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Roar Ege: The Lifecycle of a Reconstructed Viking Ship

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In 1962, the remains of five late Viking Age ships were excavated from Roskilde Fjord, near Skuldelev on the Danish island of Zealand (See Figure 1: Crumlin-Pedersen and Olsen, 2002). Twenty years later, the Viking Ship Museum in Roskilde began the process of building its first full-scale Viking ship reconstruction, the 14 m long coastal transport and trading vessel, Skuldelev 3. Over the next two years, *Roar Ege* was built at the Museum boatyard and the *Roar Ege Project* marked the start of a process that would form the core of the Museum's research endeavours: the experimental archaeological reconstruction of ship and boat finds.

> For the first time, we have a comprehensive data set over the lifespan of a reconstructed Viking ship, from the first axe cuts into oak logs in 1982 to the last moments on the water in 2016.

Roar Ege was launched in 1984, and after more than 30 years on the water, has many sea miles under its keel. The years have, however, taken their toll on the ship. *Roar Ege* has undergone several major phases of repair – most recently in 2014. It was hoped this repair would keep *Roar Ege* afloat for several more years but by spring 2016, the ship had deteriorated to such an extent that it was clear that *Roar Ege's* sailing days were over.

With *Roar Ege's* retirement on land, its contribution to maritime experimental archaeological research has entered a new and vital phase. For the first time, we have a comprehensive data set over the lifespan of a reconstructed Viking ship, from the first axe cuts into oak logs in 1982 to the last moments on the water in 2016.

This paper presents an object biography of *Roar Ege*, from the perspective of both the boatbuilder and archaeologist, focusing on the manner in which the hull has deteriorated and the components that are involved in its decline. This biography is compared to the evidence of repair on the original ship-find, exploring the potential these data have for developing an understanding of the prospective lifespan of Viking Age ships, and the materials and resources entailed in maintaining and repairing them throughout their active use.

The recovery of the Skuldelev Ships

The excavation and analysis of the Skuldelev ships has been published in depth elsewhere but warrants a brief summary here (Crumlin-Pedersen and Olsen, 2002). There had long been a local tradition that there was a shipwreck on Roskilde Fjord, off the coast at Skuldelev. Following two underwater surveys to determine the extent of the site in the late 1950's, a coffer dam of sheet pilings was erected out on the fjord, in the summer of 1962 (See Figure 2). This allowed the water to be pumped out, giving the archaeologists access to the fjord bed. The layers of sand and silt were then removed, revealing five late Viking Age ships (Crumlin-Pedersen and Olsen, 2002, p.29).

These were no shipwrecks, however. They hadn't been lost in a storm or run aground. Rather, the five ships proved to have been intentionally scuttled during the late 11th century, as part of an extensive system of barriers on the fjord, built to protect the town of Roskilde from seaborne attack (Crumlin-Pedersen and Olsen, 2002, p.331). Over the course of the summer, the excavation team successfully uncovered and raised all five ships – an enormous jigsaw puzzle of over 50,000 ships parts, all of which were then documented prior to being conserved (Crumlin-Pedersen and Olsen, 2002, p.54).

The Skuldelev ships were – and still are – an exceptional find in terms of Danish maritime archaeology. The five ships also present a unique snapshot of the specialisation of late Viking Age maritime technology, which in turn reflects the multifaceted nature of late 11th century society:

Ship-find	Ship-type	Date of construction	Place of construction	Materials	Length	Beam	Draft
Skuldelev 1	Ocean-going trading vessel	Ca. 1030 AD	Sognefjord region, Norway	Pine, oak and lime	15.8 m	4.8 m	1 m
Skuldelev 2*	War ship	1042 AD	Eastern Ireland	Oak	Ca. 30 m	3.8 m	1 m
Skuldelev 3	Coastal cargo and transport vessel	Ca. 1040 AD	Denmark	Oak	14.0 m	3.3 m	0.9 m
Skuldelev 5	War ship	Ca. 1040 AD	Denmark	Oak, pine, ash and elder	17.3 m	2.5 m	0.6 m
Skuldelev 6	Fishing and transport vessel	Ca. 1030 AD	Sognefjord region, Norway	Pine, birch and oak	11.2 m	2.5 m	0.5 m

TABLE 1: GENERAL INFORMATION CONCERNING THE FIVE SKULDELEV SHIPS.
* DURING EXCAVATION, THE TIMBERS BELONGING TO SKULDELEV 2 WERE ORIGINALLY THOUGHT TO BELONG TO TWO SEPARATE SHIPS AND WERE THEREFORE NAMED SKULDELEV 2 AND SKULDELEV 4. ONCE THE EXCAVATORS REALISED THAT IT WAS IN FACT ONE EXCEPTIONALLY LONG SHIP, THE FIND HAD SOME YEARS WHERE IT WAS REFERRED TO AS SKULDELEV 2 + 4, BUT IS NOW MOST COMMONLY REFERRED TO AS SKULDELEV 2.

The best-preserved of the five ships is Skuldelev 3: a 14 m long cargo and transport vessel built of oak in Denmark around 1040 AD (See Figure 3; Crumlin-Pedersen and Olsen, 2002, p.239). Roughly 75% of the hull had survived the many centuries on the bottom of the fjord, making it the most complete Viking ship found in Denmark to date (Crumlin-Pedersen and Olsen, 2002, p.240).

The idea of reconstructing the ships in full-scale had emerged very early on in the process of excavating and analysing the Skuldelev ships. As the most intact of the five, Skuldelev 3 was the obvious choice to start with. Twenty years after the initial excavation, the Museum embarked upon its first full-scale experimental archaeological reconstruction.

Roar Ege: Skuldelev 3 as an archaeological experiment

The *Roar Ege Project* ran from 1982 – 84, under the direction of a steering committee led by Ole Crumlin-Pedersen (Crumlin-Pedersen, 1986a; 1986b; Andersen, *et al.*, 1997, p.11). This was the project that would mark the start of the Viking Ship Museum's experimental archaeological endeavours and as such, much thought was given to the project's framework prior to its commencement. As with all archaeological experiments, the *Roar Ege Project* also had a clear set of goals, defining the overall scope of the project:

1. The project would provide the opportunity to conduct scientific investigations into Viking Age ship-building and seafaring
2. Through photos and film documentation, the project would provide a unique insight into Vikings ships and how they were handled
3. The project would create a direct link between the original ship-find as exhibited in the Ship Hall and the full-scale reconstruction for visitors to the Museum
4. The project would also allow visitors to the Museum to try their hand at various craftwork processes.

From the beginning, the steering committee had a clear ambition that the research-based elements of the project should always take precedence over the education and outreach aspects of the build (Andersen, *et al.*, 1997, p.10). As such, they laid out the following rules, which provided the basis for the archaeological experiment:

1. The build should be led by a group of specialists within the fields of Viking ship research, ship-building, rigging and sailing, with Ole Crumlin-Pedersen (archaeologist), Morten Gøthche (architect and secretary), Søren Vadstrup (leader of the building project), Erik Andersen (rig master and responsible for reconstruction of the form) and Max Vinner (responsible for the sailing trials).
2. The ship should be built using the same materials and techniques as can be seen on the original find.
3. The ship should be built as an exact reconstruction of the original ship, as it would have appeared when newly built.
4. The entire process should be documented in text and photographs.
5. A programme of test-sailing must be undertaken after the launch to establish the ship's sailing capabilities, cargo capacity etc.
6. The work would be concluded with the publication of the project and its results.

   (Andersen, *et al.*, 1997, p.11)

They had one further specification in terms of the execution of the actual building process: the work of constructing the ship would primarily be carried out by a group of young people with experience from previous ship-reconstruction projects but without formal boatbuilder educations (See Figure 4). This decision was based on the idea that modern boatbuilders – even those versed in traditional methods – would be unable to leave their inherent learning and understanding of tools, techniques and materials 'at the door'. That they would inevitably, consciously or otherwise, apply a twentieth century craftsman's mindset to the task at hand, which could have an impact on the process of re-discovering Viking Age boatbuilding techniques (Andersen, *et al*., 1997, p.80).

This is perhaps one of the primary differences in terms of how the Museum approached experimental archaeology 30 years ago and how we approach it today. With *Roar Ege*, much emphasis was placed on the 'clean slate' approach whereas now, the professional traditional boatbuilder's understanding of materials, tools use, form and function is something that is valued and prioritised, and which has become an integral part of experimental archaeological practice at the Museum boatyard.

Interestingly, two of the non-professional participants in the *Roar Ege Project* - Søren Nielsen and Tom Nicolajsen - went on to train as professional boatbuilders and have established careers working with the building of experimental archaeological ship reconstructions. Another of the team, Vibeke Bischoff, has specialised in the process of reconstructing the hull form of archaeological ship-finds, under the tutelage of Erik Andersen. All three are still working at the Viking Ship Museum today, and their combined experience is a well-spring that we continue to draw from in the work at the boatyard.

Back in 1982 however, the *Roar Ege* team had to 're-learn' the various techniques associated with Viking Age boatbuilding. During the course of the construction of *Roar Ege*, they became proficient in the use of reconstructed Viking Age woodworking tools and techniques (See Figure 5). The skill-set and understanding of materials that they developed during this project has been passed on to subsequent boatbuilding teams, essentially becoming the foundation for all proceeding experimental archaeological reconstruction projects at the Museum boatyard.

The construction of *Roar Ege* took two years, with some of the team working full-time on the build while others were involved seasonally. The quantities of materials used in constructing the hull were recorded in the *'Roar Noter'*, a series of notes that were written during the course of the build (Roar Ege Byggedagbog, section 15). Unfortunately, the exact dimensions of the logs used were not written down. Rather, they recorded the amount of material in cubic meters. Likewise, apart from the quantities involved in making the keel, stems and radially cleaved planking, the other amounts are rather generally recorded, with different components listed under the same numerical total. Table 2 below gives an overview of the materials necessary for building a reconstruction of Skuldelev 3's hull:

Component	**Material Type**	**Quantity of timber material in m3**	**Quantity**
Keel and stems	Oak	6.11	
Planking material (radially split)	Oak	14.62	

Planking material (tangentially split), keelson, stringers, deck	Oak	19.73	
Frames and knees	Oak	11.22	
Treenails	Willow	1.05	
Mast and yard	Pine	1.48	
Rivets and roves	Iron		1,204 of each
Spikes	Iron		323
Cubic meters timber in total		**54.21**	

TABLE 2: SUMMARY OF THE QUANTITIES OF WOOD AND METAL REQUIRED TO CONSTRUCT *ROAR EGE'S* HULL. (ROAR EGE BYGGEDAGBOG, SECTION 15).

A total of 54.21 m3 green timber was required to build *Roar Ege.* In layman's terms that equates to roughly:

- 10 oaks, varying in diameter from 0.45 m – 1 m and in length from 4.4 m – 12 m
- Two pine logs, with diameters of 0.3 m and lengths of 10.5 m
- Two willow logs, with diameters of 0.4 m and lengths of 4 m
- 60 pieces of crooked oak for knees
- 25 pieces of crooked oak for floor timbers

Upon completion, the hull weighed in at 2000 kg. The amount of timber incorporated in *Roar Ege's* hull therefore represents ca. 4.85 % of the volume of raw timber acquired. While a good proportion of the remaining ca. 95 % of timber was hewn and chipped away, and ended on the ground surrounding the building site, other larger sections were reused for other purposes outside the project. It should also be borne in mind, that there was likely little to no waste at boatbuilding sites in the Viking Age, as leftover wood could be used for any number of purposes and failing all else, burned as fuel for fires.

It lies beyond the remit of this article, but it should be stated that a final tally of materials would of course include a far broader range of materials and resources. Tar and oil for treating the hull, charcoal for producing the iron fastenings, the various wooden elements of the rigging, rope, sail, oars and anchor, and so on.

For the purpose of this article and the examination of the processes involved in *Roar Ege's* decline, the focus will remain on the hull itself.

Roar Ege's active service begins

Roar Ege was launched on August 25th, 1984 and the waterborne part of the archaeological experiment could begin (See Figure 6; Crumlin-Pedersen, 1986b; Andersen, *et al.*, 1997). A volunteer boat guild was established, largely composed of the same group that had built *Roar Ege*, and they were given responsibility for the general maintenance of the ship, as well as for sailing the vessel. *Roar Ege* and its crew were highly active both in terms of sailing regularly in their home waters on Roskilde Fjord and in promoting the Museum and experimental archaeology by participating in regattas and other events abroad (See Figure 7). Some of these events were travelled to under their own steam. In 1986, for example, they undertook a voyage to Gotland in Sweden, which took two months in all. Other events such as the renowned wooden ship regatta at Douarnenez in France (1988) and the Viking festival at Hafnarfjördur in Iceland (1995) involved transporting the ship by freight. *Roar Ege* has also been exhibited on land several times, including a stint on display outside the National Museum of Ireland in Dublin from 1998-99.

All of these actions – both the everyday stresses incurred while sailing in all kinds of wind and weather and the more occasional extended periods on dry land – have an impact on the hull, requiring maintenance and repair on both minor and major scales.

Maintenance, repair and documentation of archaeological ship-reconstructions

As with all of the reconstructions in the Museum's collection, there is a division of labour in terms of the maintenance and repair of vessels. Boat guilds are responsible for the general maintenance – tarring, painting, small repairs to the sail and rig and so on – while any repairs demanding a more experienced hand are carried out by the Museum's professional boatbuilders.

Each reconstructed ship is documented in what has become affectionately known at the boatyard as a 'Service Book'. Here, record is made of the repair work carried out on the ship, as well as any changes that are made to the construction or components of the sail and rigging which are replaced and renewed.

The service books are an invaluable resource for us as a Museum in our work with experimental archaeology. In the case of *Roar Ege*, the service book represents an archive going back over three decades. It is also the collective output of many different people over the course of these years, and an indirect repository of the way in which our approach to experimental archaeology has developed over time. This kind of long-term perspective is a great asset to us as a research institution and one that we're deeply appreciative of. Being able to look back at how other boatbuilders have dealt with the problems that inevitably arise with wooden boats and ships is a great resource for our current boatbuilding team, and one that means that we can avoid constantly having to reinvent the wheel when finding solutions for repairs.

Rot, rust and clinker-built complications

Various small running repairs were carried out during the first two decades in which *Roar Ege* was in use. The first major repair came in 2003, when the mast, the two uppermost strakes, stringers, and several knees and futtocks had to be replaced due to rot.

This repair encapsulates one of the major challenges associated with maintaining clinker-built boats. Clinker-built boats are constructed using a technique where boards and other components overlap each other (See Figure 8). Even with regular care, maintenance and cleaning, these overlaps can create ideal conditions for rot. Of particular note here are the longitudinal reinforcing timbers – the stringers. Clinker-built ships are designed to have a degree of flexibility – this is one of the advantages of the method as it allows for light constructions which can take a considerable beating when at sea. The downside of this flexibility is that components – such as the stringers – which are only fastened using treenails, can work themselves loose over time. This creates gaps between components, trapping moisture and organic matter between the contact surfaces of the stringers and the boards they are fastened to, facilitating the growth and spread of rot. The outer shell of the hull, which is comprised of overlapping boards is not affected by rot in the same way. The land, or overlap, between the boards is caulked using tar and wool, and this helps to exclude moisture from the joint. Where planking material has become subject to damage from rot, it has generally been because it started in the internal stringers and then spread to the surrounding planking material.

The other significant problem our reconstructions face is the rate at which the iron rivets corrode. They expand as they rust and this leads to cracks occurring in the planking material around the rivets (See Figure 9). The iron fastenings used in the construction of *Roar Ege* are perhaps the main element that deviates from the project's ambitions about using the same materials as would have been used in the Viking Age. In the early 1980's, very little archaeometallurgical analysis of ship's fastenings had been carried out. The project team therefore relied on the limited information that was available, drawing heavily on the work of Olfert Voss and Vagn Fabricius Buchwald[1] (Voss, 1962: Andersen, *et al.*, 1997, p.42).

Siemens-Martin steel, produced using the open-hearth method in Daval, France, was chosen for the production of rivets and roves (Andersen, *et al.*, 1997, p.44). Siemens-Martin steel is a very homogenous material, and with the benefit of hindsight, it could be argued, that it bears very little resemblance to the heterogenous bog iron the majority of Viking Age ship's nails were produced from (Lyngstrøm, 2008, p.9). However, at the time, the team felt that Viking Age boatbuilders would have sought the best-quality material they could source for fastening their ships and that the purity of Siemens-Martin steel, coupled with its low carbon-content, would make it a good match for this hypothetical material (Andersen, *et al.*, 1997, p.44; Buchwald, 2005).

Our experiences with the rapid rate of corrosion and rust of the rivets in *Roar Ege* – and with the other subsequent Skuldelev reconstructions – would seem to suggest otherwise. Rivets tend to need to be replaced after ca. 15 years (rivets below the waterline degrade at a faster rate than those above) and the majority of our reconstructions have seen several phases of rivet replacement through the years. While rivets that have been removed from ships are a common enough find in the archaeological record - especially at ship-breaking sites such as Fribrødre Å here in Denmark - there is limited evidence for a double-imprint of the accompanying rove on surviving ship's components (Skamby Madsen and Klassen, 2010). This is something you would expect to see on the archaeological timbers if the original ships had also been subject to repairs as extensive as our reconstructions.

In recent years, the theory that the relatively higher phosphor content in the bog ores used to produce Viking Age iron may have made the material more corrosion-resistant than modern day iron has gained traction (Buchwald, 2005, p.173). This is an issue that the Museum will be setting an increasing focus on in the future, as it is of significance both in terms of furthering our understanding of Viking Age metallurgy and potentially prolonging the lifespan of our full-scale reconstructions.

Sequence of repairs: Roar Ege's Service Book

The sequence of maintenance and repair that was carried out on *Roar Ege* since the launch in 1984, has been documented, both in text and photos, and represents a unique data set in terms of the experimental archaeological reconstruction of ship-finds. Many archaeological finds are reconstructed in full-scale and used in a manner similar to that in which the original find was employed, but to have this kind of detailed documentation over a time period spanning more than three decades is quite rare, and therefore of some significance in terms of furthering our understanding of Viking Age ship-building and seafaring.

That said, it must also be acknowledged that we often 'use' our ship reconstructions in ways in which they were never intended to be used: extended periods of exhibition on land, being lifted by crane when under transport by cargo ship and so on. For example, some of the earliest repairs that were carried out on *Roar Ege* were undertaken to remedy damage that occurred when lifting the ship by crane. In other words, we occasionally inflict stresses on the hulls of our reconstructions, which they were never designed to take, and this caveat must also be held in mind when analysing *Roar Ege's* sequence of maintenance and repair.

Roar Ege's service book is an extensive one. The list below summarises the primary phases of repair carried out on the hull, during the period from 1984 – 2014:

1984 – 1994:	Minor running repairs

1995:	Repairs to cracked boards after transport damage. Several knees replaced due to rot
1996:	Repairs to treenails
2003:	Mast replaced due to rot. 7th and 8th strakes and the stringers and futtocks in both sides replaced due to presence of brown rot and soft rot. 10 knees and 1 breasthook also replaced due to presence of white rot.
2004:	Treenails replaced at frame stations 0, 1F and 1A
2005:	1 beam knee replaced. Cracked sheerstrake repaired. After stem repaired after a collision at sea.
2007:	Rivets and spikes in garboards replaced
2008:	Repairs to the rudder.
2009:	Section of the port side 4th strake replaced.
2012:	Sections of lead sheathing added to repair cracks in the garboards.
2013:	New hood ends for the 4th and 6th strakes due to spread of white rot from the second step of the stem. General problems with leaks in the 2nd strake. Treenails replaced in the port side middle stringer.
2014:	5th and 6th strakes replaced on both sides. 6 new *biti*, 1 beam and 17 new knees.

Perhaps unsurprisingly, the frequency of the repairs increased as *Roar Ege* got older. Once the first decade on the water was over, repairs – both minor and major – became a fairly regular fixture.

It's stating the obvious perhaps, but the degree of difficulty – and time and materials - involved in a repair varies greatly depending on which part of the hull is affected. Boards can be repaired and replaced without too much difficulty from the keel up to the fourth strake. From here on up, it gets more complex as you have to remove more of the internal components in order to carry out the work.

Each repair is therefore assessed in terms of its feasibility – is it worth carrying out the repair and is it something that we can defend within the framework of an experimental archaeological reconstruction project?

The last major repair to *Roar Ege* was carried out in 2014 and saw the replacement of the fifth and sixth strakes as well as several major internal components (See Figure 10). It had been hoped that this repair would keep *Roar Ege* on the water for another five to ten years but unfortunately, this was not to be the case. By 2015, the state of the hull had deteriorated significantly below the waterline. Considerable leaks appeared where rusting rivets began to crack the surrounding planking materials. When the ship was hauled up that autumn, a phase of discussion began as the boatyard team had to plan their course of action.

Should *Roar Ege* be repaired again in the hopes of keeping the ship afloat for another few years or should we accept that the investment of time and materials it would take to render the ship seaworthy again was simply beyond what was realistic within an experimental archaeological framework?

After much thought, it was decided in the spring of 2016 that *Roar Ege's* sailing days were over. The ship was 32 years old at this point and the first of our Skuldelev ship reconstructions to be retired from service (See Figure 11).

When is an archaeological experiment over?

Roar Ege's retirement at 32 years of age gives us a benchmark against which to assess the hypothetical lifespan of the other Skuldelev ship reconstructions (See Figure 12). It also raises a number of issues concerning how and when to 'end' an experiment. With the benefit of hindsight, the authors would contend that the work carried out in 2014 could be seen as one repair too many. It's difficult to imagine that Viking Age boatbuilders – or boat owners, for that matter – would have invested so much time and so many resources in repairing such an aging vessel. They would most likely have split the hull apart, reused what they could and scrapped the rest.

This problem does however highlight some of the difficulties of working with experimental archaeology in a museum context, where reconstructions are not just the preserve of researchers but also play a large role in dissemination to museum guests. There is perhaps a tendency towards wanting to prolong the life of a reconstruction, and the limitations set by museum budgets also create a set framework within which we must operate.

Some might also argue that the experiment isn't over yet – that's its natural conclusion would be to strip the ship of all loose components, patch it up so it could make the journey and tow it out to be scuttled in the fjord, just as Skuldelev 3 was. This process would give us better insight into the manner in which the original ships deteriorated under water and perhaps provide a more precise understanding of the damage we see on the original hulls – were the various cracks and splits present when they were scuttled or are they something that occur as the hull falls apart on the sea floor?

However, the dissemination value *Roar Ege* has acquired for us as a museum means that the ship will end its days on exhibit rather than on the bottom of Roskilde fjord. As a ship-reconstruction, *Roar Ege* has also assumed almost mythical status within the field of maritime experimental archaeology. It was the first reconstruction built here at the Viking Ship Museum and after retirement, has essentially become an artefact in its own right - and one that features prominently in the Museum's current plans for future exhibitions, where *Roar Ege* is expected to stand centre stage.

The ship is also still an important reference object for us in terms of further research. As is the way of long-term archaeological experiments, new questions continue to arise – patterns of wear and tear on *Roar Ege's* hull can contribute to future research into rigging, boat-handling and more. So for now, the experiment continues – albeit, on land.

Repair work carried out on Skuldelev 3 and Roar Ege

Skuldelev 3 is estimated to have been between twenty to thirty years old when it was scuttled at the barrier at Skuldelev (Crumlin-Pedersen and Olsen, 2002, p.333). This total tallies well with the 31 years *Roar Ege* had in active service. Skuldelev 3 had been repaired several times during its lifetime, with short sections of planking being replaced below the waterline (See Figure 13; Crumlin-Pedersen and Olsen, 2002, p.230). Strikingly, the situation with the sequence of repairs on *Roar Ege* can be seen as quite the opposite. Apart from the sheathing added in 2012 and the general deterioration of the lands in 2016, the majority of the repairs have been located above the waterline.

It is difficult to say exactly what has given rise to this disparity, and it's a result that leaves more questions than answers in its wake – questions that will shape the form and focus for maritime experimental archaeological research at the Museum for some years to come.

Below, is a short summary of just some of the issues that have been up for discussion at the boatyard since *Roar Ege's* retirement:

- *Bog iron's potential resistance to corrosion:* Would iron fastenings produced from bog iron have greater resistance to corrosion, reducing the frequency of the need for replacement of planking? This is an issue of pressing importance for us with the knowledge we now have in hand concerning *Roar Ege's* lifespan and one that we intend to explore in much greater depth in coming years. Currently, it is hoped that we can build a small rowing boat in 2021/22, which will be entirely fastened with rivets and roves of bog iron, allowing us to explore this issue more fully.
- *Treatment of the ship when not in use:* Our Viking ship reconstructions live a very seasonal existence. They are launched in late spring and spend the summer months either on Roskilde Fjord or further afield when undertaking longer voyages. When not in use, they lie moored in the Museum harbour. At the end of the sailing season in late October, they're hauled up on land and 'put to bed' for the winter. The boatbuilders carry out any major repairs that need to be done and come the following spring, the tarpaulins and covers are removed and the crews begin tarring, painting and generally readying the ships for launch again. And so the cycle continues, no doubt in many ways parallel to what ship owners and users were also doing in the Viking Age.

One part of this cycle which may deviate however, is the way that our ships lie moored in harbour. Skuldelev 3's keel is quite worn, suggesting that the original ship may have been more regularly hauled out of the water when not in use and hereby more often removed from the damp conditions at sea – might this slow both the onset of rot and decay in the timbers and the rate of corrosion of the iron fastenings?

- *Saltwater v. freshwater:* The brackish waters of Roskilde Fjord have a relatively low salinity of just 11 psu (practical salinity unit, a measurement equivalent to parts per thousand) in comparison with the more saline waters of the North Sea, which average over 30 psu (Erichsen, *et al.*, 2017, p.134). Could a higher salinity potentially help to hinder the development of rot in the ship's timbers?

The materials involved in the repairs carried out on *Roar Ege* also present an interesting picture of the resources required in keeping the ship seaworthy over the course of its use. Table 3 below illustrates the quantities of material involved in repairing *Roar Ege's* hull from 1984 – 2014:

Component	Material	Replaced during the period from 1984 - 2016	Quantity involved in repair	Total in m3 (wooden components)
Fore stem	Oak	-	-	-
After stem	Oak	-	-	-
Keel	Oak	-	-	-
Planking material (radially split)	Oak	Yes	Section of the 4th strake on both sides. 5th and 6th strakes on both sides.	4.71
Planking material (tangentially split)	Oak	Yes	7th and 8th strakes on both sides	4.04
Frames	Oak	-	-	-
Keelson	Oak	-	-	-
Stringers	Oak	Yes	4 and a half stringers	2.86
Biti	Oak	Yes	6 *biti* produced from leftover planking material	-
Cross beams	Oak	Yes	1 cross beam produced using leftover planking material	-
Knees	Oak	Yes	23	0.58
Treenails	Goat Willow	Yes	162	0.69
Deck	Oak	Yes	Several boards replaced using leftover planking	-

			material	
Mast	Pine	Yes		0.92
Yard	Pine	-	-	-
Rudder	Oak	-	-	-
Rivets and roves	Iron	Yes	648 of each	-
Spikes	Iron	Yes	142	-
Cubic meters of timber in total				**13.8**

TABLE 3: MATERIALS UTILISED IN REPAIR AND MAINTENANCE OF ROAR EGE'S HULL FROM 1984 – 2014.

A total of 54.21 m3 of oak was used in the initial construction of *Roar Ege's* hull and a further 13.8 m3 were involved in the various phases of maintenance and repair. This seems a striking amount of material but one that is difficult to draw concrete conclusions from as it is the only tally of its kind that we have to date. Comparison with the subsequent Skuldelev ship reconstructions will no doubt prove a fruitful exercise in the future.

Preliminary conclusions – and questions for future research

Roar Ege's retirement in 2016 marked the end of the life-cycle of the first full-scale, sailing reconstruction of the five Skuldelev ships. However, *Roar Ege's* contribution to maritime experimental archaeological research is far from over. The collation of *Roar Ege's* 'Service Book' is the first step in the research programme of a new reconstruction project at the Viking Ship Museum's boatyard - *'Skuldelev 3 Revisited'*. The project began in 2017 with Vibeke Bischoff undertaking a reinterpretation of the original ship-find, which resulted in a new 1:10 reconstruction of the hull form. Construction of the full-scale reconstruction of the reinterpreted form of Skuldelev 3 began in May 2017 and the ship is expected to be launched in late summer 2021 (See Figure 14).

The data represented in *Roar Ege's* hull, and in the documentation of the many repairs conducted over the years, is now the subject of further study, as we seek to extract as much information as we can concerning the materials and resources required in sailing and maintaining Viking Age ships.

However, some preliminary conclusions can already be drawn:

1. *Life span of the hull: Roar Ege* was retired after 32 years and would appear to have had approximately the same life span as Skuldelev 3. Yet *Roar Ege's* hull displays far more wear and tear than that of Skuldelev 3 – the potential reasons for this have been outlined above and are still under investigation.
2. *Life span of the sail: Roar Ege* was initially equipped with the linen pilot sail, which was then replaced by a wool sail in 1985, handwoven by a team of weavers at Fosen Folkehøjskole in Norway, under the direction of Solfrid Aune, Yngvild Andersen and Kirsti

Godal (Andersen, *et al.*,1997, p.213). This sail has also had running minor repairs over the years but is otherwise still in perfect condition.
The sail has therefore outlived the ship.
The wool sail is currently in storage and we plan to continue using the same sail on the new full-scale reconstruction of Skuldelev 3, allowing us to continue monitoring the life span of the sail and see this aspect of the archaeological experiment through.

3. *Material use:* A total of 54.21 m3 of timber was required to construct *Roar Ege's* hull. A further 13.8 m3 were required to maintain the hull over a thirty-year period. These totals can now be used to explore issues concerning the control and management of raw materials for ship-building in the Viking Age.
4. *Maintenance of other Viking ship reconstructions:* The collation of *Roar Ege's* service book has led to the identification of several weak points on the ship, such as the contact surfaces between the stringers and the board material. While we can't be sure that extra vigilance in terms of keeping this area of the ship free from organic debris would have helped inhibit, or perhaps even negate, the development of rot, it is still a detail worth paying attention to. It's important that we relate the insights gained into the process of deterioration of *Roar Ege's* hull to our volunteer boat guilds who sail and maintain the other Skuldelev ship reconstructions, so they are more informed as to where and how potential problems can arise.

Roar Ege's retirement and the preliminary conclusions that can be drawn from this first phase of the archaeological experiment raise a great many questions, some of which can be addressed promptly while others will require more long-term experimental archaeological analysis.

Roar Ege was built on a foundation of the shared expertise of craft specialists, archaeologists and sailors: concluding the research aspects of the *'Roar Ege Project'* will also require the skills and knowledge of each of these groups. The documentation carried out during *Roar Ege's* construction and during the three decades in which the ship was in use provides a solid foundation for this work. It also creates a framework of materials and resources within which we can begin to plot the other Skuldelev ship reconstructions as they gradually move towards retirement, ensuring the continuation and development of maritime experimental archaeological practice at the Viking Ship Museum.

1 Andersen et al states that Buchwald was consulted on the process. The majority of his publications on the subject, however, came after the completion of the Roar Ege Project.

Keywords boat / ship
(re)construction

Country Denmark

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Gallery Image

FIG 1. MAP OF DENMARK MARKING THE FIND LOCATION OF THE FIVE SHIPS AT SKULDELEV AND THE TOWN OF ROSKILDE (COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).

FIG 2. AERIAL PHOTO OF THE EXCAVATION AT SKULDELEV (COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).

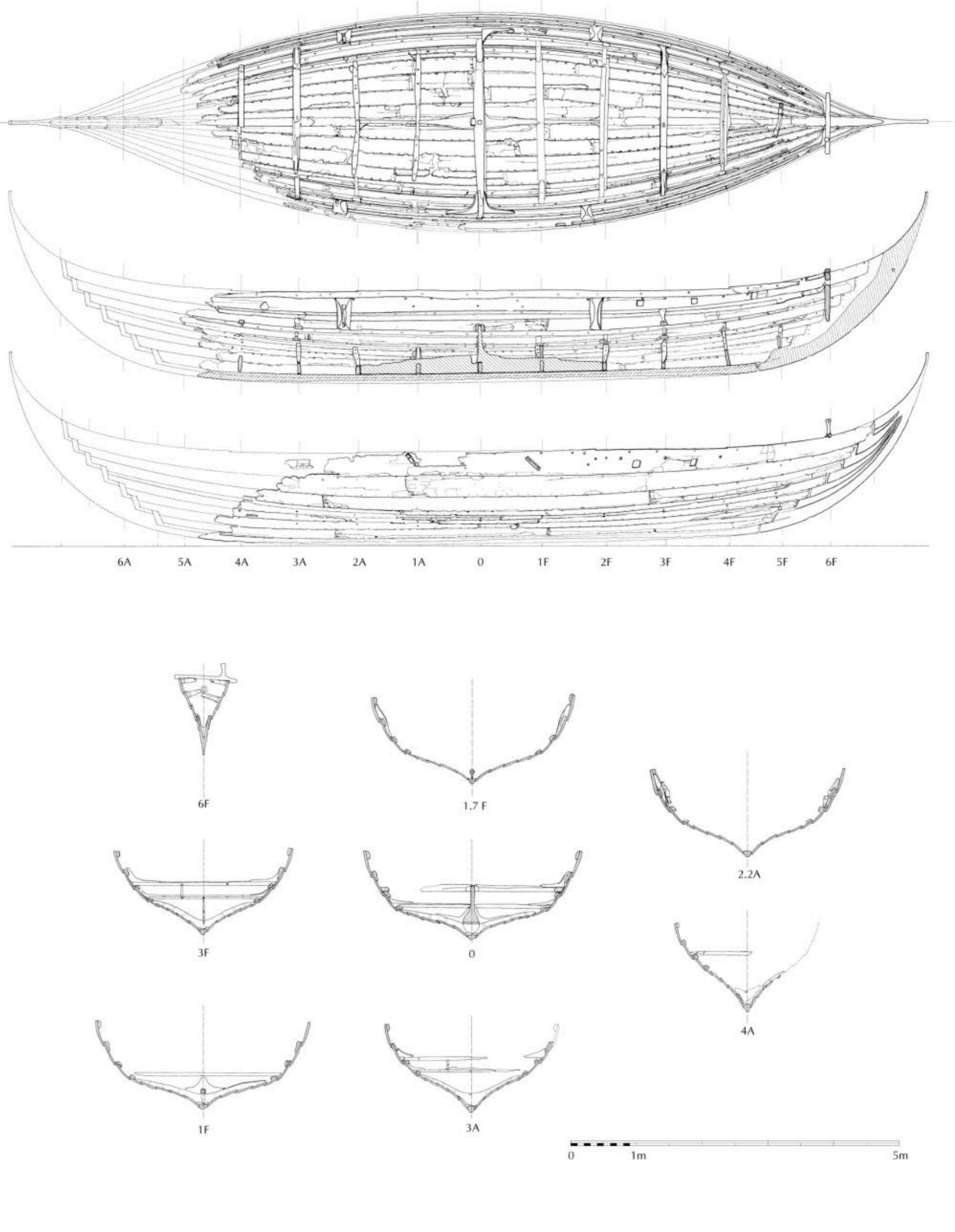

FIG 3. TORSO-DRAWING OF ALL PRESERVED PARTS OF THE SHIP-FIND, SKULDELEV 3, ASSEMBLED TO THEIR ORIGINAL CONTEXT AND SHAPE (AFTER CRUMLIN-PEDERSEN AND OLSEN 2002, 229, FIG. 40).

FIG 4. GROUP PHOTO OF THE TEAM THAT BUILT ROAR EGE (COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).

FIG 5. ROAR EGE'S BUILDING TEAM, WORKING WITH SHAPING THE STEMS AND CLEAVING OAK FOR PLANKING MATERIAL (COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).

FIG 6. LAUNCH OF ROAR EGE, ON AUGUST 25TH 1984 (PHOTO: BO NIELSEN. COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).

FIG 7. ROAR EGE UNDER SAIL ON ROSKILDE FJORD (COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).

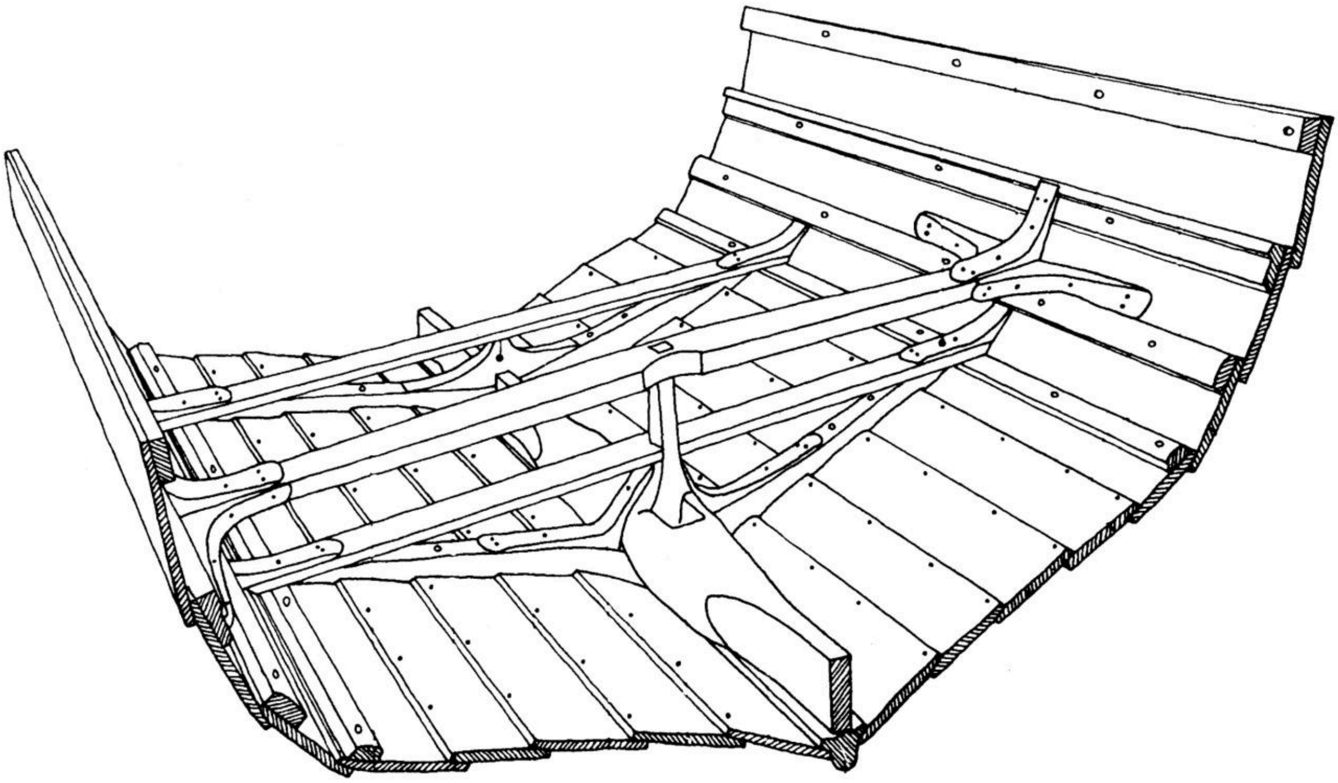

FIG 8. RECONSTRUCTED CROSS-SECTION OF SKULDELEV 3, SHOWING THE MANNER IN WHICH THE VARIOUS COMPONENTS OVERLAP EACH OTHER (AFTER CRUMLIN-PEDERSEN AND OLSEN 2002, 198, FIG. 3).

FIG 9. DAMAGE CAUSED TO SURROUNDING PLANKING BY RUSTING RIVETS (PHOTO: WERNER KARRASCH. COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).


FIG 10. EXTENSIVE REPAIRS WERE CARRIED OUT ON ROAR EGE IN 2014 WITH A VIEW TO KEEPING THE SHIP AFLOAT FOR SEVERAL MORE YEARS. THIS ENDEAVOUR WAS ULTIMATELY IN VAIN AS ROAR EGE WAS RETIRED ON LAND TWO YEARS LATER (PHOTO: WERNER KARRASCH. COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).


FIG 11. ROAR EGE WAS RETIRED PERMANENTLY ON LAND IN THE SPRING OF 2016. (PHOTO: WERNER KARRASCH. COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).

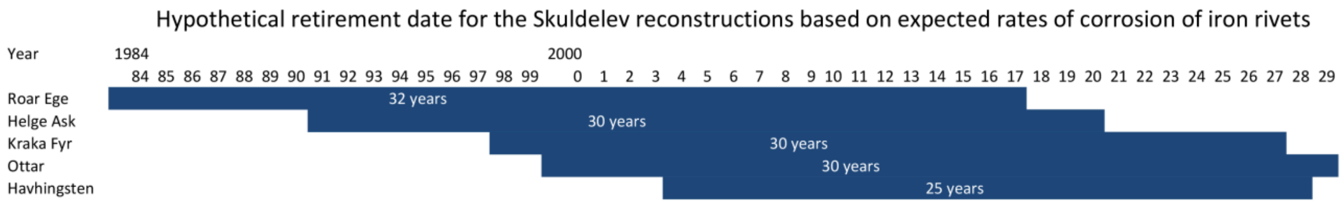

FIG 12. ESTIMATED LIFE EXPECTANCY OF THE REMAINING SKULDELEV SHIP RECONSTRUCTIONS, AS CALCULATED BY BOATBUILDER, ASGER RØRDAM.

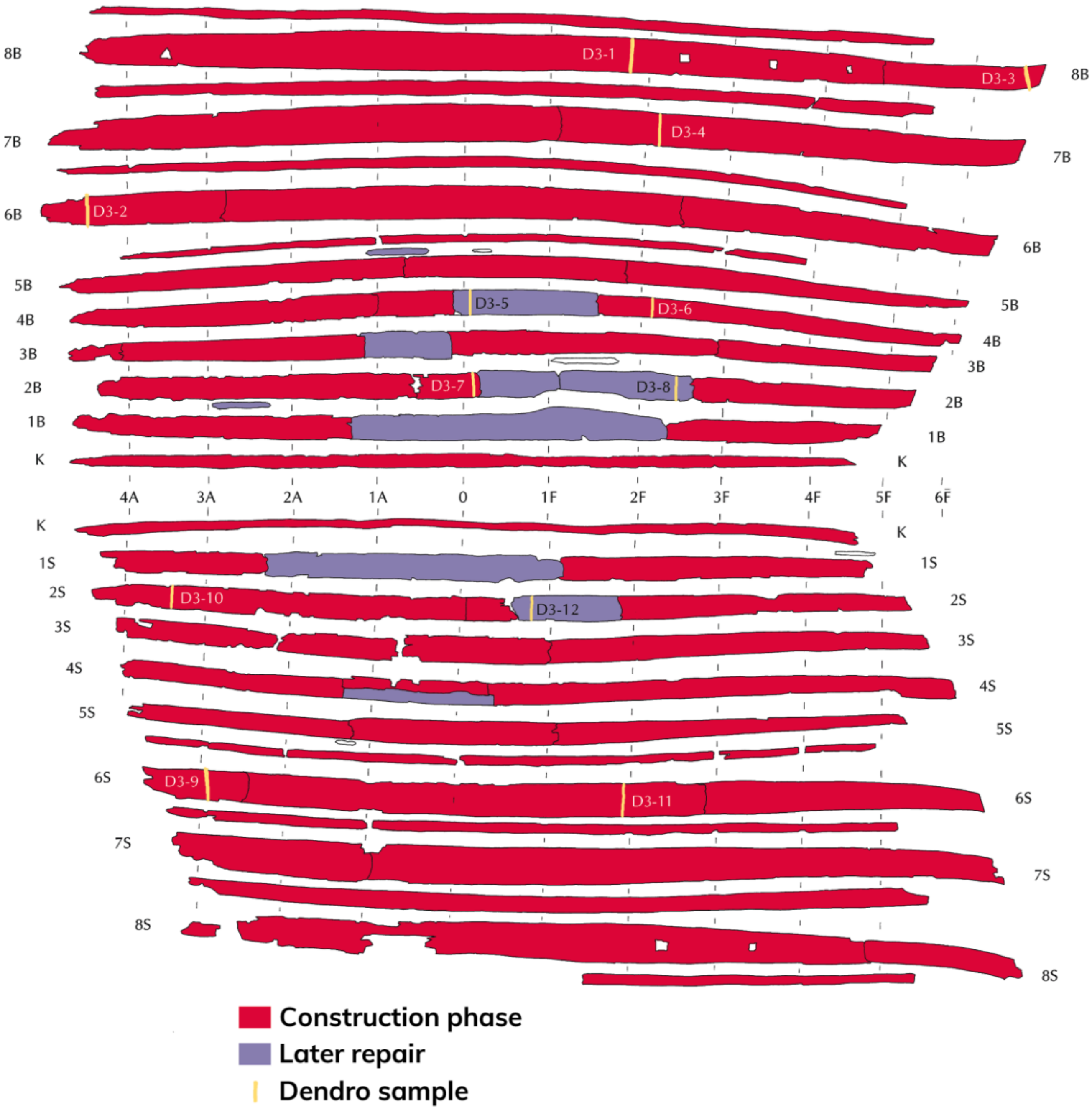

FIG 13. THE PLANKING OF SKULDELEV 3 WITH INDICATION OF REPAIRS MARKED IN PURPLE (AFTER CRUMLIN-PEDERSEN AND OLSEN 2002, 230, FIG. 41).

FIG 14. IN 2017, THE PROJECT SKULDELEV 3 REVISITED BEGAN. VIBEKE BISCHOFF UNDERTOOK A REINTERPRETATION OF THE RECONSTRUCTED FORM OF SKULDELEV 3 AND THE NEW FULL-SCALE RECONSTRUCTION IS EXPECTED TO BE LAUNCHED IN LATE SUMMER 2021 (PHOTO: WERNER KARRASCH. COPYRIGHT: VIKING SHIP MUSEUM IN ROSKILDE).