SO-III Research on preservation strategies for fragile alum-treated objects from Oseberg

1. Background and justification for project

Challenges with alum-treated wood from Oseberg

Museum collections conserved by discontinued treatments may require specialized knowledge to enable their proper care. This is especially true in cases where older conservation treatments are the cause of unacceptable damage, sometimes only revealed after a great elapse of time. At the Museum of Cultural History (KHM) it took almost 100 years for observable damage, such as new cracks, to manifest itself on a collection of archaeological wooden objects which were conserved in the early 1900s by a once widely used method which is now obsolete. This method used alum salts (potassium aluminum sulfate dodecahydrate, $KAl(SO_4)_2 \cdot 12\, H_2O$) to preserve highly degraded archaeological waterlogged wood. It was actively in use from the mid-1800s to the 1950s, especially in Scandinavia (Christensen, 1970a, 1970b; Eaton, 1962; Häggström, Lindahl, Sahlstedt, & Sandström, 2013; Madsen & Andersen, 2013). Many collections may therefore have alum-treated wooden objects. However, due to the fact that this method is no longer in use and knowledge about it is limited, preservation professionals may not be aware of how to identify alum-treated wood, understand reasons behind the observed damage or which measures are possible to preserve it.

At KHM, alum salts were used to conserve a significant portion of the wooden objects from the Oseberg mound, a Viking Age ship burial for two women constructed in 834 AD, located near Tønsberg, Norway and excavated in 1904 (Bonde & Christensen, 1993). This collection represents one of the richest, most complete collections of Viking Age wooden objects in the world: alongside textiles and metal objects, lay ornately carved wooden objects such as a ceremonial wagon, three ceremonial sleds, animal head posts and hundreds of everyday artefacts (Brøgger, Shetelig, & Falk, 1917). The find was exhibited at the Viking Ship Museum in Oslo and is planned to be re-installed in the new Viking Age Museum, currently under construction.

We now know that the alum treatment has caused both chemical and mechanical degradation of the wood. High acidity originating from the alum method is the main cause of observed degradation, but also metal ions inside the wood, present from burial or from corrosion of metals used to reconstruct the objects after alum-treatment, contribute to the decay in highly complex mechanisms which are not fully elucidated (Łucejko et al., 2021).

To chemically and physically stabilize alum-treated objects from the Oseberg find – which present challenges in terms of variability in condition, size and in degree of restoration – a combination of preventive and invasive reconservation approaches is needed.

Step-wise knowledge building

Successful preservation strategies can only be designed if the causes of the observed damage are understood. Few details about the alum treatment method are recorded in archival and published sources, and earlier research did not investigate the material's chemical properties (Bojesen-Koefoed, 2012; Häggström et al., 2013). For this reason, the Alum Research Project (2007-13) and later the Saving Oseberg (SO) research project (Phase I from 2014-17; Phase II from 2017-2020) were established at KHM. Figure 1 shows the gradual build-up of knowledge in previous work, and what we wish to accomplish in the next phase, Saving Oseberg-III.

In SO-I, research was directed towards investigating chemical and physical properties of the material in order to gain a better understanding of the reasons behind the observed deterioration.

In SO-II, we continued to investigate the chemical properties but also investigated reconservation methods, both water-based and solvent-based systems. By the end of SO-II, we had tested and evaluated both aqueous and non-aqueous methods on 75 Oseberg Test Fragments of alum-treated wood (Braovac et al., 2021). We found that reconservation using water-based methods (aqueous) gave the best results for robust wood. However, in order to chemically and mechanically stabilize wood in poorer condition, a non-water based method (non-aqueous or solvent-based) is needed. None of the non-aqueous methods tested in SO-II stood out, all having pro's and con's.

In the period after SO-II, named SO-Interim, we took new knowledge and experience to the 'collection' level, specifically aimed at that which is held in storage[1]. This was accomplished through a collection survey undertaken in April 2021 (Braovac & Zisi, 2021).

Collection Survey

During the collection survey, either Aqueous (PEG) or Non-aqueous reconservation was assigned to individual objects or fragments[2]. Objects were then sorted into risk categories, based on the risks relative to aqueous retreatment. Risk categories ranged from Low to Very High. We also included categories named 'Beyond our experience' and 'No retreatment?'. See Figure 2.

The survey uncovered two main object groups which require different approaches and likely different funding sources:

A. <u>SO-III Reconservation</u>: Low, Medium and Medium-High risk groups (ca 3600 objects). These objects are possible or likely possible to retreat with PEG 2000.
   Potential funding source: Internal, ex. REVITA grants
B. <u>SO-III research</u>: High, Very High, Beyond Experience/No retreatment? risk groups (ca 2790++ objects). Research focuses on aqueous (for ex. pre-consolidation) for the High risk objects (ca 1040 objects), and on non-aqueous and preventive conservation for the Very High, Beyond Experience/No retreatment? risk groups (ca 1750++ objects).
   Potential funding source: External, ex. Research grants

Each part is planned as a 6-year project, with separate budgets.

SO-III Reconservation is linked with SO-III Research, but it is not necessary that they run simultaneously. However, it would be an advantage if they could overlap, so as to exchange experiences and knowledge.

<u>SO-III Research is described in this document.</u>

[1] The Survey took place at the same time as the dismantling of the exhibition at the Viking Ship Museum in preparation for the new building project. As such, the collection was not available for assessment regarding retreatment risks. However, most objects at VSH are reconstructed, and as such represent objects which are not possible to retreat using PEG 2000. The preservation of this part of the collection requires further research.

[2] Here 'object' refers to individual pieces, regardless if they are only part of an object or a whole object.

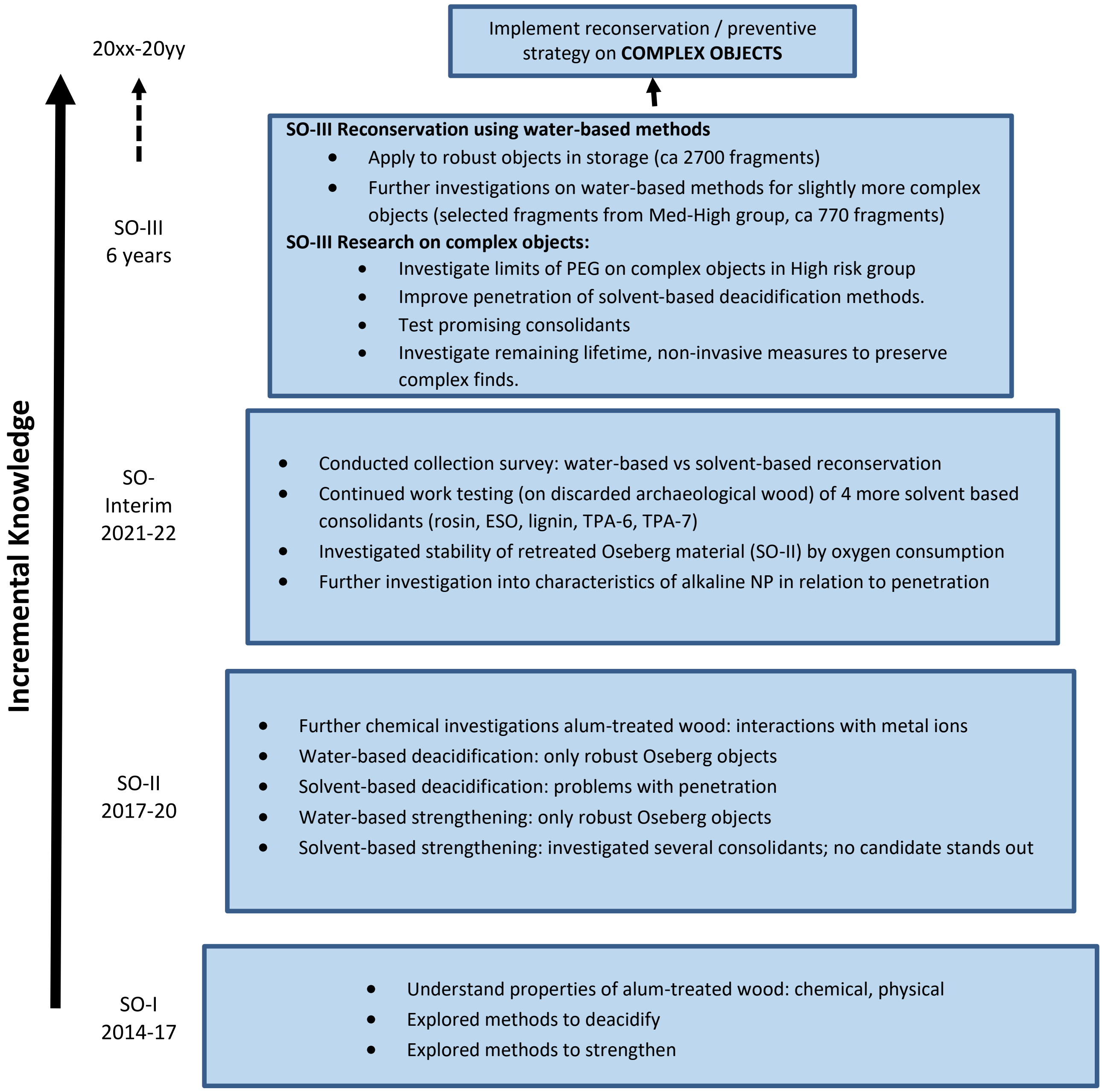

Figure 1. Diagram summarizing knowledge-building in successive Saving Oseberg research phases. The diagram also shows that we reach an Apex at some point in the future, only when we can confidently say we are ready to reconserve complex objects.

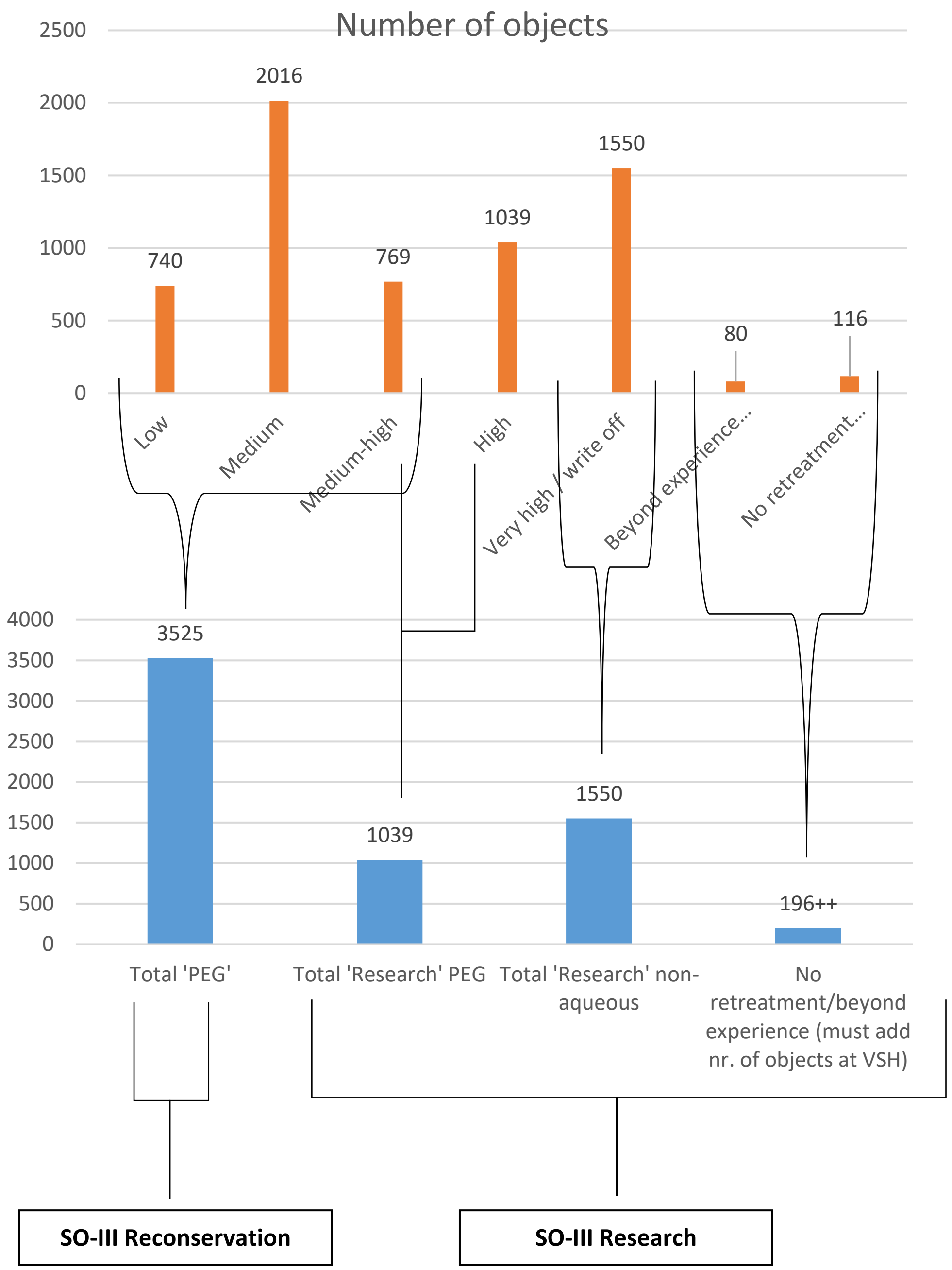

Figure 2. Distribution of alum-treated 'objects' (i.e. individual pieces of wood) into Risk groups.

Risk groups from Low to Medium-High are considered for 'PEG' retreatment, and are part of the project **SO-III Reconservation**.

The project **SO-III Research** involves testing of various methods on the High, Very High and Beyond Experience / No retreatment? risk groups. High risk objects are considered for 'Research' on the PEG method and Very High risk objects are considered for 'Research' on non-aqueous retreatment. Beyond Experience / No retreatment? will likely be preserved by either non-aqueous retreatment or by preventive conservation measures. Decisions about this group is dependent on results from research on objects from the Very High research group and which preventive options are available.

2. Aims and desired achievements for SO-III Research

By the end of SO-III Research we will have:

- Improved knowledge about the limitations of the PEG method, based on tests on complex objects from the High risk group. Results from SO-III Reconservation on the Medium-High risk group will be important.
- Improved penetration of non-aqueous deacidification agents.
- Selected the best consolidants and methods to strengthen highly fragile alum-treated wooden objects from the Very High risk group.
- Understand limitations of the non-aqueous methods to deacidify and consolidate wood from the Very High risk group, which will in turn improve understanding of which objects from the Beyond Experience / No Retreatment? group can be reconserved with acceptable results.
- Better understand remaining lifetime of the collection if no retreatment is applied.
- Identify potential preventive strategies (i.e. non-invasive) to preserve the most complex objects.
- Disseminated new knowledge through museum events, conferences and publications.

Nivå	Beskrivelse	Suksesskriterier
Formål: Mål for UiO som dette prosjektet bidrar til oppfyllelsen av	Preservation of the more complex alum-treated Oseberg collection for future research and display	Chemical and mechanical stability, while preserving appearance
Effektmål (langsiktige positive gevinster. Merk at disse kan være både «harde» og «myke»)	Resultatmål (de målene som prosjektet skal oppnå i prosjektets levetid; f.eks. målt i tid, kostnad, kvalitet)	See bullet points above

3. Framework conditions

Facilities required

The project will be undertaken at Økern. We will need:

- Office space for 2-4 people.
- to use the photo studio and X-ray equipment for documentation before and after re-treatment, the freezer and freeze dryer. Must be coordinated with other projects.
- access to instruments and equipment (for ex. FTIR, SEM, XRD, Raman, etc.), to evaluate the results of retreatment tests.
- space to carry out testing on the different risk groups: tanks, bench space, etc.
- KHMs facilities and personnel for 3D documentation of selected objects before and after reconservation. Must be coordinated with other projects.

4. Project deliverables and limitations

Leveranser	Beskrivelse
Improved knowledge	Improved knowledge of: • limitations of the PEG method (WP1) • best non-aqueous consolidants and methods for more complex objects (WP3) • remaining lifetime • potential preventive measures that can reduce rate of degradation (WP4) • wood chemistry, the fundamental factors contributing to degradation (WP5)
Improved non-aqueous deacidification	In WP2, efforts to improve penetration capability of alkaline nanoparticles will hopefully result in a method that can effectively deacidify the wood, to increase remaining lifetime of complex objects.
Final report	The final report will summarize results from all WPs and discuss the best options for reconservation of the most complex objects and provide recommendations for implementation of preservation strategies and methods for long-term monitoring of retreated material.

Limitations of this project (hva er ikke en del av leveransen):

As this project only focusses on research on *how* reconservation should be approached, only objects in test groups will have undergone reconservation. As such, the *actual* reconservation of the collection's most complex objects using methods developed in SO-III Research must be applied in a following phase, as indicated in Figure 1.

5. Evaluation of uncertainties in the projects: risks and mitigation strategies

Trusler	Beskrivelse	Reduserende tiltak
Cannot improve penetration of deacidifying agents.	Despite all efforts to improve penetration of deacidifying agents, it may turn out that we cannot adapt the methods used in existing research.	We have asked a world expert to help us in this research. Try to keep an open mind about possible alternatives, and methods, while at the same time focusing on the approach planned for in the project.
Objects fall apart	Despite efforts to avoid this, it is possible that objects become irreparably damaged during reconservation.	For the High risk group where PEG will be tested, it will be essential to have access to the in-house knowledge built up in SO-III Reconservation, so we do not repeat eventual mistakes, etc. For the Very High and Beyond Experience risk groups, applying conservation agents

		by injection instead of immersion will greatly reduce risk of damage. Most important objects must be documented by photography and by 3D;
Results show that it is too risky to reconserve the most complex objects.	Research is a risky endeavor. No one in the world has already accomplished what we are trying to do. At the end of SO-III we may or may not have solutions for stabilizing the most complex objects, such as the sleds.	The work package investigating Remaining Lifetime of the collection will provide important information about future plans. What is important is to keep the research themes alive as long as is necessary…that is, keeping knowledge in-house, and getting help with funding applications.
Increase in costs due to world events	Price increases have been unpredictable, and surprisingly high.	The equipment budget includes a buffer of ca 20%.
Failing equipment	Essential analytical instruments and equipment may take months to repair.	The budget includes contributions to maintenance contracts for essential instruments, such as the freeze dryer, the Xray unit, XRD, climate chamber etc.
Muligheter	Beskrivelse	Tiltak
Lasting impact on conservation methods	Decision making with confidence! Knowing the risks and benefits of reconservation of alum-treated wood is transferrable to general reconservation of archaeological wood. This also includes improved knowledge on post-retreatment repair: what is possible, what is not.	Publish the methods that are of wider interest in professional journals and handbooks.
Attract new research projects according to KHMs ambitions in Strategy 2030	Research competence gained from investigations on new consolidants, nanoparticles, their methods of application, and methods of evaluation is transferrable to conservation of other types of materials, not only archaeological wood. This will make KHM attractive collaboration partners in projects on the preservation of museum collections.	Ensure visibility of the scientific and practical work by means of publications, conference presentations and future hands-on workshops.
Retreatment competence is	Other museums, in Scandinavia, and also world-wide, have collections of	We can provide guidance to other museums for the best care strategies.

transferrable to other collections according to KHMs ambitions in Strategy 2030	alum-treated objects. No one has yet managed to deal with reconservation / stabilization of more complex objects.	

6. Alternative choices and Overview of acheivements

6.1 Alternative solutions or concepts

The alternative for retreatment is the status quo. Research so far indicates that the degradation of the objects is critical and ongoing, even though a rate of decay has not been established. As the collection is considered to be invaluable, this is not an attractive solution.

6.2 Overview of achievements

Gevinster	For hvem, og hvordan fremkommer gevinsten?	Forutsetninger for at gevinsten skal kunne realiseres
Oseberg collection remains available for research and education	UiO-KHM, research community and general public and tourist industry in Oslo. Slower degradation can be shown by long-term monitoring of objects and a few reference samples that have not been retreated.	Resources for retreatment and resources and awareness to ensure health of conservators during the project.
Improved knowledge on the conservation of alum-treated objects and retreatment options, according to KHMs ambitions in Strategy 2030	Object conservators globally	Publication of scientific results and conservation methods

7. Estimated time plan and milestones

Here, we will investigate preservation strategies for the most fragile and complex part of the Oseberg collection, that is objects in risk groups High, Very High, Beyond Experience/No retreatment?. Figures 3-5 show representative objects from these groups.

Investigations in SO-III Research will be organized into work packages, described below. Original Oseberg material from the High and Very High risk groups will be primarily used for testing. Testing on the group Beyond Experience/No retreatment? will only occur after we gain experiences with the former risk groups. The testing and evaluation protocols will generally follow those established in SO-II for Oseberg material (Braovac et al., 2021).

Objects chosen for testing from the High risk group will undergo retreatment using PEG 2000. It is very important to find out limits of PEG treatment on this group, as it is very effective at reducing acidity. However, we are very unsure which types of High risk objects can withstand this treatment method. This group demands much more time than those in Medium-High group, which will be tested in SO-III Reconservation.

Objects chosen for testing from the Very High risk group will undergo retreatment using non-aqueous methods, that is deacidification and consolidation using non-water based methods. For this group, most objects will not be able to be immersed; therefore injection with a syringe will be used to apply both deacidifying agents and consolidants.

All objects in the group 'Beyond Experience' are highly reconstructed. Research on the Very High risk group will increase our knowledge about what is possible and what is not, and thus enable us to make more confident decisions on which preservation strategies are most beneficial for this challenging group. It is very likely that some objects will shift risk categories initially assigned during survey.
Negotiating test material for these investigations will involve Head of Collections, Prof. Jan Bill and will occur at the beginning of the project so that testing can begin as early as possible.

The final report will discuss the best options for reconservation of the most complex objects. For ex. whether it is necessary to apply consolidation in all objects; for some of the objects in the higher risk groups, it may be enough to only deacidify the wood.

After completion of SO-III, we will have enough knowledge to assign concrete preservation strategies for objects from the High, Very High and Beyond Experience risk groups. The actual reconservation of these objects will take place in a following phase.

High

Figure 3. High Risk profiles are characterized by objects:

- Mainly which do not powder spontaneously
- Mainly without repairs, or with repairs with glue only, but there are some which are more complex, moreso than in Medium-High group
- Many of which do not have surface coatings

Very high

Figure 4. Very-High Risk profiles are characterized by objects:

- Which have poor wood condition (powder spontaneously)
- Which have more complex repairs than in High risk group
- Most of which do not have surface coatings (more fragile)

Reconstructed – beyond our experience

Figure 5. Beyond our Experience Risk profiles are characterized by objects:

- Which have poor wood condition (powder spontaneously) or have new breaks
- All of which have repairs, most are complex
- Most of which have surface coatings

Milestones for the 6-year Project Period are given in the table below

Work package		Description	Timeframe
WP0	**Coordination and administration**		Years 1 to 6
	Hire staff and Establish project in UiO system	Hire staff, and get them on-board	First 9 months
		Organize contracts with collaborators	
		Organize steering committee and reference group, and send invitations	
		Gather necessary background material from SO-II and SO-Interim	
		Budget approval	
	Organize meeting frequencies for Kick-off, core research group, steering committee and reference group.	Kick-off meeting and final meeting are in person. All other meetings are digital, when possible.	
	Negotiate and organize test groups of orignal Oseberg wood. In close collaboration with Head of Collections, Prof. Jan Bill	Five Test Groups: 1. High risk objects for PEG testing (WP1) 2. Fragments of sufficient dimensions for testing of improved NP-system (similar to fragment types used in SO-II) (WP2) 3. Fragments of sufficient dimensions for initial testing of consolidants (similar to fragment types used in SO-II) (WP3) 4. Very High risk group for improved-NP and consolidants (WP3) 5. Representative group of fragments for WP5 Alum-wood chemistry	
	Establish protocol for documentation of the different Test Groups	Dialog with Jan Bill, other KHM experts	
	Organize timeline for 3D documentation in collaboration with WPs 1, 2 and 3	Dialog with DigDok/3D-Team	
	Establish protocol for sampling of objects from the different Test Groups	Must figure out when we can do destructive sampling like in SO-II and when we can only do micro-sampling, how to document, and where to store results). dialog with Jan Bill, Analyseutvalget, DigDok/MUSIT	

Work package		Description	Timeframe
	Establish Evaluation Protocol for each Test Group	Some test groups can undergo more destructive evaluation methods (SEM-EDS, ICP, IR, Py-GC/MS, etc), while others, which involve whole objects, will have to focus more on non-sampling / micro-sampling evaluation methods (3D, X-ray, colour change, pH, etc).	
	Establish Data Management Plan	In collaboration with Partner Institutions and in dialog with SF, SciCult, DigDok/MUSIT	
	The final report with recommendations for preservation strategies	With input from Steering Group, Reference group and other stakeholders	Year 6
	Principal investigator and WP-staff travel to external collaborators for focus meetings on WPs.		When required
WP1	**Find limits of Aqueous methods on High risk group**		Years 1 to 4
	Documentation Test Group 1, according to agreed protocol.		
	Sample the materials used to repair and reconstruct Test Group 1 (whole objects) - to be analyzed in WP5	NB! limited sampling!	
	Reconservation test group 1 using PEG 2000		
	Evaluate results	According to established protocol	
	Reports into MUSIT		
WP2	**Non-aqueous deacidifying agents for Very High risk group, and possibly Beyond Experiene group** (in close collaboration with conservation expertise)		
	Prepare mock ups for initial experiments. Use discarded archaeological wood		Years 1-4

Work package		Description	Timeframe
	Samples from mockups - to be analyzed in WP5 (if necessary)		
	Investigate methods to improve NP penetration		
	Evaluate results	According to protocols relevant to the research	
	Documentation Test Group 2, according to agreed protocol.		Year 4
	Sample from Test Group 2 (fragments) - to be analyzed in WP5		
	Apply improved NPs to Test Group 2 (conservators do this)		
	Evaluate results	According to established protocol	
WP3	**Non-aqueous consolidants for Very High risk group and possibly Beyond Experiene group**		
	Consolidants to test: terpene, rosin		Years 1-3
	Documentation Test Group 3, according to agreed protocol.		
	Sample from Test Group 3 (fragments) - to be analyzed in WP5		
	Apply consolidants to Test Group 3		
	Evaluate results above with consolidants tested in SO-II and choose max. 2 to use on Test Group 4	Include Test Fragments from SO-II to compare	
	Sample the materials used to repair and reconstruct Test Group 4 (whole objects) - to be analyzed in WP5	NB! limited sampling!	Years 4-6
	Apply Improved-NPs to Test Group 4	Results from WP 2	

Work package		Description	Timeframe
	Apply consolidants to Test Group 4 after Improved-NPs	Apply consolidants after NP	
	Evaluate results	According to established protocol	
	Reports into MUSIT		
WP4	**Remaining lifetime and possible preventive measures**		
	Estimate effect on lifetime by changing preventive parameters using HERIE model developed in Poland.	Need data from WP5, Alum-wood chemistry. In collaboration with Polish Academy of Sciences	Years 1-4
WP5	**Alum-wood chemistry**		Years 1-6
	Characterize the materials used to repair and reconstruct Test Groups 1 and 4	NB! limited sampling!	
	Design experiments in WP5 using Test Group 5	According the the research themes described in the project description	Early on, immediately after Test Group 5 is established
	Carry out experiments in WP5 using Test Group 5	In collaboration with WPs 1 to 4	
	Results stored according to Data Management Plan	As they are generated	
WP6	**Dissemination, publications, etc.**		Years 1-6
	Establish project website, social media accounts, etc.	All WPs in collaboration with the different Partners	

Work package		Description	Timeframe
	Participate in UiO and KHM events (Forskningsdagene, Turist i egen by, etc.)		
	Present at conferences (WOAM, InArt, Chem-CH, etc.) and Publish results		
	Final syposium presenting final results, open to all interested		

Description of SO-III Research work packages

WP1. Determine limitation of aqueous method (PEG 2000) on High risk group

From KHM: Researcher-2 (Angeliki Zisi) and Conservator-1 (NN)

Develop methods to widen applicability of the PEG 2000 and freeze drying method on more complex objects, since this is the most effective way of chemically stabilizing the wood.

Choose a small group of objects (together with Head of Collections) to test different physical supports, including pre-consolidation before immersing in water.

Since these objects are in a higher risk group, more preparation time is required to ensure proper documentation before and after retreatment. Decision making will be greatly aided by the results of SO-III Reconservation, where the PEG method will be tested on the Medium-High risk group.

WP2. Improve penetration of non-aqueous deacidifying agents

From KHM: Researcher-2 (Angeliki Zisi)

Collaborator (not confirmed): Professor Lars Berglund, Division of Biocomposites, Dept. of Fibre and Polymer Technology, KTH, Sweden and Post-doctoral researcher-1.

Improve penetration of the alkaline nanoparticles (NPs) tested in SO-II by modifying surface charge on particles. This work must involve a laboratory that has experience with such issues and which has specialized equipment for this work. We have contacted Professor Lars Berglund, but have not yet received a reply.

We have valuable practical experience from SO-II and can foresee possible technical drawbacks. Therefore, the Collaborator in Sweden will work closely with Researcher-2 from the beginning of their research to ensure research offers practical solutions, including modes of delivery. Researcher-2 will also provide appropriate test material at the different stages of research.

WP3. Non-aqueous consolidants

From KHM: Researcher-2 (Angeliki Zisi) and Conservator-1 (NN)

Collaborator: Professor Stephen Harding, Professor of Applied Biochemistry, and Professor Robert Stockman, Organic Chemistry, University of Nottingham, UK.

SO-II tested and evaluated a number of non-aqueous-based consolidants on Oseberg wood, both commercially available and newly developed in the project. Additionally, consolidation with a lignin-based polymer was tested, but as it produces a very dark wood, its relevance is limited and as such it is not considered as an actual candidate in further work.

The two most promising non-aqueous consolidating agents not yet tested on Oseberg wood are a terpene-based consolidant developed at the University of Nottingham (Cutajar, Braovac, Stockman, Howdle, & Harding, 2022) and a commercially available rosin resin.

Since the terpene-based consolidant is not commercially available, it must be synthesized in the laboratory in Nottingham, where they are equipped with the necessary inventory required for making batches larger than 10 g. We have budgeted for the synthesis of 1 Kg.

Our efforts to inject worked well for consolidants tested in SO-II on original Oseberg wood, and injection will continue to be used as the delivery method of consolidants tested here. This form of application mimics real-life situations in cases where objects cannot be immersed, as in for example reconservation of the Oseberg sleds. An extra focus on the ergonomics of injection are also necessary in order to avoid injury (for ex. Tendonitis). However we will keep in mind that in some cases immersion may be the best option.

This work package is dependent on the results of WP 2. Therefore, a part of the object test group chosen for this WP will study the effectiveness of consolidant only, and another part of the test group will be treated with both deacidifying agent and consolidant.

WP4. Remaining lifetime and possible preventive measures

From KHM: PI / Researcher-1 (Susan Braovac)

Collaborator: Professor Lukasz Bratasz, Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences and Post-doctoral researcher-2.

We believe that the degradation is ongoing, due to low pH in wood. But we are unsure as to how fast it is going at this point in time. We have tried to look into this by comparing the chemistry of wood samples from real objects treated at different times: 1880, 1910 (Oseberg), 1930s (Łucejko et al., 2021), but it was difficult to gain a clear picture. The aim of the investigations planned here will help us understand which short-term and long-term decisions we should be making.

This work package will focus on investigating the effectiveness of non-invasive preservation strategies (i.e. through climate control (RH, T) and possibly air filtration if deemed necessary)). To estimate the effects of different parameters on object lifetime, we will use the openly accessible HERIE digital platform developed in at the Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences for 'quantitative assessment of risks to heritage assets', in collaboration with Professor Lukasz Bratasz. (https://herie.pl/)

After several discussions with various experts (Pamela Hatchfield, Lukasz Bratasz), it turns out that oxygen reduction in display cases is too complex to design and its preservation effect is too uncertain.

WP5. Alum-wood chemistry, as is and retreated

From KHM: Researcher-3 (Calin Steindal), Researcher-1 (Susan Braovac)

Collaborator and WP Coordinator: Associate Professor Jeannette Lucejko, Analytical Chemistry, Department of Chemistry and Industrial Chemistry of the University of Pisa, Italy (Researcher-4)

In close collaboration with the project PI, WP 5 will coordinate research investigating important aspects of wood chemistry which have not yet been elucidated. It will also coordinate experimental design and provide chemical support for all other WPs in collaboration with the SciCult lab at KHM, including support in evaluation and understanding of results of, for instance, the progress of applied retreatments.

- Identification and characterization of materials used to repair and reconstruct objects in the early 1900s.
- The interaction between applied materials and alum-treated wood, as well as the interaction between new materials and older ones used in object reconstruction, will be studied. Evolved Gas Analysis (EGA) and Py-GC-MS (Analytical Pyrolysis coupled with Gas Chromatography and Mass

Spectrometry) will be conducted on selected treated and retreated woods. This includes characterizing new materials and studying their behavior over time, with consideration of their interaction with environmental parameters. In order to understand the mechanisms of degradation, we also plan to conduct accelerated artificial aging through UV irradiation and variations in temperature and humidity of retreated objects (also those from SO-II) and pure conservation materials. If necessary, NMR (Nuclear Magnetic Resonance) will also be used to investigate the interaction between new/old materials and wood.

- The evaluation of both terpene-based and rosin-based treatments will be possible by semi-quantitative Py-GC/MS (evaluating both the lignocellulosic matrix and terpene-based material) as well as by the quantitative GC-MS procedure after extracting and analyzing the terpenic fraction.
- Supporting WP 4, investigations on Remaining Lifetime. Analysis of Volatile Organic Compounds (VOCs) released after retreatment (also samples from SO-II) using Solid Phase Microextraction (SPME), both within a closed box (in the laboratory) and within display cases (in a museum setting). The treated material will be subjected to monthly exposure for monitoring purposes. This will be compared with the Oddy Test, a standard test for materials for museum use.
- Analysis of the inorganic content (compounds made of iron, sulfur, aluminum, etc) is also crucial to understanding degradation processes of archaeological wood, before and after retreatment and will contribute to understanding variability in wood condition, and its remaining lifetime (WP 4). We plan to quantitatively identify metal ions using ICP-OES (Inductively Coupled Plasma Optical Emission Spectroscopy) and anions using IC (ion chromatography) (i.e. elemental analysis). Analyses at KHM will complement those undertaken in Pisa, using XRD (X-ray diffraction) and Raman spectroscopy, in order to identify the actual compounds present in the wood.
- CO_2 emission from degrading wood will be studied, to see if this method can provide information about rates of degradation.

WP6. Dissemination, publications, etc.

Knowledge and experience from SO-III Research will be disseminated to conservators and natural scientists at museums and other institutions who have alum-treated wooden objects and are interested in re-conservation of archaeological wood and/or wood chemistry. Dissemination will be through publications (reports and papers), museum-related events (for ex. *Turist i egen by, Forksningsdagene*), hands-on workshops, conferences, website and social media. A final symposium is planned to summarize the main findings (registration fee for external attendees).

8. Organization, roles and responsibilities

Project owner of SO-III Research is KHM's Department Head of Collection Management, as was the case for SO-I and SO-II.

The Core Team

- Principal investigator (Project leader) / Researcher-1 (50%) is responsible for planning, reporting and overall coordination. The position includes some research as well (WP 4 Remaining Lifetime, preventive measures, in collaboration with Prof. Bratasz in Poland and WP 5 Alum wood chemistry).

- Project coordinator (100%) assists with communicating with external collaborators, visiting scientists and students, organizing meetings, website set-up and maintenance, ordering supplies, general budget overview

- Conservation expertise:
    - Researcher-2 (80%) (Angeliki Zisi) and Conservator (40%) (NoName): Developing, testing, and evaluating aqueous (WP 1) and non-aqueous (WP 3) retreatment methods on groups of test objects from Oseberg. Conservators will collaborate with University of Nottingham, which will synthesize one of the consolidants that will be tested on Oseberg wood (a part of WP 3). Conservators will also work closely with WP 2, Improvement of NP penetration, and WP 5, Alum wood chemistry.
- Conservation scientists / Chemists:
    - WP 2 improving NP penetration: Post-Doc-1 (100%) – 4 years with Prof. Lars Berglund, KTH, Stockholm (not confirmed)
    - WP 4 Remaining Lifetime: Post-doc-2 (100%) - 4 years with Prof. Lukasz Bratasz, Polish Acad. Sciences
    - WP5 Alum wood chemistry: Researcher-3 KHM 30% (Calin Steindal): Complementary Chemical analyses to Pisa
    - WP5 Alum wood chemistry: Researcher-4 University of Pisa 100% (Jeannette Lucejko): Advanced analyses University of Pisa

- Collaborators from the University of Nottingham will synthesize the terpene-based consolidant (1st year), a service for which we have budgeted. Professors Harding and Stockman will undertake characterization studies of polymers and be involved in general discussions, especially with conservators working in WP 3.

Other expertise

A *Steering Group* (SG) will supervise the project's progress and advise the Project Owner and the project Team. The SG will have up to 5 members, with relevant expertise in object conservation, archaeological research and museology / museum exhibitions. The SG meets in person or digitally ca 4 times annually and whenever required by extraordinary circumstances. We have budgeted for only 1 in-person meeting per year. If desired, members can also join the Reference group in technical discussions during digital meetings (as in SO-I and –II).

A *Reference Group* (at least 1 meeting per year) will enable project members to present their research, receive feedback and discuss all relevant technical issues. It can have up to 4 external members. Annual meetings will alternate between digital (years 2, 4, 5) and in-person (years 1, 3, 6).

9. Stakeholders/target groups

The main stakeholder is the project owner, the Museum of Cultural History, whose cares for the Oseberg collection. Other stakeholders are the users of the Oseberg collection in either research or exhibition, and conservators at other institutions who have alum-treated wooden objects, who are interested in (re-) conservation of archaeological wood and in general wood chemistry. The project offers interdisciplinary opportunities for cooperation between scientists and conservators on many facets of archaeological wood, a complex and highly varied material whose long-term preservation demands more research.

10. Budget

SO-III RESEARCH								
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Staff								
Principal investigator / researcher-1, KHM	50 %	560 000	588 000	617 400	648 270	680 684	714 718	3 809 071
Project coordinator, KHM	100 %	970 000	1 018 500	1 069 425	1 122 896	1 179 041	1 237 993	6 597 855
Researcher-2 (conservator), KHM	80 %	728 000	764 400	802 620	842 751	884 889	929 133	4 951 793
Experienced conservator, KHM	40 %	360 000	378 000	396 900	416 745	437 582	459 461	2 448 689
3D expert (internal) Frikjøp KHM	1.5 årsverk	275 000	288 750	297 413	306 335	315 525	324 991	1 808 013
Researcher-3 (30%), Chemical analyses, KHM	30 %	309 000	324 450	340 673	357 706	375 591	394 371	2 101 791
Researcher-4 Chemical analyses, University of Pisa (kostnad ved arbeid og ansettelse i utland; gjennomgang av HR)	100 %	771 750	810 338	850 854	893 397	938 067	984 970	5 249 376
Post-Doc-1 - Non-aqueous deacidification with Lars Berglund, KTH, Stockholm	100 %	1 020 000	1 071 000	1 103 130	1 136 224	--	--	4 330 354
Post-Doc-2 - Preventive conservation researcher with Lukasz Bratasz, Polish Acad. Sciences, Krakow	100 %	1 020 000	1 071 000	1 103 130	1 136 224	--	--	4 330 354
Travel								
Kick-off meeting Oslo year 1;	travel and drift (food)	240 000						240 000
Steer group meetings: 2 per year (1 digital, 1 physical)	travel	65 000	65 000	65 000	65 000	65 000	65 000	390 000
Ref group meetings: 1 per year. Physical meetings in years 1, 3, 6. Digital meetings years 2, 4, 5.	travel	70 000		70 000			70 000	210 000
Travel for collaboration within WP, years 2, 4, 5	travel		90 000		90 000	90 000		270 000
Dissemination								
Publications 3 per year	drift		60 000	60 000	60 000	60 000	120 000	360 000
Public engagement: website, museum events (1 per year, years 2, 3, 4, 5), film, etc	drift	100 000	100 000	100 000	100 000	100 000	100 000	600 000
Conferences 1 per year per person	travel	270 000	270 000	270 000	270 000	270 000	270 000	1 620 000
Final symposium (2 days) + evt. workshop (at end)	drift						500 000	500 000
Collaboration Costs (Consumables, running costs, travel)								
Person at Nottingham to do scale-up, quality control and development of green method for terpene acrylates	service: fikk tallet fra Nottingham	675 000	0	0	0	0	0	675 000
KHM analytical facilities, 3D equipment (bench fees, 'leiested')	drift	497 000	497 000	497 000	497 000	497 000	497 000	2 982 000
KHM Equipment, consumables	drift	1 443 000	103 000	103 000	103 000	103 000	103 000	1 958 000
University of Pisa; Pisa	drift	240 000	240 000	240 000	240 000	240 000	240 000	1 440 000
University of Nottingham, Nottingham	drift	240 000	240 000	240 000	240 000	240 000	240 000	1 440 000
KTH, Stockholm	drift	210 000	210 000	210 000	210 000	210 000	210 000	1 260 000
Polish Academy of Sciences, Jerzy Haber Institute of Catalysis and Surface Chemistry, Krakow	drift	210 000	210 000	210 000	210 000	210 000	210 000	1 260 000
SUM NOK pr year		10 273 750	8 399 438	8 646 544	8 945 548	6 896 379	7 670 637	50 832 296
							NOK	**50 832 296**
Påslag for usikkerhet (5% av total pr år)		513 688	419 972	432 327	447 277	344 819	383 532	**2 541 615**
TOTAL BUDSJETT		**10 787 438**	**8 819 409**	**9 078 872**	**9 392 826**	**7 241 198**	**8 054 169**	**53 373 911**

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12. Overview of versions and edits

Versjon	Dato	Endring	Ansvar for å beskrive endringen	Ansvar for godkjenning av endring
	14.08.23			