Dendrochronological analysis of 19 Norwegian grain chests

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Abstract

Nineteen Norwegian grain chests made of Scots pine (*Pinus sylvestris* L.) were analysed by measuring tree-ring widths on photographs and scanned pictures. Seventeen of the chests were successfully dated by dendrochronology. Two of the dates are corrections of an earlier dating; the ages of these two chests were verified by radiocarbon dating. The grain chests were expected to be medieval, but four, all without carvings, proved to be post-medieval. The mean curve constructed from the dated chests matches all regional Scots pine chronologies in central and southern Norway and several from southern Sweden. All the chests were probably constructed in central Norway. Originally only sixteen chests were known, but several new ones were discovered in the course of this project.

Keywords: Grain chests, Dating, Medieval, Provenance

Introduction

This paper is a continuation of a previous article (Thun & Alsvik 2009) on dendrochronology performed on four solid wooden grain chests which were constructed in an unusual manner; nineteen have now been analysed. They were expected to originate from Oppdal in central Norway (Fig. 1), but over time the construction technique is likely to have been adopted in other areas. The technique is based on quadrangular, vertical corner posts (Fig. 2), while the fronts and backs normally consist of one or two broad boards. The bottom is fastened with pegs and strengthened with hooks of wood or iron.

Many of the chests have impressive carvings (Fig. 3) whose style, according to Anker (1961), clearly indicates a medieval date (AD 1030 – 1537 in Norway). Anker (1961) also described some of the chests, including the carvings, in detail and referred to them as "grain chests" (Norwegian: "kornbyrer"; more recently called "kornkister"), as he believed they were used to store grain.

All the chests are made from Scots pine (*Pinus sylvestris* L.). This enables dendrochronological analysis based on regional Norwegian chronologies (Thun 2002, 2005), most of which go back to the early Viking period. Some of the chests (nos. 11-15 in Table 1) are now kept near Molde (Fig. 1).

Planing of the outer wood has removed tree rings from the boards in most of the chests and a dendrochronological dating of the last remaining ring would therefore indicate their age as a "*terminus post quem*". Four of the chests were dendrochronologically analysed and described by Thun & Alsvik (2009). This gave a surprising result as two were apparently post-medieval (nos. 1 and 4 in Table 1). This result was strongly at odds with the construction technique (Thun & Alsvik

2009). A project was therefore started that included dendrochronological analysis of more chests, measuring all the available radii. It also included ^{14}C dating of chests 1 and 4 (Table 1). The ^{14}C dating was performed by the SUERC Radiocarbon Dating Laboratory at the University of Glasgow.

Originally, only 16 chests were known (Thun & Alsvik 2009), but new ones were discovered while those chests were being analysed (Table 1).

Aims

The main aim of this study was to find out whether all the chests were medieval in origin, or if the construction techniques were copied in the post-medieval period. We also wished to test the provenance of grain chests of this type which are found stored at several locations.

Method

As the chests are items of archaeological significance it was not possible to take cores. Tree-ring widths were therefore measured on photographs and scanned pictures from various radii on all the available boards. Originally, the tree rings were measured *in situ* with a micro-lens, but this did not permit any check of the measurement after returning to the laboratory. Instead, the radii were photographed and even very narrow tree rings could successfully be measured. The cross-section is often not available due to the construction technique (Fig. 2). Therefore the only available radii are along the longitudinal section of the board. Measurements along the longitudinal section have been successfully used to date planks from various building phases in the walls of three Norwegian stave churches (Bartholin 2002, 2008, 2014, Stornes et al. 2013, Thun 2012, Thun & Stornes 2014) and wooden artefacts from Scots pine (Føllesdal 2005, Myhr et al. 2007). For most of these objects, measuring tree rings along the longitudinal section was the only option as the cross-section of the material is not available (cf. Fig. 2).

As the tree rings were visible in most of the chests, accurate measurements could be performed, but in some cases the radius to be measured had to be thoroughly cleaned with water (Fig. 2). White tape (Myhr et al. 2007:183) was put along the section to be measured and every tree ring was marked on the tape to avoid missing rings during the measurement. The gaps between the marks on the tape were also measured in addition to the measurement of tree rings on the photograph. This resulted in the same tree-ring pattern, but only the measurements on the photograph were used. The procedure is fully described in Myhr et al. (2007).

The outermost tree rings had been planed away on every sample, but the number of rings in the sapwood was noted when present (Table 1). Sometimes it can be difficult to determine whether sapwood is present on conifers. Consequently, in Table 1, the number of sapwood tree rings is noted, but question marks are used when there is doubt. For oak (*Quercus* sp.), an estimate of missing tree rings in the sapwood can normally be given with high precision if all the heartwood is present (Baillie 1982, Schweingruber 1989). It is more difficult with conifers, but Gjerdrum (2002, 2013) constructed a formula to estimate missing sapwood if the number of rings in the heartwood is known. Most of the sapwood is present in the post-medieval chests in Table 1, and the outer dated tree ring is therefore probably close to the felling year. The medieval chests on the other hand are more problematical as sapwood is not detected. If only the sapwood is missing, the formula presented by Gjerdrum (2002, 2013) gives an estimate of the felling years for the medieval chests from 1265 to 1380 (Table 1). It shows that all the chests are medieval and were felled during a hundred year period from approximately the mid-13th century.

The dendrochronological processing was performed with the CATRAS program package (Aniol 1983) using the t-test (Baillie & Pilcher 1973) and the percentage of agreement (Eckstein & Bauch 1969), referred to as the sign test. The tree-ring pattern from individual boards was cross-dated and the mean curves compared with all the Norwegian Scots pine chronologies presented by Thun (2002, 2005) and also a recent, still unpublished, Scots pine chronology from Molde (Fig. 1), (see Table 2). The Molde chronology, constructed by the first author, is based on 52 samples of recently felled trees and timber logs. It only goes back to AD 1320, but may be able to suggest whether post-medieval dated chests might originate from this area. Comparison was also performed between the mean curves constructed from the chests and Swedish Scots pine chronologies constructed and provided by Thomas Bartholin. These chronologies are based on material from Jämtland, Härjedalen, Hälsingland and Dalarna (Fig.1).

Samples for ^{14}C dating were taken from the 10 outermost tree rings in chests 1 and 4. The results as calibrated years AD are in Table 1. The chests were numbered from 1 to 19 according to the order they were analysed.

Results

Dendrochronological dating

Seventeen of the nineteen chests were dated with dendrochronology and they all match the Scots pine chronology from central Norway (Thun 2002, 2005), (Table 1). An internal cross-dating between each chest was performed (Table 2). The match with the regional chronologies, however, gave much higher correlation values as the chronologies consist of many samples with a sensitive tree-ring pattern. Four of the chests (nos. 9, 11, 12 and 14 in Table 1) are post-medieval and the mean curve from AD 1263 to 1688 from these four chests matches the Scots pine chronology from central Norway with a t-test of 7.5 and a sign test of 62.1 % (Table 3). The remaining dated chests are all medieval and a mean curve from AD 996 to 1298 from these chests matches the Scots pine chronology from central Norway with a t-test of 6.6 and a sign test of 66.4 %. No match was found for chests 10 and 19 (Table 1). Additional radii were measured on chests 1 and 4 and the results show that all four chests presented by Thun & Alsvik (2009) are medieval.

A mean curve constructed on measured radii from all the dated chests covers the period AD 996 – 1688. This chronology matches the chronology for central Norway with a t-test of 11.9 and a sign test of 66.7 % (Table 3). The high t-test with the mean curve from all the chests is due to the large number of overlapping years, but the sign test shows the same percentage and significance level as the mean curves from individual chests. As shown in Table 3, the mean curves constructed from the chest also correlate with the other regional tree-ring chronologies from south-east Norway and west Norway, respectively (Fig. 1). In addition to the mean curve based upon measured radii from all the chests, two separate chronologies, one based only on the medieval chests and the other only on the post-medieval chests were constructed, and both match with the regional chronologies in Norway (Table 3). There is no match between the regional pine chronology from west Norway and the medieval mean curve, probably because most of the medieval chests originate from inland central Norway. The post- medieval chests on the other hand, with the exception of chest 9, originate from the Molde district and may have more coastal climatic signals that match the chronology from west Norway (Table 3). Four unpublished Scots pine chronologies from southern Sweden, all constructed and provided by Thomas Bartholin, also match the mean curve based upon all the chests and the mean curve from the post-medieval chests. However, the poor correlation between the medieval chests and the Swedish chronologies may be because of less material in the oldest part of the Swedish chronologies.

Dendrochronological dating of chests 10 and 19 (Table 1) was unsuccessful. Both chests have narrow tree rings and are therefore difficult to measure. The compressed growth pattern may indicate that the tree rings in these chests experienced suppressed growth. Thirteen of the chests have their outer dated tree ring from the 1100s and 1200s and are clearly medieval. The medieval chests, and the undated chest no. 19, have carvings (Fig. 3), while none of the post-medieval chests have carvings.

^{14}C dating of the outermost tree rings in chests 1 and 4

The calibrated age of chest no. 1 in Table 1 is 1174 – 1266 cal. AD with 95.4% probability (Lab. code SUERC-47386 (GU31341), radiocarbon age BP: 817±26), and that of chest no. 4 in Table 1 is 1166 – 1266 cal AD with 95.4% probability (Lab. code SUERC-47385 (GU31340), radiocarbon age BP: 821±29). Radiocarbon ages are given in years before present, i.e. before 1950. The calibrations were done in OxCal v. 4.1.7. (Bronk Ramsey 2009, Reimer et al. 2009). The dated samples from both chests were taken from the 10 outermost tree rings along the measured radius. Including the correction of the age of chests 1 and 4 (Table 1), 19 chests have been analysed by dendrochronology. The results are in Table 1.

The dendrochronological dating of chests 1 and 4 (Table 1) is based on measurements along all available radii and is in accordance with the ^{14}C dating, the construction technique and the carvings.

Provenance

The dated chests have a tree-ring pattern that matches the Scots pine chronology from central Norway (Thun 2002, 2005). The four post-medieval chests, nos. 9, 11, 12 and 14, have also been compared with the newly constructed chronology from Molde. Three of them, nos. 11, 12 and 14, are now in locations near Molde. Their tree-ring patterns match internally and their mean curve matches the Molde chronology for the years 1320 – 1688 with a t-test of 6.9 and a sign test of 64.8 %, while they match the chronology from central Norway with a t-test of 6.5 and a sign test of 61.6 %. Chest 9, which is in Oppdal, matches the chronology from central Norway for the years 1414 – 1683 with a t-test of 5.9 and a sign test of 63.0 %, but does not match the Molde chronology and it is likely to have been constructed in Oppdal. Nine additional, narrow tree rings in the outer wood date this chest to after 1692 (Table 1).

The medieval chests numbered 13 and 15 in Table 1 are in private residences near Molde, but as the Molde chronology only goes back to AD 1320, a more precise provenance than central Norway cannot be determined for these chests.

Discussion

An important topic for this work is how to deal with the "surprising" results presented by Thun & Alsvik (2009). High correlation values can sometimes occur in wrong positions, especially if mean curves are constructed on few samples from an object. The right procedure would therefore be to perform a wider investigation, primarily to measure more samples from the object and increase the quality of the mean curve; this normally provides a correct date. It is always important that not only the correlation value is considered. Ultimately, the visual matching of the tree-ring pattern – with sufficient overlap – is the deciding factor as to whether the dating is correct. The other fundamental requirement is that there be sufficient replication of samples in constructing mean curves; the absence of this in the previous study led to the incorrect dating of chests 1 and 4 in Thun & Alsvik (2009). When, in addition, the discrepancy between the dendrochronological dating and the cultural historical dating was several centuries, the result should have been more thoroughly investigated. If too few samples are available, it is correct to consider the object as undated, cf. chests 10 and 19 (Table 1). If the discrepancy is several centuries, obtaining a ^{14}C date is an additional means of providing necessary confirmation, as in the case of chests 1 and 4.

This article is a follow-up of Thun & Alsvik (2009), which analysed four chests using dendrochronology. As 19 chests have now been analysed, a better foundation is provided to date the material. Chests 1 and 4 were misdated in the previous article (Thun & Alsvik 2009). Their dendrochronological dating is now corrected, and ^{14}C dating validates the result.

Although several tree rings are missing from the outer wood because the boards were planed, dating of the outer tree ring to the 1100s or 1200s clearly indicates that the chest in question is medieval and, according to the formula presented by Gjerdrum (2002, 2013), indicates a date from the mid-13th century to approximately the mid-14th century. Since dendrochronology suggests that hardly any building activity took place during the first decades after the Black Death (Thun 2002: 170, 172), when the population was decimated, few or no new grain chests would be required. This is also in accordance with historical data (Dybdahl 2012), which describe the period as being dominated by climatic and demographic crises when grain crops did not ripen.

Anker (1961) described in detail the chests that were known at that time and deduced that the construction technique originated in central Norway. As the chests are now found in various parts of Norway, the mean curves from the chests were compared with all the Norwegian regional chronologies presented by Thun (2002, 2005). All the dated chests matched the chronology from central Norway, showing that they originated in this part of the country. This is in accordance with the historical and art-historical analysis presented by Anker (1961).

All the chests dated to the medieval period in Table 1 have carvings on the front, some with impressive details (Fig. 3). On the other hand, none of the post-Reformation chests have carvings. The solid, stable construction of these chests may be one reason why they continued to be built in the same way into the post-Reformation period. They were, however, made only for utilitarian purposes, to store grain, and little or no effort was put into decorating them.

Although the juvenile tree-ring widths normally are broader in the longitudinal section than the cross-section, the relative variation gives much the same year-to-year pattern as the measurements along the cross-section do (Føllesdal 2005). The originally misdated chests (Thun & Alsvik 2009), nos. 1 and 4 in Table 1, clearly demonstrate the necessity to measure all available radii on all available boards in a chest. Originally, only two boards were measured on chest 4 and the wrong position gave high correlation values and a matching tree-ring pattern, even though the series contained more than 150 tree rings (Thun & Alsvik 2009: 73). The results presented in this paper are therefore based on mean curves from each chest containing measurements from all the available boards and radii.

We have been unable to match the tree-ring patterns of chests 10 and 19 with any Scandinavian conifer chronology. The construction technique indicates that chest 10, which lacks carvings and is smaller than the other chests, may represent a post-medieval revival of the construction technique. Chest 19, which is also undated but has complex carvings, is rather big and probably medieval.

Conclusion

Seventeen of the nineteen investigated chests were dated by dendrochronology using a non-destructive method. Thirteen of the chests were constructed from trees felled in the medieval period, and four are post-medieval. Only the medieval chests have carvings. Radiocarbon dating of two of the chests confirms that measurements obtained from photographs of longitudinal sections give accurate dendrochronological results.

Two of the dating results given by Thun & Alsvik (2009) are now corrected. The new results are based on several measurements from every object and all the chests correlate with the regional chronology from central Norway, indicating their likely provenance. Chest 9 may have originated near Oppdal, and chests 11, 12 and 14 probably originated near Molde in central Norway. The mean curve not only matches the regional chronology from central Norway, but also regional chronologies from southern Norway and southern Sweden.

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Figure captions

Fig. 1. Map showing places referred to in the text.

Fig. 2. Decorative carvings on chest 8 in Table 1, Bakk in Orkdal. The tree rings were photographed and scanned (using an HP Scanjet 5300c) as demonstrated. The measured radii had to be thoroughly cleaned to reveal the tree rings.

Fig. 3. Detail of the carving on chest 8 in Table 1 and Fig. 2, Bakk in Orkdal.

Table 1. The analysed chests numbered. NF = Norsk Folkemuseum (Norwegian Museum of Cultural History) in Oslo (chests 16-18). STF/FTT = Sverresborg Trøndelag Folkemuseum (Sverresborg Trøndelag Museum of Cultural History) in Trondheim (chests 5-8). ^{14}C dates are given in calibrated ages AD, the calibration being based on Reimer et al. (2009). See body text for radiocarbon ages.

Table 2. Internal cross-dating between the chests. U = undated. X = no overlap.

Table 3. Correlation values between the mean curves constructed from all the chests and the regional chronologies in southern Norway.

No.	Name/Origin	cal. age AD	Sapwood tree rings	Carvings	Outer tree ring (AD)	t-test sign test central Norway	t-test sign test west Norway	t-test sign test south-east Norway
1	Bø in Oppdal, private	1174-1266	0	Yes	1192[a]	5.3 62.9		3.4 60.0
2	Vang[b]		0	Yes	1210	4.2 60.0		4.3 65.8
3	Lo in Oppdal, private		0	Yes	1250	4.5 63.0		
4	Skrea in Oppdal, private	1166-1266	0 ?	Yes	1252[a]	4.0 60.4	3.2 67.4	3.6 61.7
5	Dørdal in Orkdal; now at STF		(40)	Yes	1269	5.0 64.1		4.5 58.5
6	Now at STF[c]		0	Yes	1208	3.6 64.2		
7	Now at STF[d]		(16)	Yes	1258	4.2 61.0		
8	Bakk in Orkdal; now at STF[e]		0 ?	Yes	1280	5.4 60.2		
9	Innestu, Vognill 241/1; now at Oppdal Museum		40	No	1692	5.9 63.0	3.4 59.5	
10	Skårvollen in Støren		0 ?	No	Undated	-		
11	Kvernberg, private		48	No	1539	4.6 58.9	4.6 66.3	
12	Skalle, private at Kleive		65	No	1640	6.7 61.0	4.2 62.8	3.9 57.1
13	Gujord, Romsdal Museum		0 ?	Yes	1245	3.5 64.5		
14	Rødven, private		80	No	1688	4.7 58.7	4.3 60.0	
15	Myklebostad, private at Vistdalen		80 ?	Yes	1298	5.1 58.2		3.0 59.5
16	Løkke in Rennebu. NF 1927 174		0	Yes	1197	5.4 64.3		
17	Nyhus, Horg in Melhus; now at NF, 1931 0135		0 ?	Yes	1274	7.0 64.1		7.0 64.1

18	Nordgård in Meldal; now at NF, 1927 1584		0 ?	Yes	1231	6.3 68.7	3.1 58.7	2.4 57.0
19	Egga in Oppdal, private		0	Yes	Undated			

[a] Corrected age

[b] Now in a church in Oppdal

[c] FTT 36496. Unknown origin

[d] FTT 36497. Unknown origin. The last measured tree ring is from 1239, but the outermost narrow tree rings are also added to reach 1258

[e] FTT 00086 (Figs. 2 and 3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	\				4.3 68.2				X	U	X	X		X	3.9 62.3			3.1 62.3	U
2		\							X	U	X	X		X	2.8 64.2				U
3			\						X	U	X	X	2.6 64.6	X					U
4				\					X	U	X	X		X				2.0 66.8	U
5	4.3 68.2				\	2.0 59.7		4.4 65.3	X	U	X	X	4.2 62.3	X	4.8 64.6		4.0 62.1	3.6 62.3	U
6					2.0 59.7	\		1.4 62.5	X	U	X	X		X		2.6 62.1			U
7							\		X	U	X	X		X					U
8					4.4 65.3	1.4 62.5		\	X	U	X	X	2.6 62.5	X	3.4 60.0				U
9	X	X	X	X	X	X	X	X	\	U	0.8 60.2		X		X	X	X	X	U
10	U	U	U	U	U	U	U	U	U	\	U	U	U	U	U	U	U	U	U
11	X	X	X	X	X	X	X	X	0.8 60.2	U	\	6.9 63.5	X	3.0 58.4	X	X	X	X	U
12	X	X	X	X	X	X	X	X		U	6.9 63.5	\	X	3.6 57.3	X	X	X	X	U
13			2.6 64.6		4.2 62.3			2.6 62.5	X	U	X	X	\	X					U
14	X	X	X	X	X	X	X	X		U	3.0 58.4	3.6 57.3	X	\	X	X	X	X	U
15	3.9 62.3	2.8 64.2			4.8 64.6			3.4 60.0	X	U	X	X		X	\		4.3 60.9		U
16						2.6 62.1			X	U	X	X		X		\			U
17					4.0 62.1				X	U	X	X		X	4.3 60.9		\		U
18	3.1 62.3			2.0 66.8	3.6 62.3				X	U	X	X		X				\	U
19	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	\

	Mean curve All chests	**Mean curve Post-medieval chests**	**Mean curve Medieval chests**
Central Norway	t-value = 11.9 sign test = 66.7 AD 996 - 1688	t-value = 7.5 sign test = 62.1 AD 1263 - 1688	t-value = 6.6 sign test = 66.4 AD 996 - 1298
West Norway	t-value = 5.3 sign test = 60.8 AD 996 - 1688	t-value = 4.1 sign test = 62.8 AD 1263 - 1688	No match
South-east Norway	t-value = 5.6 sign test = 59.3 AD 996 - 1688	t-value = 4.0 sign test = 56.6 AD 1263 - 1688	t-value = 3.2 sign test = 61.6 AD 996 - 1298
Molde	t-value = 6.3 sign test = 64.0 AD 1320 - 1688	t-value = 6.1 sign test = 62.4 AD 1320 - 1688	No overlap

Figure 1


Figure
North Norway
South
Norway
Molde
Trondheim
Jämtland
Oppdal
Central
Härjedalen
Hälsingland
Dalarna
West
South
east
Oslo
Sweden
0 100 200 km

Figure 2

Figure 3