Dendrochronological dating of Roman time

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Abstract

Based on published and otherwise available tree-ring data, we have analyzed the dendrochronological support for the current dating of Roman activities in western Europe. Among other things, we have reconstructed the Belfast oak chronology with its gaps and depletions, and found the current links to be too weak to make a definitive statement about the continuity into Roman time of the reviewed curves.

We have then found a distinct correlation between recent Danish and Norwegian oak curves, and supra-long pine curves from northern Scandinavia. Moreover we have found a distinct correlation between a long north-west European oak curve anchored archaeologically in Roman time, and the Scandinavian pine curves, but 218 years later than expected. There is no correlation at or near to the expected point of match.

To resolve this problem, more data – still not available – would need to be analyzed, but from a dendrochronological point of view we can not exclude the possibility that Roman time is conventionally dated too old by more than 200 years.

Introduction

Chronology criticism (in German "Chronologiekritik", in English "Revised Chronology") is an umbrella term for various hypotheses doubting the correctness of the historical course widely accepted by historians (i.e. the established historical model). These hypotheses claim that historical events have to be redated and/or that historical eras never took place, which would imply invented years in our history. The academic community has definitely rejected chronology criticism in this form.

When the first long continuous tree-ring chronologies were announced in Europe about 30 years ago, they were claimed to confirm the conventionally assumed length of the Christian era, i.e. about 2000 years between our time and Western Roman Emperor Augustus. Moreover, these tree-ring chronologies were used to build calibration curves for radiocarbon dating which allowed floating chronologies from e.g. ancient Egypt to be placed on the time line. However, this prompted the chronology critics to reject dendrochronology and also radiocarbon calibration (e.g., Newgrosh 1992, Blöss & Niemitz 2000) as the dates generated with the new methods did not fit their hypotheses. But there were critics also among historians and dendrochronologists, who complained about inconsistencies and lack of transparency concerning methods and data (Baatz 1977, Cüppers 1979, Baatz 1983, Lambert & Lavier 1991, Seigne 2007).

The main subject of our work has been to prove with dendrochronology alone, if possible, where tree-ring sequences measured from wood with archaeologically Roman origin fit on an absolute time line, in order to reject or confirm the existence of invented years in the Christian era.

The long and supra-long tree-ring chronologies of Europe

The first prerequisite for our project was to find demonstrably continuous tree-ring chronologies with an absolute anchor in living trees and with at least 2500 years length. As the Romans seem to have preferred oak as construction wood, there are considerable amounts of internally well replicated tree-ring sequences with archaeologically Roman origin from Germany, France and England. Therefore we first had a look at the more than 2000 years long European oak chronologies.

In 1984, a continuous oak tree-ring chronology for western Europe, which spanned more than 7000 years, was announced as completed (Pilcher *et al.* 1984). It was a joint venture by the dendro-labs in Belfast, Köln and Stuttgart Hohenheim, involving oak chronologies from the north of Ireland, northern Germany and southern Germany. This joint venture was necessary because neither the Irish nor the German chronologies were at that time stand-alone, with the weakest link in the Irish chronology then thought to be at 250 BC, and in the German chronology at 550 BC where there was actually an error and the article added in 71 extra years at that point.

Furthermore, in order to connect the BC chronology to the absolute AD chronology, additional material had been necessary. In the Belfast case, the English chronologies from Carlisle and Southwark were used as a bridge. In Germany, the link between late BC/Roman time and early medieval time was reinforced by the West German chronology of Ernst Hollstein.

The German oak chronologies

Köln, Hohenheim, Bernd Becker

The raw measurement series from both Köln and Hohenheim are still unpublished and unavailable to us. Though it is claimed that the Hohenheim chronology now confidently bridges the so called "Hallstatt gap" at 550 BC (Friedrich *et al*. 2004), this is nothing we can verify.

For a suitable reference curve over the past 2350 years, the Hohenheim lab (M. Friedrich, personal communication) refers to Bernd Becker's oak chronology from southern Germany (Becker 1981).

Ernst Hollstein

The only so far available German detail-data (not the raw data though) is published as "Jahrringtafeln" by Ernst Hollstein (Hollstein 1980). We retrieved 174 single-site mean value curves from the hand drawn tables (details available at: http://www.cybis.se/forfun/dendro/hollstein). These mean value curves form a 2698 years long chronology (724 BC to AD 1974) which matches the Becker chronology with corr. 0.62, t=37.8 at 2317 years overlap (Hollstein normalization used if not otherwise specified).

We then analyzed the internal consistency of the Hollstein chronology with CDendro (see ref.), using the Hollstein normalization and the following criteria: we excluded all sequences shorter than 100 years, and required a correlation coefficient of at least 0.40, a t-value of at least 6.0 and a minimum overlap of 70 years.

This resulted in an absolute, continuous chronology (HollsteinRecent, AD 383 to1974) and a floating continuous chronology containing a lot of archaeologically Roman sequences (HollsteinRoman, 546 BC to AD 315). Dating reports and downloads are available at: http://www.cybis.se/papers/data1 .

We excluded Hollstein's youngest Roman mean value sequence, the Rhine bridge in Köln (AD 149 to 336), from our HollsteinRoman chronology even though it fits convincingly in its older part. This is because we suspect an error at about AD 250, and because the sequence does not match too well against the Becker chronology.

Hollstein used, except for the Köln Rhine bridge, three site collections to bridge the gap between the two chronologies: Broichweiden (AD 129 to 365), Köln Knabengrab (AD 273 to 511) and Berlegem (AD 284 to 550). But these site collections do not by a long way fulfil our criteria for cross correlation and can therefore neither be incorporated in the chronologies, nor be regarded as providing a credible bridge. Figure 1 and Table 1 describe the relation in time of the sequences involved, and their crossdating quality with the dating assumed by Hollstein. The Becker master chronology is present as a reference.

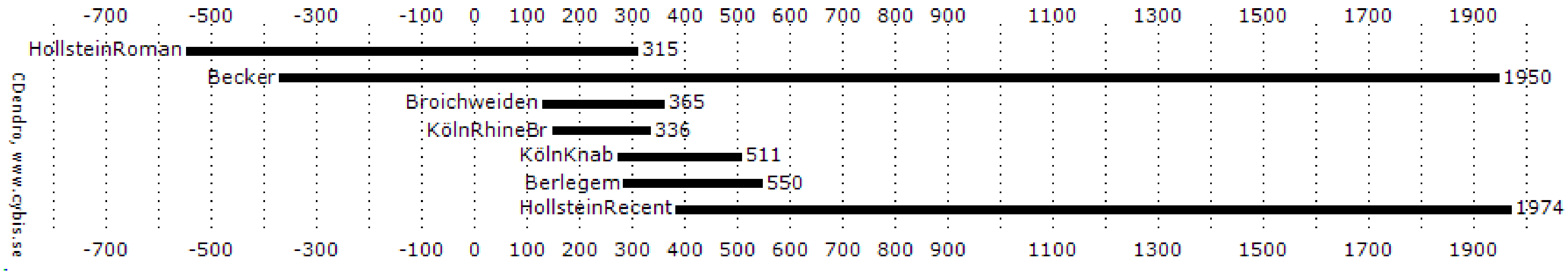

Figure 1: Time line diagram for the conventionally assumed dating; Becker master chronology and Hollstein sequences bridging the period known as the "Migration gap".

		Becker			HollsteinRecent			HollsteinRoman			KölnRhineBr			KölnKnab			Berlegem			Broichweiden		
Sortkey		19,2			14,7			9,2			6,0			4,0			3,9			3,6		
	Years	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap
Becker	2320				0,70	38,2	1567	0,51	15,7	684	0,26	3,6	187	0,21	3,2	238	* 0,17	2,8	266	* 0,03	0,5	236
HollsteinRecent	1592	0,70	38,2	1567										0,27	3,2	128	0,21	2,8	167			
HollsteinRoman	861	0,51	15,7	684							0,61	9,8	166	* 0,17	1,1	42	0,01	0,1	31	* 0,17	2,3	186
KölnRhineBr	188	0,26	3,6	187				0,61	9,8	166				0,44	3,8	63	* 0,18	1,3	52	0,30	4,3	187
KölnKnab	239	0,21	3,2	238	0,27	3,2	128	* 0,17	1,1	42	0,44	3,8	63				0,30	4,8	227	* 0,16	1,5	92
Berlegem	267	* 0,17	2,8	266	0,21	2,8	167	0,01	0,1	31	* 0,18	1,3	52	0,30	4,8	227				0,41	4,1	81
Broichweiden	237	* 0,03	0,5	236				* 0,17	2,3	186	0,30	4,3	187	* 0,16	1,5	92	0,41	4,1	81			

Table 1: Crossdating quality at the conventionally assumed position, Becker master chronology and Hollstein sequences bridging the "Migration gap".

(An '*' indicates a very low correlation value though the overlap is not too low (corrCoeff < 0.2 and overlap > 40). Sortkey is used to let the member with the best mean value match towards any three other members appear in the left upper corner of the table.)

Table 1 shows the excellent compliance of the two Hollstein main chronologies with the Becker master. The correlation of the HollsteinRecent chronology is better than that of the HollsteinRoman chronology probably because Becker and Hollstein partly used the same samples for this time, e.g. the tree coffins from Oberflacht, Hüfingen and Zöbingen.

However, the three site collections forming the bridge do not correlate properly with the Hollstein or Becker chronologies. Although both Berlegem and Köln Knabengrab probably are synchronized and dated correctly, this can not be demonstrated with the available reference curves.

Therefore, the overall conclusion concerning Hollstein's West German oak chronology is that it fails to bridge the gap in the fourth century AD and, consequently, that its Roman block is floating. The bridge in the Becker chronology can not be analyzed as the raw data is not available.

The Belfast oak chronology

The Irish oak chronology announced in 1984 (Pilcher *et al.* 1984) spanned more than 7000 years, but with two important gaps at 950 BC and the BC/AD transition which had to be bridged with English sequences. In 1995, M.G.L. Baillie (Queen's University Belfast, QUB) described the history behind this chronology from an Irish point of view in his book *A Slice Through Time*. A recent paper (Brown & Baillie 2012) confirms that the original gaps and depletions in the Irish oak tree-ring record are still evident.

In 2010, the complete QUB raw data was published on the Internet, unsynchronized and undated but with site information, as 9500 single files. This publication allowed us to check the consistency of the Irish oak chronology according to the references mentioned above. Again we used CDendro with the Hollstein normalization and the following criteria when building site collections: we excluded all sequences shorter than 100 years, and required a correlation coefficient of at least 0.35, a *t*-value of at least 6.0 and a minimum overlap of 70 years. Mean value curves of our site collections including dating reports are available at http://www.cybis.se/papers/data1 .

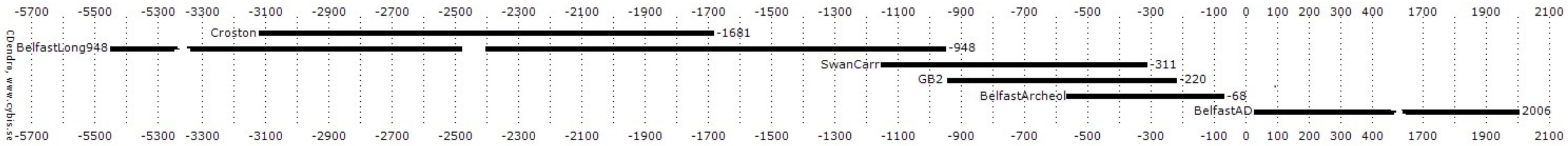

Figure 2: Time line diagram for the conventionally assumed dating of the Belfast oak chronology.

Summing up, we agree with the description of the Belfast oak chronology according to Brown & Baillie (2012), with the following comments and exceptions:

The gap at 2400 BC

This gap is not mentioned in the recent paper by Brown and Baillie, but we actually find a gap between 2479 and 2405 BC which we are not able to close with Irish sequences. However, the gap is confidently bridged by an English collection from Croston moss (3123 to 1682 BC, 1442 years long with almost equal overlaps on both sides of the gap, corr. 0.30, *t*=8.4 and corr. 0.39, *t*=10.6, respectively).

This gap is discussed in Baillie *et al.* (1983), under the heading "The 1546 link". In that paper the gap is bridged by the sample Q1546 and the link is called "weakest link in the Belfast Long chronology". We cannot reproduce the link described in that paper.

The 9th century AD depletion

We found two samples labelled "Ballinderry" which stretch over the weak period AD 839 to 895: Q9850, dated AD 804 to 1041, and Q9846, dated AD 782 to 1021. This is worth mentioning as there is no other Irish timber bridging the gap, except the ship timber with almost the same range found at Skuldelev,Denmark, but originating from Ireland.

The Swan Carr collection

Our interpretation of the QUB samples labelled "Swan Carr" is an 844 years long collection, conventionally dated 1155 to 312 BC. QUB always refers to a length of 775 years, dated 1155 to 381 BC (e.g. Baillie 2009). We do not know when this dating appears for the first time, but in a paper (Hillam *et al.* 1990) we find Baillie *et al.* (1983) as the reference for Swan Carr, though the dating is not mentioned there.

A look into our SwanCarr collection reveals that there is only one sample reaching to the fourth century BC, Q4415. This sample is 327 years long and matches well (corr. 0.48, t=8.1, 218 years overlap) towards the rest of the collection. The end date is 312 BC. To get an end date of 381 BC, this sample has to be truncated (there is no other sample labelled "Swan Carr" which produces an end date of 381 BC). But there is no reason to truncate Q4415; though it is only one stem it matches in its full length towards Garry Bog 2 (GB2; corr. 0.35, t=6.6). Therefore we suspect that QUB's end year 381 BC is just an early writing error which never has been corrected.

The gap at 948 BC

We also agree with the description of this gap in the recent paper by Brown and Baillie, except for two points.

1) The crossdating quality of the match of Swan Carr towards the Belfast Long chronology is given as a t-value of 7.6 at 206 years overlap in figure 4 of Brown & Baillie 2012. This high value is due to a drawing error; the best match is still claimed to be t=4.7 (Baillie *et al.* 1983) (D. Brown, personal communication).

2) We found a 380 years long oak curve from Ballymacombs More (Q10705M, measured in 2009, dated 1210 to 837 BC) extending the Belfast Long chronology by 112 years with a convincing corr. 0.49, t=9.2. But there is no match towards Garry Bog 2 (GB2; corr.

0.13, t=1.4 at 110 years overlap, see table 2) though Garry Bog 2 also contains samples from that same Ballymacombs More, especially in the oldest overlapping part.

Figure 3 and table 2 show the relation in time of the collections and samples involved in the 948 BC gap, and the quality of their matches with the proposed dating.

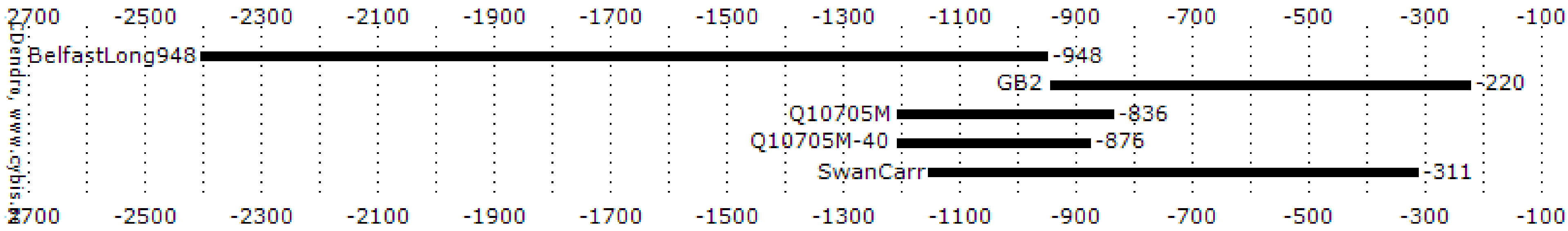

Figure 3: Time line diagram for the conventionally assumed dating, bridging the 948 BC gap in the Belfast chronology.

		BelfastLong948			GB2			Q10705M			Q10705M-40			SwanCarr		
	Years	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap	Corr	TTest	Olap
BelfastLong948	1451							0,49	9,2	261	0,49	9,2	261	* 0,19	2,8	206
GB2	727							* 0,13	1,4	110	* 0,18	1,5	70	0,31	8,3	635
Q10705M	374	0,49	9,2	261	* 0,13	1,4	110				1,00	99,9	333	* 0,20	3,6	318
Q10705M-40	334	0,49	9,2	261	* 0,18	1,5	70	1,00	99,9	333				0,22	3,7	278
SwanCarr	844	* 0,19	2,8	206	0,31	8,3	635	* 0,20	3,6	318	0,22	3,7	278			

Table 2: Crossdating quality at the conventionally assumed position, bridging the 948 BC gap in the Belfast chronology.

According to QUB, the bad match of Q10705M towards GB2 is due to the sample's last 40 years being very narrow and difficult to measure, and periods with problematic rings and eccentric growth patterns with included sapwood. Therefore the tree-ring pattern could be truncated at 950 BC, and only the inner section back to 1210 BC could be used. (D. Brown, personal communication).

In our opinion, this is a very drastic unparalleled measure which would mean that the whole overlapping part has to be cut away just at the critical key link between the two chronologies. If we instead truncate Q10705M at 877 BC thus removing the 40 youngest narrow rings, the correlation towards Garry Bog 2 becomes only slightly better (corr. 0.18, t=1.5 at 70 years overlap). Therefore we suspect that the original link between the Belfast Long chronology and Garry Bog 2 is wrong and that the gap has to be widened with a considerable amount of years as we could not find a consistent match in the existing material.

Conclusions about the Belfast chronology

It is evident that the Belfast oak chronology has two remaining weak links in the first and tenth centuries BC which means that it actually consists of three parts:

- The absolute AD-part, corresponding to our BelfastAD, anchored in living trees and covering the last two millennia.
- The floating part between the weak links (GB2, BelfastArchaeol and SwanCarr), roughly covering the first millennium BC and clearly connecting to the Carlisle and Southwark chronologies containing English series of archaeologically Roman origin (Pilcher *et al.* 1984).
- The floating Long chronology, corresponding to our BelfastLong948, roughly covering the second to sixth millennia BC, coarsely put in place by radiocarbon wiggle-matching against the Suess calibration curve (Suess 1978, Baillie *et al.* 1983).

Therefore when analyzed this chronology (as well as the Hollstein chronology) fails to provide an unambiguous bridge between recent time and Roman time and does not solve our problem.

The English oak chronologies

A lot of archaeological oak timbers have been retrieved in England, both from Roman and later times. It has been possible to build robust Roman masters up to about AD 300, and absolute recent masters back to about AD 400. But a dendrochronological bridge between these blocks has not yet been established. This is described in detail in a Council for British Archaeology (CBA) Research Report (Tyers *et al.* 1994), and also in the leaflet *Dendrochronology* (English Heritage 2004).

This means that the situation in England is very similar to what we find in the Hollstein chronology, a fact which is also highlighted and discussed in the CBA Research Report.

<u>The French oak chronologies</u>

The gap between Roman and recent time chronologies is also evident in France (Lambert 2008). The recent chronology for northern and central France is called "Historic Oaks" and spans about AD 500 to 2000, while the Roman chronology is called "Classic Oaks" and spans 449 BC to AD 193 (Durost 2005).

A new master compiled by us from French data included in the QUB material, and a lot of series from north-eastern France put on the Digital Collaboratory for Cultural Dendrochronology (DCCD) by Willy Tegel, provides additional years reaching into the gap from both sides but still does not bridge the gap. Mean value curves of site collections including dating reports are available at http://www.cybis.se/papers/data1 . As these samples are of archaeological origin, they are generally shorter and we therefore included samples down to 75 rings length in our site collections.

FranceAbsoluteAD, AD 343 to 2008, is discontinuous but well replicated by the Becker chronology, HollsteinRecent and Historic Oaks (see Figure 4 and Table 3). All sample identifiers with prefix "Q" or other letters denominate QUB measurement series; all other samples are retrieved from Willy Tegel's projects placed on the DCCD in 2012.

TegelRoman, 511 BC to AD 217, is a strong Roman master which is well replicated by the Becker chronology, HollsteinRoman and Classic Oaks (see Figure 4 and Table 3). The samples were retrieved from Willy Tegel's projects placed on the DCCD in 2012.

Figure 4 and Table 3 show the relation in time of the collections mentioned, and the quality of their matches with the conventional dating.

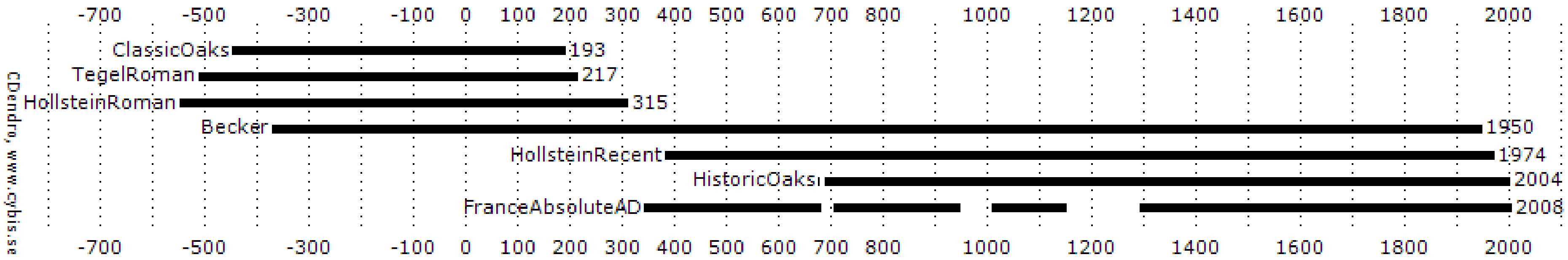

Figure 4: Time line diagram for the conventionally assumed dating of recent and Roman blocks of some European oak chronologies.

		HollsteinRecent	Becker	HistoricOaks	FranceAbsoluteAD	HollsteinRoman	TegelRoman	ClassicOaks
Sortkey		27,7	24,1	20,9	19,0	14,6	13,8	9,7
	Years	CorrTTest Olap	CorrTTest Olap	CorrTTest Olap	CorrTTest Olap	CorrTTest Olap	CorrTTest Olap	CorrTTest Olap
HollsteinRecent	1592		0,69 38,2 1567	0,56 24,3 1285	0,49 20,8 1366			
Becker	2320	0,69 38,2 1567		0,46 18,2 1261	0,40 16,0 1382	0,51 15,7 684	0,43 11,7 586	0,26 6,5 562
HistoricOaks	1333	0,56 24,3 1285	0,46 18,2 1261		0,52 20,1 1097			
FranceAbsoluteAD	1666	0,49 20,8 1366	0,40 16,0 1382	0,52 20,1 1097				
HollsteinRoman	861		0,51 15,7 684				0,55 17,6 727	0,39 10,6 641
TegelRoman	728		0,43 11,7 586			0,55 17,6 727		0,43 12,0 641
ClassicOaks	642		0,26 6,5 562			0,39 10,6 641	0,43 12,0 641	

Table 3: Crossdating quality at the conventionally assumed position for recent and Roman blocks of some European oak chronologies.

The overall conclusion is again: excellent replication within the recent block and the Roman block respectively, but the blocks fail to confirm the bridge defined by the Becker master.

The Scandinavian pine chronologies

There are also supra-long absolute masters of other species. One of these is a pine curve from northern Finland (Eronen *et al.* 2002), (Helama *et al.* 2008) which was kindly made available to us by Mauri Timonen for research at single sample level. Therefore we were able to check its synchronisation and found that this master curve is indeed continuous over more than 7600 years. A pine curve from Torneträsk in northern Sweden (Grudd *et al.* 2002), given to us as a mean value curve by Håkan Grudd, matches the Finnish master clearly in its full length and therefore is absolute as well.

However, both these pine masters do not contain archaeological material which can be linked to e.g. Roman activities; they are mostly built from "anonymous" stems preserved for centuries in the lakes from which they were retrieved.

Crossdating European oak with Scandinavian pine

After having checked some available important long and supra-long tree-ring chronologies of Europe, we apparently have a dilemma. The oak chronologies containing material of archaeologically Roman origin appear to have gaps or at least somewhat uncertain continuity between recent time and Roman time, and on the other hand, the supra-long continuous pine curves do not contain Roman material.

Our challenge now is to find a match between European oak and Scandinavian pine masters, i.e. both interregional and interspecies. Is this possible, and under what conditions? As a first step we experimented with absolutely dated, recent material.

<u>Interspecies correlation over short distances</u>

The QUB raw data includes a lot of sub-fossil pine samples which can be crossdated to form quite long site collections. These are the same sites which also yielded long oak collections, and there is a clear cross correlation between oak and pine (corr. coeff. about 0.20). This has been investigated and described in detail at QUB (Pilcher *et al.* 1995), and gives an indication that an interspecies match is possible, but that the correlation is so low that very long and strong chronologies are necessary to reach significance.

The supra-long masters from Finland and Sweden are both from the north far above the tree line for oak, so we will not find recent oak chronologies from the same region. The nearest absolute oak chronology we could find is from southern Norway (Christensen & Havemann 1992, on ITRDB). We assembled a mean value curve of 26 site members, 281 years long and dated AD 1709 to 1989. This mean value curve shows excellent cross correlation "as dated" towards both Torneträsk and Finland, according to Table 4.

We also compared a long oak master from West Denmark (WestDK, National Museum Copenhagen) with the Scandinavian pine masters.

	end date	overlap	Corr. coeff. and TTest in position **"as dated"** towards FinlandPine	 TorneTräskGrudd
SNorwayOakRecent	1989	280	0,25 4,2	0.33 5,8
WestDKOak	1986	1786	0,14 6,0	0.16 6,7

Table 4: Crossdating quality at the conventionally assumed position, for recent Scandinavian oak towards Scandinavian pine.

The Danish "as dated" match is evidently significant, which can be shown with figure 5 displaying the correlation coefficients and *t*-values for all possible positions of WestDKOak towards Torneträsk pine. The true synchronous position (1986) has a well discriminated *t*=6.7, compared to all false matches with the "next best" reaching *t*=4.3.

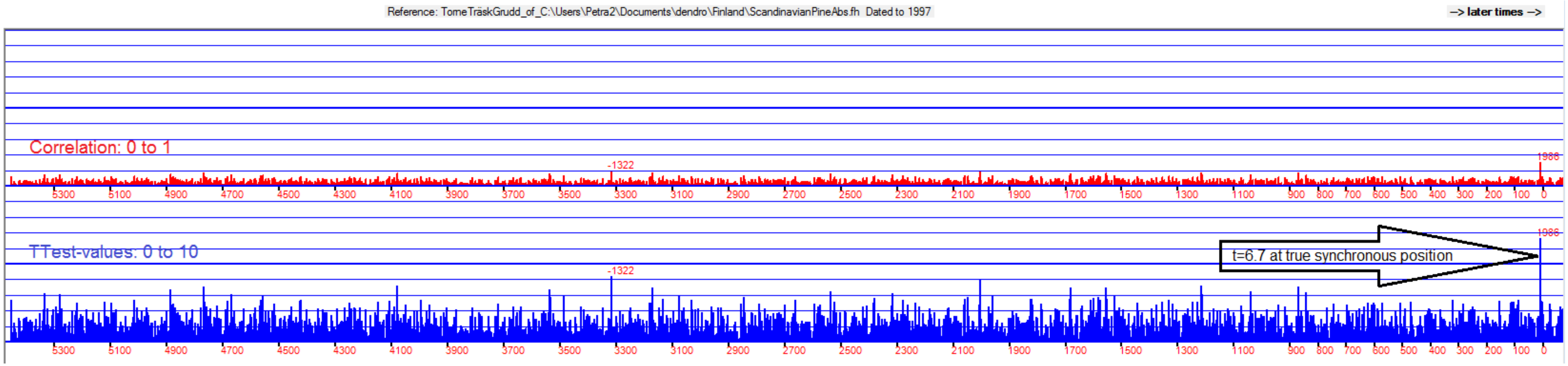

Figure 5: Correlation coefficients and *t*-values for all possible positions of WestDKOak towards TorneträskGrudd pine. Hollstein normalization used, diagrams with other normalization methods are available at http://www.cybis.se/papers/data1 .

Interspecies correlation over long distances

As expected, the correlation becomes lower with increasing distance. Our long and well replicated absolute oak masters from Ireland, Germany and France show quite low but still positive correlation towards Scandinavian pine.

However, combined as a mean value curve (AbsoluteAll) these three oak masters show "as dated" as the best match towards Torneträsk pine for an average of the normalization methods, but of course this is not significant.

	end date	overlap	Corr. coeff. and TTest in position **"as dated"** towards FinlandPine		TorneTräskGrudd	
BelfastAD	2006	1979	0,03	1,4	0,07	3,0
HollsteinRecent	1974	1591	0,03	1,3	0,06	2,3
FranceAbsoluteAD	2008	1436	0,04	1,4	0,08	3,0
AbsoluteAll	2008	1979	0,04	1,9	0,08	3,7

Table 5: Crossdating quality at the conventionally assumed position for recent European oak towards Scandinavian pine.

The Becker master chronology, from southern Germany, shows very low correlation (0.02) against Scandinavian pine.

An attempt to date European oak of Roman time towards Scandinavian pine

In a similar approach to that described above, we combined our Roman time oak masters from Ireland, Germany and France and cross correlated the mean value curve (RomanAll) towards the pine masters. This mean value curve is 1470 years long and dated 1155 BC to AD 315 (fig. 6). We expected the true match to appear among the 20 best matches.

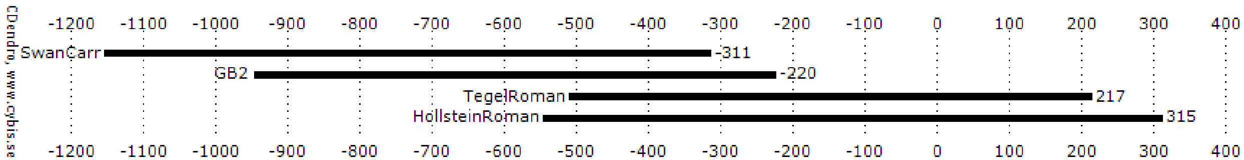

Figure 6: Time line diagram for the conventionally assumed dating of members of RomanAll.

We found that "as dated" (AD 315) did not appear at all, but instead there is a best match 218 years later (end date AD 533). This match is well discriminated and significant towards Finland pine (corr. 0.16, t=6.2). Fig. 7 shows correlation coefficients and t-values for all possible positions of RomanAll towards Finland pine.

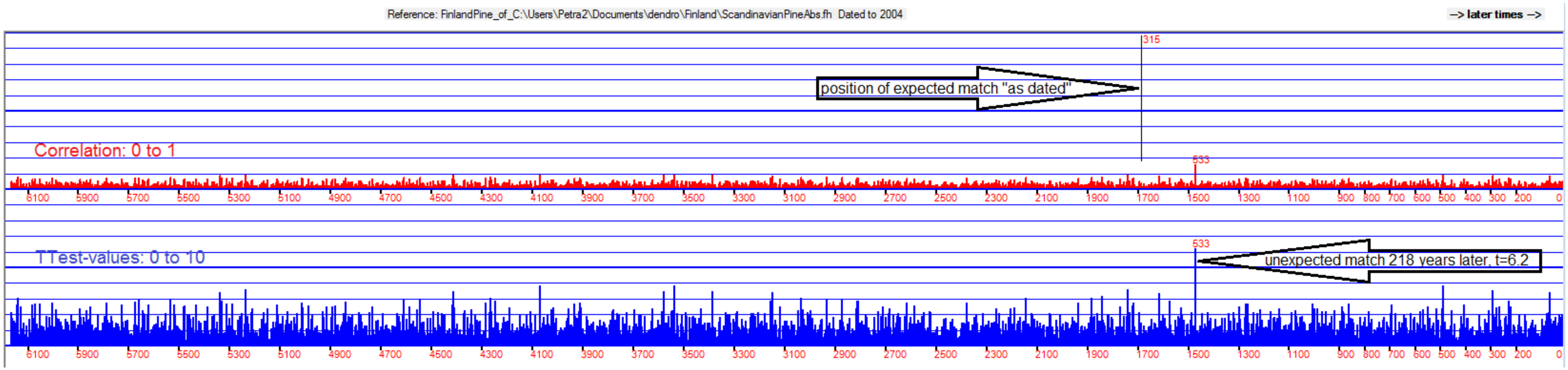

Figure 7: Correlation coefficients and *t*-values for all possible positions of RomanAll oak towards FinlandPine. Hollstein normalization used, diagrams with other normalization methods are available at http://www.cybis.se/papers/data1 .

To exclude the possibility of a spurious match, we tested the independent French Roman time dataset called "Classic oaks" (Durost 2005). This curve, 642 years long and dated 449 BC to AD 193, also did not match at the expected position (corr. -0.01, *t*=-0.3), but 218 years later (corr. 0.15, *t*=3.9, end date AD 411) towards Finland. If this curve is combined with our other Roman time masters, the match towards Finland 218 years later than expected increases slightly to corr. 0.16, *t*=6.3.

We also made a block analysis of this match between European oak and Finnish pine (block length 350 years, block distance 30 years), which demonstrated that the match is consistent over its whole length and that the assumed end year AD 315 is not suggested at all by CDendro.

Table 6 shows correlation and *t*-value for each single member of the mean value curve towards the Scandinavian pine masters, both for the expected "as dated" position and for the match 218 years later. It is evident that all members show much better values at the unexpected new offset.

	end date	overlap	Corr. coeff. and TTest in position **"as dated"** towards FinlandPine	TorneTräskGrudd	Corr. coeff. and TTest in position **"as dated" plus 218 years** towards FinlandPine	TorneTräskGrudd
RomanAll	315	1469	0,01 0,3	0,01 0,3	0,16 6,2	0,11 4,3
TegelRoman	217	727	-0,01 -0,3	-0,01 -0,4	0,13 3,6	0,09 2,3
HollsteinRoman	315	860	-0,06 -1,7	-0,12 -3,5	0,15 4,3	0,08 2,3
GB2	-220	726	0,06 1,5	0,04 1,0	0,12 3,4	0,08 2,1
SwanCarr	-311	843	0,04 1,0	0,04 1,3	0,09 2,6	0,09 2,6
ClassicOaks	193	641	-0,01 -0,3	-0,06 -1,5	0,15 3,9	0,10 2,5

Table 6: Crossdating quality at both the conventionally assumed position and with 218 years offset for Roman time European oak towards Scandinavian pine.

A compilation of all the collections and chronologies mentioned above, their conventional dates and their new dates suggested by this study is given in Table 7.

Chronology	**Start year**	**End year**	**Reference**	**Suggested start year**	**Suggested end year**	**Comments**
AbsoluteAll	25	2008	---	25	2008	compiled from BelfastAD,FranceAbsolutAD, HollsteinRecent
Becker	-369	1950	Becker 1981	---	1950	a)

Chronology	Start year	End year	Reference	Suggested start year	Suggested end year	Comments
BelfastAD	25	2006	Brown&Baillie 2012	25	2006	b)
BelfastArchaeol	-569	-68	Brown&Baillie 2012	-351	150	b)
BelfastLong948	-5451	-948	Brown&Baillie 2012	---	---	b)
Berlegem	284	550	Hollstein 1980	284 (?)	550 (?)	a)
Broichweiden	129	365	Hollstein 1980	---	---	a)
ClassicOaks	-448	193	Durost 2005	-230	411	a)
Croston	-3197	-1681	Baillie 1995	---	---	b)
FinlandPine	-5633	2004	Eronen *et al.* 2002, Helama *et al.* 2008	-5633	2004	e)
FranceAbsolutAD	343	2008	Tegel 2012	343	2008	d) Tegel, b) QUB
GB2	-946	-220	Brown&Baillie 2012	-728	-2	b)
HistoricOaks	672	2004	Lambert 2008	672	2004	a)
HollsteinRecent	383	1974	Hollstein 1980	383	1974	c)
HollsteinRoman	-545	315	Hollstein 1980	-327	533	c)
KölnKnab	273	511	Hollstein 1980	---	---	a)
KölnRhineBr	149	336	Hollstein 1980	---	---	a)
Q10705M	-1209	-836	Brown pers. comm.	---	---	b)
RomanAll	-1154	315	---	-936	533	compiled from GB2, HollsteinRoman, SwanCarr, TegelRoman
SNorwayOakRecent	1709	1989	Christensen & Havemann 1992	1709	1989	c)
SwanCarr	-1154	-311	Brown&Baillie 2012	-936	-93	b)
TegelRoman	-510	217	Tegel 2012	-292	435	d)
TorneTräskGrudd	-5319	1997	Grudd *et al.* 2002	-5319	1997	a)
WestDKOak	200	1986	Nationalmuseum Copenhagen	200	1986	a)

Table 7: The collections and chronologies mentioned above with their conventional dates and their new dates suggested by this study.

a) dated mean value curve available from originator

b) undated raw measurement data available from originator, our compilation

c) dated mean value site collections available from originator, our compilation

d) dated raw measurement data available from originator, our compilation

e) dated raw measurement data available from originator

Discussion

With the data available to us, it is not possible to demonstrate a significant bridge between Roman time chronology and recent chronology for European oak. Above all, this seems to be due to a severe timber depletion between AD 200 and 400 in most places in Europe.

So we changed strategy when we understood that the situation is different for Scandinavian pine and that there are indeed continuous and absolute supra-long tree-ring chronologies readily available. With these pine chronologies we are able to demonstrate correlations towards long recent, absolute oak chronologies from north-western Europe which confirm the dating of the oak curves. However, the match of the European Roman oak complex extended with Irish late BC collections against the absolute Scandinavian pine masters does not confirm the conventional dating. Instead there is a significant match 218 years later than expected.

We can not exclude the possibility that the significant match 218 years later than expected indicates that the Roman oak complex has a wrong conventional dendro-date. This would mean that the floating middle part of the Belfast chronology (Garry Bog 2) has to be slid 218 years towards recent time, opening a gap of probably more than 200 years towards the prehistoric Belfast Long chronology. An error of this kind has been predicted after our analysis of Q10705M (see above).

A direct consequence of a misdating of Roman time would also be that the Becker chronology is in error. In the publication of that chronology (Becker 1981), figure 1 gives the distribution of site chronologies and shows a marked timber depletion between AD 200 to 400. The only site chronology linking Roman time and early medieval time is D5 made up from Danube (Donau) river valley oaks. Figure 8 is a redrawn version of Becker’s figure 1.

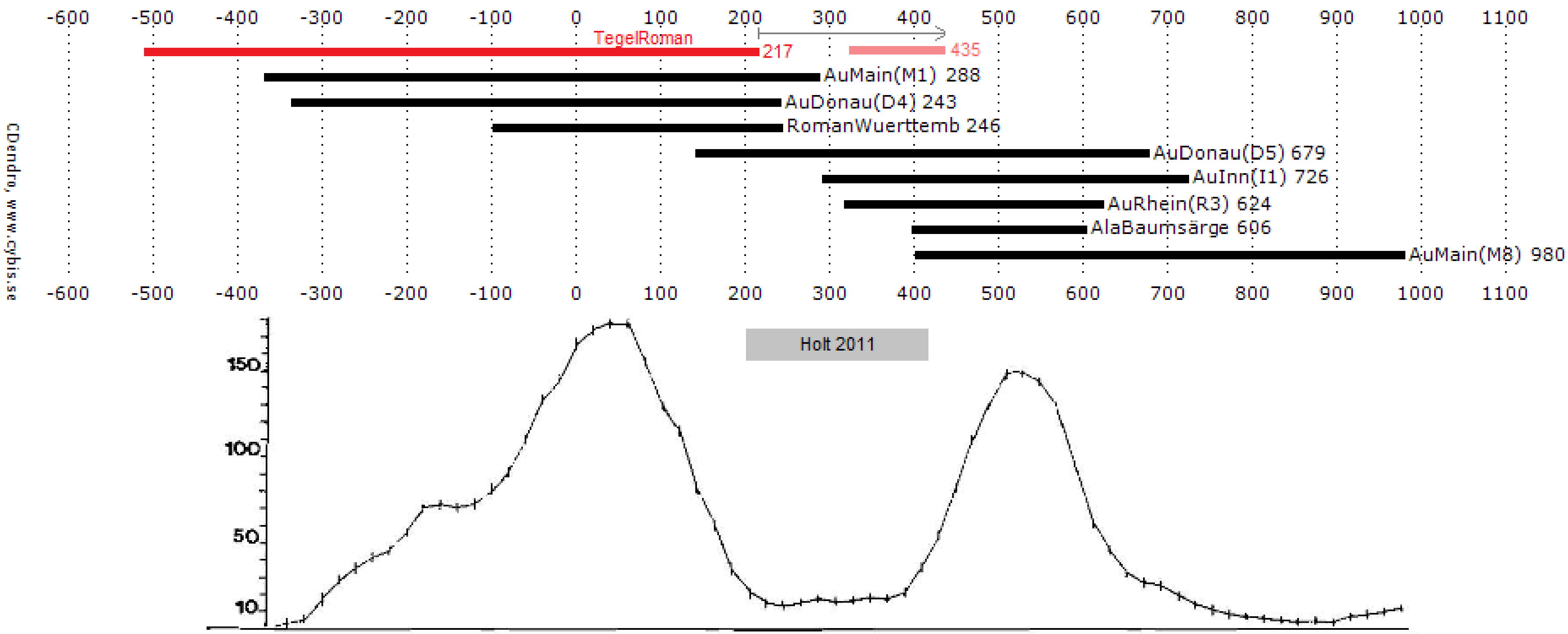

Figure 8: Time line diagram for TegelRoman compared to elements of the Becker chronology, and internal replication (number of trees) of the Becker chronology across the Migration period gap, with conventional dating.

As discussed earlier, the TegelRoman chronology matches the Becker chronology at AD 217 (as conventionally dated) with corr. 0.43, *t*=11.7 at 586 years overlap. Therefore it is remarkable that the youngest 110 years of TegelRoman also show a second match exactly 218 years later at AD 435 (Table 8).

--Rel	Over	P2Yrs------		BaPi-------		C84F-------		BesIE------		**Hollst----		GLK--	Skel-	(year)	OffsetTo
-year	lap	CorrC	TTest	CorrC	TTest	CorrC	TTest	CorrC	TTest	CorrC	TTest	GLK	Chi2		asDated
1515	110	0,33	3,7	0,28	3,0	0,34	3,7	0,34	3,8	0,31	3,4	0,59	3,3	(435)	****218
1733	110	0,32	3,5	0,27	2,9	0,25	2,6	0,22	2,3	0,30	3,3	0,65	7,1	(217)	(as dated)
1708	110	0,27	2,9	0,22	2,3	0,24	2,6	0,25	2,6	0,29	3,2	0,58	1,5	(242)	25

Table 8: Matching positions and crossdating quality for the youngest 110 years of TegelRoman towards the Becker chronology with various normalization methods shown.

The second match is in fact better for all normalization methods (P2Yrs, Baillie-Pilcher, Cross84, Besançon Index E and Hollstein), except Gleichläufigkeit and Skeleton Chi2.

As the old Becker chronology has been revised (Friedrich *et al.* 2004), we tried to get more recent data to see if this double match with 218 years interval was still present in the Hohenheim data. We found a 215 years long section of the Hohenheim chronology covering AD 200 to 414 in an article by David Holt (Holt 2011). The youngest 110 years of TegelRoman show the 218 years offset against a site collection with data from the Danube valley with even better correlation:

--Rel	Over	P2Yrs------		BaPi-------		C84F-------		BesIE------		Hollst----**		GLK--	Skel-	(year)	OffsetTo
-year	lap	CorrC	TTest	CorrC	TTest	CorrC	TTest	CorrC	TTest	CorrC	TTest	GLK	Chi2		asDated
-21	89	0,39	4,0	0,33	3,2	0,37	3,7	0,41	4,1	0,33	3,3	0,63	0,3	(435)	****218
-31	79	0,27	2,5	0,23	2,1	0,23	2,1	0,25	2,2	0,34	3,2	0,64	1,5	(445)	228
74	110	0,24	2,6	0,27	2,9	0,26	2,8	0,22	2,4	0,27	2,9	0,58	4,7	(340)	123

Table 9: Matching positions and crossdating quality for the youngest 110 years of TegelRoman towards a part of the Danube chronology (Hohenheim), various normalization methods shown. There is of course insufficient overlap for the “as dated” case.

Another direct consequence of shifting HollsteinRoman 218 years towards recent time would be that this collection comes to fit exactly between two narrow ring events visible in the FinlandPine curve, at 330 BC and AD 536 to 542 (Helama *et al.* 2013), see Figure 9. In the Finnish pine master, the event at 330 BC caused a servere timber depletion which made it difficult to bridge this period (Eronen *et al.* 2002). The 330 BC event is clearly evident in the Torneträsk pine master as well (Grudd *et al.* 2002).

The oldest tree-ring of HollsteinRoman (conventionally 546 BC) directly succeeds a severe and still unexplained timber depletion in the German oak record known as the "Hallstatt gap" (Becker 1993, Friedrich *et al.* 2004), which with 218 years offset would coincide with the Scandinavian pine depletion at 330 BC.

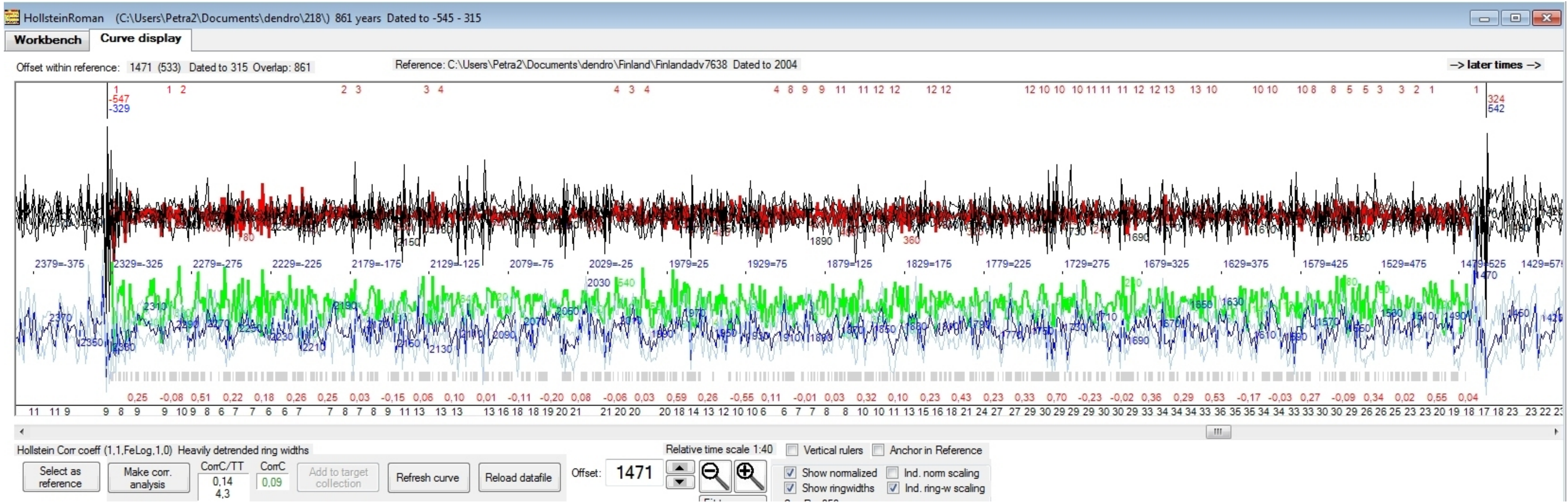

Figure 9: Part of FinlandPine showing the narrow ring events at 330 BC and AD 536 to 542 resp., with HollsteinRoman fitting exactly in between if redated 218 years. HollsteinRoman (red normalised curve and green ring width curve) matched against FinlandPine (black normalised curve and blue ring width curve) using the Hollstein normalization, offset 218 years, corr.coeff. 0.14, t=4.3 at 860 years overlap.

Conclusions

We would like to see our findings and the questions arising from them as the start of a scientific discussion, and a call for further investigations. If the dating of Roman time is wrong, this would also have consequences for the radiocarbon calibration curve

(IntCal13), at least for the part corresponding to the first millennium BC, as both the Belfast chronology and the Becker chronology have been fundamental for its construction. However, the overall course of the calibration curve has been confirmed by measurements of wood used to build the Torneträsk pine master (Grudd *et al.* 2002). Regrettably, no Torneträsk samples have been carbon dated between 2170 and 2770 BP which corresponds to Garry Bog 2.

Finally, an error of the size mentioned would have consequences for our calendar as it seems to indicate the existence of invented years in the Christian era.

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