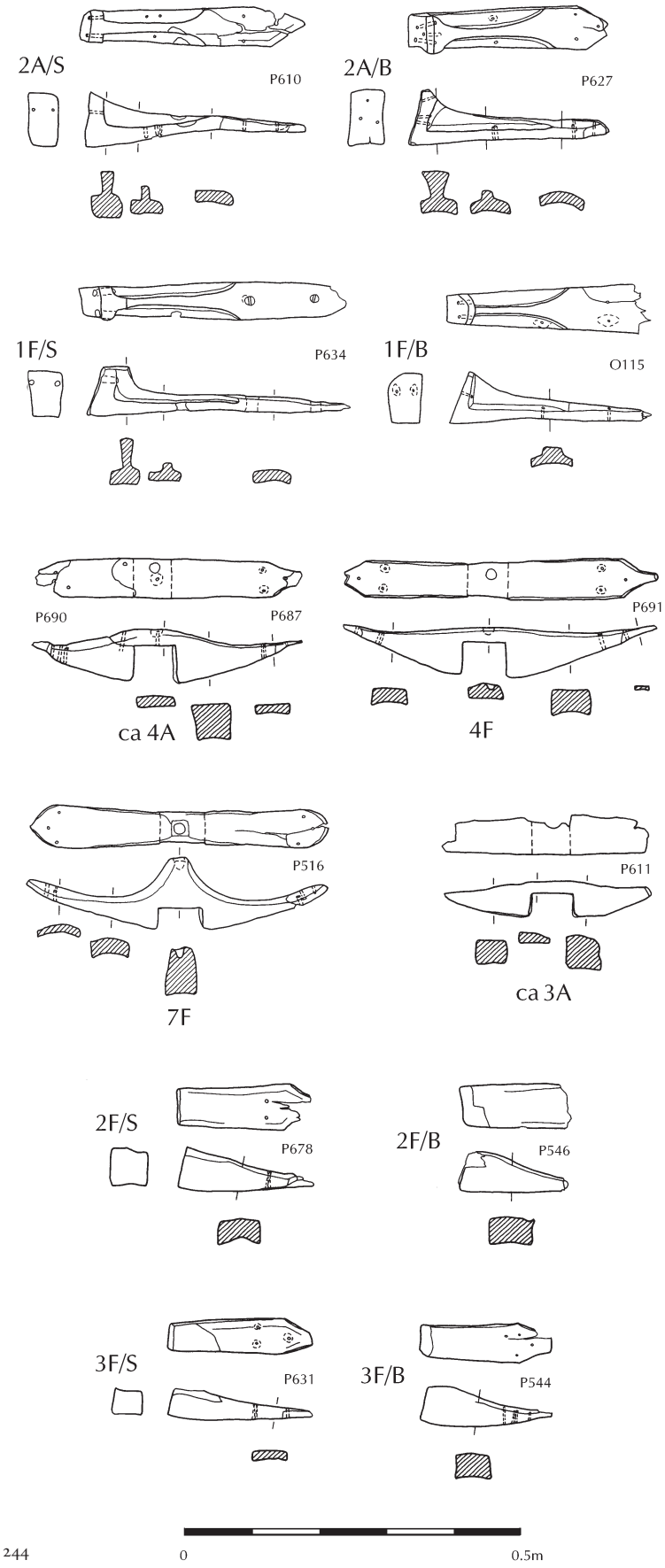


Fig. 35. Skuldelev 2. The keelson knees. Scale 1:20.

No.	raised	element	found	frame position
P687, P690	1962	keelson chock	area C	ca 4A
P611	1962	keelson chock	area E	ca 3A
P627 P610	1962 1962	keelson knee keelson knee	area C area E	2A, B 2A, S
O115 P634	1957 1962	keelson knee keelson knee	in situ area C	1F,B 1F, S
P546 P678	1962 1962	keelson knee keelson knee	in situ area C	2F, B 2F, S
P544 P631	1962 1962	keelson knee keelson knee	in situ area D	3F, B 3F, S
P691	1962	keelson chock	area C	4F
P516	1962	keelson chock	area B	7F

Table 11. Skuldelev 2. Keelson knees and chocks.

The small oak knees mentioned above (Table 10) might have been positioned as supplementary connections between the keelson and the floor timbers. In Skuldelev 3 and in Hedeby 3,[3] small knees are mounted between the keelson and the sides of the floor timbers, in addition to the single and double knees of the same nature as those in Skuldelev 2.

It has not been possible to ascertain if these small knees were used in such a way. If they had connected the floor timbers and keelson, it ought to be possible to observe spike holes or traces of rust from spikes in the sides of the keelson and floor timbers. However, such traces may have remained unnoticed in the main part of the keelson, as this was recorded at scale 1:10. When the keelson was recorded, it was not subjected to as careful observation and recording as was normally the case in the 1:1 recording process. Most of the floor timbers, however, were recorded at full scale and in considerable detail, and no spike holes for such knees were revealed.

3. Crumlin-Pedersen 1997a: 244