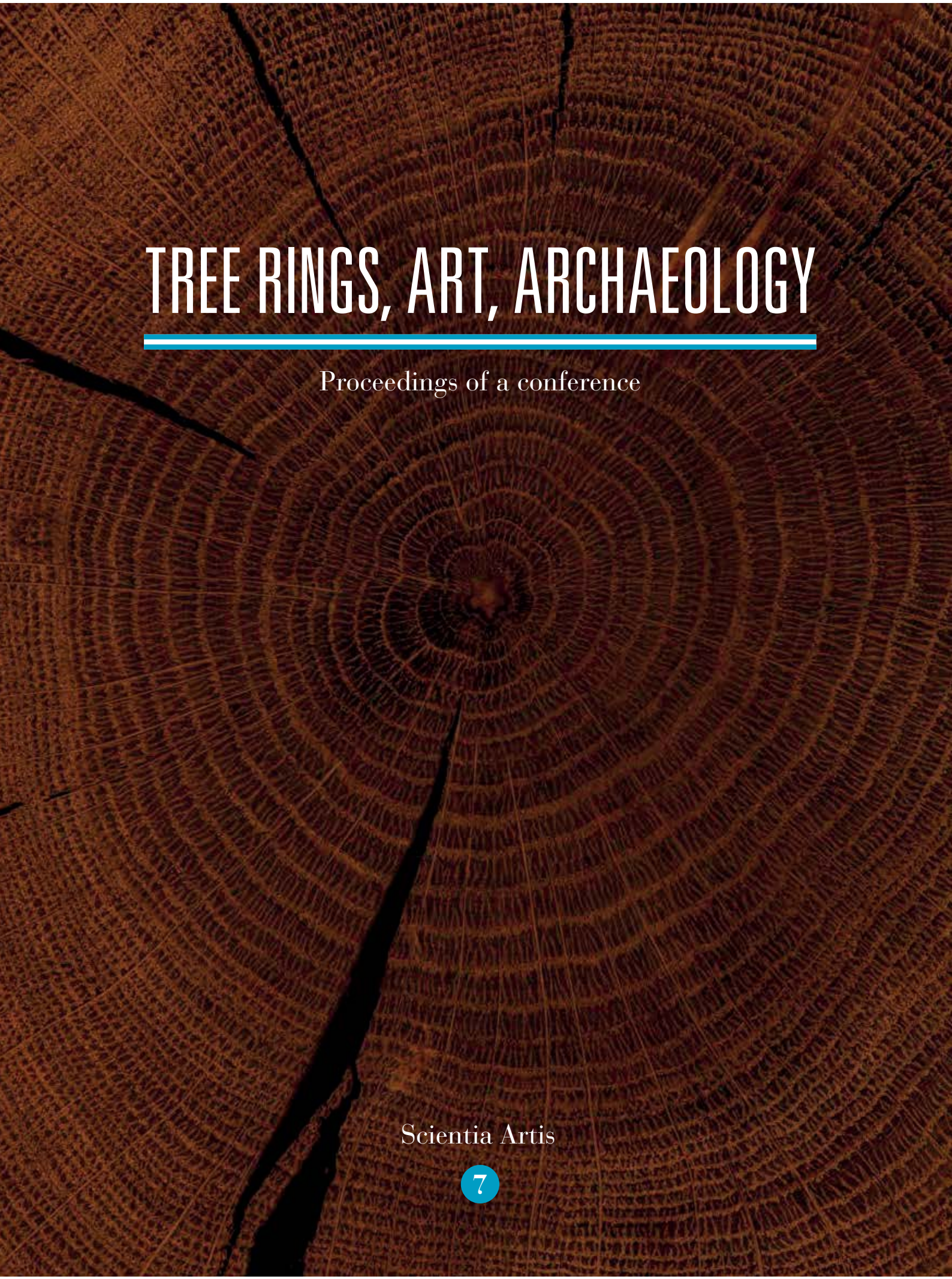

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The letter "d" following a year indicates that the date has been provided by dendrochronology (the inverse has not been systematically applied).
All of the dates cited are AD, unless indicated as BC.

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Slice of an oak trunk from a forest in the surroundings of Liège, Belgium. © P. Fraiture, IRPA/KIK

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Tree Rings, Art, Archaeology

011 → **Preface**
Christina Ceulemans, Director *a.i.* of the Royal Institute for Cultural Heritage

013 → **Introduction**

015 → **Beyond dates. For a global appraoch in dendrochronology**
David Houbrechts and Pascale Fraiture

019 → **Dendrochronology, archaeology and science**
Georges Lambert

033 → **La dendrochronologie : de « nouveaux documents » pour l'historien de l'économie médiévale ?**
Jean-Pierre Sosson

039 → **Part 1: History, climate and forest management**

041 → **How to make the Forest of Carnutes speak.**
Dendrochronology as a source for the history of the Roman Empire: Methodological considerations
Benoît Rossignol and Sébastien Durost

049 → **Last-millennium summer-temperature variations in Briançonnais, French Alps, based on a composite larch tree-ring chronology**
Christophe Corona, Jean-Louis Édouard, Frédéric Guibal, Georges Lambert, Vanessa Py, Joël Guiot and André Thomas

067 → **The influence of historic forest management practices on oak chronology building in Flanders**
Kristof Haneca

077 → **Dendro-archaeological contribution to the history of forest exploitation.**
The case of the Gallo-Roman settlement of Oedenburg (Alsace, France) between 10 and 180 AD
Olivier Girardclos and Christophe Petit

097 → **Part 2: Trade**

099 → **Dendro-provenancing between the Baltic Sea and the East Mediterranean**
Tomasz Ważny

107 → **Dendro-geography. Mapping the Northern European historic timber trade**
Aoife Daly

125 → **New dendrochronological, historical and archaeological evidence of long-distance floating of timbers to Riga**
Māris Zunde

137 → **Timber transport and dendro-provenancing in Thuringia and Bavaria**
Thomas Eissing and Christoph Dittmar

151 → **Timber supply in Groningen (northeast Netherlands) during the early modern period (16th-17th centuries)**
Marta Domínguez-Delmás, Jeroen F. Benders and Gert L.G.A. Kortekaas

175 → **Part 3: Archaeology**

177 → **Applying dendro-typology to large timber series**
André Billamboz

191 → **Preventive archaeology and dendrochronology. A parallel development in northeastern France**
Willy Tegel and Jan Vanmoerkerke

201 → **From the Late Bronze Age to the Roman period. Dendrochronology, archaeology and history**
Gilbert Kaenel

211 → **Working with dendrochronology. The interaction of the evidence in English building history**
Nicholas A.D. Molyneux

225 → **How tree-ring dating can provide historical contexts to buildings "without history"**
Thomas Coomans

241 → **Dendrochronology and human behaviour.**
Experiences and results in the province of Liège (Wallonia/Belgium)
Caroline Bolle and Jean-Marc Léotard

255 → **On Brussels carpentry (15th-18th centuries). Contributions of dendrochronology to the study of buildings**
Vincent Heymans and Philippe Sosnowska

271 → **Part 4: Art**

273 → **Dendro-organology? The dendrochronological method applied to musical instruments**
Micha Beuting

285 → **Dendrochronology applied to Belgian pianofortes**
David Houbrechts and Pascale Vandervellen

299 → **Interpreting evidence from dendrochronology. A case study from research on 16th-century British panel paintings**
Tarnya Cooper

313 → **Dendrochronological and technological examination of painting supports. The case of Rubens's studio practice**
Pascale Fraiture and Hélène Dubois

331 → **Conclusion**

333 → **Tree Rings, Art, Archaeology. Dialogue for a better understanding of dendrochronology**
Pascale Fraiture, Dieter Eckstein and Jean-Pierre Garcia

PART 2: TRADE

Dendro-geography. Mapping the Northern European historic timber trade

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Key words dendro-geography / dendro-provenance method / timber trade / Polish-Baltic timber / shipwrecks / barrels

Summary

Insight into many aspects and dynamics of the trade of timber in Northern Europe, through time, are possible through the combination of archaeological, historical and dendrochronological analyses. A selection of examples from the analysis of material from a range of archaeological sites shows the range of information that emerges. Barrels from the 8th century found in Ribe in Denmark show links to archaeological material in England, the Netherlands and the Middle Rhine in Germany. Finds in Denmark of barrels from the 14th and 15th centuries confirm the pattern that dendrochronological research in many laboratories throughout Northern Europe has shown of the explosion in trade of panels, wainscots, boards etc., from the southern Baltic Sea coastal region. A summary of barrel finds, chiefly from Denmark, allows us to take a chronological view of the changes in sources for this often mundane find type. In many cases we also see regional differences in the standard dimensions of barrels. A shipwreck from the island of Darss, in northern Germany, is dated to around 1590. Two timber sources were utilised in the building of this ship, and the timbers from these two regions were worked and utilised differently. The results from these many examples raise the possibility of future multidisciplinary investigation into the regionality (or geography) and chronology of Northern European timber-working traditions. A new term suggested for this analysis might be "dendro-geography".

Introduction

With the developments in dendro-provenancing over the last few years, detailed analysis of the material evidence for trade across Europe in timber, and timber products, is now increasingly possible. The results of these analyses allow insight into the availability of timber, and the extent and nature of trade in timber, in Northern Europe, over *ca* the last two millennia.

When detailed mapping of connections between timber objects and structures in Europe is carried out, different interpretive questions must be asked, specific to the period being studied. Consideration must be taken of the logistics of transporting bulk timber using the technology available. We must in this regard make the distinction between bulk timber which is not easy to transport, and timber products like wainscots and boards, which are prepared in the forest and are much more manageable. We must also take account of the geographic conditions when we identify timber sources and trade routes. Where we have large rivers, rafting of large cargos of timber is possible. In regions where we do not have major rivers, the transport of timber might be on a smaller scale. Additionally, we need to look at the shipping technology, to study the capacity for timber transport by sea through time. We also need to look at the ships themselves, as their building is also subject to the availability of suitable timber. When we determine the provenance of ships' timbers in the archaeological record we must ask: when are we identifying the region where the ship was built and when do we see the transport of timber for shipbuilding elsewhere?

We can also take into account the availability of timber. In regions where we see a considerable amount of imported timber in the dendrochronological record, can we see a pattern of timber shortage locally?

Despite these considerations, the identification of the provenance of wooden objects and constructions through dendrochronology is allowing connections to be mapped between regions, and at different periods. We can for example take the evidence from archaeological barrel finds. Barrels dating to the early 8th century found in Ribe in western Jutland, Denmark, were made from oak trees that grew in central Germany near the Rhine (Daly, 2007). Barrels from France from the 12th century are found in London (England), Aberdeen (Scotland) and Ribe (Denmark) (Crone *et al.*, 2004). From the mid-14th to the mid-15th centuries the source for oak barrels, at any rate in the Danish material, is predominantly from the southern Baltic Sea coast (Daly, 2007). We see again in the 16th century French barrels appearing, this time in Ireland: while a boat found in 2007, in Drogheda Harbour, was built in around 1520s of Irish oak timber, the barrels found in its cargo came from France (Daly, forthcoming).

As we move in time toward the modern era, the interpretation of detailed provenance analysis has to take account of the increasingly complicated historic timber trade network. In this paper, detailed provenance analysis and the insights these analyses allow is presented, in a discipline that the author now calls "dendro-geography".

Background

During the 1990s, a research project funded by the European Union, entitled "Climate from tree rings" resulted in the assemblage of a large tree-ring dataset for oak covering large parts of Northern Europe. This dataset consists of the individual tree-ring width measurements carried out by dendrochronologists in laboratories throughout Northern Europe over the last several decades, from Ireland in the west to Poland in the east. This data was used in research into climate change and the results published in a complete volume of the journal *Holocene* (for example the oak material is described in Kelly *et al.*, 2002; Leuschner *et al.*, 2002; Spurk *et al.*, 2002). When in 2004, I began my PhD studies, I was kindly allowed to use this extensive dataset. The aim of the PhD thesis was to refine the method by which we determine the region of origin of ancient oak timbers that we find on archaeological sites and in historical buildings. Previously, provenance determination using dendrochronology was carried out using large regional so-called master chronologies, which had been built by different researchers in different laboratories across Northern Europe, and which contain tree-ring data from very many trees. The material included in these master chronologies is derived from living trees, historical buildings and archaeological sites. The timbers from these old buildings and sites have their own history of transport and many timbers, especially as we move into the Early Modern Period, may have been transported a considerable distance before they ended up used in such structures. There is thus the possibility that regional master chronologies contain timbers that are not from that region, causing problems in using these master chronologies for determining the origin of timbers in the archaeological record. It was therefore the aim of the PhD to go back to the original individual tree-ring measurements and re-group this original data for Northern Europe so that we could achieve more detailed and accurate provenance determination.

Details of the methodology are described in Daly (2007), which is available online. A short summary is presented here. After cleaning and checking the data (the tree-ring measurements were checked for errors and dating accuracy, and the site location was also controlled, enabling accurate placement into a geographic information system [GIS]), site chronologies were made for each individual site. Only tree-ring measurements from a single site that matched well together were included in each site chronology. The management of all this tree-ring data was done using the program DENDRO (Tyers, 2004). Provenance determination (using Student's *t*-test as described in Baillie and Pilcher, 1973) was then carried out on three levels, all of which were mapped: the first level is where the site being tested (tree-ring measurements from a shipwreck, a barrel, an historical building, etc.) is compared with the large network of master chronologies; at the second level, a site is compared to all the newly built site chronologies; and the third level is the testing of the site against all single measurements in the dataset. In each case, the results of correlation were mapped: it is the distribution of the correlation values that is important to the interpretation of the results and the final conclusion of the provenance determination.[1] Let us take an example.

A wreck was found in Kolding Fjord, in 1943 (Hansen, 1944). The ship is a cog, as defined by Crumlin-Pedersen (2000). It was the subject of investigation by Dokkedal (2001) and initially five samples (Eriksen, 2000b) and subsequently an additional 13 samples (Daly, 2002) were analysed dendrochronologically. Complete sapwood to bark edge on three samples meant that a date of winter 1188/89 was achieved. Already in the initial analysis of the five samples, the very high correlation with a Jutland chronology (built at the National Museum of Denmark) indicated a western Danish origin of the oak timber.

1. All maps are produced by the author.

An average for the ship was made using 13 samples, which represents 11 trees (60873M01). This average is 207 years long and covers the period 982–1188. The test at the second level, with all site chronologies in the Northern European dataset, is shown in Figure 1. The higher the *t*-value, the larger the circle shown on the map. The highest correlation ($t = 15.11$) is with a site chronology from Haderslev (Eriksen, 1996) and the distribution of the correlation values shows that a cluster of high values appears in the Southern Jutland region. In this case then, in an example from the late 12th century, a very clear provenance determination distribution map can be produced. This is discussed further in Hocker and Daly (2006).

In the application of this methodology, I decided to allow transported timbers, which were apparent in the dataset, to remain rather than removing them. There are several reasons for this: one is that allowing the exotic timbers to remain meant that, when I tested a ship or other object against this data, the distribution of the *t*-values (Student's *t*-test, a commonly used correlation statistic) serves to highlight these exotic examples. Let us take some examples.

8th-century barrels from Ribe, Denmark

Over the last many years many barrels have been found in archaeological excavations in the town of Ribe and four of

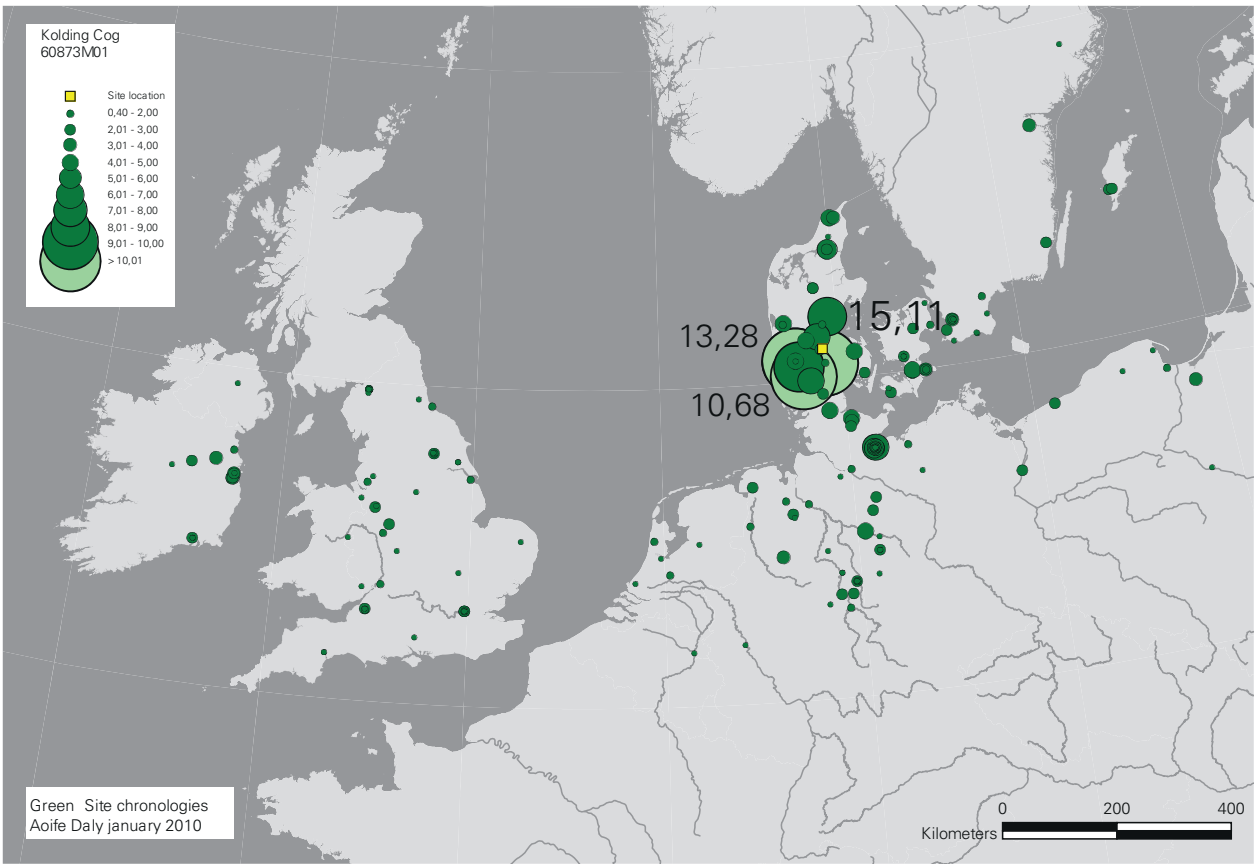


Fig. 1

The Kolding cog, Jutland. Map showing the distribution of correlation values achieved between the mean for the Kolding cog and site chronologies from Northern Europe (the second level test).

these barrels have been dendrochronologically dated to the 8th century.[2]

The barrel staves from Dommerkontorets Have were dated to after *ca* 705 using German chronologies.[3] As early as 1979 before the barrel staves were dated, an analysis of the substance adhering to the barrel was analysed and identified as a tar, from spruce, pine or larch. This, in combination with the narrow tree rings of the barrel staves, led to the suggestion that the barrel and the tar might come from a mountainous region in Central Europe.[4]

Carsten Sønderby's original conclusion for the analysis of four barrel staves from well A7 at Giørtzvej was that the outermost tree ring was formed in the year 700, and that the oak came from the Rhine River in the region of Mainz.[5] No sapwood was preserved on the barrel staves, so only *termini post quem* dates are possible. If we add 15 rings to account for missing sapwood the felling date for the tree that supplied the timber can be placed at after 715.

Three staves, two from a complete barrel and one additional stave from Well A159, were analysed from another excavation at Giørtzvej. The tree-ring curves from the two staves were so similar that they might be from a single tree. The third stave matched quite well with the staves from the complete barrel. Sapwood on one of the staves meant that a date for the felling of the oak for the complete barrel could be placed at *ca* 712 (Daly, 2000b). An interesting observation in the analysis was that the barrel matched quite well with German chronologies utilised at the time, and with just one site in Denmark, again data from Ribe, at Dommerkontorets Have mentioned above. The barrel matched with just four samples from Dommerkontorets Have, and this was at the time puzzling, but was not pursued further.

When all these separate analyses were gathered together, a link between these finds emerges. The two Giørtsvej barrels, analysed in different dendrochronological laboratories, but from adjacent archaeological excavations, match well to each other and to the four measurements from barrel staves from Dommerkontorets Have. The correlation matrix in Table 1 shows how well these three barrels match, and an average of the three barrels has been made. It can also be seen in the matrix that the fourth 8th-century barrel, from Seminarievej, does not match as well with the other three.

The average tree-ring curves for the four barrels and the average of the three well matching barrels from Giørtzvej and Dommerkontorets Have are compared with master chronologies for Northern Europe (Tab. 2). Very clearly there is quite a spread, geographically, of high values, noticeable for all barrels. High values occur with southern German chronologies, but also with a chronology for the Southern Netherlands. Now this might not be a problem when we remember that the Rhine River flows out of Central Europe exactly in the Southern Netherlands, so the suggestion of a Rhine provenance for these barrels is not impossible. It is, in this light though, considered important to carry out a third level test using the average of the three similar barrels (Fig. 2). The individual sites that the three barrels match with are spread out from Middle Rhine, a site in the Southern Netherlands and even a site in southeast England. This is a product of the inclusion in the European dataset of exotic oak data in different regions. When the tree-ring measurements of the English and Dutch examples that match very well with the three Ribe barrels are run against masters, they also match best with the Middle Rhine region.

The details of the find context of the tree-ring data from the many different sites in the dataset from the 1990s EU-funded project were not included, as the original aim of the data collection was for climate reconstruction. It would be necessary to go back to the different laboratories that originally analysed these timbers to identify the context of these measurements. Are they also barrels, for example, or are they evidence for the transport of timber in the 8th century? Therefore this example demonstrates the limitations of using the raw ring-width data without the accompanying details of the archaeological or historical context of the material. The new initiative now started in a collaborative project Digital Collaboratory for Cultural-Historical Dendrochronology (DCCD), where these details (Jansma *et al.*, 2009) can be included in future data sharing, is a very important step in improving the detail of interpretation of the results that provenancing of timber provides, in discussion of the Northern European historic timber trade.

2. Two of the barrels, Giortzvej ASR990 and Seminarievej, were analysed by Carsten Sønderby, whose results are archived at the Antikvariske Samling in Ribe. The other Giortzvej site (ASR 1357) was analysed by Daly (2000b). The barrel parts from Dommerkontorets Have were examined in the 1970s at the Natural Science Unit at the National Museum of Denmark, but it was not until 1989, when the tree-ring data was looked into again by Kjeld Christensen, that the barrel was dated (Christensen K., 1989. *Dommerkontorets Have, Ribe*, Nationalmuseets Naturvidenskabelige Undersøgelser (NNU) archive journal A5820, 4 p.).

3. NNU archive journal no. A5820, report by Kjeld Christensen dated 18 May 1989.

4. NNU archive A5820 letter from Mogens Bencard to Poul Sigsgaard dated 2 November 1979.

5. Letter from Carsten Sønderby dated 1 December 1997 in ASR 990.

	7005M00x dommerk	7035M001 giortzvej ASR1357	w466M01 giortzvej ASR990	w425x1 seminarievej
7005M00x dommerk		9.22	7.38	
7035M001 giortzvej ASR1357	9.22		9.29	4.77
w466M01 giortzvej ASR990	7.38	9.29		4.71
w425x1 seminarievej		4.77	4.71	

Table 1

Dommerkontorets Have, Seminarievej and the two Giørtzvej barrels. Matrix showing the correlation between the means of these four barrels.

		Three Ribe barrels	Dommerkontorets Have	Giørtzvej ASR1357	Giørtzvej ASR990	Giørtzvej ASR990
Filenames	-	Ribe 700s M1	7005M00x	7035M001	w466M01	w425x1
-	-	AD438	AD449	AD516	AD438	AD621
-	-	AD700	AD679	AD694	AD700	AD740
WD400std	W. Germany (Hollstein, 1980)	15.24	10.12	9.98	12.69	4.55
NIzuidmm	S. Netherlands (Jansma, 1995)	14.40	9.65	11.81	10.09	6.02
Zdlmidde	S. Germany (Jansma, pers. comm.)	10.38	8.80	6.65	8.44	3.61
BOG00000	Göttingen (Leuschner, pers. comm.)	7.12	4.58	5.10	5.33	< 3
DM200004	Weser (Leuschner, pers. comm.)	7.07	4.64	5.04	5.27	< 3
DM700001	S. Germany (Leuschner, pers. comm.)	6.60	5.78	3.82	5.62	3.14
vlaanzn2	Flanders (Jansma, pers. comm.)	6.08	4.17	5.58	5.51	3.18
GBM00007	London (Tyers, pers. comm.)	5.80	3.19	< 3	6.43	< 3
Ofrmidde	W. Friesland (Jansma, pers. comm.)	5.28	4.66	4.21	3.89	< 3
9M456781	W. Denmark (National Museum Denmark)	< 3	3.05	< 3	< 3	< 3

Table 2

Four barrels from Early Ribe, Denmark. Correlation between the means from the four barrels and a mean of three of the barrels combined and master chronologies from Northern Europe. Matrix showing the correlation between the means of these four barrels.

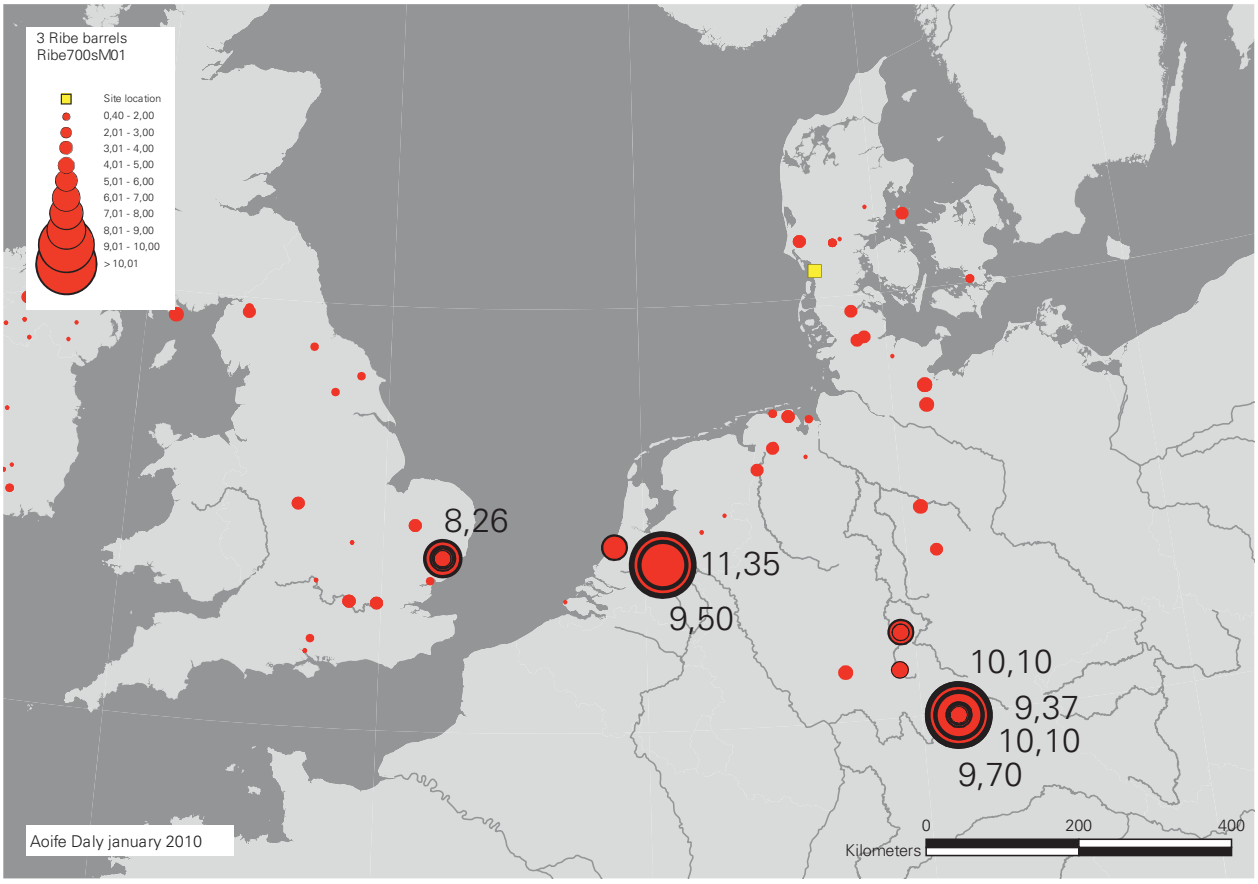


Fig. 2

Three 8th-century barrels from Ribe. Map showing the distribution of correlation values achieved between the mean for the three barrels and single tree-ring measurements from Northern Europe (the third level test).

The southern Baltic Sea coast barrel group

A considerable group of barrels dating from the 14th and early 15th centuries have been found to be of a southern Baltic Sea coast origin. This group consists of barrel staves (or other parts) from several Danish sites, as described here. Just one stave from G. Åby Kirkegaard, Århus dates to after *ca* 1325.[6] Two of four staves from two barrels found at Kathredralskole, Ribe match well together and are from trees felled in *ca* 1320; a mean of these is tested in Table 3. The tree-ring curves from the other two staves could also be dated to *ca* 1315, although the conclusion that the timber was of local Danish origin seems not to be the case: highest correlations for both these series appear also with southern Baltic references.[7] Three staves from Suså, Næstved, were analysed in 2001 (Daly, 2001a). No sapwood was preserved on the staves; the date for the felling of the trees is after 1337.

6. Barrels from G. Åby Kirkegaard and Århus Kathredralskole, Ribe were analysed by Carsten Sønderby.

7. Den Antikvariske Samling, Ribe, archive ASR1445, Carsten Sønderby in analysis report.

Parts of several barrels were analysed from a fortified farmstead in Jutland at Boringholm (Kock, 2005): three staves and three lids. The tree-ring curve from one of the lids matched less well with the remaining five, and therefore this one was left out of the average for the barrel parts. Sapwood on two staves allowed the felling date for the oaks to be placed at *ca* 1372 (Daly, 2005a). Barrel parts from excavations in Skattergade, Svendborg, were analysed in 1982, but no date emerged at the time (Bonde, 1982). Two staves and a board have been dated subsequently: after *ca* 1355, after *ca* 1390 and after *ca* 1400. Right in the heart of Copenhagen a large oak barrel-shaped vat was found in 2000 during excavation in Niels Hemmingsensgade.[8] Three staves were analysed and a felling date for the trees used for the barrel is estimated to after *ca* 1410 (Daly, 2000a). The final barrel in this group was found at excavations in Kompagnistræde, Næstved. It was one of several, but is dealt with alone here, as it showed a different provenance than the other pieces from the excavation. Three oak staves were analysed from it. As the internal correlation (the *t*-value of every tree-ring curve against every other) shows relatively low agreement between the staves, they have been analysed separately: the felling dates for the trees could be placed at after 1400, *ca* 1400–1425 and *ca* 1418–1440 respectively.

As can be seen in the table of correlation for this group (Tab. 3), organised chronologically, all these barrels are made from oak that grew in the southern Baltic Sea coast region. Now the pattern of this period where we find so many timbers of southern Baltic origin is reflected in the results of the shipwrecks dating to the period (for example Bonde and Jensen, 1995; Ważny, 2002; Daly and Nymoen, 2008), and we have seen it in the many analyses of panel paintings, furniture, etc. (for example Baillie *et al.*, 1985; Eckstein *et al.*, 1986; Hillam and Tyers, 1995; Klein, 2003; Haneca *et al.*, 2005; Fraiture, 2009).

Trade in wainscots for panelling in the medieval and early modern periods are just one commodity that was traded across Northern Europe. The barrels presented here represent the more mundane objects that could be made from the same type of material, from similar sources to the wainscot panelling, and might be taken as an indicator of the regions where this material was available for export. Ships' planking can also have been an important timber product exported from forest-rich regions, and many examples of ships built of southern Baltic timber as mentioned above might be ships that were made of southern Baltic timber but built elsewhere. The case of three ships, dating to the first half of the 15th century, found in Copenhagen harbour at Dokøen (Gøthche and Høst Madsen, 2001; Eriksen, 2001a; 2001b; Bonde and Eriksen, 2002) are a key to this discussion (see Daly 2007, p. 220-225). It seems that in this period the enormous amount of southern Baltic timber that we find in the dendrochronological record is confined to finds of planking, panelling and boards, while structural timber is still locally available and utilised (for example Fraiture, 2007). By the early 16th century we see structural oak timber transported long distances (for example Crone and Fawcett, 1998), but when does this become a regular practice? An interesting task that the Northern European dendrochronological community could undertake is to identify the origin of the structural timber (roofing beams for example) to map the rate, chronology and source of building-timber transport.

The "4AM Wreck", Darss, Germany[9]

In summer 2009, a wreck was found off the coast of the island of Darss, Mecklenburg-Vorpommern, Germany, during survey work under the supervision of Jens Auer, from the University of Southern Denmark. The boat is built of clinker planking, but was re-built with an additional layer of carvel planking.[10]

Samples from nine timbers, all of oak (*Quercus* sp.), were dated (Fig. 3a). Sapwood is preserved on five of the samples. Taking the dating results for the material as a whole, and allowing for missing sapwood, the felling date for the trees from which the samples come, is estimated to *ca* 1590.

The internal correlation is shown in Figure 3b. The tree-ring curves from two samples (clinker plank 120 and clinker plank 131) are so alike that it might be suggested that they come from the same tree, and these two are therefore averaged to one tree-ring curve. From the correlation results it is apparent that two distinct groups are represented in the material, so two mean curves have been made: the first mean curve (Z043M001) includes six samples (the clinker planks and two frames, representing five trees), consists of 258 years and covers the period 1320–1577; the second mean (Z043M002) is made from three samples (one of the frames and the two carvel planks), is 196 years in length and covers the period 1394–1589.

It might also be mentioned that the carvel planks are both cut tangentially from the parent timber, while three of the four

8. Excavation was carried out by Copenhagen City Museum.

9. FPL 77. The ship was given the name "4am wreck" as this was the time of day that the archaeologists excavated the find.

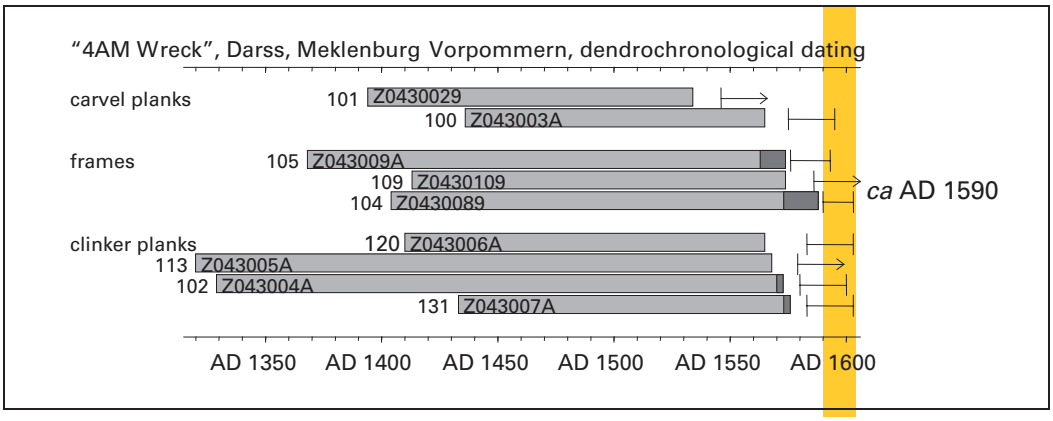
10. Jens Auer, University of Southern Denmark, September 2009, pers. comm.

		G. Åby Kirkegaard Århus	Kathredralskole Ribe	Suså Næstved	Boringholm	Svendborg	Niels Hemmingsensgade Copenhagen	Kompagnistræde Næstved
		WM20 29A14	WM200 5M01	2121 4M01	6013 2M02	4079 M001	2129 M001	B011 1M01
		AD1211	AD1193	AD1138	AD1145	AD1241	AD1125	AD1201
		AD1310	AD1312	AD1321	AD1368	AD1388	AD1399	AD1417
Art-historical	Baltic 1 (Hillam and Tyers, 1995)	3.18	3.62	5.10	6.42	3.16	7.06	4.73
	Baltic 2 (Hillam and Tyers, 1995)	< 3	4.52	< 3	4.97	3.30	7.30	3.66
	Hull Chapel Lane boat planks (Tyers, 2000)	4.29	5.30	4.48	6.32	< 3	13.27	4.72
	London Southwark GAS88 (Tyers, 1996)	< 3	4.04	4.54	5.71	3.43	11.07	3.95
	Hull Yorkshire 37 coffin boards (Tyers, 1998)	5.92	6.98	5.40	8.54	< 3	12.77	5.57
	York Vicars Choral 7 boards (Tyers, 2005)	4.91	< 3	< 3	4.38	< 3	10.70	5.46
	York St Crux Church (IT)	3.42	< 3	3.63	3.90	< 3	11.26	3.73
Poland	Bransk (TW)	< 3	< 3	< 3	< 3	< 3	6.24	< 3
	Pl-Pruszcz Gdański (TW)	3.01	5.71	7.79	5.77	4.54	3.63	3.65
	Pultusk (TW)	< 3	< 3	< 3	4.70	< 3	8.18	3.99
	Kolobrzeg (TW)	6.80	8.31	9.63	11.06	6.10	7.59	10.49
	Gdańsk Pomerania (TW, 2009)	10.67	8.32	6.79	11.21	7.62	9.53	9.28
	Elblag (TW)	9.20	7.73	6.84	10.54	5.90	7.83	7.60
	Gdańsk-St,Nikolaus (TW)	7.22	5.25	5.23	10.15	5.81	5.57	7.39
	Pl-Przezmark (TW)	7.97	6.16	4.72	6.63	5.21	5.68	6.02
	Pl-Starzyno (TW)	6.36	4.11	4.26	5.36	< 3	6.39	7.28
	Pl-Puck Kirche (TW)	5.46	< 3	< 3	6.59	5.69	3.69	6.17
	Elblag (TW)	4.67	3.88	4.40	5.03	< 3	5.50	4.99
	Dabrowno (TW)	3.69	4.19	3.66	6.16	5.03	4.33	3.21
	Szczecin (TW)	< 3	6.59	4.28	5.72	< 3	3.60	< 3
	Gdańsk Wyspa Sp. (TW)	4.16	< 3	< 3	6.29	4.82	5.13	3.74
	Gdańsk/Powroznicza (TW)	< 3	3.82	3.23	3.92	< 3	< 3	3.23
Germany	Schleswig-Holstein (DE)	5.08	5.38	6.80	7.39	3.63	3.56	4.34
	Lübeck (DE)	4.66	6.31	5.56	4.38	< 3	3.24	< 3
	Niedersachsen Nord (HL)	3.54	5.08	4.60	7.14	< 3	5.93	3.52
	Lüneburger Heide (HL)	3.90	4.64	5.02	6.85	< 3	5.68	3.60
	G Weser (HL)	5.67	4.40	3.90	5.48	< 3	5.48	< 3
	Hamburg (DE)	< 3	4.33	< 3	5.13	< 3	4.71	< 3
Denmark	Zealand (NMD)	4.77	3.40	5.33	6.55	< 3	5.28	3.55
	Jylland/Fyn (NMD)	3.08	< 3	5.44	5.43	< 3	< 3	3.88
Sweden	Sydvestskaane (TB)	4.63	3.51	4.92	5.46	< 3	3.69	3.01
	Smaaland-Oeland (TB)	4.22	3.83	< 3	5.09	< 3	4.33	4.09

Table 3

The southern Baltic barrel group. Table showing the correlation between the measurements or means for the southern Baltic barrels and master and site chronologies from Northern Europe. The sources of the chronologies are DE = Dieter Eckstein, Hamburg University, pers. comm., 2004; HL = Hans-Hubert Leuschner, Göttingen University, pers. comm., 2004; IT = Ian Tyers, Dendrochronological Consultancy Ltd., pers. comm., 2010; NMD = National Museum of Denmark; TB = Thomas Bartholin, Lund University, pers. comm., 1997; TW = Tomasz Ważny, Academy of Arts Warsaw, pers. comm., 1999.

A



B

		frame 109	clinker 102	clinker 113	clinker 120	clinker 131	frame 105	carvel 101	carvel 100	frame 104
Z043M001	frame 109	*	3.2	3.82	3.33	4.63	3.86	-	-	-
	clinker 102	3.2	*	6.35	4.26	3.03	-	-	-	-
	clinker 113	3.82	6.35	*	5.04	3.22	3.89	-	-	-
	clinker 120	3.33	4.26	5.04	*	14.67	4.59	-	-	-
	clinker 131	4.63	3.03	3.22	14.67	*	-	-	-	-
	frame 105	3.86	-	3.89	4.59	-	*	-	-	-
Z043M002	carvel 101	-	-	-	-	-	-	*	6.83	4.62
	carvel 100	-	-	-	-	-	-	6.83	*	5.04
	frame 104	-	-	-	-	-	-	4.62	5.04	*

Fig. 3

The so-called "4AM Wreck", Darss, Germany.

A The chronological position of the dated samples from the boat. Heartwood is in light grey, sapwood in dark grey. The yellow marks the estimated felling date range for the trees used in the ship.

B Matrix of internal correlation. Clearly, there are two distinct groups.

clinker planks are cut radially. It is interesting that the timbers from the two groups are both worked differently and used differently in the ship construction.[11]

The results of the correlation between the two mean curves from the ship and master and site chronologies from Northern Europe clearly show that the two timber groups from the ship originate from different regions (Fig. 4 and 5).

The first group, consisting of the four clinker planks and two frames, matches best with a range of chronologies that come from the region around Øresund, i.e. Skåne or Zealand. In addition, the clinker group mean achieves highest correlation ($t = 10.82$, not mapped) with timbers from a shipwreck found at Amager Strand off Zealand's east coast (Daly, 2008). The second group, that consists of the two carvel planks and one frame, achieved the highest correlation with timbers from the towns of Lübeck, Schwerin and Wismar, and with material from rural contexts in west Mecklenburg.[12]

We have quite a number of examples of boats and ships from the 15th and 16th centuries where the timbers used are from different sources, and this example is no exception. It underlines the importance of analysing several samples from any timber structure, as has not always been the practice, since more information can be attained in this way. For this wreck it was already supposed that the boat might have a less simple building history, given the mixed use of clinker and carvel techniques in the construction. The analysis provides us with an estimate of the date for the felling of the trees for the boat, but this is not precise enough to tell us whether there is a time difference between the clinker-built parts and the added carvel construction. In the analysis, however, we can clearly discern two distinct timber groups and the provenance analysis shows us that this is because the groups are from two geographic sources, and these also coincide with the way the planks have been cut from the parent timber. We might ask what determines the preference for radially or tangentially converted planks. Has this to do with the condition of the timber source, or the function for which the plank is intended, or are we seeing regional traditions? A comprehensive analysis of the timber used in shipbuilding, with the chronological and geographic detail that dendrochronology provides, could bring us toward answers to these questions.

Barrels, an overview

Archaeological finds of barrels are a frequent occurrence, particularly on urban sites. These barrels are usually re-used as lining for wells or latrines. As barrels are containers that were made for the transport of a range of products throughout Northern Europe and beyond, their place of origin is not always the same as the place where they were found archaeologically. Therefore, a number of such barrel finds were analysed (Daly, 2007) to determine their date and timber origin. A summary of the results of this analysis is presented in Table 4 and this is ordered chronologically. The barrels are all Danish finds except one barrel from Aberdeen in Scotland and a group of barrels from a shipwreck in Drogheda, on the east coast of Ireland. It might be mentioned that we only analysed oak barrels here. In terms of function, certain wood species might be suitable or unsuitable for certain goods.[13]

There are 28 barrels or barrel groups listed here, although some are represented by just one barrel stave. Can we make generalisations on the basis of the results of these dated barrels, despite the uncertainty of the extent to which these were re-used and transported to and from several markets or sites with a varying range of goods, before they were finally re-used as the lining of wells and latrines? A number of barrel finds have also been analysed in dendrochronology laboratories throughout Northern Europe over the years (for example Eckstein *et al.*, 1975; Houbrechts and Pieters, 1999; Crone *et al.*, 2004). We might take the assemblage here to represent the picture of timber sources, for such objects, through time.

It can be seen that a pattern might be apparent in the barrel results. Three of the barrels in the 8th-century group from the early phase of the town of Ribe, as described above, may represent a single shipment of goods, as the date, correlation and origin for these three are so similar. The barrel results serve to confirm the trading status of Ribe at this early period, and the dates also coincide with the building of a causeway at Nybro (Frandsen, 1999; Ravn, 1999; Daly, 2006) showing increased infrastructure in Ribe's hinterland in this century. Dendrochronological analysis of oak barrels found in the town of Dorestad in the Netherlands resulted in the dating of 34 barrels (Eckstein *et al.*, 1975). The

11. It was not possible to determine how the fourth clinker plank had been cut.

12. Karl-Uwe Heußner, Deutsches Archäologisches Institut, 3 September 2009, pers. comm.

13. It has been suggested for example that oak barrels are not suitable for transporting salt, as the tannin will colour the salt (Jens Vellev, Århus University, 2005, pers. comm.).

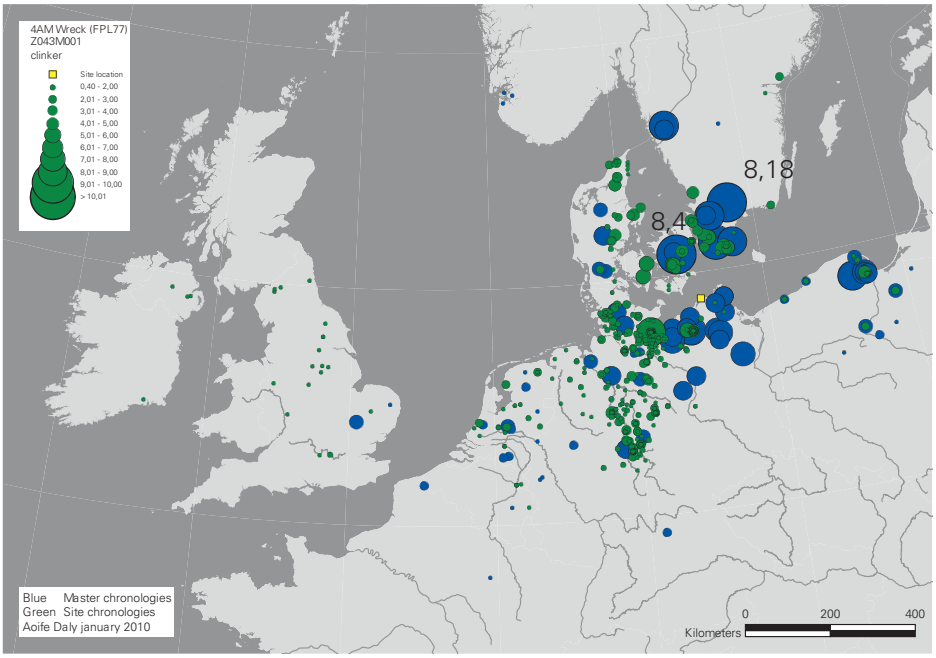


Fig. 4

The so-called "4AM Wreck", Darss, Germany. Map showing the correlation between the tree-ring average from "the clinker group" and master and site chronologies from Northern Europe.

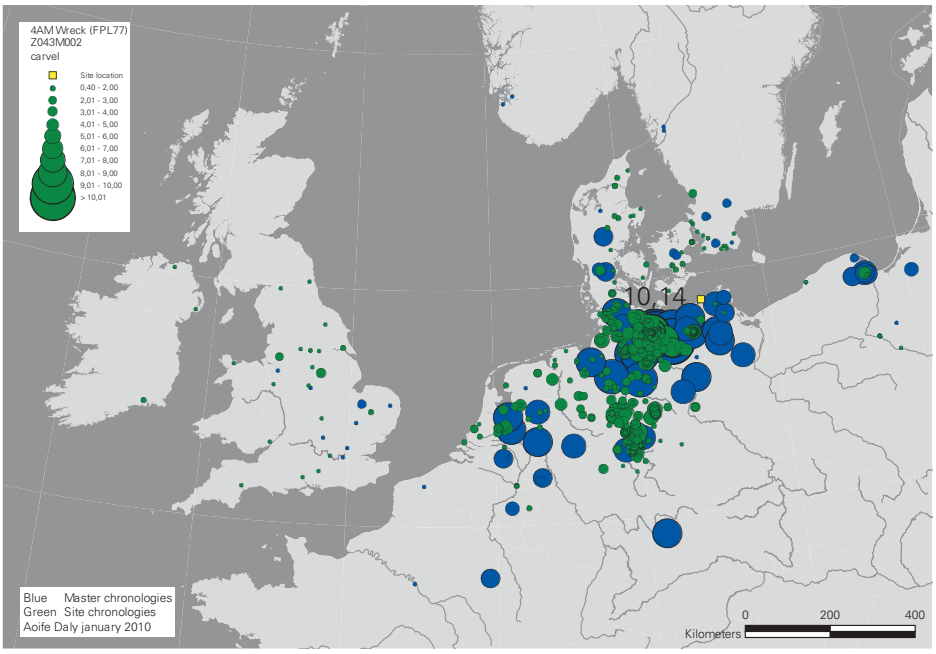


Fig. 5

The so-called "4AM Wreck", Darss, Germany. Map showing the correlation between the tree-ring average from "the carvel group" and master and site chronologies from Northern Europe.

Table 4

Dating and provenance determination of a range of barrels, chiefly from Danish sites.

dates range from late 7th century to mid-9th century, but by far the most were from *ca* 715 to *ca* 770. It was found that the barrels matched best with chronologies from the Mainz region of the Rhine basin. Our Ribe barrels fit very neatly into this group of Dorestad barrels. It is explained that wine from the Rhineland was transported down the Rhine to Dorestad, and it could be from here wine was transported further to Ribe.

The single bucket stave analysed, from the late 10th or early 11th century, reminds us of the expansion of the Viking world at that time, where one piece of a bucket, made from oak from northern England, ended its days discarded on the floor of the Smithy at Viborg Søndersø. Four barrel parts from the 12th century show that at this period a variety of sources for oak appear in the Danish finds. We see one example of local wood, and three examples of barrels of oak from a variety of origins. It can be noted though that all three origins for these 12th-century barrels are western continental Europe. One is from somewhere along the Rhine River in Germany, one from the Burgundy region of France while the third is from coastal Lower Saxony.[14]

Barrel parts from six sites are dated to the 13th century. A reliable provenance could not be identified for two of them, dated from the first half of the century, but a region of origin could be given for the four others, dated from the late 13th century: while some still came from the western European region, now we also find barrels made of oak that seems to come from east of Denmark, in the region of Lübeck.

One barrel from the beginning of the 14th century has a similar provenance as the two Lübeck barrels from the preceding century, after which the picture changes radically. The southern Baltic group is very clearly a chronologically well-defined phenomenon, as the large block highlighted in yellow indicates. From around the 1320s to the 1420s barrels built from southern Baltic oak predominate, which has already been shown, for example, by many barrels dating to the 15th century found at Raversijde in northern Holland that match best with a chronology from Gdańsk (Houbrechts and Pieters, 1999). In fact, all the barrels are of southern Baltic origin except one, which seems to be from the Burgundy region of France. The southern Baltic barrels are very uniform in size, while the French barrel is of different dimensions:

De tonnen zijn onderling zeer gelijkend, men zou haast zeggen identiek. Slechts één ton – deze die vermoedelijk uit Bourgondisch hout is vervaardigd – lijkt iets groter dan de overige" (Houbrechts and Pieters, 1999, p. 255).

The same phenomenon was observed in the case of barrels at Boringholm in Denmark: two barrel lids of identical dimensions are of southern Baltic timber, while a third, larger lid was of timber from southern Germany (Daly, 2005a).[15]

From the 15th century we again see a variety of sources of oak for barrels, reflecting the diversity of traded goods in Northern Europe. Most recently, analysis of eight barrels from a group of 13, found as cargo in a ship in Drogheda harbour, on Ireland's east coast, has been carried out (Daly, forthcoming). Staves from one of the barrels are shown in Figure 6. It has been found that the barrel material matches best with tree-ring data from western France.[16] Again here, most barrels were of a standard, uniform size, and belong within a single group dendrochronologically, but one barrel is of different dimensions, and also sits apart dendrochronologically, thus seeming to come from a different region in France.

In the future it will be possible, by assembling the diverse analyses of barrels finds throughout Northern Europe through collaboration between laboratories, to map the barrel sizes with the dendrochronological provenance determination, and

14. The French barrel, from Præstegade in Ribe, can also be linked to two other barrels, one found in London, England and the other in Perth, Scotland (Crone *et al.*, 2004).

15. The same southern Baltic origin is demonstrated for a large number of ships from this period also (for example Bonde and Jensen, 1995; Daly and Nymoen, 2007; Daly, 2007).

16. Vincent Bernard, University of Rennes 1, 27 November 2008, pers. comm. and Catherine Lavier, Centre de Recherche et de Restauration des Musées de France, 27 November 2009, pers. comm.

17. Information from Christensen K., 1989. *Dommerkontorets Have, Ribe*, NNU archive journal A5820, 4 p.

Name	Type	Dendro no.	Felling	Date	Provenance	Samples	Date length	Museum no.	Report status
Dommerkontorets Have, Ribe	Barrel	7005	After *ca*	705	Rhine Mainz	4	231	NNU A5820	(Christensen, 1989[17])
Giørtzvej	Barrel	W466	After	715	Rhine Mainz	4	263	ASR 990	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Giørtzvej	Barrel	7035	After *ca*	712	Rhine	3	179	ASR 1357	(Daly, 2000b)
Seminarievej Ribe	Barrel	W425	After	750	Southern Germany	5	120	ASR 863	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Viborg Søndersø	Barrel	F008	After	998	Northern England?	1	119		(Daly, 2005b; 2007)
Horsens A130	Barrel	W438	Last ring	1125	Danish local Tamdrup K.	3	138	HOM 505	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Dagmarsgården	Barrel	W575	*ca*	1160	West Germany Rhine	3 × 3	258	ASR 1015	(Sønderby, Wormianum, pers. comm., 2 jan 2007)
Præstegade 13 Ribe	Barrel	7022	After	1160	France	9	185	NNU A7577	(Eriksen, 1995) (Crone *et al.*, 2004)
Ribelund	Barrel	W426	After *ca*	1163	Coastal Lower Saxony	14	117	ASR 926	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Nygade 10, Ribe	Barrel	G001		1210-30	Western continental Europe	1	59	ASR 11	(Daly, 2007)
Skjern Bro	Barrel	7031203A	After	1238	?	1	108		(Daly, 2001b)
Skt Pederstræde Viborg middelalder	Barrel	F0040	*ca*	1270	Sleswig-Holstein / Lübeck	11	132	VSM990C	(Daly, 2007)
Slotsgade 3-7 Ribe	Barrel	W570	*ca*	1273	West Germany Rhine	6	142	ASR 1200	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Saltgade 4 Ribe Brønd A	Barrel	W80	After	1272	France/London	14	112	ASR 2M80D	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Stege	Barrel	3032	*ca*	1280	Sleswig-Holstein / Lübeck	7	178	SMV 7737	(Bonde, 2003)
Horsens A116	Barrel	W439	Last ring	1299	Lübeck / Szczecin	3	143	HOM 505	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Gl. Åby Kirkegård, Århus	Barrel	WM2029	After	1320	Southern Baltic	1	100	FHM 4407	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Kathedralskole Ribe	Barrel	W20718/ 2005	*ca*	1325	Southern Baltic	4	120	ASR 1445	(Sønderby, Wormianum, pers. comm., 2 Jan. 2007)
Suså Næstved	Barrel	21214	After	1337	Southern Baltic	3	184	98:113	(Daly, 2001a)
Aberdeen	Barrel	0056		1350s	Southern Baltic	?	162		(Crone, AOC Archaeology, pers. comm., 1995)
Boringholm	Barrel	60132	*ca*	1372	Southern Baltic	6	224	NNU A5885	(Daly, 2005a)
Svendborg	Barrel	4079	After *ca*	1400	Southern Baltic (weak)	3	148	NU A6382	(Bonde, 1982)
Niels Hemmingsensgade Copenhagen	Barrel	2129	After *ca*	1413	Southern Baltic	3	276	KBH2138	(Daly, 2000a; 2007)
Kompagnistræde, Næstved polish	Barrel	B0111	*ca*	1425	Southern Baltic	3	214	NÆM2004:200	(Daly, 2007)
Brolæggerstræde København	Barrel	B004	After	1466	France	10	100	KBM 2801	(Daly, 2007)
Drogheda boat barrels, Ireland	Barrel	Z022	*ca*	1530s	France	31	146		(Daly, forthcoming)
Pilestræde 8 København fridge	Barrel	B0090	After	1585	West Germany Rhine	3	168	KBM 2897	(Daly, 2007)
Skt Pederstræde Viborg renæssance	Barrel	F0041	Winter?	1652/53?	Lower Saxony Weser	3	220	VSM990C	(Daly, 2007)

Fig. 6

Staves from one of the barrels found in the Drogheda Boat, in Drogheda harbour on the east Irish coast. These barrels were made in the early 16th century, from oak that grew in western France. © A. Daly, dendro.dk

to investigate the regional and chronological traditions and standards.

In conclusion

Due to the cooperation of dendrochronology laboratories over Northern Europe, connections between regions in Europe are shown through the analysis of tree rings. The precise dating that dendrochronology provides, combined with the analysis of the source of the timber, allows a detailed interpretation of Northern Europe's historic timber trade. The potential for even more detail on the types of timbers and timber products that were transported, the techniques and traditions that were prevalent in different regions, on problems of overexploitation of the forest resource, etc., can be tackled with a view to identifying and discussing regional and chronological differences. The examples described above show how such analyses are currently producing new and exciting details, but are just appetizers of the potential this material has for greater insight into Europe's historic timber industry and timber trade. In combining the extensive and detailed information that we have on timber trade, timber workmanship, the timber resource, dendrochronological dating and provenance analysis, across the entire Northern European region, we can describe and analyse details of this important industry. This new discipline could be called "dendro-geography".

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TREE RINGS / ART / ARCHAEOLOGY

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Tree Rings, Art, Archaeology

In 2010 the Royal Institute for Cultural Heritage (IRPA/KIK) organised the *Tree Rings, Art, Archaeology* conference. Its main objective was to bring together dendrochronologists and other researchers – historians, archaeologists and art historians – to discuss the uses of dendrochronology.

The proceedings of this conference bring together articles by authors from fifteen European countries, from different backgrounds and skills. They successively explore the different facets of dendrochronology with a common motto: "Beyond dates". Indeed, more than just a dating tool, dendrochronology provides data through time and space in fields as varied as provenance of the wood, ecology, climate, environment, etc. It is clear that such data obtained are not an end in themselves; they must be integrated within a broader historical approach in order to realise their full potential and significance. To achieve this goal, the need to compare and integrate approaches from researchers with the different skills involved should be self-imposed. However, this is rarely the case. Moreover, such indispensable collaboration should lead to a better knowledge of the potential and limits of the tree-ring approach and thus to better understanding of its contributions. These proceedings are, we hope, a significant step in this direction.

Pascale FRAITURE was the organiser of both the conference and this publication. Doctor in archaeology and art history, she is specialised in the dendro-archaeology of works of art and heads the Laboratory of Dendrochronology at the IRPA/KIK.

The *Scientia Artis* series is published by the Royal Institute for Cultural Heritage (IRPA/KIK, Brussels). The works in this series – monographs, exhibition catalogues and conference proceedings – present the results of research projects and scientific events (co)organized by IRPA/KIK. Since 1948 this Federal Scientific Institution has been charged with the study, protection and promotion of Belgium's cultural heritage.

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