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Dendrochronological dating of an 18th century shipwreck from the Tallinn harbour

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INTRODUCTION

Shipwrecks discovered in the sea bottom where they have sunken in a sea catastrophe awaken our imagination of what befell the sailors from our past. But many ships served long and fruitful years on the water, enabling trade, travel and strife between regions, until they could no longer maintain seaworthiness. The coast of Tallinn in Estonia is a special place where old shipwrecks are found in the ground at the Baltic Sea coast (Roio *et al*. 2016; 2017). After the Ice Age and during the last centuries, the land surface at the coastal region of west and north Estonia is rising. So the former shallow sea in the harbour areas was often filled for creating new territory for the town. This was the situation for a shipwreck at Petrooleumi St. 12 ground near the D-terminal of the Tallinn harbour. The shipwreck was partly unearthed in the course of the construction of the seaside bank protection. After the documentation the wreck was covered with sand and the planned construction was built on top of it.

DESCRIPTION OF THE WRECK

The shipwreck was found in the seabed northwest-southeast oriented. Only the bottom part of the ship was preserved. The complicated conditions on the construction site allowed to unearth only a small part of the wreck (Fig. 1). The wreck's port was measured to be 3.5 metres, so the whole width of the ship was probably at least 7 metres. The wreck in the excavation area was documented in a length of 13.6 metres. The wooden details of the wreck were coated with tar.

The visible remains of the inner hull included a keelson and the ceiling planks. Nine strakes of oak ceiling planking were visible; seven on the port, and two on the starboard sides. The ceiling planks were placed close together. The stem knee was found when the wreck was discovered.

Fig. 1. *Location of the shipwreck found in the filled seashore near the D-terminal of Tallinn harbour, at Petrooleumi St. 12 (above). A pump helps to lower the water level in the pit (below). Loose timbers were removed to the background of the excavation.*

Jn 1. *Täidetud mererannast leitud laevavraki paiknemine Tallinna sadama D-terminali lähedal Petrooleumi 12 (ülal). Pump alandab veetaset kaevandis (all). Lahtine puit tõsteti kaevandi servale tagaplaanil.*

Photos / Fotod: Rivo Bernotas

Two strakes of oak hull planking were visible on the port side. Carvel planking was used to join planks together. The planks were 32–35 cm wide and 6–7 cm thick. A small repair patch was found on the outboard face of one hull plank. Framing timbers were fastened to the planking with treenails. The frames, made of oak, had a mean diameter of 24–30 cm.

The massive keelson and a wooden block can be associated with the wreck of a sailing ship.

A tin from the 1970s and a couple of metal teapots were found inside the wreck. Also a steel cable was found wrapped around the bow of the shipwreck. Therefore very likely the shipwreck was not in its original location. It seems probable that it was re-located in the 1970s, due to the construction work in the harbour area or the wreck's former location, which may have obstructed the shipping routes. We have not been able to collect written or oral information regarding the possible moving of the wreck thus far.

MATERIAL AND METHODS

To keep the impact on the wreck remains minimal, we sampled loose wreck timbers that were collected from the excavation (Fig. 2). With a chain saw, more than 20 cross sections were cut from the planks and frames (Fig. 3). The locations of the cross sections of the timbers were chosen with a view to getting long ring sequences and where possible rings nearest to the bark. By visual observation all the timbers appeared to be oak wood (*Quercus* sp.). As the location of the loose timbers in the wreck were not known, the sample disks were numbered in the lab for identification.

The ring widths of 22 wood samples were measured to 0.01 mm precision by using stereomicroscope Leica S4E and measuring device Lintab (Rinntech). There were twelve samples from the planks and ten samples from the frames of the ship. A few samples remained unmeasured due to insufficiently short tree-ring series. The sample series of tree-ring widths were saved in Heidelberg format in the program TSAP-Win (Rinntech).

All the measured tree-ring series were compared between themselves in the program TSAP-Win and the series most similar to each other were averaged, to synchronize them with oak chronologies from Europe (ITRDB). All series were also converted to the Sheffield dendro format and analysed using the program DENDRO (Tyers 1997).

RESULTS

An average ring-width series 0eqdtrM004 was compiled from nine sample series of ship planks. Two additional planks, a ceiling plank and six frames could also be dated. The correlation between the series from all dated timbers with each other is shown in Table 1. There is no clear distinction between the planks and the frames, indicating that the timbers for these different components were from the same source. Indeed, samples no 12 and no 16 are so similar they might be from two timbers from a single tree. One of these is a frame, the other a plank.

The outermost tree-ring preserved in the material is on sample no 13, from a frame, and it was formed in AD 1774.

Dating of the material is illustrated in Fig. 4. The grey bars show the time period that the tree-ring series from each sample is positioned. The arrows in the diagram represent the estimated felling time for each tree, where only heartwood was preserved. We cannot know how much heartwood was trimmed off these timbers when they were shaped. Thus the dating of these are termini post quem. Sapwood was preserved on one of the samples, however. The dark grey block on sample no 13 in the illustration represents the preserved sapwood.

Fig. 2. *Sampling loose timbers of the shipwreck with chain saw.*
Jn 2. *Mootorsaega proovide võtmine lahtisest vrakipuidust.*
Photo / Foto: Alar Läänelaid

Fig. 3. *Cross sections of the shipwreck timbers (oak) after sampling.*
Jn 3. *Vrakipuidu (tamm) ristlõigud pärast proovivõttu.*
Photo / Foto: Alar Läänelaid

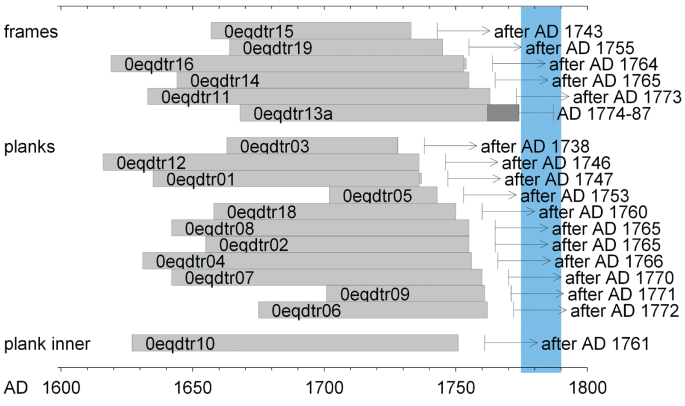

Fig. 4. *Temporal span with probable cutting time of the dated timbers of the D-terminal wreck, Tallinn. The diagram illustrates the dendrochronological dating of the timbers from the ship.*
Jn 4. *Tallinna D-terminali vraki dateeritud puidu aastarõngaridade ajaline ulatus koos tõenäolise raiumisajaga. Diagramm illustreerib laevapuidu dendrokronoloogilist dateerimist.*
Compiled by / Koostanud: Aoife Daly

Table 1. *D-terminal wreck, Tallinn. Correlation (t-value) between all the dated samples and each other. The grey tone highlights the high t-values.*
Tabel 1. *D-terminali vrakk, Tallinn. Kõigi dateeritud proovide vaheline korrelatsioon (t-väärtus). Hall taust näitab kõrgeid t-väärtusi.*
Compiled by / Koostanud: Aoife Daly

			0eqdtr15	0eqdtr03	0eqdtr01	0eqdtr09	0eqdtr11	0eqdtr04	0eqdtr02	0eqdtr06	0eqdtr18	0eqdtr05	0eqdtr13a	0eqdtr07	0eqdtr08	0eqdtr19	0eqdtr10	0eqdtr12	0eqdtr16	0eqdtr14
	frame	0eqdtr15	*	2,3	1,89	0,53	1,22	2,63	2,07	2,51	2,69	0,35	1,66	2,31	0,97	1,5	0,8	-	0,52	-
Average 0eqdtrM006	plank	0eqdtr03	2,3	*	3,17	\	1,67	2,63	3,11	2,66	3,37	\	2,41	2,57	2,44	1,17	0,33	2,97	2,21	0,85
	plank	0eqdtr01	1,89	3,17	*	1,46	3,88	2,4	4,37	2,6	3,07	0,78	3,36	4,05	3,5	4,36	3,11	1,4	0,8	2,73
	plank	0eqdtr09	0,53	\	1,46	*	5,21	0,1	3,18	3,95	4,3	2,99	2,04	3,89	3,28	1,54	2,73	3,03	1,48	0,22
	frame	0eqdtr11	1,22	1,67	3,88	5,21	*	3,44	4,07	2,48	4,67	3,37	2,55	3,63	3,75	0,58	3,34	2,96	1,91	1,29
	plank	0eqdtr04	2,63	2,63	2,4	0,1	3,44	*	3,78	4,51	5,3	2,85	3,4	3,75	4,92	3,65	3,13	0,15	0,08	2,44
	plank	0eqdtr02	2,07	3,11	4,37	3,18	4,07	3,78	*	6,96	6,19	5,16	3,72	4,15	4,57	2,41	3,95	1,71	2,23	3,22
	plank	0eqdtr06	2,51	2,66	2,6	3,95	2,48	4,51	6,96	*	9,88	5,22	5,01	4,59	3,86	3,28	2,45	1,98	0,61	2,84
	plank	0eqdtr18	2,69	3,37	3,07	4,3	4,67	5,3	6,19	9,88	*	6,30	3,31	4,36	3,63	2,04	1,92	1,84	1,77	0,71
	plank	0eqdtr05	0,35	\	0,78	2,99	3,37	2,85	5,16	5,22	6,30	*	3,66	3,7	3,47	1,78	3,36	0,23	0,21	1,6
	frame	0eqdtr13a	1,66	2,41	3,36	2,04	2,55	3,4	3,72	5,01	3,31	3,66	*	3,27	2,89	4,51	3,55	0,67	1	1,2
	plank	0eqdtr07	2,31	2,57	4,05	3,89	3,63	3,75	4,15	4,59	4,36	3,7	3,27	*	6,42	1,75	3,99	3,79	3,29	1,84
	plank	0eqdtr08	0,97	2,44	3,5	3,28	3,75	4,92	4,57	3,86	3,63	3,47	2,89	6,42	*	2,32	4,16	3,43	2,4	1,75
	frame	0eqdtr19	1,5	1,17	4,36	1,54	0,58	3,65	2,41	3,28	2,04	1,78	4,51	1,75	2,32	*	3,39	0,3	-	2,53
	ceiling	0eqdtr10	0,8	0,33	3,11	2,73	3,34	3,13	3,95	2,45	1,92	3,36	3,55	3,99	4,16	3,39	*	-	0,31	2,66
	plank	0eqdtr12	-	2,97	1,4	3,03	2,96	0,15	1,71	1,98	1,84	0,23	0,67	3,79	3,43	0,3	-	*	11,9	0,62
	frame	0eqdtr16	0,52	2,21	0,8	1,48	1,91	0,08	2,23	0,61	1,77	0,21	1	3,29	2,4	-	0,31	11,9	*	0,54
	frame	0eqdtr14	-	0,85	2,73	0,22	1,29	2,44	3,22	2,84	0,71	1,6	1,2	1,84	1,75	2,53	2,66	0,62	0,54	*

Fig. 5. *Sample no 13 from a frame of the ship. Sapwood rings were measured in two perpendicular radii of the disk.*
Jn 5. *Laevakaare proov nr 13. Maltspuidu aastarõngaid mõõdeti kahest perpendikulaarsest raadiusest.*
Photo / Foto: Alar Läänelaid

We did not observe waney edge or bark remains on the wreck timbers. However, sample no 13, from a frame, contained 12 sapwood rings (Fig. 5). The outermost sapwood ring was formed in AD 1774. The outer surface of the sample is coarse and we cannot be sure that it is the surface under the bark, i.e. waney edge. Fortunately, the average numbers of sapwood rings of oak trees growing in Europe are known (Haneca *et al.* 2009; Sohar *et al.* 2012; Sohar 2013). Thus we can estimate that the tree that was used to make frame 13 was felled within the period AD 1774–1787. As the other timbers from the ship seem to have come from a homogeneous source, and as the estimated dating for the other samples all fall before the dating

for frame 13, we might suggest that all were felled at the same time, around AD 1775–1790 (highlighted with blue in Fig. 4).

An average tree-ring series 0eqdtrM006 is made from 11 planks, a ceiling and four frames, as indicated in Table 1. It is 159 years in length and it covers the period AD 1616–1774. The correlation between this average and a selection of oak chronologies from Northern Europe is shown in Table 2. The highest correlations appear with a range of site chronologies for north-eastern Germany.

Table 2. *D-terminal wreck, Tallinn. The correlation (t-value) between the average series 0eqdtrM006 from the ship and a range of tree-ring datasets from Northern Europe.*
Tabel 2. *D-terminali vrakk, Tallinn. Vraki keskmise aastarõngarea 0eqdtrM006 korrelatsioon (t-väärtus) paljude Põhja-Euroopa aastarõngaridadega.*
Compiled by / Koostanud: Aoife Daly

Filenames	-	-	**Average 0eqdtrM006**	
-	start	dates	AD 1616	
-	dates	end	AD 1774	
Master and site chronologies				
GO11QZ01	AD 1543	AD 1719	6.61	Stralsund 3 timbers (Göttingen Uni revised Daly 2007)
GO10FZ01	AD 1584	AD 1755	6.24	Güstrow 2 timbers (Göttingen Uni revised Daly 2007)
germ6	AD 1376	AD 1972	5.88	Oldenburg 138 timbers (Eckstein ITRDB)
GO106Z01	AD 1696	AD 1758	5.80	Güstrow 3 timbers (Göttingen Uni revised Daly 2007)
E_German	AD 1343	AD 1968	5.71	East Germany 339 timbers (Daly 2007)
DM200001	AD 1082	AD 1972	5.59	Nieders. Kuestenraum (Göttingen Uni)
GO10TZ01	AD 1493	AD 1731	5.31	Güstrow 7 timbers (Göttingen Uni revised Daly 2007)
CD30IZ02	AD 1595	AD 1699	5.16	Hunseby kirke 3 timbers (Nationalmuseet revised Daly 2007)
H110BM01	AD 1483	AD 1691	5.12	Eutin Schloss 8 timbers (Hamburg Uni revised Daly 2007)
GO106Z02	AD 1630	AD 1758	5.06	Güstrow 2 timbers (Göttingen Uni revised Daly 2007)
ZEALAND0	AD 452	AD 1770	5.02	Sjælland Denmark 249 timbers (Daly unpubl)
G312FZ01	AD 1664	AD 1794	4.89	Einbeck 8 timbers (Göttingen Uni revised Daly 2007)
G330ZZ02	AD 1498	AD 1735	4.82	Bramsche 12 timbers (Göttingen Uni revised Daly 2007)
SM000005	AD 1274	AD 1974	4.80	Skåne Blekinge (Lund University)
HO34FM01	AD 1653	AD 1731	4.79	Wittenburg Toitenwin 5 timbers (Hamburg Uni revised Daly 2007)
Chronologies from imported timber				
B027oak fishbox	AD 1558	AD 1731	6.57	Gammel Strand Copenhagen oak fishbox 2 timbers (Daly 2016)
B027oak F g...	AD 1543	AD 1754	6.47	Gammel Strand Copenhagen oak F green 1750s 16 timbers (Daly 2016)
B003M001	AD 1563	AD 1731	6.18	Copenhagen Vindebrogade 10 timbers (Daly 2003)
2146m001	AD 1485	AD 1673	5.19	Rosendal 2 timbers (Daly 2001)
Chronologies from shipwrecks				
Z227M001	AD 1663	AD 1749	6.52	Kostervraket Stockholm 2 timbers (Daly 2018)

DISCUSSION

Considering the probable provenance of the ship's oak as Germany, based on the highest similarity of the shipwreck tree-ring series with German oak chronologies, we can apply the average sapwood numbers established for oaks grown in Germany. According to Hollstein (1965; 1980), the average number of sapwood rings in 100–200 years age (here 107 tree-rings in the series 13A) was 20 and the 95% confidence interval was 8–38 rings. According to Wrobel and Eckstein (1993) the average number of sapwood rings in northern Germany was 16 (range

10–30 rings). The measured number of sapwood rings, 12, in this shipwreck timber No 13A exceeds the minimal sapwood number for German oaks, 8 rings (95% confidence). The upper limit of the sapwood ring number is 30 or 38 (95% confidence). It means that the ship timber could not have been cut later than AD 1792 or AD 1800. These are the extreme latest years of timber cutting for the ship. More probably, there was less sapwood in the timber under study and the oak trees were cut between ca. AD 1775 and 1790 (marked with blue in Fig. 4).

We may assume that ships at that time were built from raw timber. There were several reasons, most importantly green timber was easier to shape and bend to make the curving planks of a ship. Therefore, cutting the trees was followed by shipbuilding probably in the subsequent year. We should, however, bear in mind that there is evidence that long-distance rafting of timber on the rivers took place, particularly by the 18th century (Grabner *et al*. 2019). The exact building year of the ship is impossible to determine from its tree-rings. Indeed, as the outer wood has not survived, the exact felling year for the trees used is not determined either. Nevertheless, the dendrochronological analysis of the tree-ring series of the wreck timber produces a probable period in which the ship was built.

The probable building period of the ship, ca. AD 1775–1790, coincides with the time when oak import from the Baltic ports had ceased (Jansma *et al*. 2004), therefore the ship's tree-ring series do not even cover the same time period of the Baltic oak chronologies, which end in the mid-1600s. This ship is built of timbers from a very homogeneous source, which can indicate that it represents a ship built close to that source.

CONCLUSIONS

The dendrochronological analysis of 22 wood samples from the shipwreck has shown that this ship found in Tallinn was built between AD 1775 and 1790 from oak trees grown in the eastern part of Germany. The identification of the ship, the exact time of burying the wreck on the coast of Tallinn and its probable relocation remains open at the time of writing.

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TALLINNA SADAMAST LEITUD 18. SAJANDI LAEVAVRAKI DENDROKRONOLOOGILINE DATEERIMINE

Alar Läänelaid, Aoife Daly, Maili Roio ja Rivo Bernotas

Tallinna sadama D-terminali lähedal Petrooleumi 12 krundil kaldakindlustuse rajamisel paljandunud 13,6 m pikkuse ja vähemalt 7 m laiuse laeva vraki uurimisel selgus, et vrakk on sellele asukohale teisaldatud, millest andsid tunnistust kaare külge kinnitatud terastross ja vrakist leitud 1970. aastate konservikarp. Teisaldamisele viitavad ka lahtised puitosad vrakipõhjal. Vrakist oli säilinud vaid põhi ja 7 plangurida. Vraki leiuala on endine merepõhi, mida on sadama laiendamisel täidetud pinnasega.

Vraki vanuse dendrokronoloogiliseks määramiseks võeti vrakipõhjalt väljatõstetud lahtistest kaartest ja plankudest üle 20 ristlõike. Kõik proovid osutusid tammepuiduks. Laboris mõõdeti aastarõngalaiused 22 proovil; mõned jäeti mõõtmata liiga vähese arvu aastarõngaste tõttu. Proovide aastarõngalaiuste ridu võrreldi omavahel ning sarnasuse alusel keskmistati 9 puiduproovi aastarõngalaiuste read, millele lisati veel 2 proovi read. Aastarõngalaiuste omavaheline sarnasus näitab, et nii kaared kui ka plangud on pärit samast allikast.

Petrooleumi tänava vraki 11 keskmistatud aastarõngarea sünkroniseerimine Põhja-Euroopa tammepuude aastarõngaridadega näitas, et vrakipuidu viimane säilinud aastarõngas moodustus 1774. aastal. Seda aastaarvu näitas vaid proov nr 13, milles on

säilinud 12 maltspuidu aastarõngast. Maltspuidu ligikaudse laiuse järgi Põhja-Euroopa tammedel saab väita, et uuritava laeva valmistamiseks tarvitatud tammed raiuti ajavahemikus 1775–1790. Vrakipuidu aastarõngalaiuste rida näitas kõige suuremat sarnasust Saksamaa kirdeosa tammekronoloogiatega ($t > 6$). Tollase laevaehituspraktika kohaselt ehitati laevu toorest puidust, s.t. vahetult pärast puude langetamist. Siiski leidub andmeid tolleaegsest puidu parvetamisest, mis võttis aega rohkem kui aasta. Teisalt oli nimetatud ajavahemikuks katkenud kaubavahetus Läänemere sadamatega, mistõttu laev ehitati tõenäoliselt Saksamaa kohalikust puidust. Seega ei saa kindlaks teha laeva täpset ehitusaastat, vaid ehitusaja vahemiku AD 1775–1790.