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RE-DATING THE "MESSIAH" VIOLIN ATTRIBUTED TO ANTONIO STRADIVARI

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ABSTRACT

The "Messiah" violin attributed Antonio Stradivari (1644-1737) crossdates with the "Archinto" viola of Stradivari setting the youngest tree ring at the year 1686 according to a previous controversial dating of the "Archinto" viola. The revised date of the "Messiah" is 1701. This date is obtained by crossdating with the larch chronology ITAL040 of the International Tree Ring Data Base. Furthermore, the violin crossdates with a viola, which bears a "Jo: Battista Ruggierius" label, though possibly made by a different instrument maker. The viola crossdates with the "Messiah" violin setting the youngest ring at the year 1699 but fails to crossdate with any other chronology. However, the comparison of its yearly tree-ring pattern with decadal-resolution climate data reveals a useful relationship, thus indirectly supporting the revised date of the "Messiah" violin. The matching with reconstructed temperatures is made via indexing of the tree-ring measurements. An exponential curve is fitted to the measurements, and the index of growth is obtained by dividing the measurements with the values of the curve. The best match is the year 1700.

KEYWORDS: Italian instrument maker, dendrochronology, climate change

1. INTRODUCTION

A viola labelled "Jo: Battista Ruggierius (Rogeri) in Brescia del 1662" (Fig. 1) can be traced back to an owner in Hamburg, Germany, in the year 1930. The label has minor relevance because labelling of the instruments of the Rogeri family is known to be inconsistent. For example, the 1720 violin of Pietro Giacomo Rogeri (1665-c.1740), the son of Giovanni Battista Rogeri (1642-c.1705), bears the Rogeri Senior label with the year 1666 (Tarisio repository; https://tarisio.com).

Figure 1. Images of the "Ruggierius" viola: top (with three pieces of attached measuring tape), back, scroll and label.

The viola has a one-piece top with 101 tree rings (Fig. 2) and exclusively crossdates with the archaeological chronology BRIT050 of the International Tree Ring Data Base (ITRDB; https://www.ncdc.noaa.gov) setting the latest tree ring at the year 1684. The BRIT050 chronology is established for the "Messiah" violin, which is assigned to Antonio Stradivari (1644-1737). The "Messiah" violin has the common two-piece top, composed of the so-called the treble side with 97 tree rings and bass side with 99 tree rings, the latest ring dating 1686 (Fig. 3). Several other dates have been proposed for the "Messiah" (reviewed by Pollens 2010-a,b and Sackman 2020). All except one date (1682) are outside Stradivari's lifetime (1644-1737). Nevertheless, the assignment to Stradivari is promoted by more recently published same-tree relationships: the wood of the "Messiah" has come from the tree used for another Stradivari violin according to Ratcliff (2016) and a violin made by Rogeri Junior according to Versteeg (2011).

This paper re-assesses the dating of the "Messiah" in conjunction with the dendrochronological and stylistic evaluation of the "Ruggierius". Decadal-resolution climate data of the Northern Hemisphere are used to support the yearly-resolution dendrochronological data.

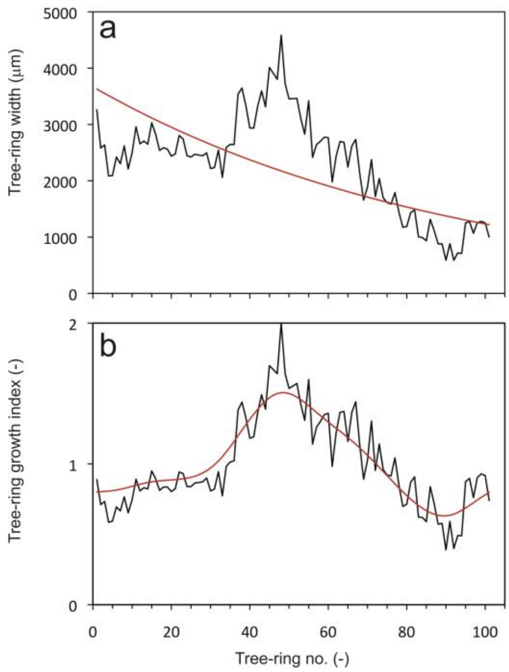

Figure 2. a Measurements of the tree-ring thickness (in μm) of the "Ruggierius" viola; the negative exponential curve or regression line fitted to measurements is also shown. b Index of growth obtained by dividing the measurements with the corresponding value of the exponential curve; the cubic spline with a rigidity of 32 years and 50% frequency response at a wavelength of 32 years fitted to the index of growth is also shown.

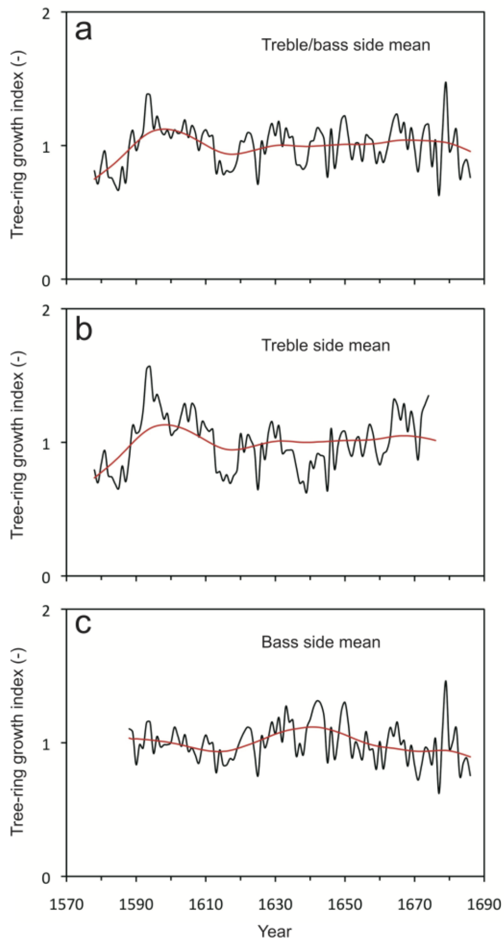

Figure 3. The growth index of the archaeological BRIT050 chronology for the "Messiah" violin, obtained by combining the individual measurement series via a mean value function after detrending with a negative exponential curve. The cubic spline with a rigidity of 32 years and 50% frequency response at a wavelength of 32 years fitted to the index of growth is also shown.

2. METHODS

2.1. *Stylistic evaluation*

The outline of the body and f-holes of the "Ruggierius" viola is traced on paper and the scanned image is vectorised in CorelDraw. Suitable images of approximately 250 published photographs and patterns of pre-1930 violas (Tarisio repository; Javolec 1957, 1959; Riley 1980, 1991; Zoebisch 2002, 2012; Pollens 2010-b) are checked and corrected for geometrical distortion using image processing software, if necessary, and matched with the vector graphic.

2.2. *Dendrochronological evaluation*

The image of the viola top with attached measuring tape (Fig. 1) is opened in CorelDRAW with the centre line parallel to the x-axis. The distance between tree rings "Δy_{ij}" is digitalised as multi-vertex line exclusively consisting of horizontal and vertical segments. The oldest and youngest ring are represented by two vertices each. The remaining rings are represented by at least one vertex. The line coordinates are exported as a text file. Suitable formats are DXF version R2.5 through R11 or the default DXF in older releases of the program. The text file is opened as spreadsheet. Double counts are recognised by notably small "Δy_{ji}" or "Δy_{ji}"$\leq$0 in addition to visual inspection. After elimination of double counts, "Δy_{ji}" is converted from DXF units into µm. In addition, the values are corrected for curvature of the viola top, optical distortion and projection on a plane (optical error). Both operations are performed with a single equation for "$\Delta_{1,i}$" and "$\Delta_{2,i}$", i.e. positions below and above the centre line, respectively:

$$\Delta_{1,i}=h_{1,i}/(1000c(e(c-n_{1,i})+f\,n_{1,i})), \quad (1)$$

$$\Delta_{2,i}=h_{2,i}/(1000(b-d)(g(n_{2,i}-d)+f\,(b-n_{2,i})), \quad (2)$$

where "$\Delta_{1,i}$" is the thickness of ring "i" above the centre line (older portion of the tree ring series), "$\Delta_{2,i}$" is the thickness of ring "i" below the centre line (younger portion of the tree ring series), "b" is the tree ring number of the youngest ring (bottom of the image), "c" is the tree ring number of the ring immediately above the centre line, "d" is the tree ring number of the ring immediately below the centre line, "e" is mm divided by DXF units at the oldest tree ring, "f" is mm divided by DXF units at the centre line, "g" is mm divided by DXF units at the youngest tree ring, "$h_{1,i}$" is the DXF unit thickness of ring "i" above the centre line, "$h_{2,i}$" is the DXF unit thickness of ring "i" below the centre line, "n_1,i" is the tree ring number above the centre line starting with i=1 at the top of the image, and "$n_{2,i}$" is the tree ring number below the centre line.

Note that the above equations can also be applied to two-piece tops, and the only difference is that the borderline between the two pieces is used as a reference line instead of the centre line in the case of a one-piece top. The measurement programs reviewed in Speer (2010) and Maxwell et al. (2011) do not have an algorithm that removes the optical error. Therefore, the manual technique (such as the one described above) is the logical choice.

The tree-ring series of the viola is reformatted to a suitable input format for COFECHA and crossdated against the ITRDB master series. The scan is performed with COFECHA version 6.06P (https://www.ldeo.columbia.edu/tree-ring-laboratory; Holmes 1983).

The scan is applied to string instruments and master series for relevant tree species in the Alps and Bayerische Wald. Species are considered to be relevant if they have already been used in crossdating of string instruments: *Larix decidua* Mill.=European larch, *Picea abies* (L.) H.Karst=Norway spruce, *Pinus cembra* L.=Swiss stone pine and *Abies alba* Mill.=European silver fir.

COFECHA crossdates undated measurement series against a dated master chronology. The individual series of the chronology are combined via a mean value function after detrending prior to crossdating. The default options in the COFECHA program are applied in the scan of the ITRDB. Autoregressive modelling (AR) is activated. The rigidity of the cubic spline curve applied for removal of the low-frequency trend in the series has a rigidity of 32 years, with a 50% frequency response at a wavelength of 32 years. Two settings of segment length are used: 50-year segments with 25-year overlapping periods (default) and segment length equal to the total series. Only a master series that yields a relevant correlation in addition to identical dates (years added/subtracted) for the total-length segment and short segments is subjected to closer inspection. This consists of the reduction of the length of the short segments and length of the overlapping periods. In addition, the results are checked with the alternative software TSAP-Win version 4.81 (RINNTECH 2011) and CDendro version 9.4 (Cybis 2020). The data are considered relevant only if the null hypothesis (i.e. the hypothesis that two series are not correlated) has a low probability of error for the total-length segment (Greenland et al. 2016). This is the case, for example, when the statistics textbook *t*-value, which is derived from the Pearson correlation coefficient, is greater than 3.5 for the total-segment length, e.g., corresponding to $p \leq 0.035\%$ for a 100-year segment. The use of a *t*-value threshold of 3.5 to indicate an acceptable match has become routine practice in dendrochronology (Baile 1982; Hassan et al. 2019). The alternative software TSAP-Win and CDendro used for checking the COFECHA results calculate textbook *t*-values according to the method of Baillie and Pilcher (1973). Note that other programs that do not calculate Pearson correlation coefficients or textbook *t*-values are not suitable for comparative purposes because they do not allow the calculation of *p*-values; this applies to the SynchroSearch program with the "personalized" correlation coefficient (Mondino and Avalle 2010-a) and the PAST5 program with the "adapted" *t*-value (SCIEM 2015, p. 128).

2.3. *Climatic evaluation*

The comparison with reconstructed temperature curves is made via indexing of the tree ring measurements with the CRONOL program (Holmes 1999-a). A negative exponential curve or regression line is fitted to the indexed measurement series computed as a "biweight robust mean", and the index of growth for each year is obtained by dividing the measurements with the corresponding value of the exponential curve. A cubic spline with a rigidity of 32 years and 50% frequency response at a wavelength of 32 years is fitted to the index of growth, using the program FMT (Holmes 1999-b). Low-frequency plots of Northern Hemisphere temperature versus time are overlaid with the spline curve whereby the position with the strongest correlation is found by visual inspection. This procedure can be successful if the spline curve exhibits a relative high amplitude, comparable to that of the low-frequency temperature curve.

3. RESULTS

3.1. *Style and sound*

The "Ruggierius" contralto viola has a body length of 40.0 cm and has a pattern that matches closely the down-scaled pattern of the c.1580 "Gordon" tenor viola of Gasparo Bertolotti da Salo (1540-1609), which has body length of 43.6 cm (Riley 1980) (Fig. 4). To a lesser degree, it matches the down-scaled pattern of the 1672 "Mahler" contralto viola of Antonio Stradivari (1644-1737), which has a body length of 41.2 cm (Tarisio repository), and that of the MS55 inside mould, which has a length of 39.6 cm and which has been used for making the instrument (Pollens 2010-b). Although the Bertolotti and Stradivari patterns do not match completely, they are sufficiently similar to suggest that Stradivari, the Rogeris or other apprentices in the shop of Nicolò Amati had access to the Bertolotti pattern, possibly via imperfect copies. Note that the pattern of the "Ruggierius" is quite different from that of later violas, i.e., up to the year to which the ownership can be traced back (1930).

An interesting feature of the "Gordon" tenor is the distribution of varnish that has been rubbed off from the back of the instrument; the wear occurred mainly on the lower portion of the instrument (underneath the chin rest). In contrast, the "Ruggierius" contralto shows more wide-spread wear, i.e., in the central and upper portion in addition to the lower portion. Generally speaking, the pre-1700 short instruments (contraltos) show more wear than contemporaneous long instruments (tenors) because they are easier to play and thus have been used more.

Note that the f-holes of the reference instruments appear to be shorter than those of the "Ruggierius" because the traces of the outline are overlaid such that they match in body length but not in f-hole length. Because the f-hole length varies minimally with body length, a short instrument such as the "Ruggierius" appears to have relatively long f-holes when overlaid with the down-scaled outline of a longer instrument such as the "Gordon" or "Mahler". In summary, the association of the "Ruggierius" with the shop of Nicolò Amati and his apprentices in terms of style is not unrealistic. Especially, the superb sound of the "Ruggierius" points to a highly competent instrument maker.

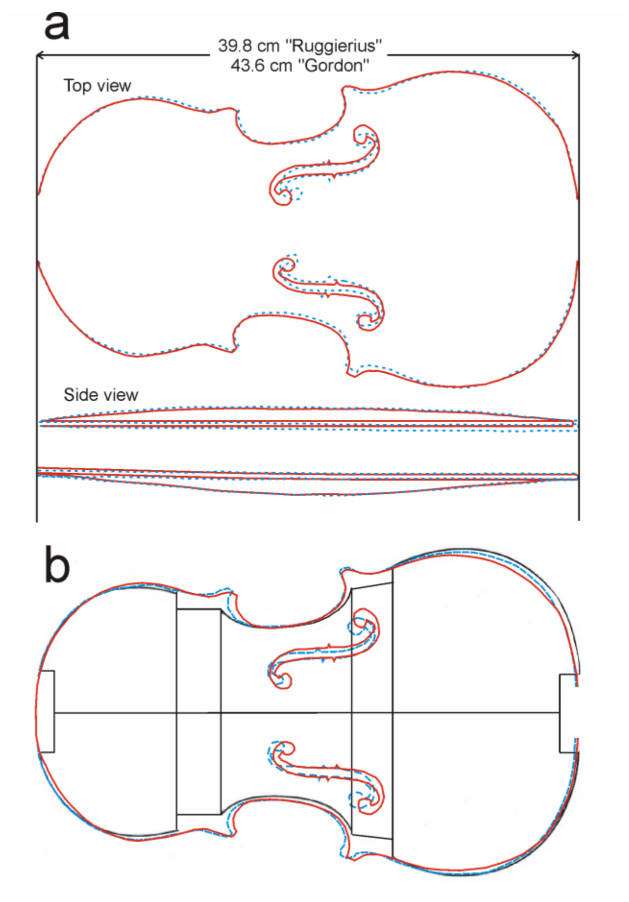

Figure 4. Pattern of the "Ruggierius" viola (solid red line), which has a body length of 40.0 cm, as parallel projection on a horizontal plane (top view) and vertical plane (side view) overlaid on the pattern/mould of reference violas with a high degree of similarity a Down-scaled reference pattern (interrupted blue line) as parallel projection of the c.1580 "Gordon" viola of Gasparo Bertolotti da Salo, which has a body length of 43.6 cm (Riley 1980). b Reference inside mould MS55 (<1672) (solid black line), which has a length of 39.6 cm and which has been used for making Stradivari's 1672 "Mahler" viola with a body length of 41.2 cm (Pollens 2010-b; Tarisio repository), and down-scaled reference pattern (interrupted blue line) as a photographic (non-parallel) projection of the "Mahler" viola (The Strad 2020).

3.2. *Dendrochronology*

The measurement series of the "Ruggierius" viola (Fig. 2) crossdate against the archaeological ITRDB chronology BRIT050 for the "Messiah" violin of Antonio Stradivari setting the youngest tree ring at the year 1684. The COFECHA program calculates a Pearson correlation coefficient of 0.36, corresponding to a *t*-value of 3.8 whereby the default segment length of 50 years allows to be reduced to 34 years with an overlapping period of 10 years (see METHODS). Both the TSAP-Win and CDendro program calculate a higher *t*-value (4.2).

The counter-check with undated and dated chronology reversed ("Messiah" crossdated against "Ruggierius") yields a similar Pearson correlation coefficient. The COFECHA program calculates r=0.40, corresponding to a *t*-values of 4.3. In this counter-check, the segment length is allowed to be reduced to 34 years with an overlapping period of 10 years. The alternative programs TSAP-Win and CDendro calculate *t*-values of 3.7 and 4.0, respectively.

The "Messiah" violin crossdates against the "Archinto" viola of Stradivari with the youngest tree ring at the year 1686; the corresponding *t*-value of <3.7 is estimated from the averaged correlation coefficient (0.34) of eight 40-years segments overlapping by 10 years (Grissino-Mayer et al. 2004). The anchoring of the "Archinto" chronology has been performed via crossdating against a regional composite chronology consisting of 16 individual regional chronologies. The anchoring of the "Archinto" chronology is controversial because more than 50 tree rings of the "Archinto" measurement series mismatch with the regional chronology used for anchoring (Grissino-Mayer et al. 2004) or are negatively correlated with the regional chronology (Mondino and Avalle 2010-b).

Except for the "Archinto" chronology, the "Messiah" BRIT050 chronology (averaged with a mean value function after detrending) does not crossdate with any ITRDB chronology. However, the averaged two treble-side series of BRIT050 crossdate with the larch chronology ITAL040 (Coppola et al. 2013) setting the youngest ring at the year 1689 for the treble side and 1701 for the bass side, which is 12 years younger. COFECHA, TSAP-Win and CDendro calculate *t*-values of 3.6, 3.9 and 3.8, respectively, for the Messiah/ITAL040 relationship.

The year 1701 is the accepted date for the "Messiah" violin. The previously published date derived from a mismatched floating "Archinto" chronology should be discarded.

The 1701 date of the "Messiah" violin obtains indirect support by crossdating against the "Ruggierius" viola via climatic relationships. The revised date of the viola, which is 1684+15=1699, matches with climate data (see below).

3.3. *Climate*

The diagrams of reconstructed temperatures of the Northern Hemisphere from a review by Smerdon and Pollack (2016) are overlaid with the index of growth of the tree rings of the "Ruggierius" viola, which is fitted to a cubic spline with a rigidity of 32 years (Fig. 5). The best fit is found by visual inspection. The temperature curve of the annual mean for the full hemisphere suggests a best match when the "Ruggierius" series has the youngest tree ring placed at the year

1700 within the 1400-1950 period. Other temperature curves of Smerdon and Pollack's review suggest a best match in the narrow range of 1700-1710. Using an equivalent procedure for the corresponding "Messiah" growth curves is not feasible because of the relatively flat shape of the splines.

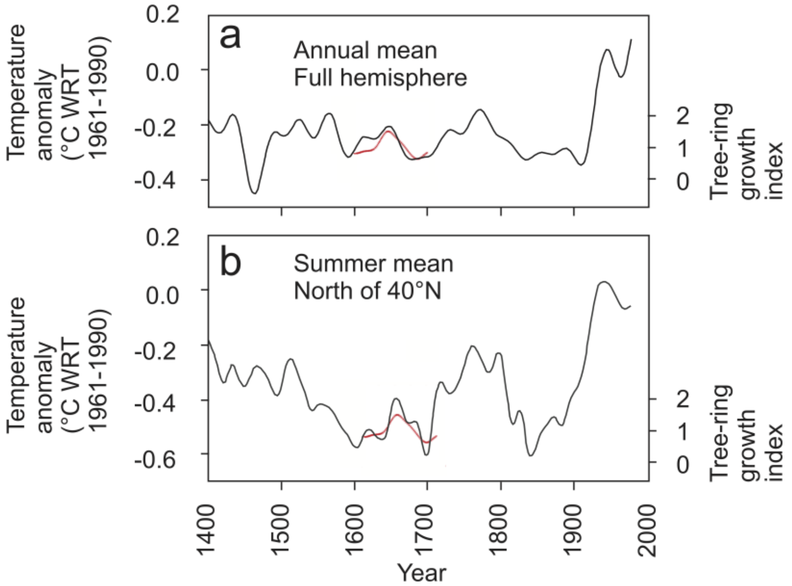

Figure 5. Northern Hemisphere temperature reconstruction (black lines), redrawn from Smerdon and Pollack (2016). The data are taken from Mann et al. (1999; Northern Hemisphere annual mean) and Jones et al. (1998; Northern Hemisphere north of 40°N summer mean) and smoothed with a 40-year Hamming-weights lowpass filter. The temperature curves are overlaid by the index of growth of the "Ruggierius" tree-ring series fitted to a cubic spline with a rigidity of 32 years (red line), whereby the best position is found by visual inspection

4. CONCLUSION

Anchoring a floating chronology in time via climate data is an attractive supplementary method, i.e., in addition to the usual dendrochronologic, stylistic and historic methods. The "Ruggierius" viola is an example of an instrument that can be anchored in time with decadal climate data, indirectly supporting the revised dendrochronological date of the "Messiah" violin. In contrast, the "Messiah" violin is an example of an instrument that cannot be directly anchored in time with climate data because the fitting splines of the dentrended time series of the "Messiah" are relatively flat. Nevertheless, the reasonably high *t*-value for the Messiah/Ruggierius crossdating (4.3) suggests that the revised dendrochronological date of the "Messiah" is supported by the relationship between the year-ring structure of the "Ruggierius" including climate data. The re-dating of the "Messiah" to the year 1701 has no consequences for the assignment of the "Messiah" to Antonio Stradivari, who died as late as 1737.

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