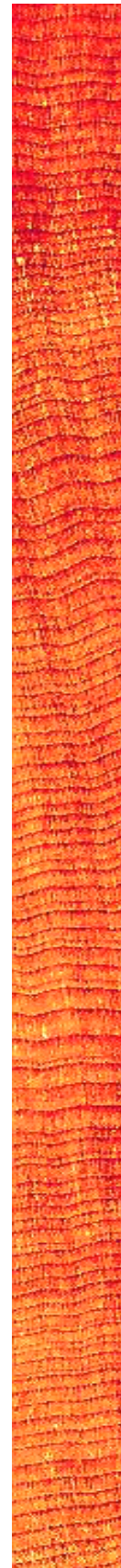


Project: Tree-ring analysis of Western Red Cedar (*Thuja plicata*) samples from Abodo.

Author: Dr Jonathan Palmer

Gondwana Tree Ring Laboratory
24 Okona Cresc.
Ngongotaha
Rotorua 3010

December 2025



1. Introduction.

Tree-ring dating, or dendrochronology, is a scientific method for precisely dating wooden objects and sites by analyzing the patterns of annual growth rings in trees. By matching the unique sequence of wide and narrow rings from an unknown sample to a known, calendar-dated chronology, researchers can assign a specific year to each ring and determine the tree's felling date. This technique is also used to study past climate conditions, as ring width is affected by environmental factors like temperature and precipitation.

This report shows the results from tree-ring analysis of 10 western red cedar (*Thuja plicata*) samples. These were supplied by Daniel Gudsell (Founder, Abodo), who obtained them from a local Auckland building firm (see Appendix A), and they consisted of 4 x 7 cm offcuts of different lengths. The sample set is seen as a pilot trial of 'randomly' chosen samples believed to represent a typical building construction scenario using imported timber.

There were two main aims of the study. The first was to determine the growth rate of the trees by measuring their annual tree-ring widths. The second aim was to establish the age of the trees that provided the timber. To achieve this, efforts were made to match the ring-width growth patterns of the timber samples with a detailed reference record of tree growth patterns over time (i.e., a tree-ring chronology; the overlapping annual growth-ring records of many trees from a specific region).

Such information was considered potentially useful to clients for a better understanding of the wood material used in their building construction.

2. Methods.

The samples were already fully dry, so no further drying was needed, and their varying lengths could be cut into 2-3 cm-thick offcuts (i.e., cross-sections) for tree-ring analysis. This was necessary to allow observation under a binocular microscope and to measure the ring widths. After cutting to size, the samples were sanded flat using increasingly finer sandpaper (from grit P120 to P600) with a hand sander, ensuring the annual growth rings became clearly visible. In some species with intricate ring structures, dyeing or staining can be used to improve the clarity of ring boundaries (Norton and Ogden, 1987). However, after sanding, the ring boundaries were distinctly visible under a microscope without any additional treatment, so dyeing or staining was not attempted in this project.

The polished sections were then examined using a binocular microscope, with the number of rings counted and their growth patterns compared. The visual inspection showed that the rings were relatively uniform (i.e., with little year-to-year variation or low mean sensitivity - see Table 1), and some samples had fewer than 50 rings—all of which reduced the likelihood of accurately determining the tree's age (i.e., the second objective). After inspection and counting, the ring-widths of the samples were measured to the nearest 0.01 mm along a radial transect using a Velmex measuring stage (<https://velmex.com/>) connected to computer systems. Each ring-width series (radial sequence of measurements) is listed in Appendix B, with descriptive summary statistics provided in Table 1.

The next step in the investigation involved comparing the ten ring-width series with established tree-ring chronologies from the International Tree-Ring Data Bank (ITRDB) (see: <https://www.ncei.noaa.gov/products/paleoclimatology/tree-ring>). Two main chronologies were identified from the data bank for screening were:

Long Island, Willapa Bay, Washington State, USA (WA129).

Seymour Watershed, Vancouver, British Columbia, Canada (CANA110).

The only site chronology that showed significant correlations of matching ring-width patterns to the unknown Abodo samples was the Seymour Watershed (site code: CANA110). The results confirm that the timber samples originated from around Vancouver Island in Canada (c.50° North) and not further south in Washington or Oregon, USA (i.e., c.46° North).

The screening between the ABODO samples and the Canadian reference chronology (CANA110) was aided by using the program COFECHA (Holmes, 1981). Before potential crossdating positions (i.e., dates) were identified, all the tree-ring series were first transformed by the program to enhance the characteristics related to crossdating while minimising features unrelated to the task. This involved using a cubic smoothing spline with a 50% cutoff at 32 years fitted to the series, with each value divided by the corresponding spline value, resulting in a series without trends or long-waves and a mean of 1. Next, the persistence of the smoothed series was removed via autoregressive modelling, eliminating short-waves that might remain after the spline fit. This step helps the series conform more closely to the Pearson correlation assumption that values are serially independent. Finally, the logarithm of each value was taken after adding a constant of one-sixth of the mean. The purpose of the log transform is to weigh proportional differences in ring measurements more evenly. Filtering through a smoothing spline, modelling, and log transformation, by removing low-frequency variance and persistence and focusing on high-frequency variance proportional to ring widths mathematically, is also thought to mimic human visual examination of a ring series for crossdating.

The results from visual examination and assistance from the program COFECHA are presented in Table 2. The ABODO samples were found to show cross-matching "signature patterns" to the reference chronology (CANA110). When running the program for each ABODO series, a note is made of segments that correlate poorly with the corresponding segments of the master dating series (i.e. CANA110). This was seen in several samples, indicating the likely presence of missing rings. The best dating match for each sample is presented in the results (see Sections 3.1-3.10). The data analysis was undertaken within the R environment (v.2.11.1. R Development Core Team 2010). Dendrochronological analyses were carried out using the dplR library (Bunn 2008, Bunn et al., 2020).

3. Results and Discussion.

The ring counts and growth rates of the ten ABODO samples are summarised in Table 1. On average, the samples contained 80 rings, but the number was quite variable (e.g., a standard deviation of 32). The same pattern is observed in the growth rates (i.e., mean ring widths), and their linked relationship is shown in Figure 1. The sample set appeared to consist of two broad clusters: faster-growing (i.e., ABD01, ABD05, ABD08; Table 1) or slow-growing trees. However, regardless of their growth rate, all the samples had low mean sensitivity values. Such a low value reflects the wood's appeal for a fine-grained visual appearance in architectural features.

Figure 1: Comparison between the mean ring-width and the number of tree-rings for the ten ABODO samples of identical size. There appears to be a significant linear relationship between the two variables. Note: 95% confidence intervals are indicated by the dashed lines.

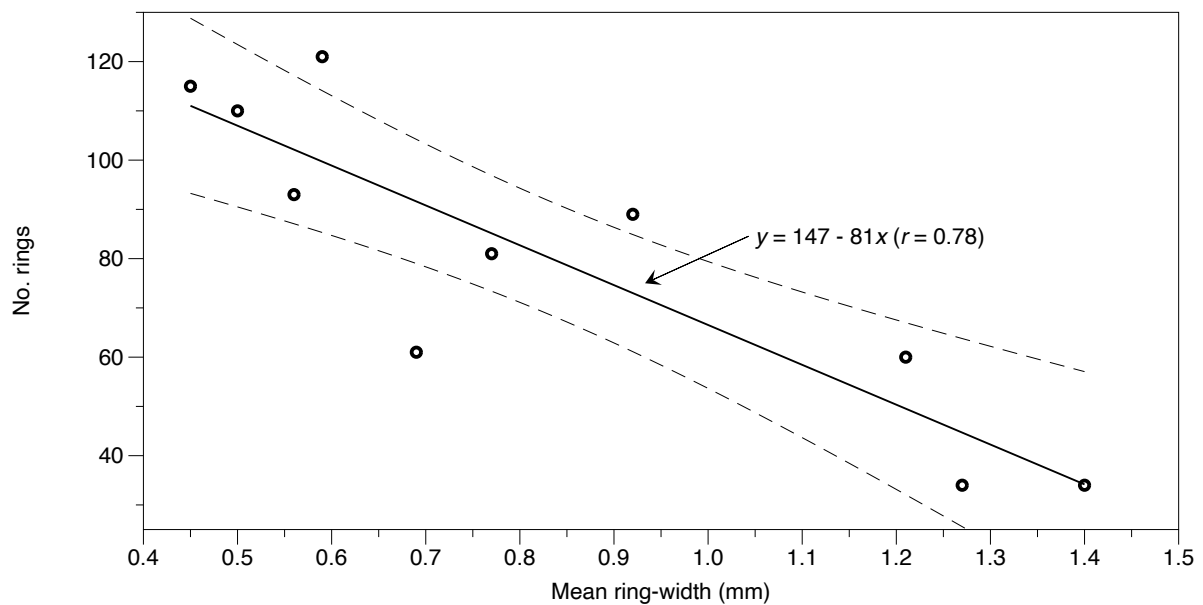


Table 1. Summary details of the ten ABODO western red cedar samples. Note: All samples were taken from similarly sized timbers (7 x 4 cm). Mean sensitivity is a dendrochronological measure of how much a tree's annual growth (ring width) varies from year to year, with higher values indicating greater sensitivity.

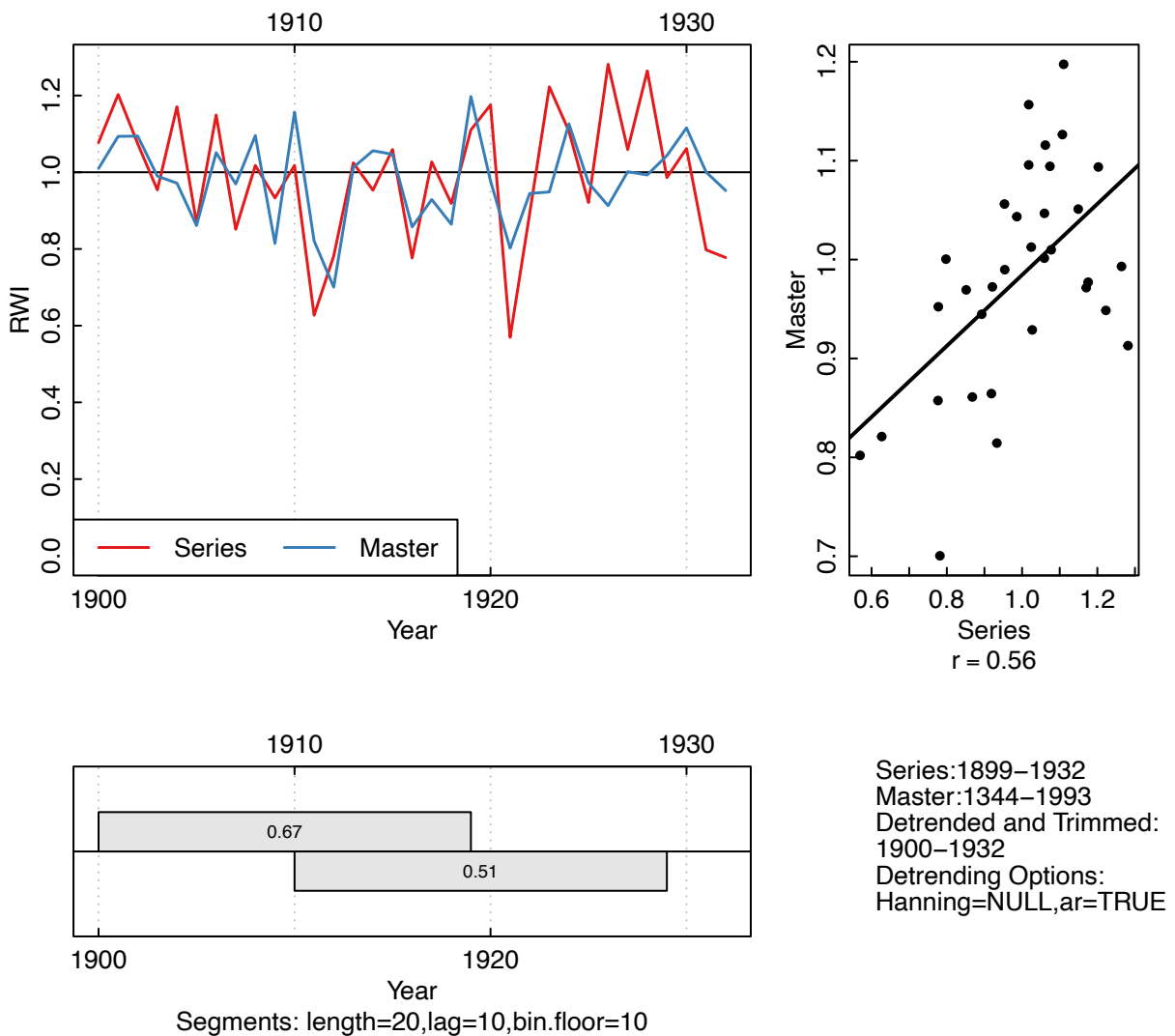
ID	No. rings	Mean ring-width (mm)	s.d.	Mean sensitivity
ABD01	34	1.27	0.31	0.16
ABD02	81	0.77	0.12	0.11
ABD03	89	0.92	0.21	0.16
ABD04	115	0.45	0.21	0.15
ABD05	34	1.40	0.38	0.16
ABD06	121	0.59	0.17	0.13
ABD07	61	0.69	0.19	0.16
ABD08	60	1.21	0.27	0.14
ABD09	110	0.50	0.21	0.15
ABD10	93	0.56	0.15	0.18
Average	80	0.84	0.22	0.15

The next stage was to determine what time period the wood samples were growing and to indicate the possible age of the trees being utilised. These results are presented for each sample in the following sections.

3.1 Sample ABD01.

This sample had only 34 tree rings (see Appendix C: Figure C1), which, given its low sensitivity (Table 1), would normally suggest a limited chance of matching it to a reference chronology to determine its age (i.e., how old the wood sample is). However, as shown in Figure 2 (below), ABD01 matched well to the period from 1899 to 1932. The correlation of the series also appears consistent across the entire overlapping time period.

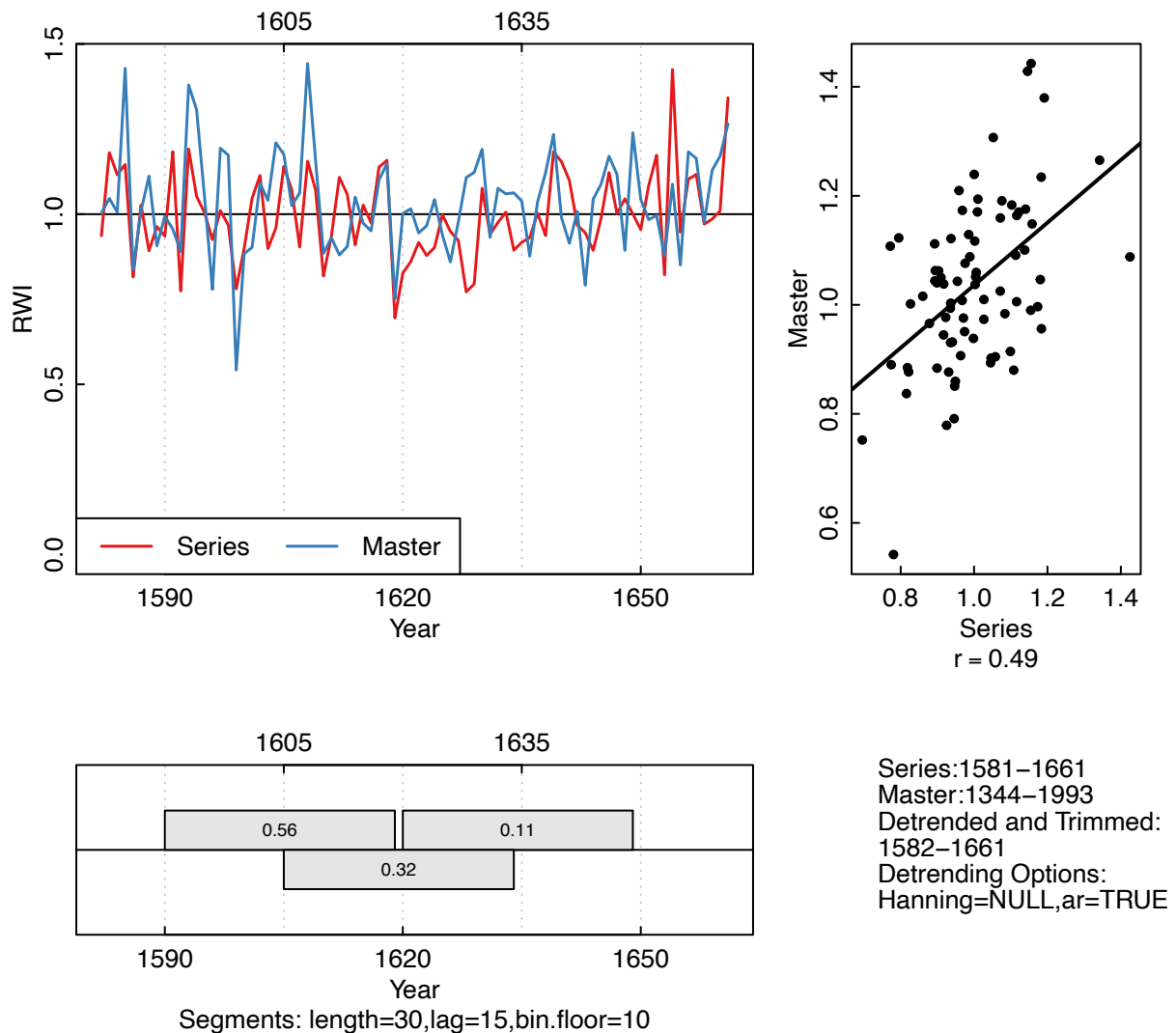
Figure 2: Matching of ABD01 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower figure illustrates the correlation strength of two overlapping 20-year segments to demonstrate the temporal consistency of the matched position.



3.2 Sample ABD02.

This sample had 81 tree rings (see Appendix C: Figure C2), which is generally considered enough to match it to a reference chronology for estimating its age (i.e., how old the wood is). As shown in Figure 3 (below), ABD02 only matched well during the earlier period and then declined towards the more recent time. This suggests the possibility of missing rings in the series. Further examination of other samples is needed to clarify this. The good match during the earlier period indicates the wood sample originated from the 1580s. The tree itself was probably considerably older (i.e., over 440 years), as the sample image (Appendix C: Figure C2) shows little sign of ring curvature that occurs near the centre or pith.

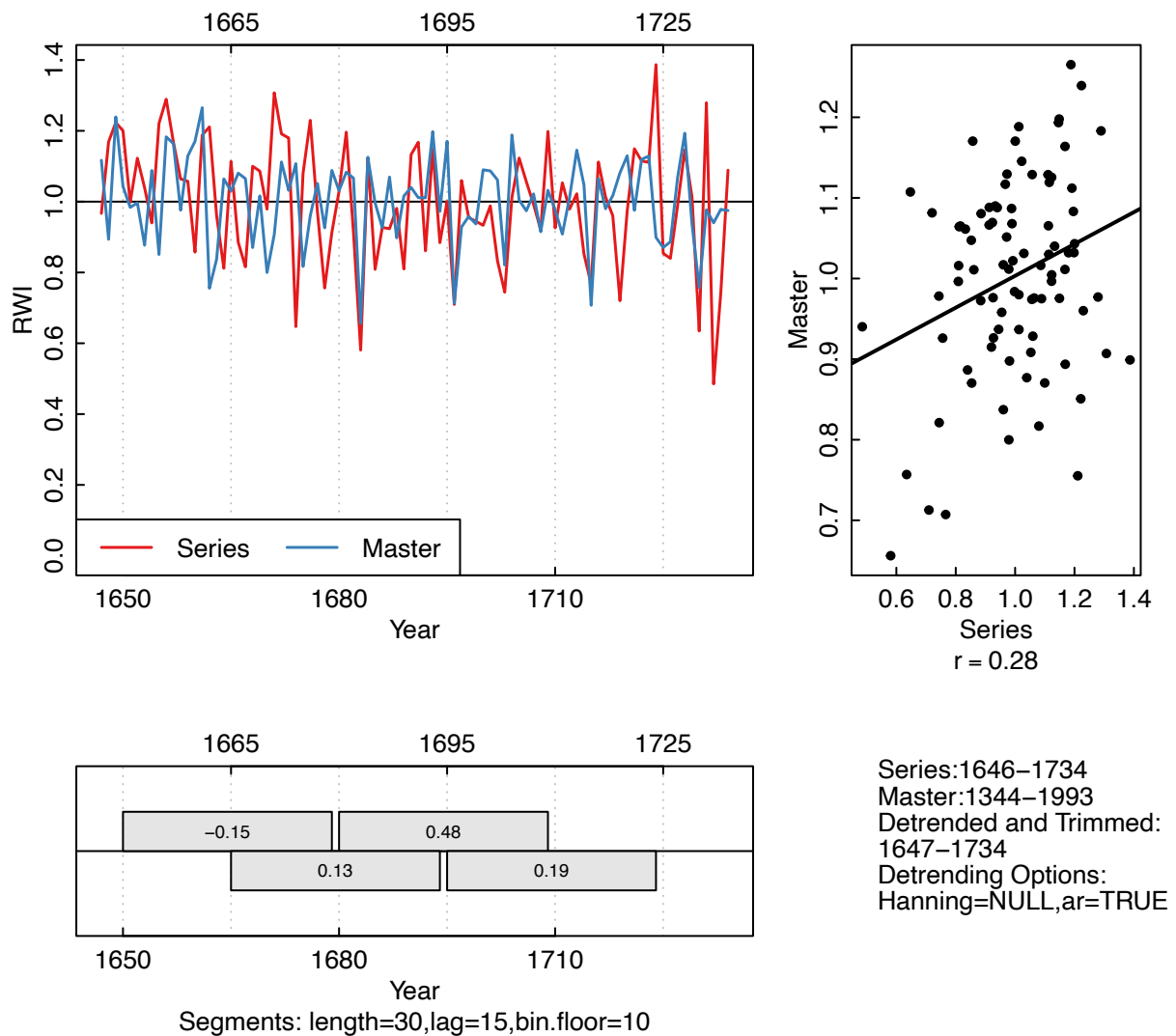
Figure 3. Matching of the ABD02 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower figure illustrates the correlation strength of three overlapping 30-year segments to demonstrate the temporal consistency of the matched position.



3.3 Sample ABD03.

This sample had 89 tree rings (see Appendix C: Figure C3), which are usually sufficient to match it to a reference chronology to determine its age (i.e., how old the wood sample is). As shown in Figure 4 (below), ABD03 only matched well during the later period and then declined towards the older time period. This is the opposite of ABD02 but also suggests the possibility of missing rings in the older part of the series. Further examination of other samples is needed to help confirm this. The good match during the later period means the estimate of how old the tree was must be considered only approximate at this point, but was certainly older than 1640 (i.e., >380 years old).

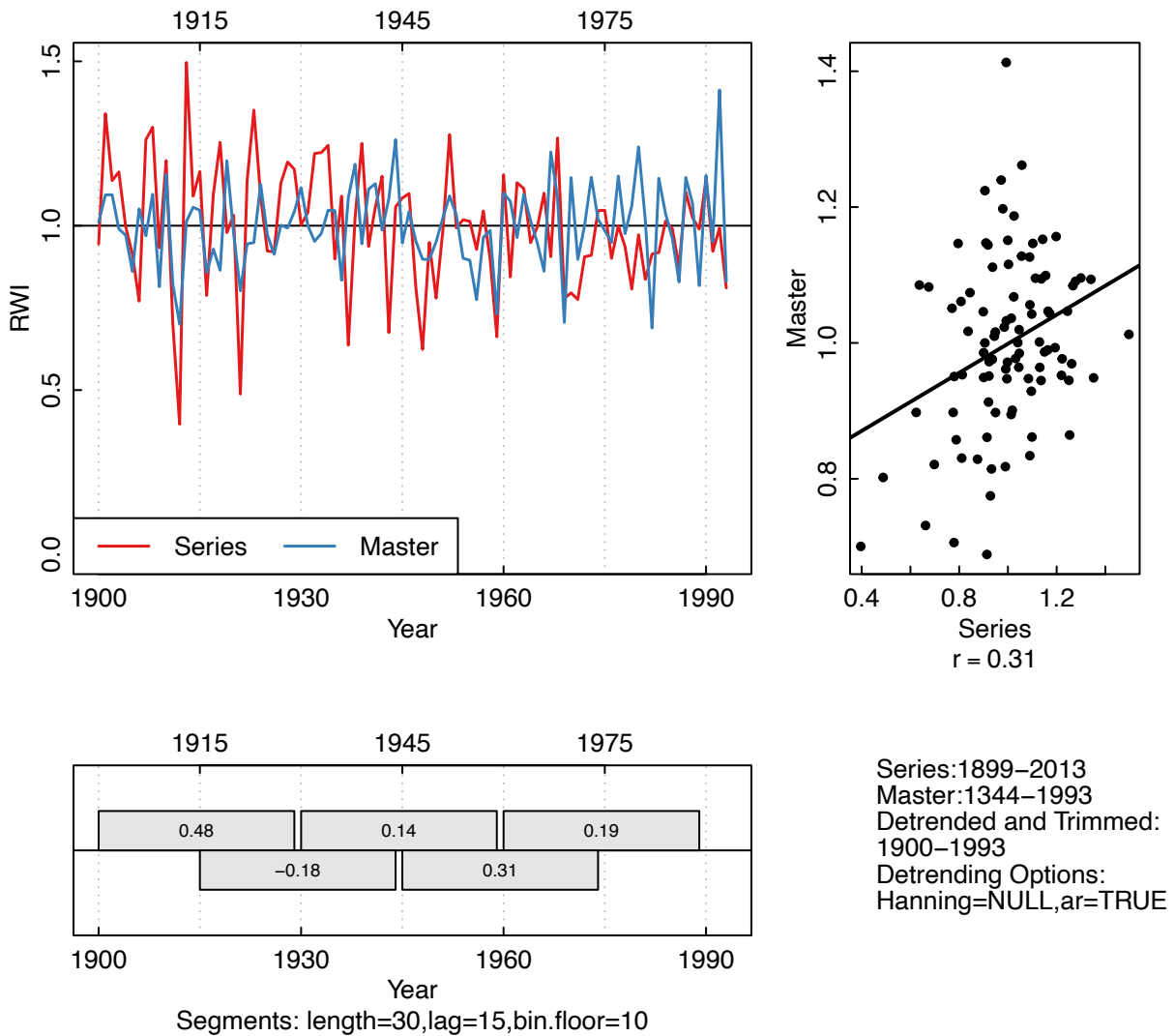
Figure 4: Matching of the ABD03 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower figure illustrates the correlation strength of four overlapping 30-year segments to demonstrate the temporal consistency of the matched position.



3.4 Sample ABD04.

This sample had 115 tree rings, making it nearly the longest of any of the samples. A distinguishing feature of this sample was the presence of sapwood and a bark edge (see Appendix C: Figure C4), which clearly limits its age. Normally, having the bark edge present is helpful as a starting point for determining the age of the series. However, in this case, the older portion of ABD04 best fitted at 1899, and then showed episodes of weaker fits towards the present day (Figure 5; below). Because of this, the bark edge year of 2013 must be considered tentative and likely closer to the present once potential missing rings have been identified. As seen from the picture of the sample (Appendix C: Figure C4), the sapwood rings are very narrow, so missing rings are plausible. A future consideration could include tracing information from milling companies about probable felling dates.

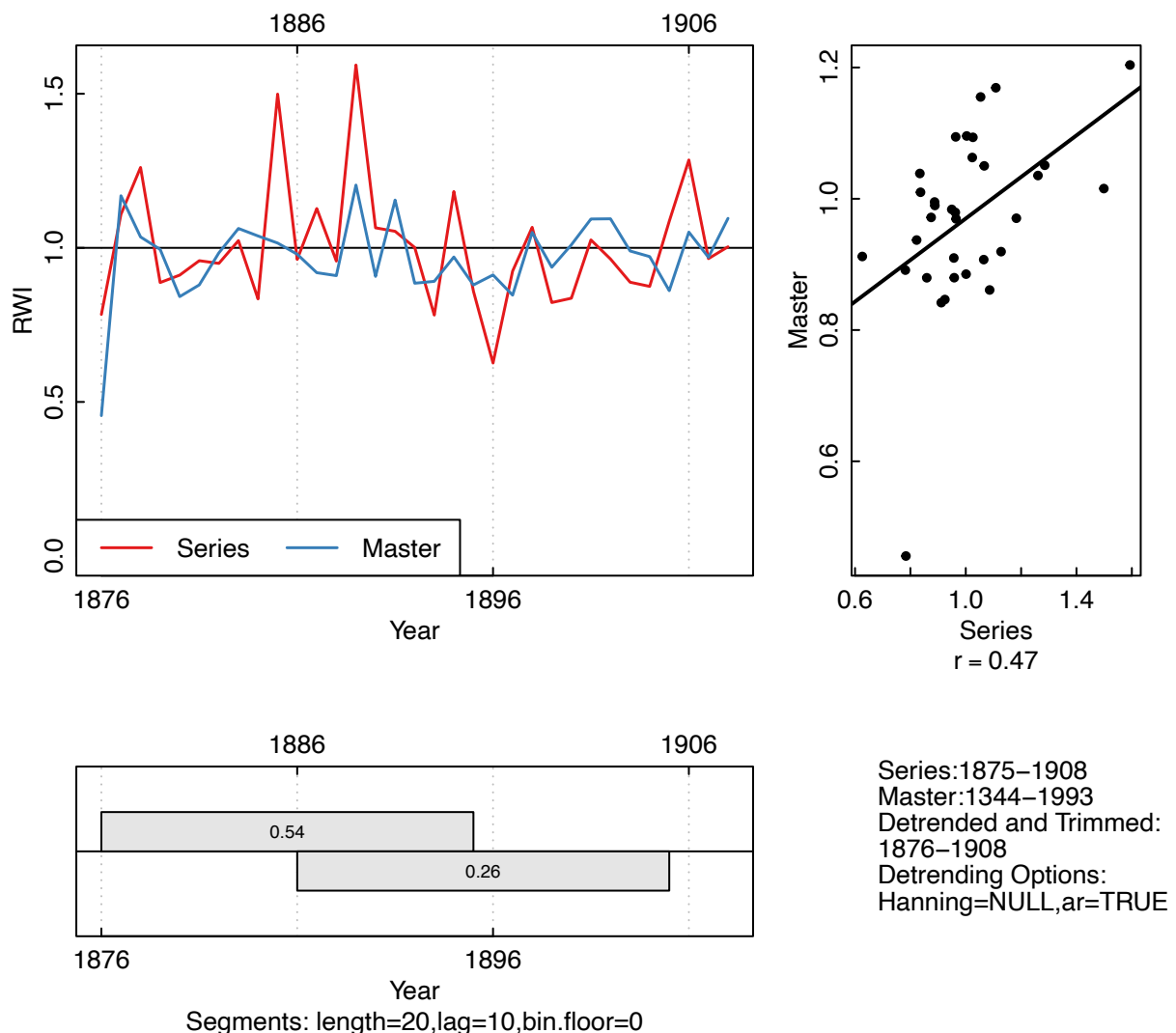
Figure 5: Matching of the ABD04 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) is in the upper right panel. The lower figure illustrates the correlation strength of five overlapping 30-year segments to demonstrate the temporal consistency of the matched position.



3.5 Sample ABD05.

Like sample ABD01, this one had only 34 tree rings (see Appendix C: Figure C5), which again, given its low sensitivity (Table 1), would normally suggest a limited chance of matching it to a reference chronology to determine its age (i.e., how old the wood sample is). However, a reasonable fit was determined for the period 1875 to 1908 (Figure 6; below). The correlation of the series also appears relatively consistent across the entire overlapping time period.

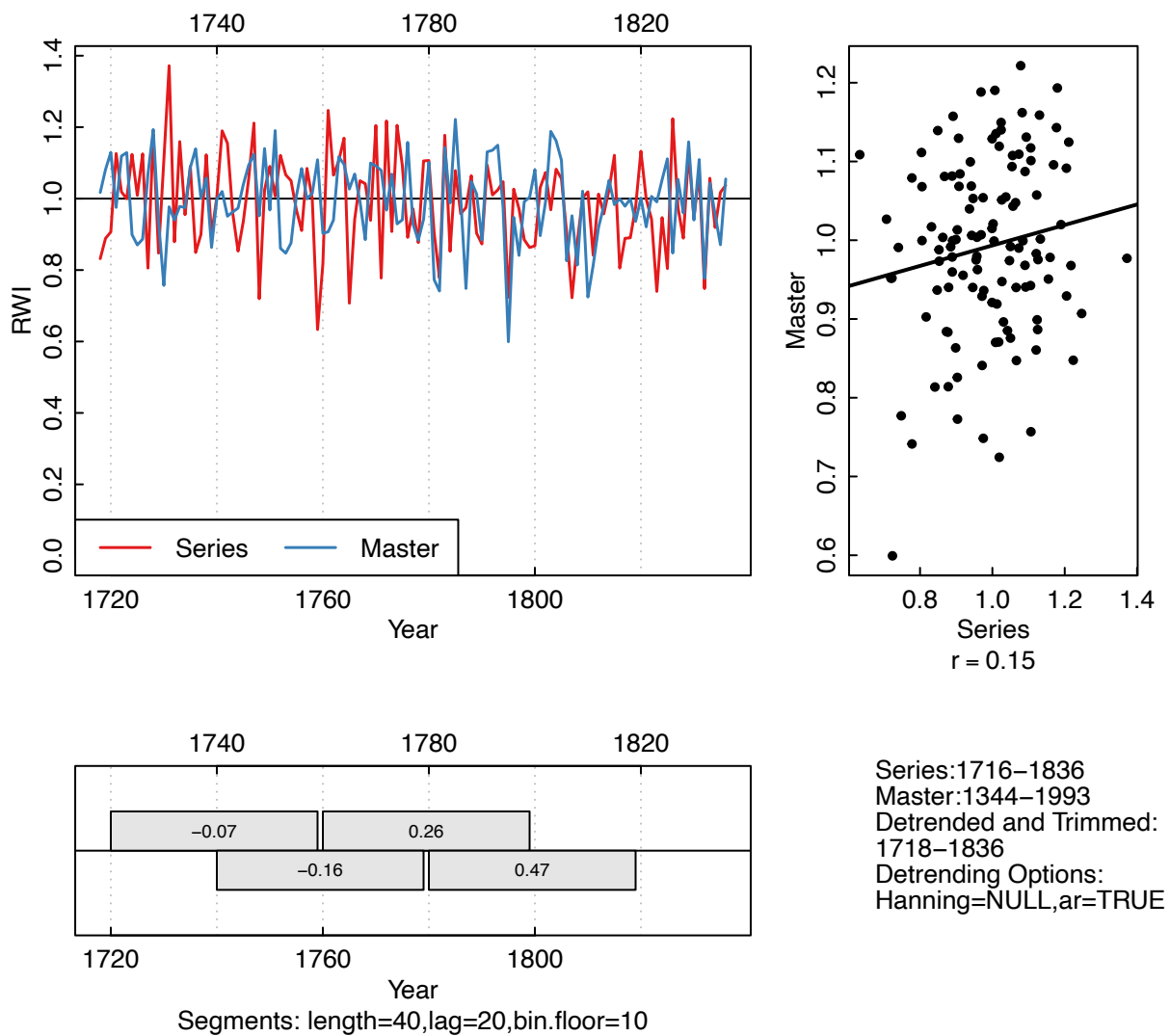
Figure 6: Matching of ABD05 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower figure illustrates the correlation strength of two overlapping 20-year segments to demonstrate the temporal consistency of the matched position.



3.6 Sample ABD06.

This sample had 121 tree rings (see Appendix C: Figure C6), making it the longest series examined and sufficient for matching to a reference chronology to establish its age. As shown in Figure 7 (below), ABD06 aligns well in the later period but then declines as it approaches the older period. This suggests that missing rings may be present in the series and highlights the need for more samples to be dated. The poor match during the earlier period indicates that the tree was likely significantly older than 1710 (i.e., >310 years old).

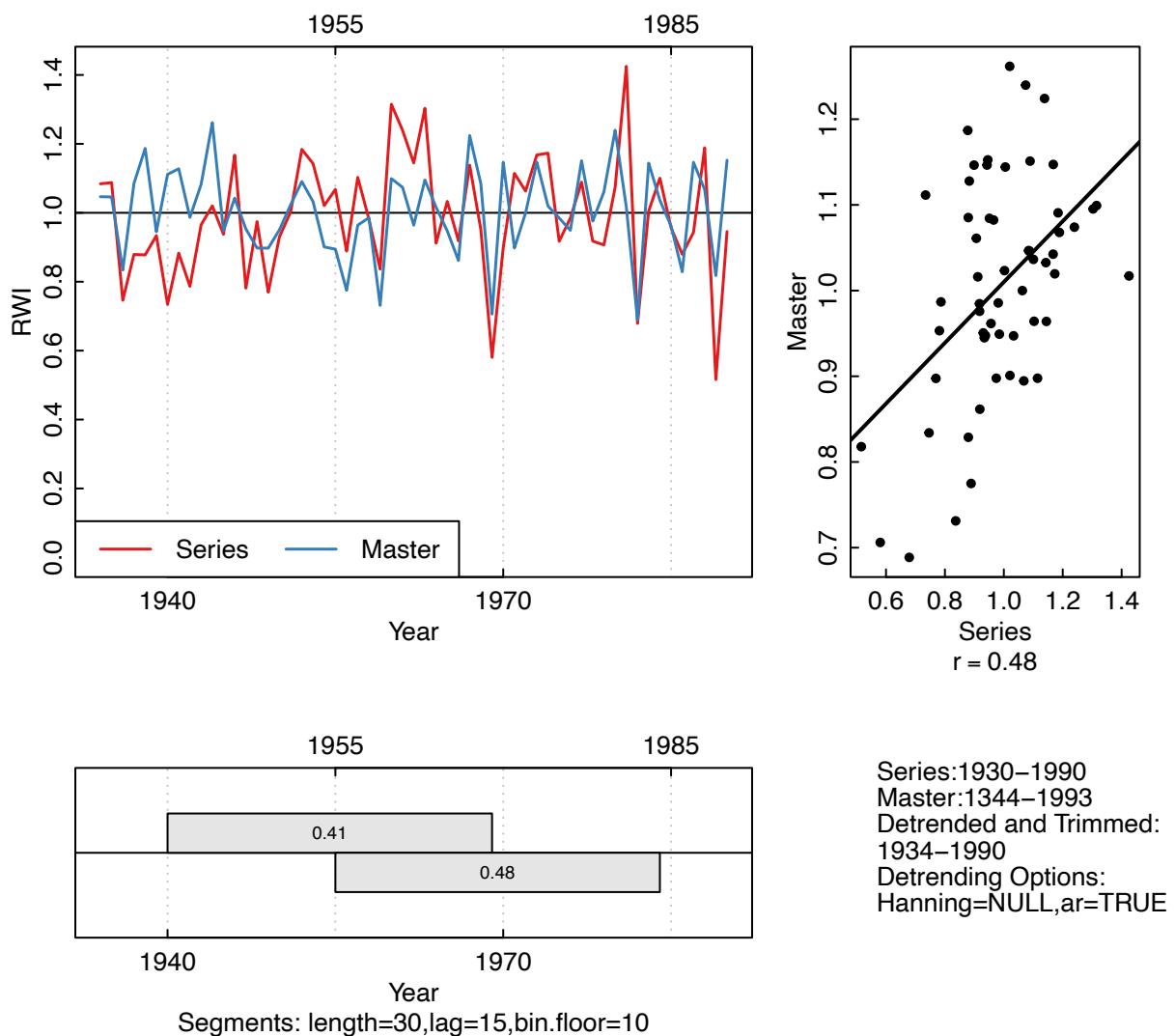
Figure 7: Matching of the ABD06 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) is in the upper right panel. The lower figure illustrates the correlation strength of four overlapping 30-year segments to demonstrate the temporal consistency of the matched position.



3.7 Sample ABD07.

Sample ABD07 had 61 tree rings (see Appendix C: Figure C7) that clearly align with the master series over the period 1930-1990. From Figure 8, the correlation appears equally strong over two 30-year periods, emphasising the confidence in the dating.

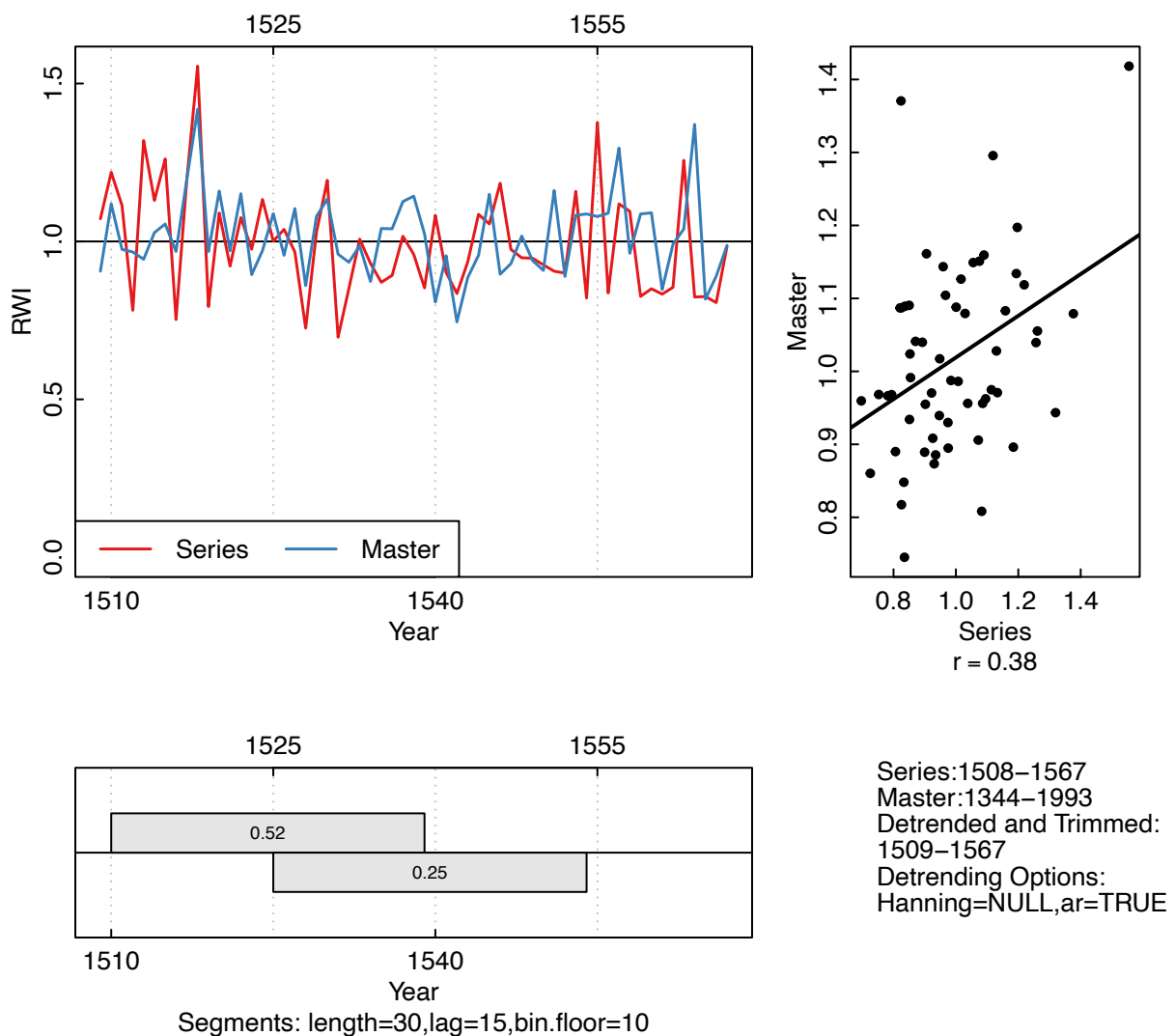
Figure 8: Matching of the ABD07 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower figure illustrates the correlation strength of two overlapping 30-year segments to demonstrate the temporal consistency of the matched position.



3.8 Sample ABD08.

This sample had 60 tree rings (see Appendix C: Figure C8) and was relatively fast-growing. The number of rings exceeded that of ABD01 and ABD05 (both with only 34 rings), despite similar growth rates, due to the sample's orientation. Both ABD08 and ABD06 display classic quarter-sawn grain traits, whereas several others, such as ABD05 & ABD07, show characteristics more typical of being flat-sawn. As shown in Figure 9 (below), ABD08 only matched well during the earlier period and declined towards the more recent time frame. This suggests the presence of missing rings in the series. The good match during the earlier period indicates the wood sample originated from the 1520s. The age of the tree from which the sample was taken was likely significantly older (i.e., >500 years). Similar to ABD02, the rings in the image (Appendix C: Figure C8) exhibit little curvature, indicating the pith was some distance away and implying the tree was much older.

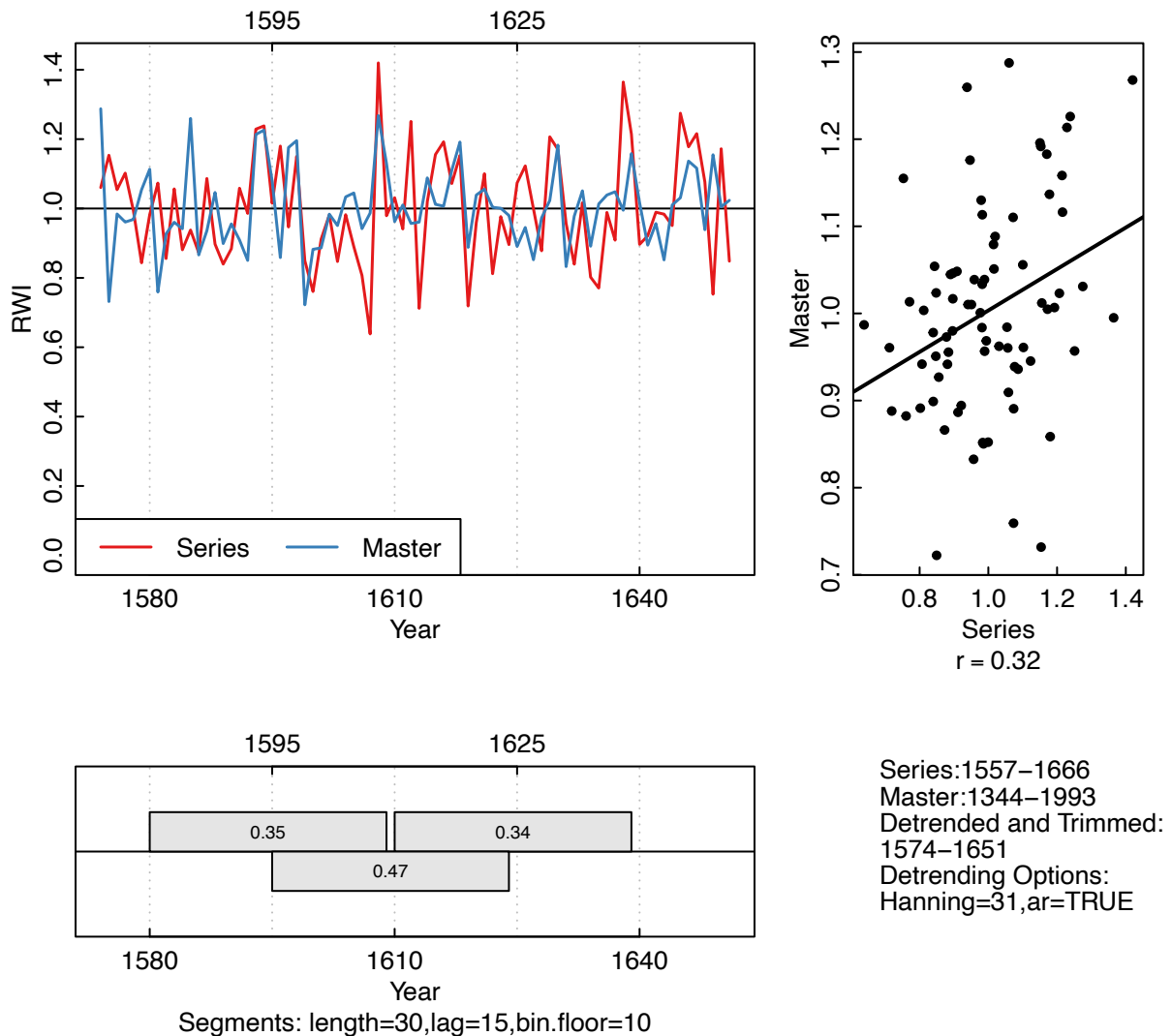
Figure 9: Matching of the ABD08 series to the reference master series (CANA110). The best-fitting match of the transformed ring-width indices (RWI) is shown in the upper left panel, and the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower figure illustrates the correlation strength of two overlapping 30-year segments to demonstrate the temporal consistency of the matched position.



3.9 Sample ABD09.

This sample had 110 tree rings and is among the longest series. A notable feature was the indication of tree-ring wedging (see Appendix C: Figure C9). This occurs when there are signs of tree-rings ‘pinching out’ or gradually becoming smaller as you follow them across the sample (or around the trunk). Wedging is often linked with missing rings. In this case, the results show a good statistical fit from 1557 to 1666. Once again, similar to both ABD02 and ABD08, the sample rings showed little curvature that might indicate proximity to the pith, suggesting the tree was likely over 500 years old.

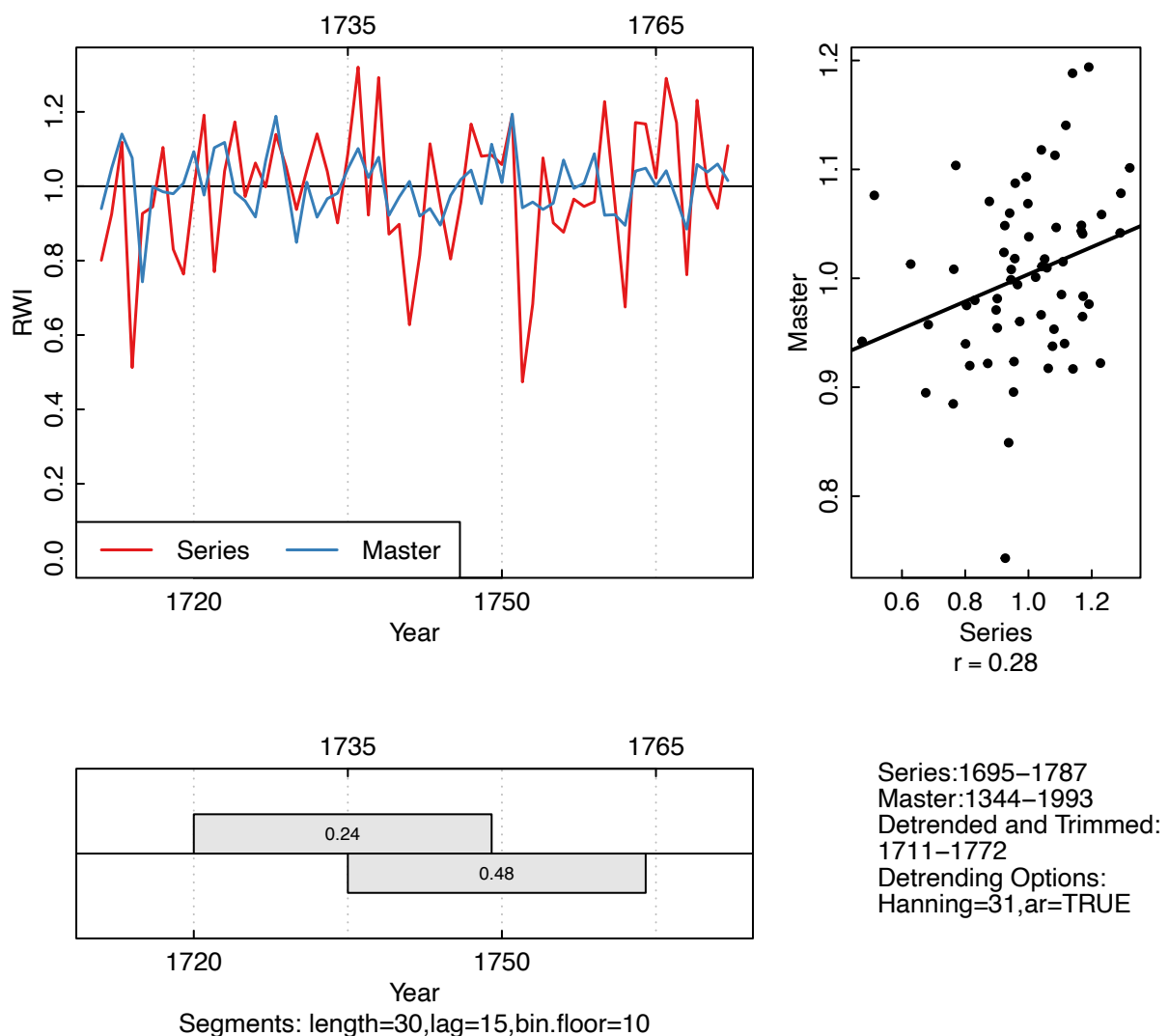
Figure 10: Matching the ABD09 series to the reference master series (CANA110). The best match of the transformed ring-width indices (RWI) is shown in the upper left panel, with the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower part illustrates the strength of the correlation across three overlapping 30-year segments, demonstrating the temporal consistency of the matched position.



3.10 Sample ABD10.

The final sample contained 93 rings and shows some resin staining (see Appendix C Figure C10), although this did not obscure the rings. The tree rings matched the reference series best towards the more recent end, with possible missing rings towards the older portion (Figure 11). This means the record may extend back slightly older than 1695. The sample came from a tree older than 330 years.

Figure 11: Matching the ABD10 series to the reference master series (CANA110). The best match of the transformed ring-width indices (RWI) is shown in the upper left panel, with the corresponding linear regression (including Pearson correlation coefficient r) in the upper right panel. The lower part illustrates the strength of the correlation across two overlapping 30-year segments, demonstrating the temporal consistency of the matched position



3.11 Summary of the sample dating.

Table 2: Summary of the growth periods (calendar years) for the ten ABODO western red cedar samples. This was determined by matching the ring-width patterns of the samples with a reference tree-ring chronology from Canada (CAN110). The Pearson correlation coefficient (r) between the sample series and the reference chronology is also included. Refer to Sections 3.1 – 3.10 for more details on individual series.

ID	No. rings	First Year	Last Year	Pearson Correlation (r)	Significance
ABD01	34	1899	- 1932	0.560	***
ABD02	81	1581	- 1661	0.490	***
ABD03	89	1646	- 1734	0.280	***
ABD04	115	1899	- 2013	0.310	***
ABD05	34	1875	- 1908	0.470	***
ABD06	121	1716	- 1836	0.170	*
ABD07	61	1930	- 1990	0.480	***
ABD08	60	1508	- 1567	0.380	***
ABD09	110	1557	- 1666	0.320	***
ABD10	93	1695	- 1787	0.280	***
			α	0.10	*
				0.05	**
				0.01	***

4. Summary and Suggestions.

This pilot study, although based on only ten samples, has been able to provide estimates of the growth rate and ages of the timber.

The sub-millimetre growth rate indicates the timber is finely grained, which likely explains its architectural appeal. Only two of the samples were clearly oriented with vertical grain on the wider timber face. This is generally preferred for tree-ring analysis as it maximises the number of rings present (an important factor for increasing the likelihood of matching to a master reference series).

The results from the ten individual ABODO samples were summarised in Table 2. The samples cover a wide range of time periods, with the earliest dating from 1508 and the latest from 1930. This broad temporal span highlights the diverse parts of logs from which the samples are taken. Only one sample contained sapwood (ABD04), with many seemingly sourced from the mid-portion of trees.

Nine out of ten samples significantly correlated with the reference master chronology (Table 2). However, as previously discussed, many series showed declining matches over different periods, most likely due to missing rings. Addressing the periods of poor matches requires a considerably larger sample pool. The sample with the lowest overall correlation (ABD06) had the longest series and, although the more recent end aligned best with the master series, earlier misalignments caused by missing rings led to the overall poor correlation. This could be greatly improved with more careful comparison to other samples and identification of likely missing ring locations.

Three of the samples were dated as being over 400 years old (ABD02, ABD08, ABD09). Pictures of those samples (shown in Appendix C) show the tree rings have very little curvature, indicating there was still quite some distance to the centre of the trees. This ‘missing’ radius suggests the actual trees these samples came from were significantly older – probably over 600 years. Such ancient trees are quite plausible, as trees of similar ages were also present in the Canadian reference chronology (Seymour Watershed, site code: CANA110).

References:

- Bunn, A. G. (2008). A dendrochronology program library in R (dplR). *Dendrochronologia*, 26(2), 115-124.
- Bunn, A., & Korpela, M. (2020). An introduction to dplR. *Processed with dplR*, 1(2), 1-16.
- Holmes, R. L. (1981). Computer-assisted quality control in tree-ring dating and measurement. *Tree-ring Bulletin*, 43: 69-78.
- Norton, D. A., & Ogden, J. (1987). Dendrochronology: a review with emphasis on New Zealand applications. *New Zealand journal of ecology*, 77-95.

Appendices.

Appendix A: Letter from NZ supplier of cedar timber samples.

H I D E A W A Y

To whom it may concern,

Confirmation of Cedar Timber samples

This letter confirms the recent provision of cedar timber samples to Daniel Gudsell of Abodo Timber.

These samples provided were random offcuts taken from a batch of Cedar timber we were using to construct seats in a Sauna project from a local company. This is a typical grade of cedar used in relation to the interior structures of our Saunas.

These specific samples were selected by our staff from our existing stock of offcuts, and provided to Daniel Gudsell as a representative example of the timber we utilize.

Please note that these samples were not selected by Daniel Gudsell but by Hideaway staff. If you require further clarification regarding the origin of timber provided please do not hesitate to contact us.

Sincerely,

Richard Hill

021971515

madebyhideaway@gmail.com

Appendix B: Table of ring-width measurements.

The ten ABODO sample ring-width measurements in Tucson Decadal Format (TDF). This is the standard text file format for sharing tree-ring data (ring widths) used by the International Tree-Ring Data Bank (ITRDB). The decadal format stores sample ID, year, and up to 10 ring widths (in 0.001mm units), and "-9999" as stop markers.

ABD01	1899	1430									
ABD01	1900	1479	1672	1641	1467	1623	1345	1512	1248	1278	1191
ABD01	1910	1239	775	653	878	942	1121	884	1040	1009	1232
ABD01	1920	1468	859	852	1267	1405	1263	1624	1589	1826	1635
ABD01	1930	1600	1240	967	-9999						
ABD02	1581	1020	830	932	928	949	706	759	680	699	
ABD02	1590	686	870	639	855	845	804	725	755	736	584
ABD02	1600	607	730	836	719	713	849	857	732	869	866
ABD02	1610	671	674	807	828	724	767	746	862	929	605
ABD02	1620	561	567	613	604	618	698	696	675	550	512
ABD02	1630	710	695	715	747	676	662	666	723	698	875
ABD02	1640	932	915	807	742	673	715	836	798	814	787
ABD02	1650	740	818	921	698	1060	856	884	907	806	772
ABD02	1660	775	1031	-9999							
ABD03	1646	844	841	1025	1193						
ABD03	1650	1279	1148	1179	1122	994	1171	1347	1348	1253	1186
ABD03	1660	959	1118	1241	1089	855	983	855	709	877	972
ABD03	1670	934	1212	1283	1318	850	949	1150	1041	773	746
ABD03	1680	836	1047	921	535	787	659	686	700	762	644
ABD03	1690	866	1040	869	1024	880	895	637	794	798	791
ABD03	1700	776	817	700	544	691	887	951	933	855	1061
ABD03	1710	942	983	941	954	806	632	839	880	858	623
ABD03	1720	705	920	1026	1090	1385	1083	877	883	1031	1003
ABD03	1730	637	996	495	412	677	-9999				
ABD04	1899	500									
ABD04	1900	471	623	671	727	704	645	526	638	758	703
ABD04	1910	772	610	325	559	591	654	542	578	682	654
ABD04	1920	652	405	470	627	653	602	554	604	679	738
ABD04	1930	716	713	791	864	941	856	864	667	661	757
ABD04	1940	704	709	756	585	600	626	656	555	377	360
ABD04	1950	268	276	415	415	426	434	403	427	384	237
ABD04	1960	324	264	338	398	379	383	433	392	517	412
ABD04	1970	323	232	207	186	228	267	237	254	241	171
ABD04	1980	181	129	116	106	140	161	128	200	231	244
ABD04	1990	325	300	309	235	247	207	193	212	259	261
ABD04	2000	232	223	176	145	300	342	369	511	432	501
ABD04	2010	553	559	415	360	-9999					
ABD05	1875	1237	984	1263	1670	1430					
ABD05	1880	1297	1270	1239	1321	1113	1899	1694	1783	1606	2374
ABD05	1890	2168	2009	1825	1390	1649	1376	860	919	1159	984
ABD05	1900	882	1076	1124	1052	983	1231	1682	1547	1507	-9999
ABD06	1716	974	1226	1000	909						
ABD06	1720	822	877	840	810	857	818	866	705	819	680
ABD06	1730	751	939	791	879	799	835	706	649	722	633
ABD06	1740	643	747	802	740	641	611	645	758	552	602
ABD06	1750	647	637	704	718	728	689	628	682	661	437
ABD06	1760	383	567	583	645	729	524	529	567	590	551
ABD06	1770	684	520	683	592	727	743	655	642	564	642
ABD06	1780	687	610	487	625	513	587	552	548	593	529
ABD06	1790	472	553	553	573	601	432	495	483	432	381
ABD06	1800	340	400	462	453	523	556	499	356	338	378
ABD06	1810	414	340	394	389	434	522	404	382	350	375
ABD06	1820	481	481	463	330	355	269	460	436	396	507
ABD06	1830	471	537	386	471	428	468	502	-9999		

Appendix C: Photographs of the ten ABODO western red cedar samples.

Figure C1. Image of ABD01. Note that the growth direction is from the bottom to the top of the image.

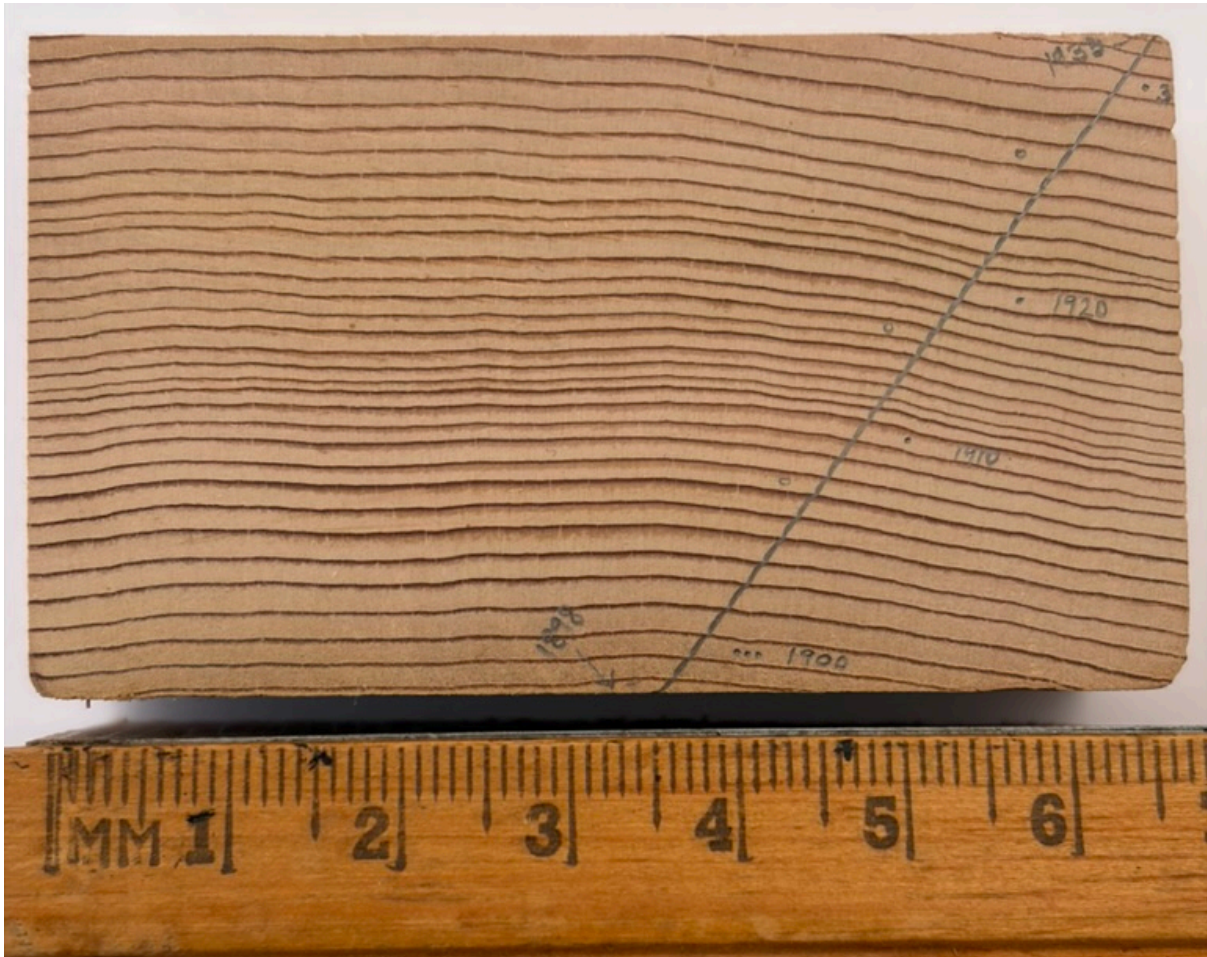


Figure C2: Image of ABD02. Note that the growth direction is from the bottom to the top of the image.



Figure C3: Image of ABD03. The growth direction is from the bottom to the top of the image. Note, ring deformation usually caused by nearby branching.



Figure C4: Image of ABD04. Note that the growth direction is from the bottom to the top of the image. Some bark is visible at the top left corner and there is a visible transition from heartwood to sapwood.



Figure C5: Image of ABD05. Note that the growth direction is from the bottom to the top of the image.

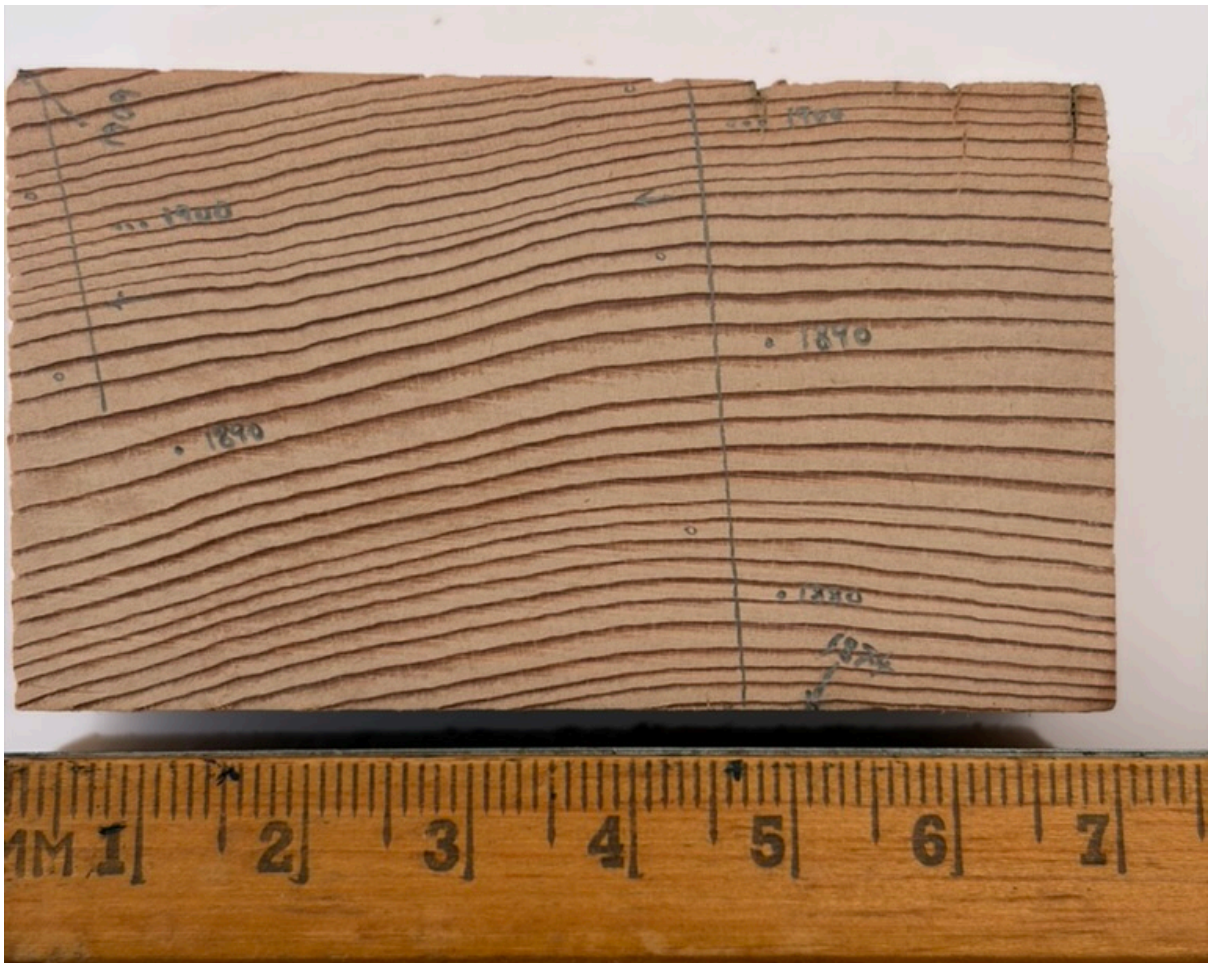


Figure C6: Image of ABD06. Note that the growth direction is from the right to the left of the image.



Figure C7: Image of ABD07. Note that the growth direction is from the bottom to the top of the image.

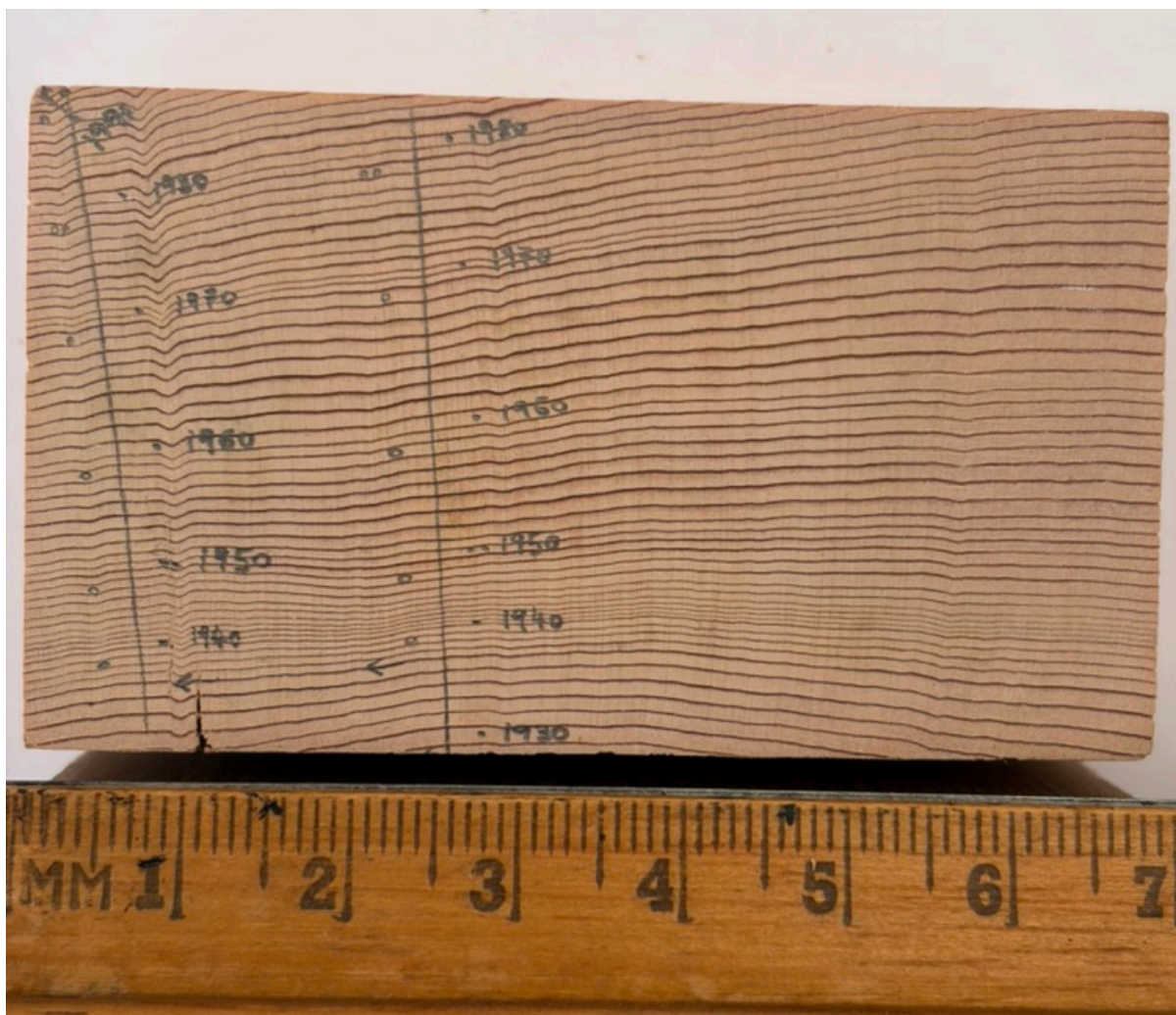


Figure C8: Image of ABD08. Note that the growth direction is from the right to the left of the image.



Figure C9: Image of ABD09. Note that the growth direction is from the bottom to the top of the image, and the rings are wedging towards the right side.



Figure C10: Image of ABD10. Note that the growth direction is from the bottom to the top of the image.

