Chapter 15

Dendrochronology

Dendrochronology is a long-established science which, in recent years, has been used as a tool for dating the spruce front plates of string instruments. Initially this science was viewed with misgivings by the string-world's style experts since it appeared to offer a level of exactitude which threatened their traditional (and expensive-to-access) skills. During the past twenty years it has been realised that dendrochronology, when it supports style expertise, is a valuable adjunct to the style-expert's knowledge, powers of observation, and memory. However, when dendrochronology fails to deliver the expected answers and, instead, exposes further uncertainties (and those uncertainties then breed competing camps of supporters who challenge each other's methodologies and results) the science becomes rather less useful. Today, some 'high end' dealers will offer dendrochronological information to underpin the authenticity of a rare and expensive violin; catalogues and books on string instruments are now beginning to publish 'dendro dates' alongside their photographs and descriptions;[1] it has been suggested that auction houses should provide a dendrochronological report for their choicest instruments.

A dendrochronological analysis of the spruce front plate of a violin can never provide results which will identify the name of the maker who built that front plate. As Stewart Pollens has commented:

> […] one cannot date [the year-specific creation of] a violin using dendrochronology.
> However, one can rule out makers who died before the tree was cut down.[2]

Death, though, does not necessarily prevent a violin maker from apparently continuing to make violins: Cremonese violin maker A dies in 1737; the following year an Alpine spruce tree is felled and extracted wedges are seasoned for five years,[3] until 1743; violin maker B (who worked alongside maker A and learned all his constructional techniques and procedures) then planes away six sapwood growth rings from the outside convex faces of two wedges (the outermost/BS growth rings thus date from 1732[4]); violin maker B then makes a violin using those wedges for the front plate, and, for commercial reasons, puts maker A's label, with a date of, say, 1736, inside the finished instrument. All that can be demonstrated by a dendrochronological analysis of that front plate is that the outermost/CJ ('youngest') growth ring – either treble-side or bass-side of the centre joint – can be dated to 1732 (the dendrochronological analysis thus inadvertently lending weight to the apparent validity of the label) and this analysis relies on there being a geographically relevant 'reference' chronology of absolutely-dated spruce growth-ring data against which the growth-ring data from the

[1] See MIAM:CC/Milnes pp. 12-13.

[2] JoVSA (XVII, 3) p. 162.

[3] See also Chapter 16.

[4] To use the term 'outermost' for the tree-trunk growth ring which was nearest to the underside of the bark but which will eventually be located on one side of the violin's front-plate centre joint is confusing (simply because, physically, it will then be one of the two innermost rings). To use the term 'innermost' for the centre-joint rings brings about the reversed difficulty of describing the tree's bark-side rings. Some writers use the term 'youngest' but that can create confusion between 1) the rings which were formed in the first few years of the tree's life, when the tree began to grow, and 2) the ring nearest to the underside of the bark (which can be termed the 'youngest' ring when the years between the date of the tree's felling and the present-day are considered in reverse – this is the intended meaning of the term 'youngest'). Since some of the tree's bark-side rings are planed away to true-up the convex face of each extracted wedge (see Chapter 16) the ring which was the outermost, or 'youngest', is now in shavings on the workshop floor and it is an inner/older ring which is now the outermost/youngest. Since none of the common descriptive terms is entirely unambiguous – and as authorial policy – 'outermost/BS' indicates 'outermost, bark-side'; 'outermost/CJ' indicates 'outermost (but now at the) centre joint'.

violin can be compared. Only, possibly, a style expert would be able to circumvent the false information on the violin's label through studying the physical characteristics of the violin's construction.

The science of dendrochronology, especially in its mathematical and statistical aspects, is very sophisticated and, for the layman, fairly impenetrable. To a large extent the lay string enthusiast has no option but to accept the published word of dendrochronologists since questioning the scientific outcomes is usually not feasible. Thus, in some respects, dendrochronology presents what might be regarded as an uncomfortable parallel to the esoteric world of string-instrument style expertise.

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The process for a dendrochronological investigation of a spruce front plate begins with measuring, to an accuracy of at least 1/100th millimetre, the width of each growth ring across each half of the lower bout. The two sequences of results can be plotted on X/Y graphs, with each dot (indicating a ring's width) plotted against a vertical millimetre scale (the 'y' axis). Joining the dots creates a zig-zag line which is termed a 'curve'. At this point, the horizontal 'x' axis can only indicate the ring numbers since this 'raw measurements' graph is floating in time – no ring dates are yet known.

The graph for the bass-side curve is laid out, from left to right, in the same orientation as the violin's physical reality (viewed face on). However, the treble-side curve is graphically reversed from the physical reality of the front plate; the violin's treble-side bout-edge rings are on the upper-left of the graph, the centre-joint rings are on the lower-right of the graph (see Figures 9 and 10). A 'raw' X/Y graph of ring growth will usually display a curve which descends towards the right-hand bottom corner of the graph; the descent is reflecting the narrowing ring widths which occur as the tree grows over time. However, the narrowing width of a tree's rings is not necessarily indicative of the tree growing any less each year – the tree might grow by the same amount in year 85 as it did in year 84, but the ring-growth in year 85, underneath the bark, is being stretched around an ever-expanding circumference of trunk:

> All trees have this trend […] It occurs due to a simple constraint of tree growth where an individual tree is creating the same amount of biomass onto an increasingly larger individual. As the tree becomes larger every year, the radial increment each year must decrease. It's simply a geometric constraint of growth. […] It's a matter of placing the same area or same volume of wood on an increasingly larger individual.[5]

Figures 9 and 10 reveal the normal trend of narrowing ring widths as the tree ages. The distinctive bass-side trough of ring 38 – indicative of very unfavourable climatic conditions – is a point of potential 'synchronisation' (or 'cross-matching')[6] not only with the treble-side ring 48 (which could help to synchronise the two halves of the *Messiah* violin's front plate), but also with X/Y raw curves derived from other instruments which are thought to be contemporaneous. Two subsequent troughs – bass rings 58 and 60, treble rings 68 and 70 – offer further synchronisation potential, as does the powerful spurt in youthful growth seen in the treble graph (Figure 10) – peaking at rings 16 and 17 – which is replicated, at a lower level, in the bass graph (Figure 9) for rings 6 and 7.

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[5] Paul Sheppard (Laboratory of Tree-Ring Research, University of Arizona, Tucson, USA), in Grissino-Mayer *et al*. (2001/2003), p. 137.

[6] John Topham and Derek McCormick ('The dating game', *The Strad*, August 2001, p. 848) define 'cross-matching' as 'comparing the ring-width patterns (curves) of different wood specimens'.

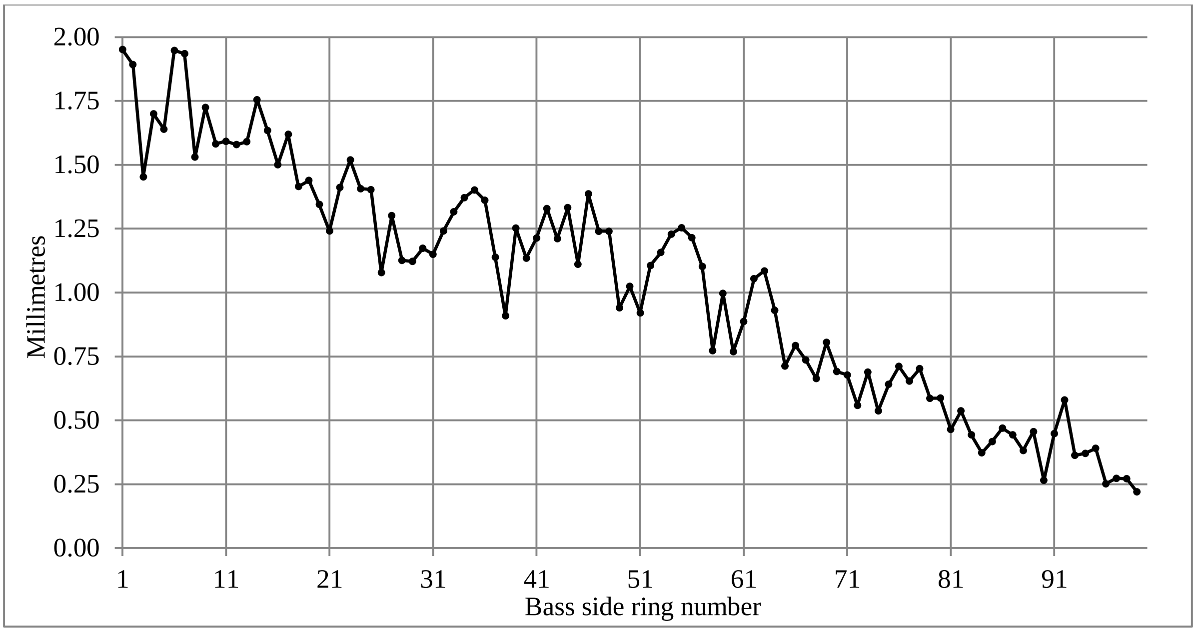

Figure 9:[7] *Messiah* violin, bass side, raw ring-measurement curve. Measurement data from ITRDB BRIT050.rwl.[8] Bass-side lower-bout edge is top-left, centre joint is bottom-right: 99 rings.

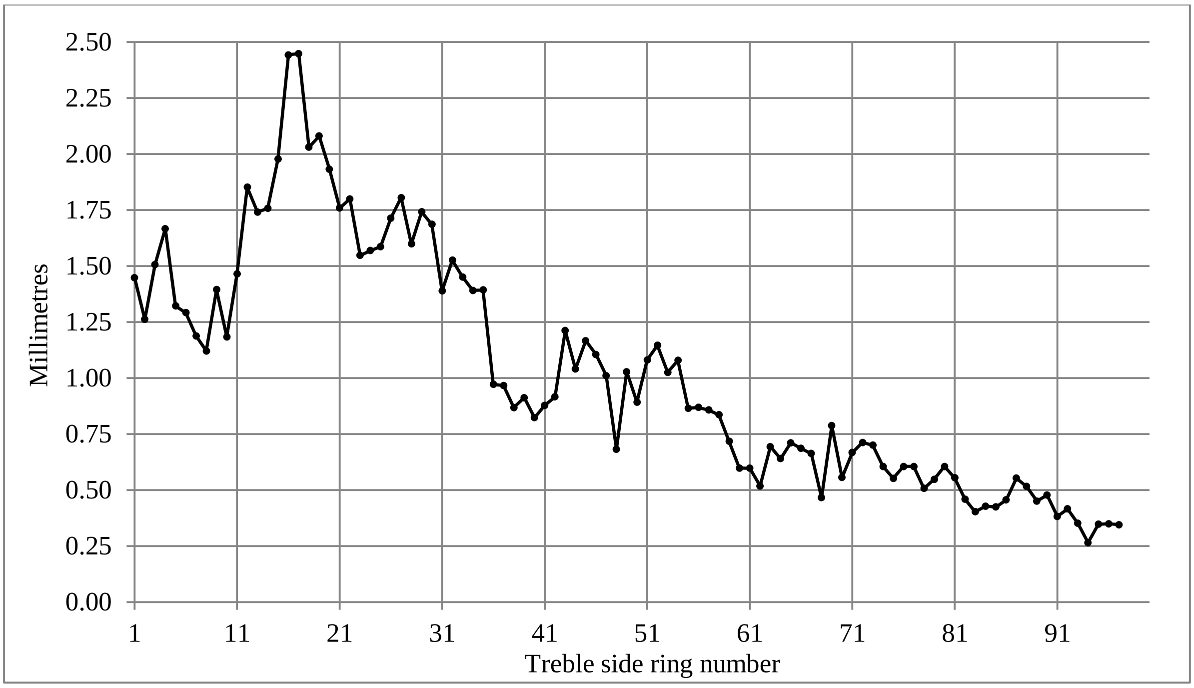

Figure 10: *Messiah* violin, treble side, raw ring-measurement curve. Measurement data from ITRDB BRIT050.rwl.[9] Treble-side lower-bout edge is on the left, centre joint is bottom-right: 97 rings.

Superimposing and synchronising the raw bass and treble curves from Figures 9 and 10 creates Figure 11, from which it is clear that there are extensive year-periods where the two curves follow each other in parallel, lending support to the statement made in MIAM:CC/Milnes that the dendrochronological

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[7] All the graphs presented in this chapter are the responsibility of the present author.
[8] International Tree-Ring Data Bank website accessed October 2012. The ITRDB suffix '.rwl' indicates raw widths of rings.
[9] Website accessed October 2012

evidence from the bass and treble sides of the *Messiah* violin reveals a match ‘close enough to suggest that [the two front-plate] pieces came from the same tree’.[10]

Nonetheless, one clearly visible feature of Figure 11 is that the bass-side curve (solid line) changes its position relative to the treble-side curve (dotted line). Initially, the bass-side rings, in almost all years, are narrower than the treble-side rings. Then the relationship reverses, and remains reversed until the ‘common’ data ends. If the bass-side curve in Figure 11 is assumed to be derived from the north-facing half of an Alpine spruce tree (i.e. always in shadow from the sun’s rays, even at the time of the Northern Solstice) then the reversal of relationship with the treble curve indicates that the north-facing half subsequently (and for the next sixty years) grew consistently more strongly than the south-facing (sun-facing) half, which, at first sight, seems questionable. Alternatively, perhaps the solid line of Figure 11 represents the south-facing half of the tree which, for twenty years, was severely hampered in its growth by a localised condition; once that restrictive biological/environmental condition was nullified the south-facing half then grew more strongly. Whether the tree in question was growing on an Alpine slope which itself faced north, or faced south (or, indeed, east or west), has also to be considered.

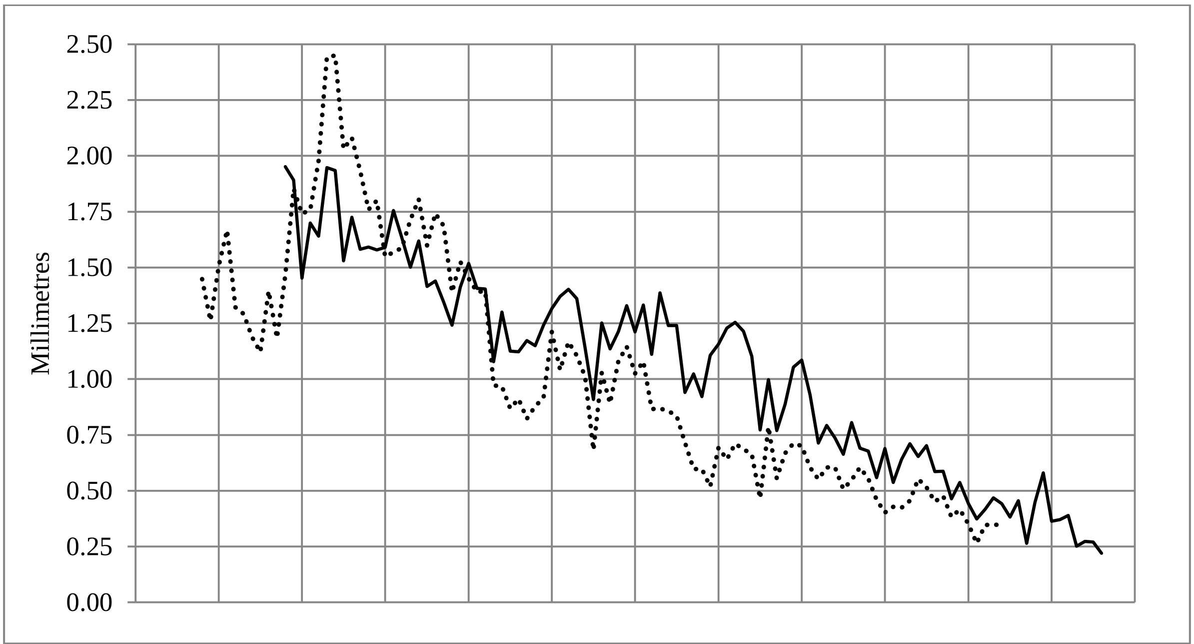

Figure 11: *Messiah* violin, raw bass and treble ring-growth curves superimposed and synchronised. Bass-side curve is solid, treble-side curve is dotted; treble-side ring 11 coincides with bass-side ring 1; lower-bout edge is top left, centre joint is bottom right; marker dots have been omitted for clarity.

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At least 80 ring measurements are needed in a curve derived from a violin’s front-plate half width to avoid erroneous results when comparing the floating-in-time data with a reference spruce

[10] MIAM:CC/Milnes pp. 12-13. Dendrochronology results in MIAM:CC/Milnes are stated (p. 11) to be ‘from Topham 2000 and 2002’. ‘Topham 2000’ indicates John Topham and Derek McCormick’s March 2000 article *A Dendrochronological Investigation of Stringed Instruments of the Cremonese School* […] in the Journal of Archaeological Science; ‘Topham 2002’ indicates John Topham’s April 2002 article for the Galpin Society Journal (Vol. 55), *A Dendrochronological Survey of Musical Instruments from the Hill Collection at the Ashmolean Museum in Oxford*.

chronology.[11] Fortunately, the ring totals for the front-plate half widths of violins are almost always greater than 80. Extensive evidence indicates that half-width ring totals, for full-size Stradivari violins, normally range between 80 and 90 but can be as low as 59 and as high as 203.[12]

Contemporary dendrochronologists carry out various mathematical procedures on the raw ring measurements to remove the distorting effects of anomalies, localised environmental variations, and statistical 'noise'.[13] The unwanted effects of the age-related, diminishing-ring-width trend can also be removed from the measurement data. The resultant 'de-trended' data for the under-test piece of spruce is graphically presented in an 'index' chronology, which, at this stage, is still undated – it floats in time. Marvin Stokes and Terah Smiley describe the investigative objective of index chronologies:

> […] one must be able to answer the question, "Is this ring wide or narrow for this particular tree at this time in its life?"[14]

Paul Sheppard has defined 'de-trended' curves:

> In dendrochronology, two types of de-trended series exist. The standard [index] chronology does not have [age-related, diminishing-width] trend, but has a bothersome feature called auto-correlation. Auto-correlation occurs when the value of an index at any time [year] has a relationship to the value just before it.[15] This, statistically, is undesirable. […] A method exists, however, to remove this bothersome auto-correlation and create the second type, known as a residual chronology. This has no trend and no autocorrelation. […] it's not good enough to use just raw ring widths, and it's not even good enough to use a standard chronology. It would be best to use a residual chronology without auto-correlation.[16]

A raw-measurements X/Y curve is converted to a standard-index chronology (albeit still containing 'bothersome auto-correlation') by fitting a negative exponential trendline to the graph and then dividing the millimetre value of each ring-width 'dot' by the millimetre value of the trendline at that same point. James Speer describes this process:

> […] standardization removes age-related growth trends and other long-term variability that can be considered noise. […] The most conservative technique of standardization is the negative exponential curve […]. The negative exponential curve is deterministic, meaning that it follows a model of tree growth. Other standardization techniques are empirical, meaning they are chosen through experimentation to find the best fit to a series of data.[17]

The standardisation procedure should be applied individually to each sequence of raw ring measurements, i.e. applied to the bass-side raw X/Y curve, and then to the treble-side raw X/Y curve. The two resultant standard-index chronologies can then be averaged (bass-side procedure, only, shown below in Figures 12 and 13).[18] The negative exponential trendline shown in Figure 12 is that

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[11] M G L Baillie's opinion (Baillie p. 68, footnote 6) is that 'Little consideration needs to be given to trees with fewer than 80 rings […] the problem with short patterns is that they can be 'dated' in a number of places – therefore they cannot be dated at all!'

[12] See Topham (2003) pp. 78-81.

[13] For a more complete explanation of these manipulations see Grissino-Mayer *et al*. (2001/2003); see, also, Speer p. 23.

[14] Stokes and Smiley p. 59.

[15] 'Biological inertia' means that the ring growth in any one year is not solely the result of the environmental conditions for that year – a part of that year's growth is created by the environmental conditions of the previous year which have, in effect, been stored within the tree. Thus, in a standard-index graph, the calculated value for an individual ring can be affected by the value for the previous year, i.e. auto-correlation.

[16] Grissino-Mayer *et al*. (2001/2003) p. 139.

[17] Speer p. 23 and (p. 25) Figure 2.11.

[18] For a complete set of procedures, using data from Stradivari's 1696 *Archinto* viola, see the supplementary Figures at the end of this chapter.

which is provided by a common, and widely-available, spreadsheet program; it has not been modified through subsequent usage of smoothing filters.

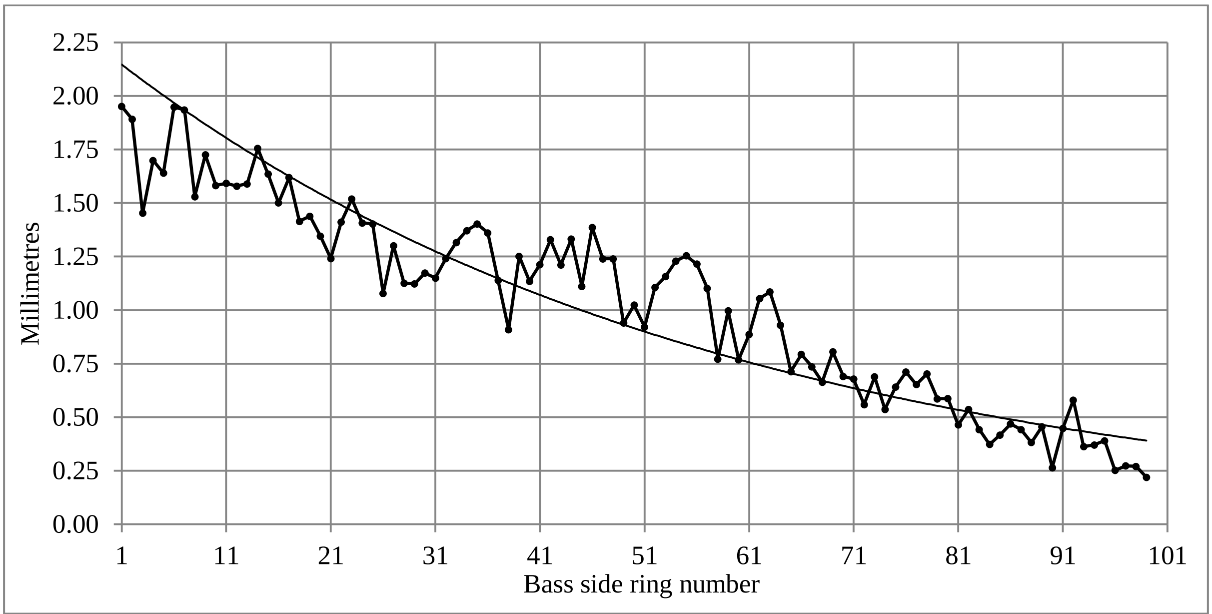

Figure 12: *Messiah* violin, bass side, raw measurements (ITRDB BRIT050.rwl) with added negative exponential trendline.

Dividing the value of each ring-width 'dot' by the same-year value of the exponential trendline produces a standard-index chronology (Figure 13). The apparently insignificant raw growth, in Figure 12, in rings 90, 91, and 92, is revealed, in the indexed Figure 13, as very significant for this particular tree at this stage of its life.

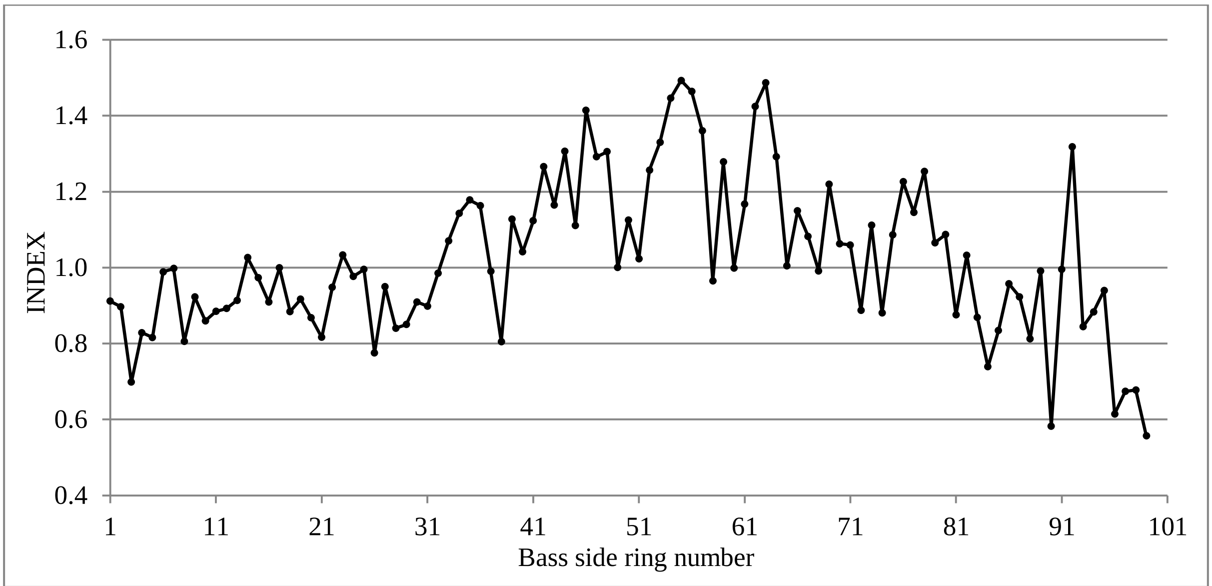

Figure 13: *Messiah* violin, bass side: standard-index chronology derived from Figure 12, including auto-correlation. The (vertical) y-axis index numbers are dimensionless.

> […] when you obtain an index that's above 1.0, you have above average growth, and below 1.0, below average growth.[19]

[19] Malcolm Cleaveland (Tree-Ring Laboratory, University of Arkansas) in Grissino-Mayer *et al*. (2001/2003) p. 149.

The present author's further calculation of the bass-plus-treble standard-index chronology for the *Messiah* violin (raw bass curve indexed as in Figure 13, raw treble curve indexed, both standard-index chronologies then averaged) is presented in Figure 14 superimposed on the bass-plus-treble standard-index chronology derived from the data established by Henri Grissino-Mayer and his American colleagues and presented on the ITRDB website:

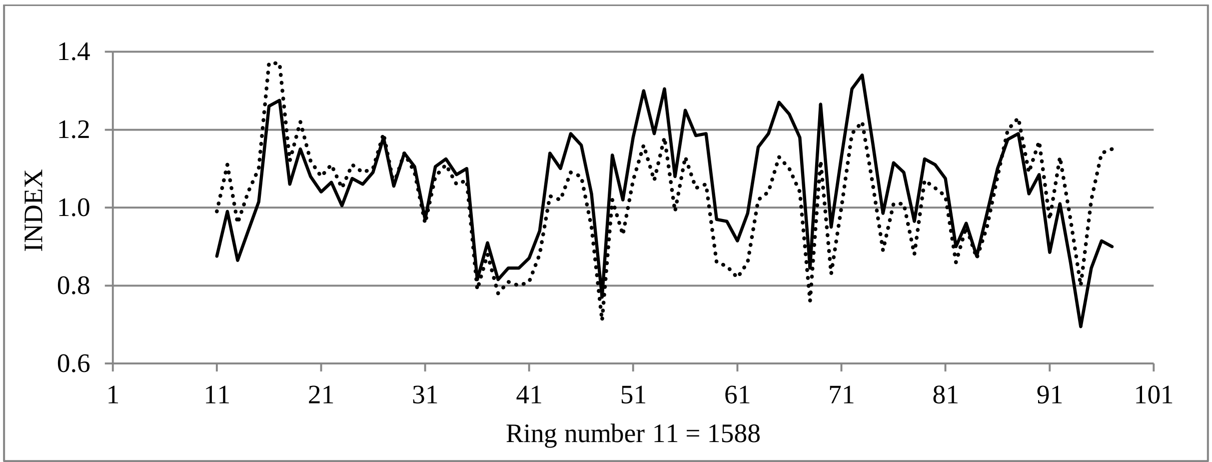

Figure 14: *Messiah* violin: present author's bass-plus-treble standard-index chronology (solid line). *Messiah* violin (ITRDB BRIT050.crn)[20] bass-plus-treble standard-index chronology (dotted line). 'Common' years of 1588-1674 (ITRDB dates); both with auto-correlation. Marker dots are omitted for clarity.

As explained by Paul Sheppard (above), the removal of the unwanted auto-correlation from a standard-index chronology produces a 'residual' index chronology. In the case of the *Messiah* violin its bass-plus-treble residual-index chronology (auto-correlation removed) does not substantially deviate from the bass-plus-treble standard-index chronology (auto-correlation still present):

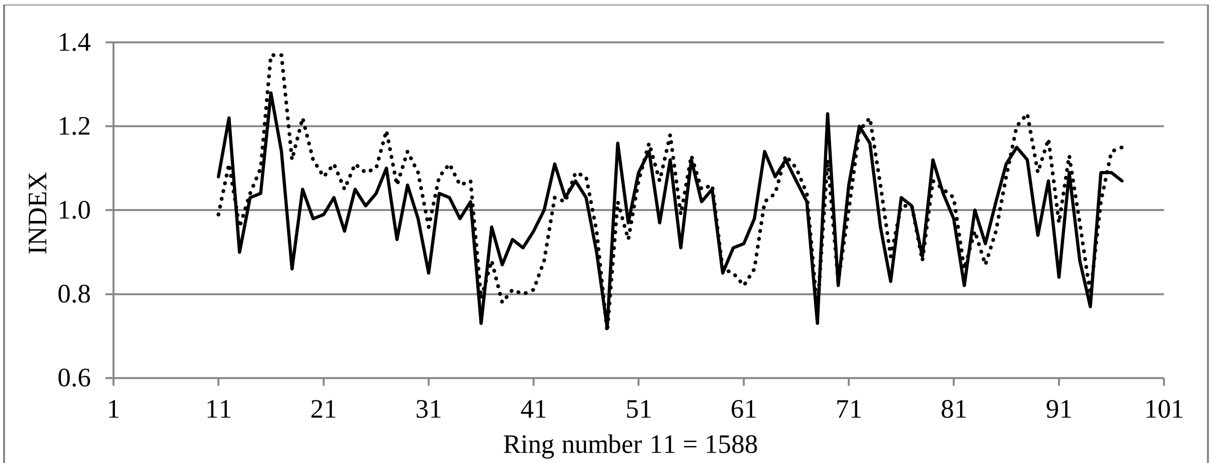

Figure 15: *Messiah* violin (ITRDB BRIT050r.crn)[21] residual-index chronology (solid line). *Messiah* violin (ITRDB BRIT050.crn) standard-index chronology, with auto-correlation (dotted line). 'Common' years of 1588-1674 (ITRDB dates).[22]

A floating-in-time standard-index chronology from an instrument's front plate can be statistically compared, by computer, against a standard-index 'reference' (or 'master') chronology which is firmly fixed in time.

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[20] The ITRDB suffix '.crn' indicates a standard-index chronology (but containing undesirable auto-correlation).

[21] The ITRDB suffix 'r.crn' indicates an index chronology with auto-correlation removed, i.e. a residual chronology.

[22] ITRDB website data accessed January 2013.

The creation of a fixed-in-time reference chronology for spruce begins with the measurements of the rings of many trees from a geographically specific area where

- the date of tree felling, or coring of living trees, is known,
- accurate measurements of the trunk's rings are made at the time of felling, or coring, and
- the results have been stored in a database such as that maintained by the International Tree-Ring Data Bank.

Because of the extensive felling of low-elevation European forests during the sixteenth, seventeenth, and eighteenth centuries – for fuel and for building materials – it becomes all the more necessary to include in the reference chronology the growth data obtained by measuring the rings from spruce tree trunks used in localised wooden buildings – for example, barns, timber-framed houses, old countryside churches, and wooden bridges. The annual rings from a 200-year-old spruce tree felled (or cored) in the year 2000 will date back to approximately 1800;[23] the annual rings from a 200-year-old complete spruce trunk used as part of a farmyard barn located in the same area as the tree (and the barn known to have been erected in 1900) should reveal growth rings which match, and thus overlap, with the tree which was felled in 2000.[24] If this is the case then the trunk used in the barn will take the dating back to approximately 1700. Further overlapping matches between wood samples will take the ring dates further and further back in time. A reference chronology should have multiple examples of each type of source-wood, all firmly matching and overlapping, with all the source-samples being geographically relevant to a specific location, before its data can be deemed reliable.[25] Note that the raw-measurement sequence from each individual wood sample needs to be manipulated (as described above) to remove each sample's inbuilt (and undesirable) age-related trend. The resultant, individual, standard-index chronologies can then be averaged to produce an 'absolutely dated reference chronology'[26] which displays the year-to-year variability of relative growth (rather than actual growth).

> […] you [need] to calculate the indices for the individual cores [samples] and compile them to create index chronologies. […] when you average them [i.e. when you average all the individual index chronologies] they all have the same contribution [to the final reference chronology]. You have stable variants from one end to the other.[27]

All the 'daisy chained' rings can then be dated, starting from the year 2000 and working backwards (but one incorrect assignment of a ring to a year can invalidate the entire process): 'If you have a tree ring for 1453 and you assign it the year 1454 that's worse than not having any data at all. You have wrong data and you can reach wrong conclusions.'[28]

The indexed, but floating-in-time, chronology from the under-test violin can now be compared against the indexed 'absolutely-dated reference chronology' – sliding the violin's chronology along the reference chronology – and, if a position is found where the violin's data convincingly 'cross-dates', both graphically and statistically, against the reference, the violin's rings can be defined with dates.[29]

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[23] The rings created by a tree during its first years of life are often indistinct and cannot be successfully measured. In addition, trees can sometimes create 'false' rings.

[24] If the rings match it will be on the basis of year-by-year relative growth, not actual growth, since the tree's early-formed rings will be being compared with the trunk's late-formed rings.

[25] It will be appreciated that this work will require thousands of ring measurements, and a painstaking (and entirely error-free) approach to the recording of all the multi-source measurements.

[26] H Grissino-Mayer *et al*., 'Mastering the rings', *The Strad,* April 2002, p. 408.

[27] Malcolm Cleaveland, in Grissino-Mayer *et al*. (2001/2003) p. 149.

[28] *Ibid.* p. 143.

[29] John Topham and Derek McCormick ('The dating game', *The Strad*, August 2001, p. 848) define 'cross-dating' as 'comparing a ring-width pattern of unknown date with a reference chronology'.

The floating chronology representing the violin, and the absolutely-dated reference chronology against which it is compared, must be of the same type – both standard-index (i.e. de-trended but with auto-correlation) or both residual-index (de-trended and without auto-correlation); statistical cross-dating should not be carried out using raw ring-width data.[30]

As John Topham has said: 'Reference chronologies are the core of dendrochronology, and without them absolute dating of the wood from other sources would be impossible.'[31] Henri Grissino-Mayer has added: 'Tree rings either date [to a reference chronology] or they don't date. If they do date, they date only to one year; they cannot date to two years.'[32] Grissino Mayer has further reinforced the point: 'In the dendrochronological sciences, an individual tree ring can have only one date. We are a precision science – there is no plus or minus.'[33] Equally uncompromising is Topham:

> If a positive dendrochronological date is obtained for a piece of wood, it is absolute – there is no margin of error – no region where there is a probability of an earlier or later date.[34]

Nonetheless, even if a positive dendrochronological result is obtained from a statistical comparison (a 'Student *t*-test') between a violin's indexed, but floating-in-time, chronology, and an indexed, absolutely dated, reference chronology – cross-dating – that positive result will still be positioned on a sliding scale between 'extremely unlikely' and 'certainly'.[35] A statistical comparison which produces a positive *t*-result of 3.0 would be rejected as having little or no cross-dating validity; however, a positive *t*-result of 10.0, or higher, would indicate a near-absolute certainty of temporal agreement between the two chronologies.

> For [European-style] t-statistics, there are threshold levels. The threshold level once published was 3.5. […] I have to tell you that a t-statistic of 3.5 is a very marginal value to show the association between two time series. It is now generally accepted that a t-statistic [result] of six or higher is preferable to show a strong association between two time series. […] You would probably have about a one in 100,000 chance of this being an error. That's how certain you are. So that's how strong the t-value of 6.0 is.[36]

Even where a strong association is apparently indicated the cautionary words of Richard P Feynman (joint winner of the Nobel Prize for Physics in 1965) should not be forgotten:

> Nothing is certain or proved beyond all doubt. […] And as you develop more information in the sciences, it is not that you are finding out the truth, but that you are finding out that this or that is more or less likely.[37]

In a similar manner Sturt [*sic*] Manning and his team of dendrochronologists at the Tree-Ring Laboratory of Cornell University, in a 2007 *Discussion of Procedures* document, state: 'High t-scores merely indicate (do not "prove") the most possible matches [and] thus dates.'[38]

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30 See Grissino-Mayer *et al*. (2010) p. 152.
31 JoVSA (XVII, 3) p. 135.
32 *Ibid.* p. 195. Henri Grissino-Mayer's comment unintentionally associates 'tree rings' with 'one year'.
33 Grissino-Mayer *et al*. (2001/2003) p. 151.
34 Topham (2002) p. 245.
35 The term '*t*-statistic' is abbreviated from 'test statistic', while 'Student' was the pen name of William Sealey Gosset who developed the '*t*-statistic' and '*t*-test' in 1908. 'It […] tests how strong an association is between two time series. So here the time series would be the tree ring time series being tested […] and how strongly it associates with the master reference chronology' (H. Grissino-Mayer, in JoVSA (XVII, 3) pp. 195-196).
36 Henri Grissino-Mayer, in JoVSA (XVII, 3) p. 196.
37 From "The Relation of Science and Religion", a talk given by Dr. Richard P Feynman at the Caltech YMCA Lunch Forum on May 2, 1956; archived at http://calteches.library.caltech.edu/49/2/Religion.htm (accessed November 2013).
38 http://dendro.cornell.edu/manuals/summaryofprocedures.pdf (accessed October 2013).

The ITRDB website has only a small range of relevant Italian, Austrian and French reference chronologies for spruce, larch, and stone pine.[39] As of March 2012 there were:

1. Italy: 29 chronologies of which only 7 are for Spruce (PCAB), Larch (LADE) or Stone Pine (PICE).
2. Austria: 12 chronologies of which 8 are for Spruce, Larch or Stone Pine.
3. France: 50 chronologies of which 15 are for Spruce, Larch or Stone Pine.

A critical decision (one of many) to be made by an investigator is: against which geographically-relevant reference chronology should the instrument's chronology be tested?

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In March 2000 an article co-authored by John Topham and Derek McCormick and entitled *A Dendrochronological Investigation of Stringed Instruments of the Cremonese School (1666-1757) including "The Messiah" violin attributed to Antonio Stradivari* was published in the peer-reviewed Journal of Archaeological Science.[40] The article relates the usual history of the *Messiah* violin and then moves on to a dendrochronological analysis. Topham and McCormick define two investigative strategies:

1. superimposing raw X/Y curves of ring-width data from a range of late-seventeenth-century and early-eighteenth-century Cremonese instruments and 'cross-matching' these curves so that they synchronise with each other, the averaged result being termed a 'floating chronology'

2. superimposing this floating chronology against absolutely-dated spruce data from Alpine reference chronologies (see below), and, when the floating chronology robustly 'cross-dates' against the references, extracting 'youngest ring' (outermost/CJ) dates for the instruments used in the floating chronology.

According to Topham and McCormick's JoAS article, twenty-one of their Cremonese instruments[41] generated treble and bass X/Y curves of raw ring-width measurements which cross-matched/synchronised strongly enough to warrant their amalgamation into what Topham and McCormick termed their 'Italian Instrument Master Chronology (IIMC21)', a synchronised (but floating in time) superimposition of twenty-one curves (each curve being averaged from each instrument's treble-side and bass-side data).[42] A single value for each year of IIMC21 could then be averaged from these superimposed curves. Topham and McCormick's data[43] indicates that, during a 27-year period (1542–1569) near the start of the IIMC21 composite, only two instruments – the 1696 *Archinto* viola and the un-named 1699 violin – generated the final, averaged, ring value for each year; conversely, during a later period of 25 years (1654-1679) twenty instruments generated the final, averaged, ring value for each year. In their JoAS article Topham and McCormick do not provide a

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[39] Larch and Swiss stone pine are not used in violin making, but the growth characteristics of these two species are very similar to those of spruce.

[40] Topham and McCormick (2000). The Journal states (p. 183) that the article's initial manuscript was received by JoAS in May 1999. A revised manuscript was received and accepted by JoAS in September 1999, and the article appeared in print in March 2000.

[41] The survey had begun with thirty-three instruments.

[42] IIMC21 comprised thirteen Stradivari violins (1699 un-named, 1708 *Davidoff*, 1708 *Tua*, 1711 *Parke*, 1712 *Fountaine*, 1715 un-named, 1716 *Booth*, 1716 *Milstein*, 1716 *Provigny*, 1716 *Messiah*, 1717 *Sasserno*, 1717 *Whitney/Park/Gillott*, 1718 *Maurin*), one Stradivari viola (1696 *Archinto*), two Carlo Bergonzi violins (1732 and 1739) together with an undated Bergonzi cello, two Guadagnini violins (1746 and 1757), one undated violin by Giuseppe Guarneri *filius Andreæ*, and one 1742 violin – the *Alard* – by Guarneri *del Gesù*.

[43] See Topham and McCormick (2000) p. 189, Figure 3.

graphical presentation of the final averaged curve thus derived from IIMC21 – a curve which (apparently) still comprised raw ring-widths.[44]

Topham and McCormick compared their floating-in-time IIMC21 averaged curve against 'two southern Alpine reference chronologies': 'Siebenlist-Kerner, 1984' and 'Hüsken, 1994'.[45]

1. Raw data for spruce, covering a 698-year period (1276-1974), was published in 1984 by Veronika Siebenlist-Kerner,[46] the data having been collected from two neighbouring locations – Larstighof and Breitlehnalm – in the central Ötztal Alps. Larstighof, an Alpine hamlet, is located twenty miles southwest of Innsbruck, in Austria, and fifteen miles north-northeast of the town of Längenfeld; Breitlehnalm is five miles south-southwest of Längenfeld. The locations, respectively, are 1550 and 1800 metres above sea level, and approximately 150 straight-line miles north-northeast of Cremona

2. Standard-index data for larch, covering a 558-year period (1433-1991), was published in 1994 by Wulf Hüsken,[47] the data having been collected from three high-altitude sites in the north-eastern Dolomite Alps – Fodara Vedla, Sennes Alm, and Grosse Fanes Alm – fifteen miles north-northwest of the town of Cortina d'Ampezzo (see this volume's map).

The 1984 presentation of Veronika Siebenlist-Kerner's raw data is under the title *Jahrringbreiten für Fichte 1276-1974* ('Year-ring widths for spruce 1276-1974') and her presentation also indicates the number of wood specimens which contributed to each decade of averaged ring-width measurements. Unsurprisingly, the ring widths for the earliest decades are derived from just a handful of tree specimens (the ring widths from the period between 1276 and 1300 are derived from just one). The number of specimens steadily increases in subsequent decades, peaking at 74 for the decade 1511-1520, but the decades between 1620 and 1700 are represented by 8, 5, 6, 9, 9, 9, 10, and 7 specimens. It is not possible to identify when each individual specimen begins and ends its contribution to the tabulated data; de-trending the raw data gathered from individual specimens in order to be able to generate individual standard-index curves (which can then be averaged) is therefore not possible from this data-set (Figure 16):[48]

[44] As far as is known, a graphical presentation of the final, averaged, curve derived from IIMC21 has never been published.
[45] Topham and McCormick (2000) p. 185.
[46] Siebenlist-Kerner pp. 21-22.
[47] Hüsken, pp. 161-163.
[48] See earlier quotation from Malcolm Cleaveland.

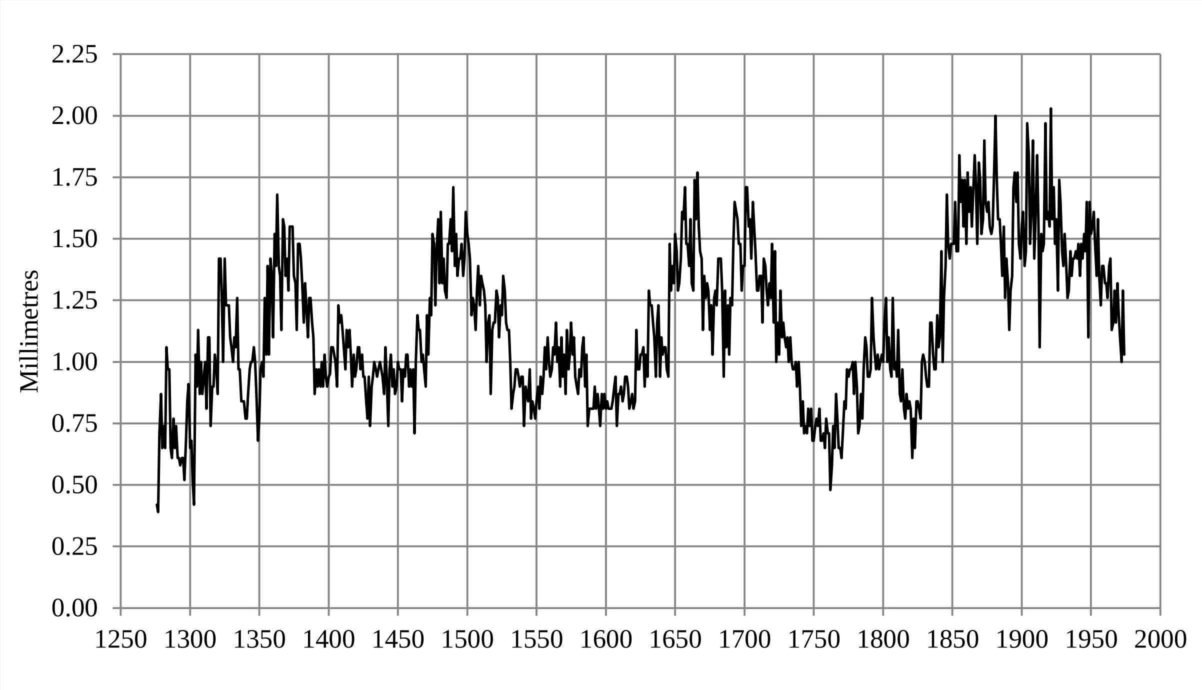

Figure 16: Data sourced from Veronika Siebenlist-Kerner (1984), Larstighof and Breitlehnalm, spruce, multi-tree, raw, averaged, ring widths, 1276-1974.

Graphically comparing the raw Larstighof and Breitlehnalm multi-tree averaged data with the raw averaged data from the *Messiah* violin (treble and bass raw measurements averaged) does not reveal a positive relationship (Figure 17):

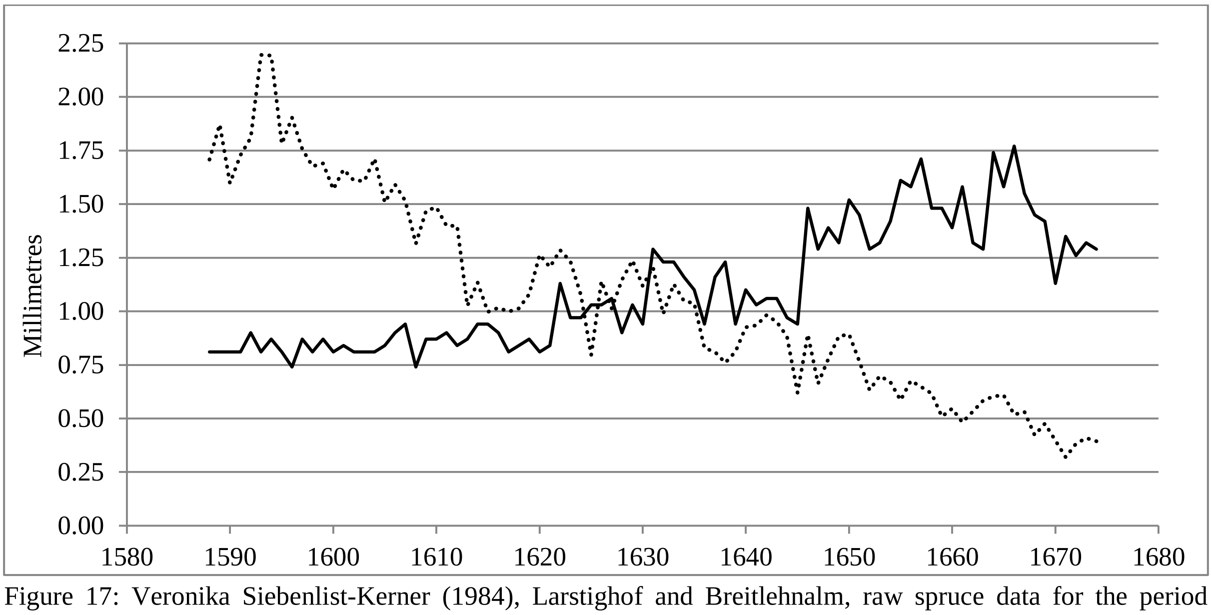

Figure 17: Veronika Siebenlist-Kerner (1984), Larstighof and Breitlehnalm, raw spruce data for the period 1588-1674, extracted from Figure 16, solid line. *Messiah* violin, raw bass and treble measurements averaged, common years of 1588-1674, dotted line. The *Messiah* ring dates are sourced from the ITRDB website.

In addition to her raw spruce-wood data published in 1984, Veronika Siebenlist-Kerner submitted to the ITRDB her raw spruce-wood data from the high-Alpine ski resort of Obergurgl (15 miles south of Breitlehnalm) – ITRDB AUST003.rwl (1276-1974) – but under her previous name of Veronika Giertz. This data-set is an amalgamation of her Larstighof/Breitlehnalm raw data (Figure 16, above) with additional raw ring-measurement data obtained from Obergurgl.[49] The additional spruce data from Obergurgl does not materially alter the shape of the Larstighof/Breitlehnalm raw spruce curve (Figure 18):

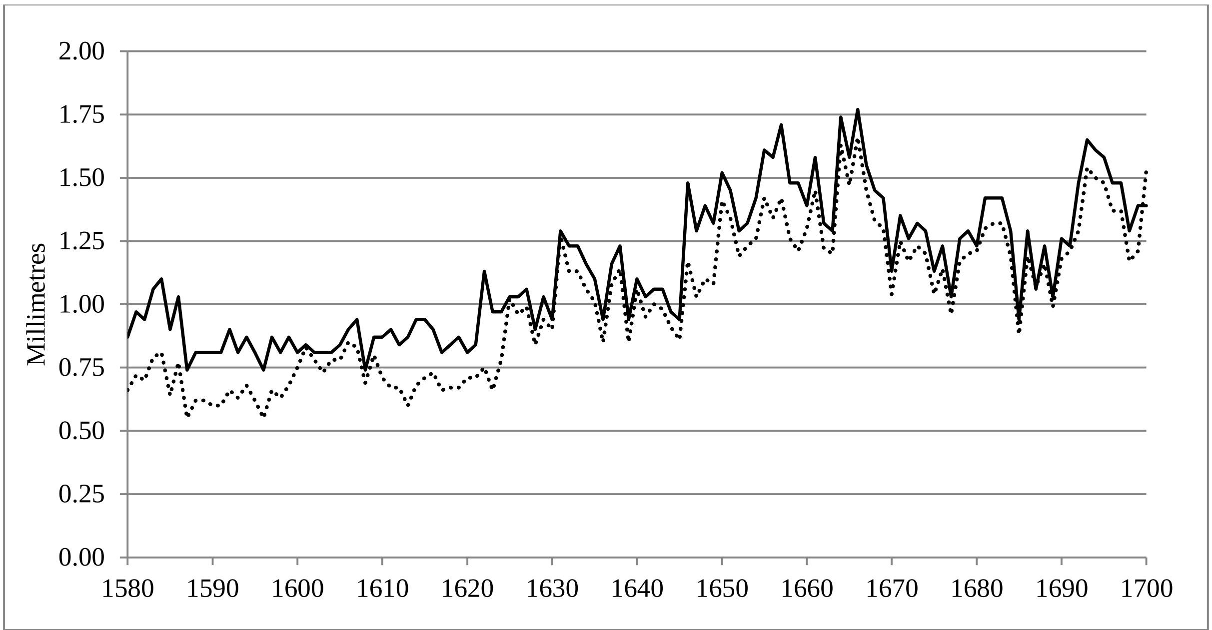

Figure 18: Veronika Siebenlist-Kerner (1984), Larstighof and Breitlehnalm, spruce, raw measurements, as Figure 16, solid line. Veronika Giertz, ITRDB AUST003.rwl, Obergurgl, spruce, raw measurements, dotted line.

The ITRDB AUST003 website presentation of Veronika Giertz's amalgamated spruce data – 'Obergurgl' – is through individual sequences of raw measurements from 115 wood specimens. In their co-authored presentation to the Violin Society of America,[50] Henri Grissino-Mayer and his American colleagues refer to this Obergurgl spruce data, provide a partial reproduction of the correlation statistics for the data, and a caption:

> […] Note that there are two groups of [wood] samples: 1) the living trees that have inside [early growth] dates in the 19th and 20th centuries with outside [late growth] dates in the 20th century, and 2) samples from dead trees or building timber that have inside dates in the 16th century with outside dates in the 17th and 18th centuries. The two groups [of samples] overlap very little, causing concern about the proper dating of the early group of samples. Unfortunately, the living tree specimens are not long enough by themselves to date the Cremonese instruments, although Topham and McCormick (2000) used this chronology as one of their principal dating tools.[51]

A graphical presentation of the raw spruce sequences (Figure 19) clearly reveals the considerable number of sequences representing the period prior to 1590 compared with the low number of sequences which represent the early and mid seventeenth century:

[49] Veronika Giertz also submitted amalgamated Swiss stone pine data (ITRDB AUST002) and amalgamated larch data (ITRDB AUST004), each under the title 'Obergurgl'.

[50] Grissino-Mayer *et al*. (2001/2003).

[51] *Ibid.*, Figure 20, p. 146. The quoted caption-text appears to indicate that Topham and McCormick's references to 'Siebenlist-Kerner (1984)' may be references to 'V. Giertz, Obergurgl, ITRDB AUST003'.

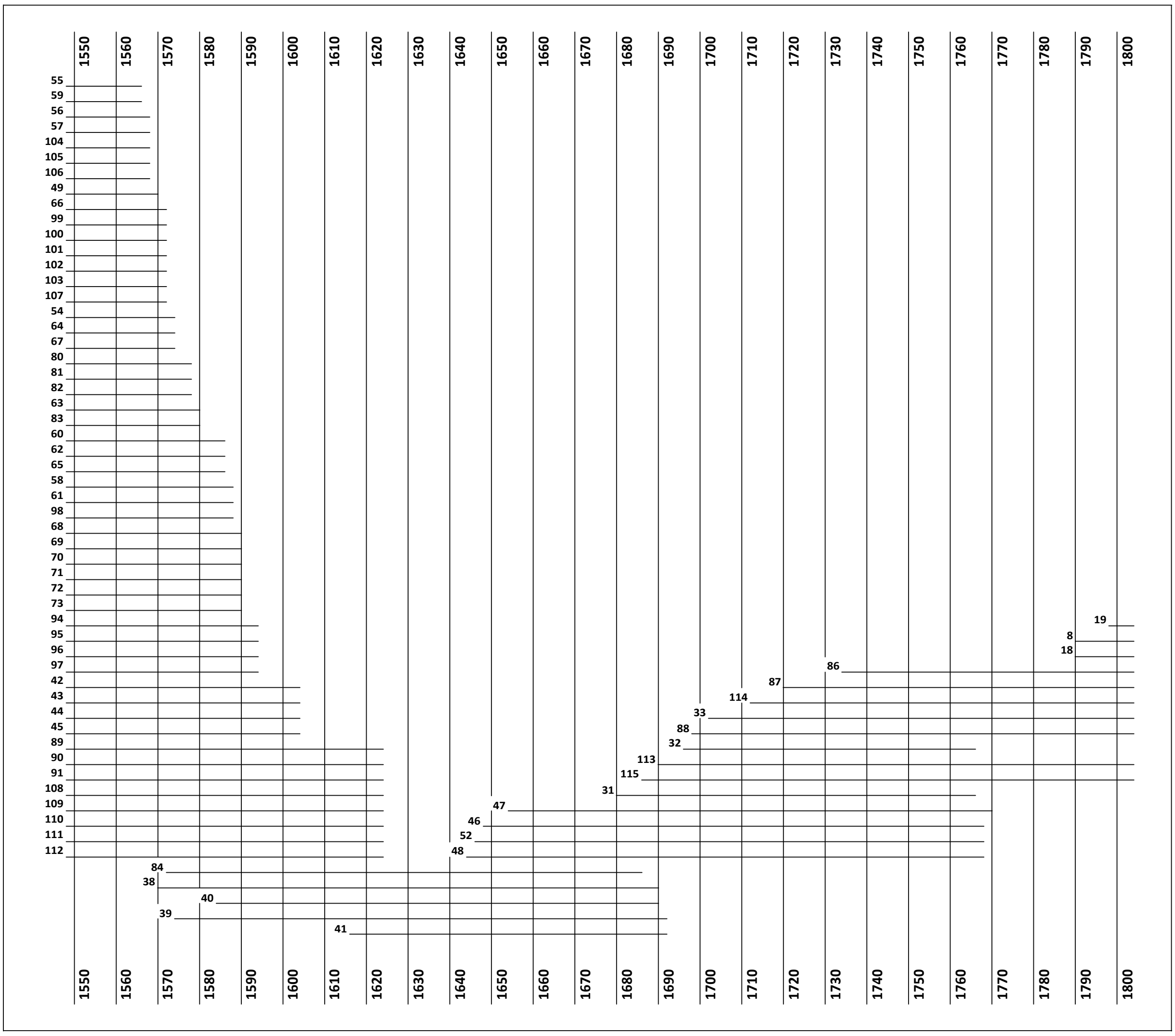

Figure 19: Veronika Giertz, ITRDB AUST003.rwl, Obergurgl, PCAB (*Picea abies* – spruce), extract.

The following sequences from Giertz’s raw measurement data from Obergurgl (Figure 19) were used by the present author to create individual standard-index chronologies which were then averaged to produce a cumulative standard-index chronology for the period 1484-1770 against which the standard-index chronology from the *Messiah* violin could be validly compared (see Figure 20):

Sequence 31: 1679-1765
Sequence 32: 1695-1765
Sequence 38: 1570-1690
Sequence 39: 1574-1692
Sequence 40: 1584-1689
Sequence 41: 1616-1692
Sequence 46: 1648-1767
Sequence 47: 1654-1770
Sequence 48: 1643-1767
Sequence 52: 1646-1768

Sequence 84: 1572-1686
Sequence 89: 1502-1623
Sequence 90: 1518-1623
Sequence 91: 1519-1623
Sequence 108: 1484-1623
Sequence 109: 1509-1624
Sequence 110: 1504-1624
Sequence 111: 1514-1624
Sequence 112: 1512-1624

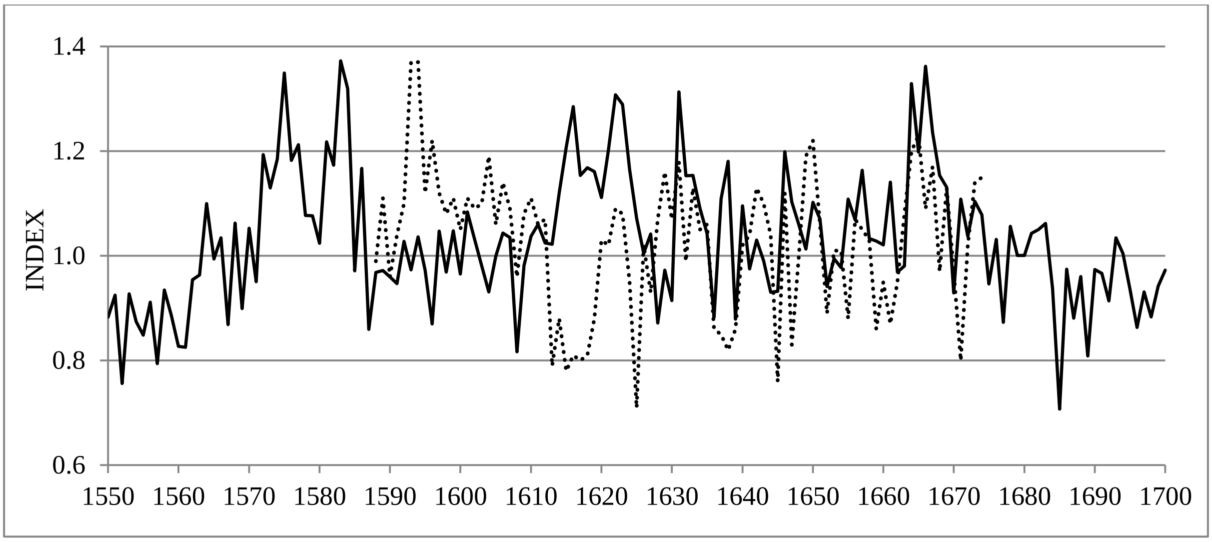

Figure 20: V. Giertz, Obergurgl (ITRDB AUST003) standard-index chronology from nineteen sequences (1484-1770, extract 1550-1700), solid line. *Messiah* violin, standard-index chronology, common years 1588-1674 (ITRDB data and allocated dates), dotted line. A robustly positive relationship between the two curves is difficult to perceive.

*****

In their JoAS (2000) article Topham and McCormick specify a high level of cross-matching agreement (‘*t* = 7.7’) between the spruce and larch chronologies from Siebenlist-Kerner and Hüsken,[52] (but graphical evidence for this agreement is not presented in their article). Unlike Veronika Siebenlist-Kerner’s 1984 spruce data, Wulf Hüsken’s 1994 larch data from Fodara Vedla (*Larix decidua*, 1520-1990) has already been converted to standard-index values (Figure 21):

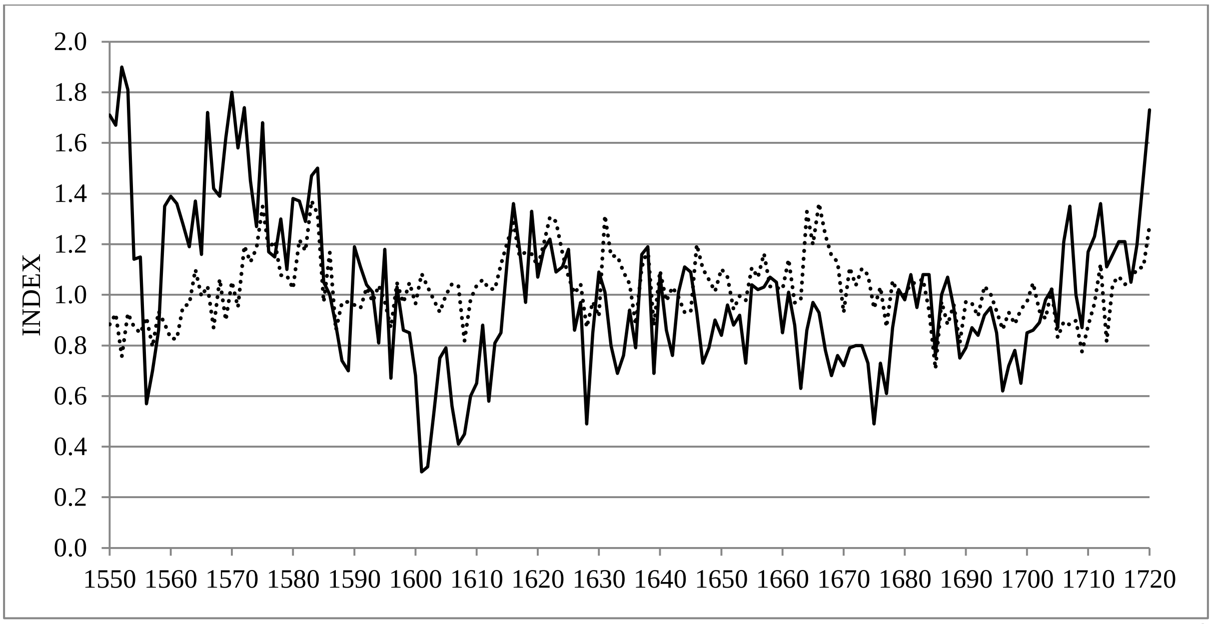

Figure 21: W. Hüsken (1994), larch, Fodara Vedla (1550-1720 extract), standard-index chronology, solid line.[53] V. Giertz, Obergurgl (ITRDB AUST003), standard-index chronology 1550-1720 (as Figure 20), dotted line.

[52] See Topham and McCormick (2000) p. 185.
[53] Hüsken pp. 161-162; also, identically, on ITRDB ITAL024.crn.

Hüsken's larch data from Sennes Alm (1433-1915) (Figure 22) – one mile from the Fodara Vedla site – was collected from fourteen beams of wood:

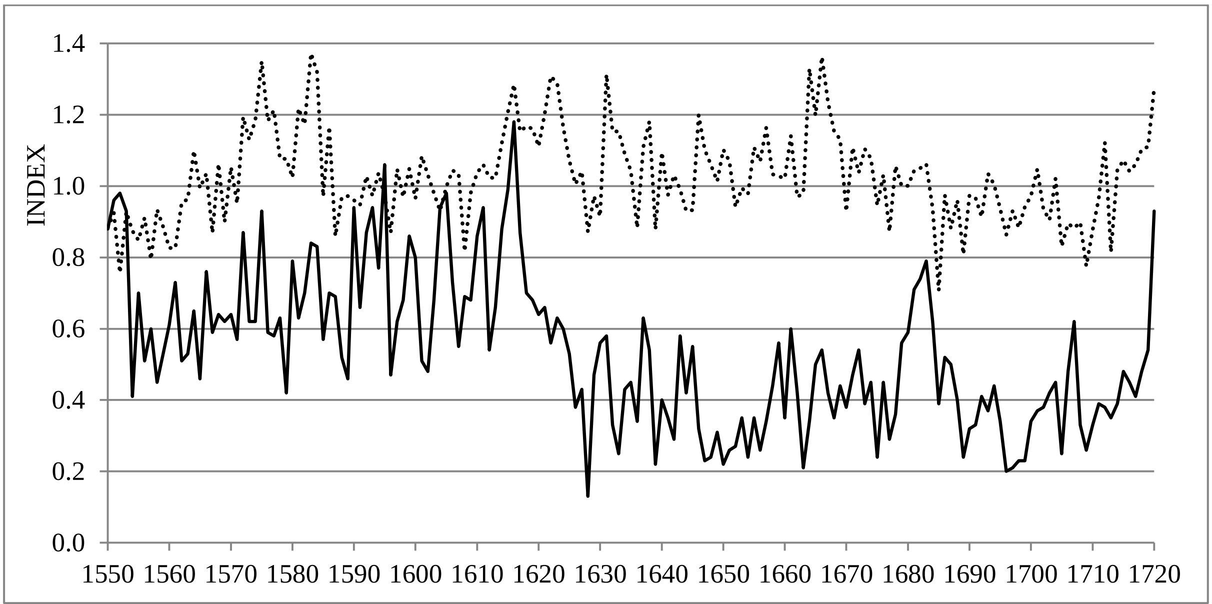

Figure 22: W. Hüsken (1994), larch, Sennes Alm (1550-1720 extract), standard-index chronology, solid line.[54] V. Giertz, Obergurgl (ITRDB AUST003), standard-index chronology 1550-1720 (as Figure 20), dotted line.

Hüsken's Grosse Fanes Alm larch data (1518-1991) (Figure 23) was collected from fourteen trees growing in chalk soil, on a slight slope, facing south-east, three miles from Fodara Vedla:

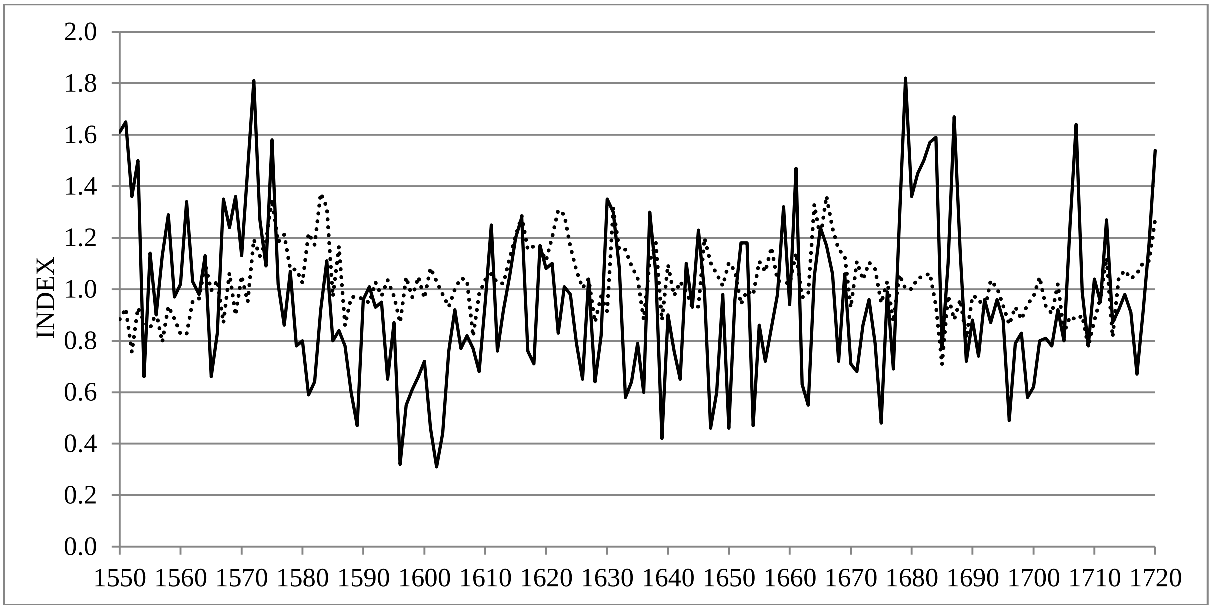

Figure 23: W. Hüsken (1994), larch, Grosse Fanes Alm (1550-1720 extract), standard-index chronology, solid line.[55] V. Giertz, Obergurgl (ITRDB AUST003), standard-index chronology 1550-1720 (as Figure 20), dotted line.

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[54] Hüsken pp. 162-163.
[55] *Ibid.* p. 163.

In their JoAS (2000) article Topham and McCormick also state that their IIMC21 floating chronology cross-dated (with a *t*-result of 7.3) 'against the Alpine spruce chronology' (assumed to be Siebenlist-Kerner) for the period 1531 to 1751 and cross-dated (with a *t*-result of 6.7) 'against the Alpine larch chronology' (assumed to be Hüsken) for the same 1531-1751 period.[56] Each of the twenty-one individual instruments could now be 'extracted' from IIMC21 and the dates specified for the outermost/CJ ('youngest') rings of each instrument. With respect to the *Messiah* violin, Topham and McCormick could now date the outermost/CJ bass-side growth ring to 1682, thirty-four years before the date on the label inside the violin.[57]

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In November 2000 the Violin Society of America held its 28th Annual Convention, in Kentucky. Dr Henri Grissino-Mayer was invited to speak, and delivered a presentation entitled *A Familiar Ring: An Introduction to Tree-Ring Dating*.[58] John Topham was also invited to the Convention and delivered a presentation entitled *The Dendrochronology of Stradivari's Violins*.[59] According to Kristen Thorner (the then editor of *The Strad*), between the publication of Topham and McCormick's March 2000 JoAS article and the November 2000 VSA Convention, Henri Grissino-Mayer

> asked Topham for his data so he could learn more about the 'Messiah' dating – and, to his surprise, came away empty-handed. 'If it were me I would love for people to verify what I'm doing', he remarks. Topham initially gave lack of time as the reason for his decision. But, bruised by the whole experience and dismayed by comments made by Grissino-Mayer in the press, he has decided not to change his mind.[60]

John Topham's presentation to the VSA was a detailed overview of dendrochronological approaches to the dating of violin wood, moving on to specific information regarding his dating of the *Messiah* violin's spruce front plate (information which had already been published in the March 2000 JoAS article). After mentioning his 'Italian chronology' (assumed to be IIMC21) Topham describes how he was

> […] given the chance to take measurements of ring widths directly from the instrument's front.[61] Initially, the sequences [curves] from both sides of the instrument[62] did not cross-match with any of my standard reference chronologies.[63] Some weeks later I measured another two Stradivari violins dated 1717, and found that the sequences from both instruments very closely matched the Messiah data. In due course I found that the combined sequences from the Messiah and the [two] 1717 instruments cross-matched the Italian chronology [IIMC21] very well, allowing me to date the sequences from the Messiah as well as the 1717 instruments.[64]

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[56] See Topham and McCormick (2000) p. 185. Topham and McCormick's text does not indicate whether the measurement sequences being compared were in raw or de-trended format, and, if de-trended, were in standard-index or residual-index format. Topham and McCormick do not provide graphical evidence to demonstrate their cross-dating results of t = 7.3 and t = 6.7.
[57] See Topham and McCormick (2000) p. 185. The date for the outermost/CJ ('youngest') ring on the treble side of the violin is not provided by Topham and McCormick.
[58] JoVSA (XVII, 3) pp. 93-116.
[59] *Ibid.,* pp. 133-157.
[60] *The Strad,* August 2001, p. 861.
[61] i.e. the front plate of the *Messiah* violin.
[62] i.e. treble side and bass side of the violin's front plate.
[63] Topham's 'standard reference chronologies' are assumed to be Siebenlist-Kerner and Hüsken.
[64] JoVSA (XVII, 3) p. 147. The data from the *Messiah* violin and the two 1717 violins was already included within the IIMC21 composite (see Topham and McCormick (2000) p. 189, Figure 3, instruments 247, 278, and 331); see also footnote 42 of this chapter.

On the next day of the VSA Convention (15th November, 2000) a panel discussion on *Le Messie* took place.[65] The opening address was given by Charles Beare who defended the traditionally accepted identification of the *Messiah* violin as being from the hands of Antonio Stradivari. Towards the end of his address Beare refers to the two Stradivari violins dated 1717:

> There was another unfinished discussion this morning about how [John Topham's] findings in respect of the Messie, the Sasserno, the Parke [*sic*] of 1717, and the Archinto of 1696 match into a main dendrochronology.[66] […] initially John was unable to date the Messie or the other two 1717s, but he knew that they were made from the same wood.[67]

Charles Beare's comment was the first to identify the soubriquet identities of the two 1717 Stradivari violins: the *Sasserno* and, apparently, the *Parke*. Standard reference books, however, give 1711 as the label-date of the *Parke* violin. The violin being referred to by Beare is assumed to be the 1717 *Whitney/Park/Gillott*.[68] The Cozio.com website for this violin (ID number 1420) quoted from the 'W E Hill Photographic Archive':

> Left half of table is not original, probably French … [69]

The treble-side front plate of the *Whitney/Park/Gillott* violin – apparently the only side which was made by Stradivari – has consistently fairly narrow growth rings which wander and ripple along the length of the body, whereas the bass side has straight and consistently wider growth rings; in addition, the front-plate treble-side purfling is narrower than that on the bass side.[70] John Topham and Derek McCormick state that the treble side and the bass side of the *Whitney/Park/Gillott* violin cross-match with each other with a *t*-value of 7.1;[71] in addition, they state that the averaged treble/bass curve from the *Whitney/Park/Gillott* violin cross-matches with the averaged treble/bass curve from the *Messiah* violin with a *t*-value of 6.5.[72]

Subsequently, during this panel discussion, Topham states:

> Just as another point, before I saw the other two instruments, the Sasserno and the Parke [*sic*], I too passed the Messie data, both the treble side and the bass side, and also a combination of the two – you can do an average – against various alpine/spruce chronologies, and could not find any fit of any significant statistical value. At any of the dates there was no significant t-value.[73]

This statement appears to confirm the graphical evidence of Figure 20.

Shortly after this, the VSA Convention ended. The Cozio.com website page for the *Messiah* violin, under the heading 'Notes', cited an article sourced from 'newswise.com' in which the American dendrochronologist Malcolm Cleaveland was quoted: '[…] the British expert [Topham] presented no

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65 JoVSA (XVII, 3) p. 181.

66 The *Archinto* viola is not discussed in Topham and McCormick's JoAS (2000) article, apart from it being listed as 'Vn253' within Table 1, p. 186.

67 JoVSA (XVII, 3) pp. 185-86.

68 The *Parke* violin is listed, though not discussed, in Topham and McCormick's JoAS (2000) article (p. 186, Table 1, 'Vn190', correctly dated as 1711). The same Table 1 lists a 1717 violin ('Vn278', no soubriquet) with ring-totals of 82/bass, 90/treble; in Topham (2003), p. 80, the 1717 *Sasserno* violin is listed with the same ring-totals. The same JoAS (2000) Table 1 further lists another 1717 violin ('Vn331', no soubriquet) with ring-totals of 72/bass, 85/treble; in Topham (2003), p. 80, the 1717 [*Whitney*] *Park* [*Gillott*] violin is listed with the same ring-totals.

69 Cozio.com website accessed June 2013; the Hills' statement is repeated on the newly-launched Tarisio.com website (ID 41420; website accessed July 2014).

70 The 1717 [*Whitney*] *Park* [*Gillott*] violin is photographed in colour, and life-size, in *Antonio Stradivari in Japan* (Gakken, Tokyo, 1984), pp. 91-99, the photographs by Shinichi Yokoyama.

71 Topham and McCormick (2000) p. 187, Table 2, Vn331.

72 *Ibid.*, p. 188, Table 3, Vn331 and Vn247.

73 JoVSA (XVII, 3) p. 193.

convincing graphical evidence or verifiable statistical evidence for his assertions.'[74] Kristen Thorner, reporting on the situation at the end of the Convention, wrote:

> Neither Grissino-Mayer nor [Peter Ian] Kuniholm – who, like Topham, was at the VSA gathering[75] – believe Topham's case is fully argued. Grissino-Mayer is complimentary about Topham's work, but two things bother him: the first, he says, is that Topham did not provide his raw measurements or present a curve showing a fit against the reference chronologies; the second is that 'certain portions of his method are not clear'. Kuniholm seems much of the same mind, summing up his argument with the challenge 'He hasn't proved it yet'. It's an opinion that puzzles – and angers – Topham, who insists his report contains 'all the information relevant to the argument'. At the end of the convention, as at the start, the situation appeared irresolvable.[76]

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The following year, the August 2001 issue of *The Strad* contained six articles addressing different aspects of the *Messiah* controversy. John Topham and Derek McCormick contributed an article entitled 'The dating game', essentially a resumé of their JoAS (2000) paper. They state:

> We then compared our Cremonese floating chronology [assumed to be IIMC21] with a range of established reference chronologies and found a highly significant cross-match which allowed us to date the Cremonese chronology at 1531-1751. After this it was a simple matter to date all the instruments contributing to it [contributing to the Cremonese chronology]. Our results showed that the treble side of the 'Messiah' corresponded to the years 1581-1675 and the bass side to 1590-1682. […] At present this is the strongest objective scientific evidence that has been applied to this debate and our findings lend support to the view that the 'Messiah' is indeed the work of Antonio Stradivari.[77]

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In November 2001 the 29th Convention of the Violin Society of America took place, in Pennsylvania. Henri Grissino-Mayer, Paul Sheppard, and Malcolm Cleaveland[78] delivered a joint presentation entitled *Dendrochronological Dating of Stringed Instruments: a Reevaluation*.[79] This presentation was based on a dendrochronological investigation, by all three scientists, of the *Messiah* violin, an investigation which had taken place earlier that year. The costs of their travelling from America to the Ashmolean Museum, Oxford (and bringing with them a considerable quantity of photographic and computer equipment) were met by the Violin Society of America.

The International Tree-Ring Data Bank contains the raw ring-measurement data obtained, independently, by Grissino-Mayer and Sheppard, from the front plate of the *Messiah* violin.[80] Because of natural human variability in taking measurements, those made by Grissino-Mayer and those made by Sheppard often differ from each other, but only minutely. As an example, the ITRDB raw

[74] The Cozio.com website for the *Messiah* violin (accessed May 2012) stated that the web-source for this quotation was http://www.newswise.com/articles/2001/11/VIOLIN.UAR.html.
[75] Peter Ian Kuniholm (Department of the History of Art and Archaeology (The Malcolm and Carolyn Wiener Laboratory for Aegean and Near Eastern Dendrochronology) at Cornell University, USA) was not present at the VSA Convention; see the comments of Helen Hayes (President of the Violin Society of America) in JoVSA (XVII, 3), p. 154.
[76] *The Strad*, August 2001, p. 861.
[77] 'The dating game', *The Strad*, August 2001, p. 851.
[78] From the Tree-Ring Laboratory, Department of Geosciences, University of Arkansas-Fayetteville, USA.
[79] Grissino-Mayer *et al*. (2001/2003).
[80] The full, raw, data is listed on the ITRDB website (accessed August 2012) under 'BRIT050.rwl'.

measurements (to an accuracy of one-thousandth of one millimetre) for the bass-side of the *Messiah* violin, from 1650 until 1686,[81] are:

	1650	**1651**	**1652**	**1653**	**1654**	**1655**	**1666**	**1657**	**1658**	**1659**
H G-Mayer	1.078	0.936	0.730	0.780	0.746	0.682	0.810	0.684	0.670	0.554mm
P Sheppard	1.092	0.924	0.696	0.806	0.726	0.646	0.800	0.698	0.686	0.564mm
AVERAGE	1.085	0.930	0.713	0.793	0.736	0.664	0.805	0.691	0.678	0.559mm

	1660	**1661**	**1662**	**1663**	**1664**	**1665**	**1666**	**1667**	**1668**	**1669**
H G-Mayer	0.684	0.552	0.674	0.744	0.626	0.702	0.630	0.586	0.460	0.518
P Sheppard	0.694	0.522	0.608	0.678	0.680	0.702	0.542	0.588	0.468	0.556
AVERAGE	0.689	0.537	0.641	0.711	0.653	0.702	0.586	0.587	0.464	0.537

	1670	**1671**	**1672**	**1673**	**1674**	**1675**	**1676**	**1677**	**1678**	**1679**
H G-Mayer	0.420	0.386	0.396	0.442	0.452	0.422	0.442	0.272	0.442	0.584
P Sheppard	0.466	0.360	0.438	0.496	0.434	0.342	0.470	0.258	0.454	0.576
AVERAGE	0.443	0.373	0.417	0.469	0.443	0.382	0.456	0.265	0.448	0.580

	1680	**1681**	**1682**	**1683**	**1684**	**1685**	**1686** (centre joint)
H G-Mayer	0.376	0.360	0.392	0.264	0.278	0.260	0.220
P Sheppard	0.350	0.382	0.388	0.240	0.268	0.282	------[82]
AVERAGE	0.363	0.371	0.390	0.252	0.273	0.271	------

With respect to these raw ring-measurements, Dr Grissino-Mayer has informed the present author:

> […] we measured the treble and bass sides along the wood surface that was most visible, and did not necessarily measure straight across at the same locations on the treble and bass sides. This accounts for the slight differences in absolute measurements obtained.

At the 29th Convention, the first speaker was Paul Sheppard who explained, in some detail, the various mathematical procedures which American dendrochronologists carry out on raw growth-ring measurements before the data can reach the status of a standard-index chronology which can then be compared to a relevant reference (index) chronology. Malcolm Cleaveland then outlined some essential aspects of reference chronologies which must be met if they are to be trusted. He was followed by Henri Grissino-Mayer, whose first substantive point was in relation to a matrix which had been presented by Topham and McCormick in their JoAS (2000) article showing the level of cross-matching between the spruce front plates of various different instruments within their surveyed group.[83] Grissino-Mayer comments:

> In that table, we saw the relationship of the Messiah tree rings against those from other instruments, and saw some very low values: 3.1, 2.9, 2.3, 2.7, 3.1, 3.4, 2.9, 2.7, 2.7. In fact, the Messiah only has what I would consider conclusive dating against three other instruments.[84] I had a problem with the Messiah because it has an average t-value of 4.0 against all the other instruments, and if you take out the two [1717] instruments [which used spruce] from the same tree (because you don't want to compare them against each other) it drops to 3.7. […] I initially had questions of the original dating by Topham and McCormick because I wanted to see more convincing graphical evidence. *I wanted to see the Messiah tree rings plotted against the*

[81] The year-dates were only established at the end of the dendrochronological investigation.
[82] No data given.
[83] Topham and McCormick (2000) p. 188.
[84] Vn253 (1696 *Archinto* viola) t = 6.1; Vn278 (1717 *Sasserno*) t = 10.0; Vn331 (1717 *Whitney/Park/Gillott*) t = 6.5.

> *reference chronologies*.[85] I remind you that tree-ring sequences must date against master reference chronologies without doubt, both graphically and statistically.[86]

Grissino-Mayer and his colleagues attempted to cross-date the *Messiah* violin against the aforementioned Obergurgl chronology:

> Could we now date the Messiah against this reference chronology? We did find some very good correspondences between the Messiah and the Obergurgl reference chronology. This particular dating[87] was one of the strongest ones we found, but it returned a t-value of only 3.3. The outermost [outermost/CJ] ring in the 1680s is contemporary with Stradivari, and essentially is the same dating Topham and McCormick found, but the t-value still does not meet our minimum criterion of 3.5. Keep in mind, what we're doing is taking the Messiah tree ring series and sliding it down the reference chronology one year at a time until we find a significant t-value. […] Using this technique, we were then surprised to find yet another possible dating for the Messiah with its outer tree ring [outermost/CJ] dating to the 1730s. This match returned a t-value of 3.2 […] essentially the same dating found by Dr. Klein.[88] […] We needed to develop a superior reference chronology representing a much wider spatial coverage in the high Alps, and then date the other instruments that we measured on this trip [to Oxford, England] to see if we could use these [as proxies] to date the Messiah.[89]

Grissino-Mayer then describes the creation of this 'superior reference chronology', achieved by combining and averaging 16 absolutely-dated chronologies from high-Alpine sites irregularly distributed in a semicircle from the mountains of the south-eastern corner of France across to mid-Austria (Katscherpass, north of the town of Villach).[90]

The 16 reference chronologies are:

1, 2. Les Merveilles, France: two larch chronologies dating between 1187 and 1974; altitude 2,165 metres above sea level; ten miles north of Menton in south-eastern France; ITRDB FRAN009. **Map location 1.** **<u>See map on p. 32 of this chapter.</u>**

3, 4. L'Orgère, France: two larch chronologies, 1353-1972; 1,900 and 2,100 m.a.s.l.; mid-way between Turin and Grenoble; ITRDB FRAN011 and 012. **Map location 2.**

5. Arosa Tritt Nord, Switzerland: spruce, 1690-1975; 1,940 m.a.s.l.; five miles west of Davos; ITRDB SWIT107. **Map location 3.**

6, 7. Obergurgl, Austria: two chronologies, stone pine and spruce, 1566-1972; 2,000 m.a.s.l.; thirty miles south-west of Innsbruck; ITRDB AUST002 and 003. **Map location 4.**

8. Stubaital Milderaun Alm, Austria, spruce, 1745-1975; 1,850 m.a.s.l.; ten miles south-west of Innsbruck, near Larstighof; ITRDB AUST007. **Map location 5.**

9. Patscherkofel, Austria, pine, 1752-1967; 2,100 m.a.s.l.; five miles south of Innsbruck; ITRDB AUST001. **Map location 6.**

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[85] Emphasis by the present author.

[86] Grissino-Mayer *et al*. (2001/2003) pp. 151-153.

[87] Henri Grissino-Mayer and his colleagues here refer to their 'Figure 32', p. 156, of Grissino-Mayer *et al*. (2001/2003).

[88] Figure 33, p. 158, of Grissino-Mayer *et al*. (2001/2003). In 1997, Dr Peter Klein, from the Ordinariat für Holzbiologie at the Universität Hamburg, proposed an outermost/CJ dendro date for the treble side of the *Messiah* violin of 1734, with 1738 for the bass side.

[89] Grissino-Mayer *et al*. (2001/2003) p. 157. The 'other instruments' were principally Stradivari's *Kux/Castelbarco* viola of 1715 and the *Archinto* viola of 1696.

[90] See the present volume's map. Henri Grissino-Mayer's sketch map of the geographical locations for the sixteen chronologies appears on p. 160 of Grissino-Mayer *et al*. (2001/2003).

10,11,12. Fodara Vedla Alm, Italy: three chronologies, larch, pine, and spruce, 1474-1990; 1,970 m.a.s.l.; forty miles north-east of Bolzano; ITRDB ITAL023 and 024. **Map location 7.**

13, 14. Cortina d'Ampezzo, Italy: two spruce chronologies, 1660-1975; 1,820 m.a.s.l.; ten miles south-east of Fodara Vedla; ITRDB ITAL006 and 007. **Map location 8.**

15. Berchtesgaden, Germany: larch, 1339-1947; 1,725 m.a.s.l.; ten miles south of Salzburg; ITRDB GERM019. **Map location 9.**

16. Katscherpass, Austria, spruce, 1838-1975; 1,800 m.a.s.l.; seventy miles southeast of Salzburg; ITRDB AUST005. **Map location 10.**

The chronologies from Stubaital Milderaun Alm, Patscherkofel, and Katscherpass might be thought irrelevant since their start dates all post-date Stradivari's death, but all three would be relevant when considering whether the *Messiah* violin was made post-1737.

Grissino-Mayer demonstrates that the Stradivari *Archinto* viola of 1696 cross-dated against the combined 16-site 'superior reference chronology': 'For the entire 159 years of tree rings for the *Archinto* against the master regional chronology developed from those 16 sites, the *t*-value is 3.9, which is very good.'[91] Using residual-index data the *Kux/Castelbarco* viola cross-dated against the *Archinto* viola with a very high *t*-value of 7.0 (Figure 24):[92]

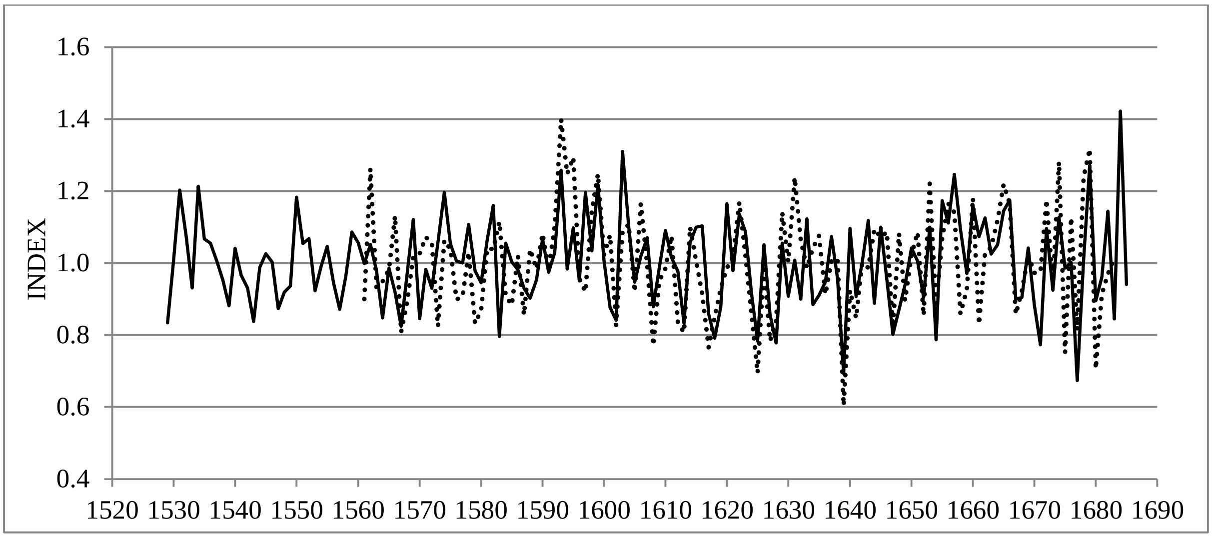

Figure 24: *Archinto* viola, residual-index chronology (solid line). *Kux/Castelbarco* viola, residual-index chronology (dotted). Data, and allocated dates, from ITRDB BRIT051r.crn and BRIT052r.crn.

Grissino-Mayer and his colleagues then used the curve from the *Kux/Castelbarco* viola and the curve from the *Archinto* viola as individual reference chronologies against which to try to date the curve from the *Messiah* violin. Using residual-indexed data, the *Kux/Castelbarco* viola against the *Messiah* violin returned a *t*-value of 4.8 (Figure 25):[93]

[91] Grissino-Mayer *et al*. (2001/2003) p. 159.

[92] *Ibid.* p. 162; note that this was a cross-dating between the *Kux/Castelbarco* viola and the *Archinto* viola, not between the *Kux/Castelbarco* viola and the combined 16-site superior reference chronology.

[93] Grissino-Mayer *et al*. (2001/2003) p. 165. The *Kux/Castelbarco* viola was not part of the group of twenty-one instruments surveyed by Topham and McCormick.

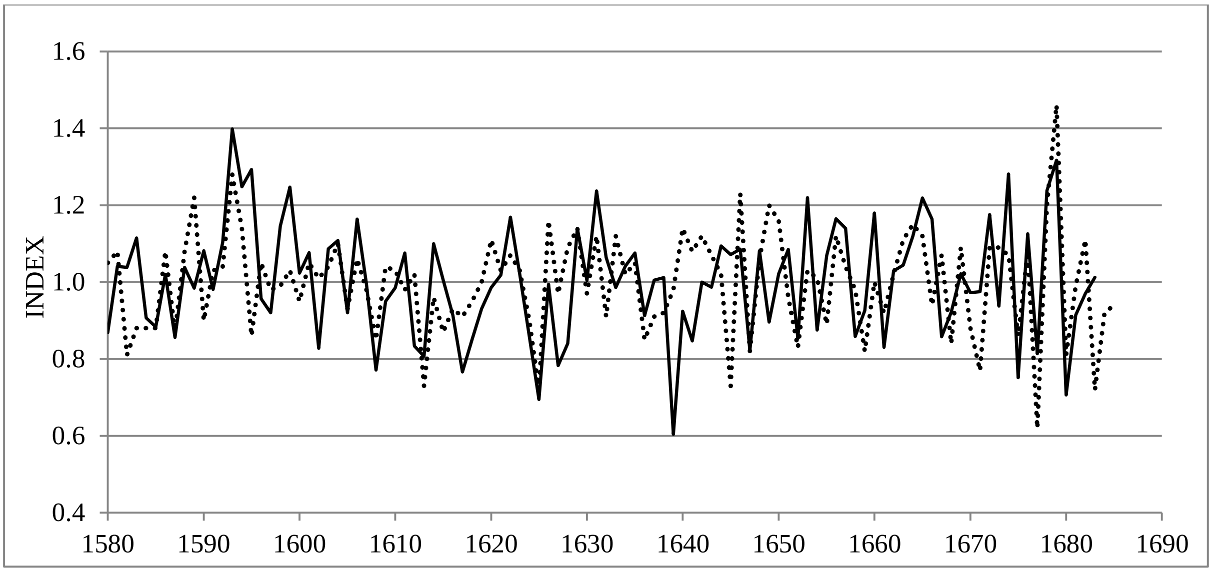

Figure 25: *Kux/Castelbarco* viola, residual-index chronology (solid line). *Messiah* violin, residual-index chronology (dotted). Data from ITRDB BRIT052r.crn and BRIT050r.crn.

The data from the *Archinto* viola, against the *Messiah* violin, returned a lower *t*-value of 4.2:[94]

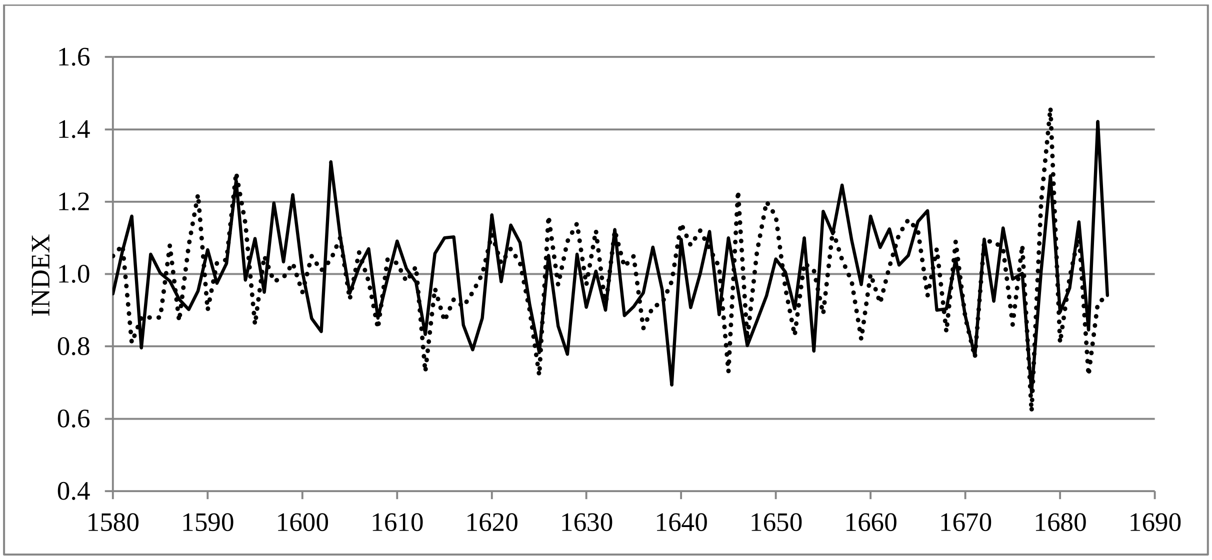

Figure 26: *Archinto* viola, residual-index chronology (solid line). *Messiah* violin, residual-index chronology (dotted). Data from ITRDB BRIT051r.crn and BRIT050r.crn.

These results are more satisfactory than the cross-dating between the *Messiah* and the Obergurgl high-Alpine chronology which only achieved a *t*-value of 3.3 (and is below the 'very marginal' level of 3.5): '[…] we found no reliable dating of the *Messiah* against the Obergurgl reference chronology.'[95]

Grissino-Mayer then addressed the resultant conundrum:

1. the *Archinto* viola cross-dated (t = 3.9) with the composite reference chronology
2. the *Kux/Castelbarco* viola cross-dated (t = 7.0) against the *Archinto*

[94] *Ibid.* p. 164. Topham and McCormick (Topham and McCormick (2000), p. 188) state that the *Archinto* viola and the *Messiah* violin cross-match with a *t*-value of 6.1 but this appears to be a value derived from raw-measurement sequences.
[95] Grissino-Mayer *et al*. (2001/2003) p. 163.

3. the *Messiah* violin cross-dated (t = 4.8) against the *Kux/Castelbarco* and cross-dated (t = 4.2) against the *Archinto*, but
4. the *Messiah* violin would not cross-date against the composite reference chronology: 'why doesn't the *Messiah* date directly against the reference chronologies?'[96]

To summarise: John Topham and Derek McCormick were unable to cross-date their data from the *Messiah* violin against their Alpine reference chronologies, and now Henri Grissino-Mayer and his colleagues were unable to cross-date their *Messiah* data against a 16-site composite reference chronology from the Alps. Grissino-Mayer comments: 'Could the Messiah have been made from a tree from a lower elevation with a different climate regime than the trees at the higher elevations?'[97]

Grissino-Mayer suggests a possible geographical explanation: that the *Archinto* and *Kux/Castelbarco* violas were made with wood derived from a mid-elevation spruce tree (where the climatic conditions had some similarities to those which conditioned the high-Alpine 16-site composite chronology), whereas the *Messiah* violin was made from a low-elevation spruce tree (experiencing climatic conditions similar to those experienced by the mid-elevation source-tree for the *Archinto* and *Kux/Castelbarco* violas but not at all similar to the climatic conditions demonstrated by the high-Alpine composite chronology). Thus A (high altitude) has similarities with B (mid altitude) but B has different similarities with C (low altitude) and therefore C has no similarities with A.[98] This, it is assumed, is the reason why Topham and McCormick were unable to show, in their JoAS (2000) article, a cross-date between the *Messiah* violin and their high-Alpine reference chronologies. Grissino-Mayer continues:

> Perhaps the *Messiah* and other instruments, however, were made from trees collected at lower elevations, where indeed you might have a different climate regime. In fact, a timely editorial just came out in *The Strad*. A very observant writer said that he knows the Alps have an incredible complexity of climates. You have north facing slopes, south facing slopes, valleys, and mountains. It's a very complex climate regime. Therefore, you do have different climates at lower and mid-elevations than you do at high elevations.[99]

The 'editorial' was a letter from a Mr Burrit Miller which appeared in the November 2001 issue of *The Strad* and addressed the issue of 'micro-climates' in the Alps, these varied environmental conditions being the result of the diverse geographical orientation of the mountain slopes and valleys:

> I think it safe to posit that, in the classic period of making, Italian makers were getting their spruce from the southern slopes of the Alps. But which Alps? Have comparisons been made, not just between Mittenwald and Bolzano,[100] but between conifers from the Tecino [Ticino],[101] Alto Adige and Piedmont regions? How do woods from Tirano,[102] where the valleys run east-west, compare with those from Bormio,[103] which is oriented south-north?

Grissino-Mayer then closed the joint address to the VSA Convention by defining the dendro date for the outermost/CJ ('youngest') ring on the *Messiah* violin, bass side, as 1686. The text of the

[96] *Ibid.* p. 167.
[97] *Ibid.* p. 167.
[98] This proposition is supported by the 2001 research of Wilson and Hopfmueller (*q.v.*) which indicates that increasing altitude prompts a progressive change of growth-response from Bavarian spruce trees, such that mid-altitude spruce chronologies will correlate with chronologies from both higher and lower altitudes but high and low chronologies will not correlate with each other.
[99] Grissino-Mayer *et al*. (2001/2003) p. 167.
[100] Mittenwald lies 20 miles north of Innsbruck; Bolzano lies 30 miles north of Trento.
[101] The Ticino region is in north-west Italy, around Lake Maggiore.
[102] The town of Tirano lies in the Valtellina valley, just to the east of Sondrio.
[103] The town of Bormio also lies in the Valtellina valley but north of Tirano.

November 2001 VSA presentation made by Grissino-Mayer and his colleagues was subsequently published in the Journal of the Violin Society of America in 2003.[104]

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Five months later, in the April 2002 issue of *The Strad*, Henri Grissino-Mayer and his two colleagues presented a revised version of their VSA presentation, under the title 'Mastering the rings', which was accompanied by the sub-heading:

> The debate over dating the wood of the 'Messiah' Stradivari seems at last to have reached a conclusion. Dendrochronologists Henri D. Grissino-Mayer, Malcolm K. Cleaveland and Paul Sheppard carried out the final tests.'[105]

The certainty expressed in this sub-heading is perhaps not justified. In essence, this *Strad* article presents the same information as had been presented at the 2001 VSA Convention, but there are some small yet important changes. Firstly, the American dendrochronologists raise an important question mark over the traditional assumptions regarding the location of sources of spruce in north-eastern Italy:

> The wood used by Cremonese makers likely came from trees growing in north-eastern Italy near the Alps, but this could not be guaranteed. Furthermore, previous efforts had failed to match the 'Messiah' with the nearest reference chronologies.[106]

It is noticeable that the 'likely' source of spruce is now only 'near the Alps' and even this 'could not be guaranteed'.

> Our initial attempt to date the 'Messiah' was unsuccessful. […] The graphs showing the ring patterns of the 'Messiah' against the reference chronologies (individually and against the composite [16-site chronology] we developed) were also not convincing. We therefore confirmed Topham and McCormick's observation that the tree rings of the 'Messiah' could not be dated directly against any reference chronology.[107]

The issue of whether the *Archinto* and the *Kux/Castelbarco* violas successfully cross-dated against the composite regional chronology is now clarified with new information:

> […] a strong match that fitted the 'Archinto' tree rings firmly in time against the regional composite chronology. Two overlapping 40-year segments representing rings 81-140 had a t-value of 5.2, indicating a very strong and conclusive match. Four 40-year segments in total, representing rings 61-159, dated significantly [with the composite chronology] with an average t-value of 4.1. Not to be outdone, three overlapping 40-year segments representing rings 43-125 from the 'Kux-Castelbarco' also dated firmly against the regional composite chronology with a t-value of 5.0. […] When the tree rings of the two violas are compared against each other, we found a t-value of 7.0.[108]

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[104] Grissino-Mayer *et al*. (2001/2003).
[105] *The Strad*, April 2002, p. 408.
[106] *The Strad*, April 2002, p. 411.
[107] *Ibid.* p. 412.
[108] *Ibid.* p. 412. See Figure 24.

To summarise the overall dendrochronological results:

Topham and McCormick

1. were able to cross-date their 21-instrument 'floating' Italian chronology – IIMC21 – against their two Alpine reference chronologies with *t*-values of 7.3 and 6.7 respectively
2. cross-matched the *Messiah* violin against two 1717 Stradivari violins with, respectively, *t*-values of 10.0 and 6.5
3. cross-matched the *Messiah* against the *Archinto* viola with a *t*-value of 6.1
4. were unable to cross-date the *Messiah*, by itself, against either of their two high-Alpine reference chronologies.

Grissino-Mayer and his colleagues, using 'de-trended' residual-index chronologies (without auto-correlation),

1. cross-dated the *Messiah* violin data against the Obergurgl high-Alpine chronology but this returned insignificant *t*-values of only 3.3 or 3.2[109]
2. created an alternative regional composite chronology from 16 high-altitude Alpine sites
3. were unable to cross-date the *Messiah* violin, by itself, against this high-altitude regional composite chronology, or against any of the individual-site chronologies contained within the composite (other than, insignificantly, with the Obergurgl chronology)
4. cross-dated two overlapping segments of the *Archinto* viola against the regional composite chronology with $t = 5.2$, and cross-dated four segments with $t = 4.1$. The entire 159 years of tree rings for the *Archinto* cross-dated against the composite with $t = 3.9$[110]
5. cross-dated three overlapping segments of the *Kux/Castelbarco* viola against the regional composite chronology with $t = 5.0$. A cross-dating *t*-value for the entirety of the *Kux/Castelbarco* tree-rings (117 rings on the bass side, 121 on the treble side) does not appear in the *Strad* April 2002 article nor in the Grissino-Mayer *et al*. (2001/2003) article
6. cross-dated the *Messiah* violin against the *Archinto* viola with $t = 4.2$, and against the *Kux/Castelbarco* viola with $t = 4.8$.[111]

One important outcome of these investigations is that whereas Topham and McCormick dated the bass-side youngest ring of the *Messiah* violin – outermost/CJ – to 1682, Grissino-Mayer and his colleagues dated the bass-side youngest ring to 1686: 'We obtained measured rings [from both halves of the front plate] of 1578 to 1686. Wood was present from 1577 to 1687. This is the same dating Topham and McCormick found.'[112] Personal correspondence from Henri Grissino-Mayer to the present author has clarified that the change in bass-side/centre-joint dendro date (Topham '1682', Grissino-Mayer '1686') was because Grissino-Mayer and his colleagues discovered additional rings at the tail-piece end of the front plate as a result of the rings not being perfectly true and parallel in their longitudinal orientation with respect to the centre joint – the rings slant outwards very slightly as they approach the tail-piece – like an inverted 'V' – and thus four extremely narrow additional rings 'emerged' next to the centre joint on the bass-side. Grissino-Mayer and his colleagues measured these four additional rings and, in effect, projected them back up the front plate to join the rings which had already been measured on the lower bout. Thus Topham and McCormick's 1682 bass-side youngest

[109] Grissino-Mayer *et al*. (2001/2003) p. 157.
[110] *Ibid.* p. 159. The *t*-value strength of this cross-dating appears to diminish according to the number of rings tested.
[111] *The Strad*, April 2002, p. 415; Grissino-Mayer *et al*. (2001/2003) p. 163.
[112] Grissino-Mayer *et al*. (2001/2003) pp. 163 and 167 (illustrations lie between these numbered pages).

ring is the same as Grissino-Mayer's 1682 bass-side ring but the additional four rings from lower down the violin's front plate continue the dating-sequence to 1686 for the 'emerging' youngest ring on the bass-side of the centre joint.[113]

In the April 2002 article published in *The Strad*, the altitudinal hypothesis suggested at the 2001 Pennsylvania VSA presentation is also expressed more firmly by Grissino-Mayer and his colleagues:

> The answer to this paradox lies in location: *clearly, the spruce tree harvested and eventually used to make the 'Messiah' did not come from the high Alps*.[114] If it had, one of the individual reference chronologies (as well as the regional composite chronology) should have been able to date it. We suspect the spruce tree came from a location lower in elevation, perhaps in a different climate zone altogether.[115]

The information which was presented at the 2001 VSA Convention (and then revised for the April 2002 article in *The Strad*) was revised again before submission to the Journal of Archaeological Science in June 2002, followed by publication in 2004.[116] The JoAS (2004) information is essentially the same as had been presented at the VSA Convention and as had been published in *The Strad*, but concerns about the Alpine climate, and the location of the tree which was the source for the *Messiah* violin, now receive yet more consideration from Grissino-Mayer and his colleagues. They hypothesize that the *Messiah* violin was made with wood sourced from a low-altitude tree 'growing distant from the high alpine areas', probably sourced from north-Italian forests which were near Cremona.[117]

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In 2011 an article by Mauro Bernabei and Jarno Bontadi[118] entitled *Determining the resonance wood provenance of stringed instruments from the Cherubini Conservatory Collection in Florence, Italy* was published in the peer-reviewed Journal of Cultural Heritage.[119] Bernabei and Bontadi identify Italian, but non-Alpine, locations for Norway spruce, specifically a stand of native Norway spruce trees located at Foce di Campolino in the Abetone forest (approximately 70 miles south of Cremona) and a smaller stand at the Cerreto Pass in the Reggio Emilian Apennines (east of the port of La Spezia). In both cases the trees are at 'the limit of the species' natural distribution range'[120] and are therefore likely to be growing under 'stressed' conditions.

James H Speer explains this 'stressed' or 'sensitive' condition:

> Trees that are growing at the center of their ecological amplitude with favourable climate year round are likely to produce complacent growth, in which each ring is a similar width. If a tree is complacent, it does not record much environmental variability that could be used for crossdating. […] The opposite of complacent growth is sensitive growth, in which the tree demonstrates considerable variability in year-to-year growth and is thus recording some environmental variable.[121]

With respect to the aforementioned opinion that the *Messiah* violin could be made of spruce which came 'from a location lower in elevation, in a different climate zone altogether' the International

[113] A fifth, partial, ring-width was therefore dated to 1687.
[114] Emphasis by the present author.
[115] *The Strad,* April 2002, p. 415.
[116] Grissino-Mayer *et al*. (2004).
[117] See Grissino-Mayer *et al*. (2004) p. 167 (Abstract), and p. 168.
[118] From the Trees and Timber Institute (National Research Council) at S. Michele all'Adige, Trento, Italy.
[119] Bernabei and Bontadi (2011).
[120] *Ibid.* p. 204.
[121] Speer pp. 22-23.

Tree-Ring Data Bank holds a reference chronology from Abetone (ITAL009) but the tree-species is Silver Fir (European Fir) – *Abies alba* – and the outer dates of the chronology are 1846-1980. An alternative chronology (ITRDB ITAL022) has been established from the area of Bibbiena, in the Pratomagno mountain range of Tuscany (approximately 80 miles south-east of Abetone, near the town of Arezzo). This fir-species chronology covers the entirety of the seventeenth century but there is no agreement with the chronology from the *Messiah* violin (Figure 27):

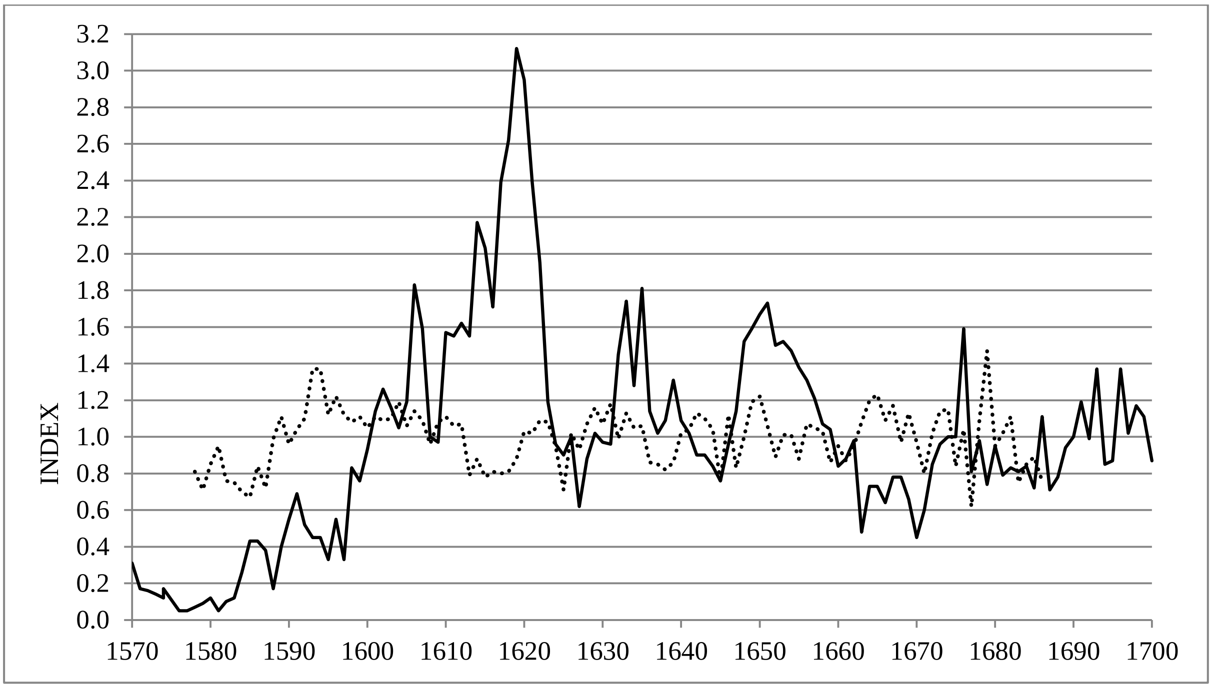

Figure 27: ITRDB ITAL022 (Bernd Becker), Bibbiena standard-index chronology, solid line. *Messiah* violin, standard-index chronology (ITRDB), dotted line.

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After the submission, in 2002, of the first version of the JoAS article *A dendroarchaeological re-examination of the "Messiah" violin and other instruments attributed to Antonio Stradivari*, but prior to its publication in 2004, there appeared in print a 'Short article' co-written by Lloyd Burckle[122] and Henri Grissino-Mayer entitled *Stradivari, violins, tree rings, and the Maunder Minimum: a hypothesis*.[123] This article drew attention to the well-documented climatic condition known as the 'Maunder Minimum', a period between approximately 1645 and 1715 (which was itself within the more extensive period known as the 'Little Ice Age') during which the climate of Western Europe became much colder than normal, especially during the winter months.[124] Winters during this Maunder Minimum period were bitterly cold and prolonged, thus reducing the growing season by several weeks; the Baltic Sea froze over, as did most of the rivers in Europe; there was widespread crop failure, famine, and, in some areas, population decline. The price of grain increased, and fishing was limited as shoals migrated south to find warmer waters. Storms and flooding were common, and glaciers advanced in the Alps and northern Europe, overrunning towns and farms in the process. During the Great Frost of 1683–84 the river Thames in London was completely frozen for two months, with the ice reaching a thickness of 28 centimetres (11 inches). Solid ice was reported

[122] From the Lamont-Doherty Earth Observatory, Columbia University, New York.
[123] Burckle and Grissino-Mayer.
[124] Other parts of the world were equally affected.

extending for miles off the coasts of England, France and the Low Countries, causing severe problems for shipping and preventing the use of many harbours. Lake Constance (Bodensee), on the northern edge of the Alps (400 metres above sea level and the third largest freshwater lake in central Europe), froze entirely in the winters of 1684 and 1695, and froze partially in 1709. It is thought that a decrease in the occurrence of sunspots was the cause of this 70-year freeze; a low rate of sunspot activity possibly indicates a less active and colder sun and, consequently, less radiant energy output to warm the Earth. These much colder conditions, persisting for decades, would likely have produced consistently narrow tree rings which, it is suggested by Burckle and Grissino-Mayer, could have made a positive contribution to the tone of Cremonese violins.

Burckle and Grissino-Mayer provide an indexed graph derived from the aforementioned 16-site alpine chronologies, encompassing the period 1500-2000.[125] A trend-curve is superimposed on the graph, representing an '11yr moving average that accentuates the low-frequency trends'. This rising-and-falling trend-curve reveals fluctuating tree-ring growth from 1500 onwards, followed by three distinct periods of below-average growth (upside-down bell curves on the graph). The first cold period is centred on 1645, followed by a short-lived recovery of ring growth around 1665. Ring growth then diminishes again to another minimum, centred on 1675, followed by another brief recovery, before another minimum – the most acute – is reached in 1695. Ring growth then steadily recovers, and moves into above-average growth until approximately 1730.

'Information Sheet 5', produced by the Climatic Research Unit at the University of East Anglia, England, is titled *The Millennial Temperature Record* and presents six superimposed curves of 'spatial reconstructions of past temperatures and estimates of average temperatures for the Northern Hemisphere' from the year 1000AD to the present day.[126] Five of the curves show a clear plunge in temperatures from approximately 1570, a temperature reduction which reaches its nadir in approximately 1620. Four of the curves then demonstrate a rapid recovery in temperature, peaking around 1650 before subsiding again, equally rapidly, to a minimum in 1680 (which was as cold as the minimum of 1620); temperatures then recovered from 1700 onwards. Thus there is some agreement between the long-range *Millennial* graph and the shorter Burckle/Grissino-Mayer alpine graph.

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The nineteenth century also saw a period of pan-European cold weather, between approximately 1815 and 1840, identified today as the 'Dalton Minimum'. The cold conditions of the Dalton Minimum are associated with the eruption of many volcanos around the world – La Soufrière (Caribbean, 1812), Awu (Indonesia, 1812), Suwanosejima (Japan, 1813), Mayon (Philippines, 1814), Tambora (Indonesia, 1815),[127] Galunggung (Indonesia, 1822), and Cosiguina (Nicaragua, 1835). These volcanic explosions created a substantial amount of dust in the atmosphere and worldwide temperatures fell in response.

> Only certain types of volcanic eruption will have an effect upon the climate. The eruption has to be of sufficient magnitude to emit very large quantities of material into the lower stratosphere (20-25km above the Earth's surface) and, for maximum impact, it should be in lower latitudes. With these conditions met, the particles in the lower stratosphere spread to form a "veil" over the whole planet. This veil then affects the amount of the sun's energy which reaches the Earth's surface. […] Major eruptions in lower latitudes are more climatically effective as the veil is capable of

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[125] Burckle and Grissino-Mayer, p. 44, Figure 1.

[126] http://www.cru.uea.ac.uk/documents/421974/1295957/Info+sheet+%235.pdf/d18c6b15-1fcb-4d89-a62e-e0d808939018 (accessed October 2013).

[127] One of the largest and most destructive volcanic explosions to have ever taken place.

reaching the higher latitudes of both hemispheres, because of the nature of the atmospheric circulation.[128]

In western Europe, during this early nineteenth-century period, crops were destroyed, food riots broke out in both England and France, and grain warehouses were looted; the Swiss government was forced to declare a national emergency in the face of food shortages; huge storms rolled across Europe, causing rivers (including the Rhine) to flood; the year of 1816, in Europe, was described as the 'year without a summer'; Lake Constance (Bodensee) was entirely frozen in the winter of 1830. The aforementioned graph provided by Burckle and Grissino-Mayer reveals the nineteenth-century's Dalton Minimum, with a severe plunge in ring-growth beginning in 1805 and reaching its nadir around 1820, with growth then recovering. This climatic period is also clearly represented on the UEA/CRU *Millennial* graph and in the standard-index chronologies from Stubaital Milderaun Alm (ITRDB, AUST007.crn) and Cortina d'Ampezzo (ITAL006.crn), the raw measurements having been submitted to the ITRDB by F H Schweingruber (Figure 28):[129]

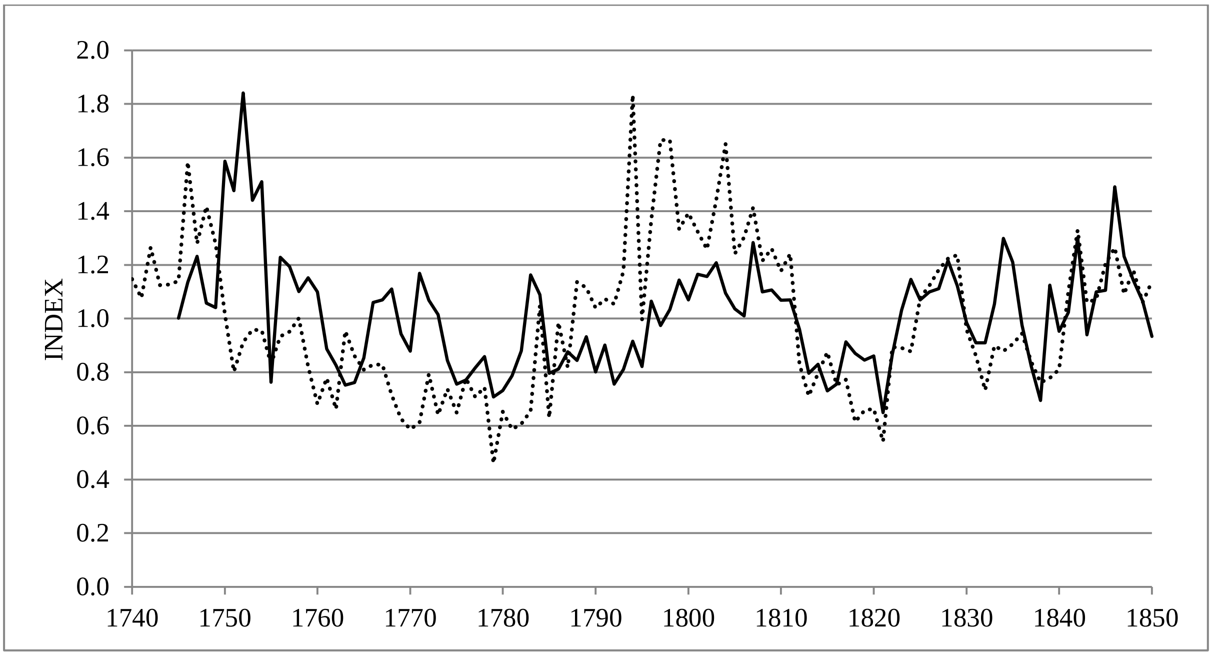

Figure 28: Stubaital Milderaun Alm, spruce, standard-index chronology, ITRDB AUST007.crn, solid line. Cortina d'Ampezzo, spruce, standard-index chronology, ITRDB ITAL006.crn, dotted line. The falling trace from Cortina d'Ampezzo (1804-1821) exhibits good similarity with the falling trace from Milderaun Alm.

A further reference chronology, covering the first half of the nineteenth century, is that which was collected by H C Fritts from Patscherkofel (five miles south of Innsbruck); his stone pine data is archived at the ITRDB under the reference AUST001 – an 'excellent high quality chronology'.[130] The Fritts/Patscherkofel standard-index chronology is presented in Figure 29 (below) and clearly shows the effect of the Dalton Minimum with a rapid reduction in ring-growth beginning in 1810 and reaching a minimum in the years around 1820 when there was barely any growth at all; the raw measurements are: 1818: 0.07mm; 1819: 0.08mm; 1820: 0.11mm; 1821: 0.07mm; 1822: 0.22mm.

[128] David Viner and Phil Jones, *Volcanoes and their effect on climate* (Information Sheet 13 from the website of the Climatic Research Unit at the University of East Anglia, England; accessed October 2013).

[129] Schweingruber's raw measurements from Cortina d'Ampezzo, for the period 1740-1847, are derived from between one and three samples; the years 1848, 1849, and 1850 are derived from four samples. The raw measurements from Stubaital Milderaun Alm (1745-1850) are derived from between one and eleven samples.

[130] ITRDB AUST001.txt (accessed October 2013).

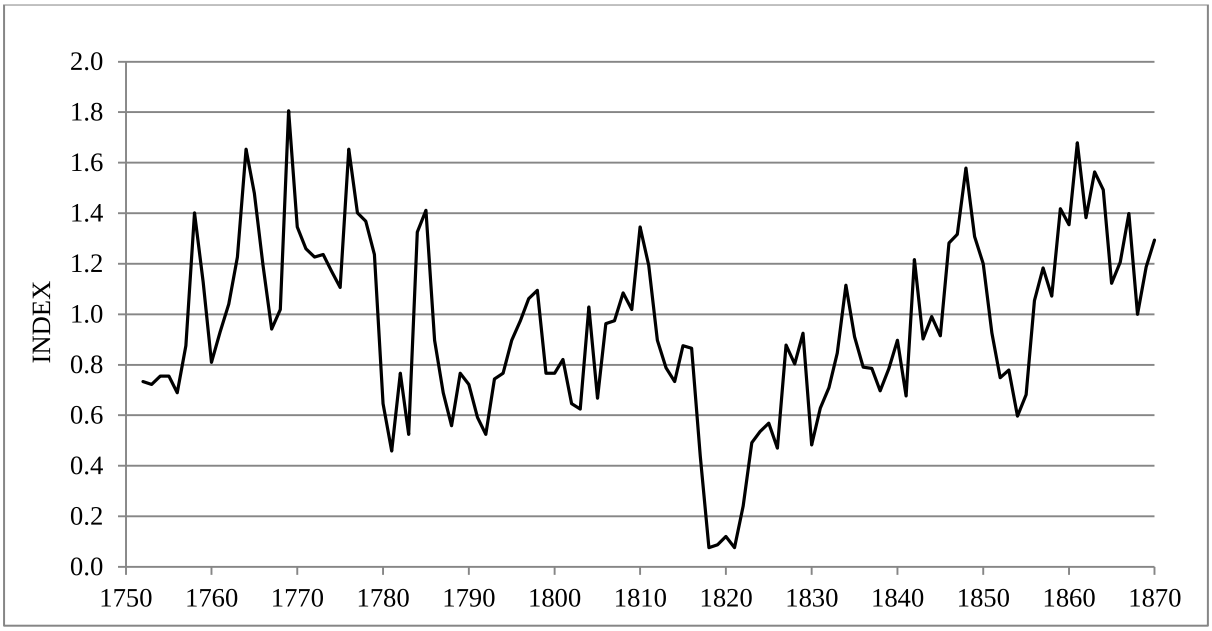

Figure 29: Patscherkofel, AUST001.crn, stone pine, standard-index chronology.

The growth-rings on either side of the *Messiah* violin's front-plate centre joint are no more than 0.5 millimetres in width, often even narrower. On the bass side the rings change colour from dark to pale, and also rapidly decrease in width, approximately 21 rings to the left of the centre joint. On the treble side the rings change colour from dark to pale, and also rapidly decrease in width, approximately 22 rings to the right of the centre joint. The physical point at which the rings abruptly change from wider/more coloured to narrower/pale (and the 'increasing' narrowness of the rings after the change in colour) could be interpreted as indicating the onset of an ever-intensifying period of deep cold, but whether this cold period dates from the seventeenth century (the Maunder Minimum) or the nineteenth century (the Dalton Minimum) is at least debatable.

The spruce and maple wood used by Stradivari to make some of his violins may be chronologically associated with the climatic period known as the Maunder Minimum, but the instruments' current tonal brilliance may have just as much to do with the centuries-long maturing and drying of the instruments' wood[131] (and the varnish), or today's highly scientific manufacture of strings (and the specific type of resin which string manufacturers recommend in conjunction with a specific type of string), or the nineteenth-century perfection in making bows, or the cutting and the shaping of the bridge, or even the care and thought which is currently applied to the manufacture of the tail-piece and how it, and the 'after length' of the strings between the bridge and the tail-piece, interact acoustically with the freely-vibrating length of the strings. In addition, almost every Stradivari violin has had its bass bar changed since it was made (the bass bar of the *Messiah* violin has been changed twice) and the bass bar's thickness, length, depth, grain-orientation, angle-of-fit, whether 'sprung' against the underside of the belly or not – all these matters are of critical importance with respect to the tone of an instrument. A contemporary cellist, for example, is acutely aware of the difference made to the tonal qualities of his/her instrument, and its musical responsiveness, by the type of floor spike which is fitted – metal or carbon fibre, angled or straight, light or heavy, thick or thin – the variations are almost endless. Stradivari's instruments, today, sound not at all how Antonio Stradivari expected a newly-completed instrument to sound, yet the remarkable design of the violin – whether made by Stradivari, Bergonzi, Guarneri, Guadagnini, or whomsoever – means that its structural

[131] Cremonese instruments often weigh very little (when compared to modern instruments).

integrity has been able to accommodate ever-increasing strains and tensions (did virtuosity beget better strings or *vice versa*?) and, indeed, the instruments seem almost to thrive on the intense demands of performance which are now made of them.

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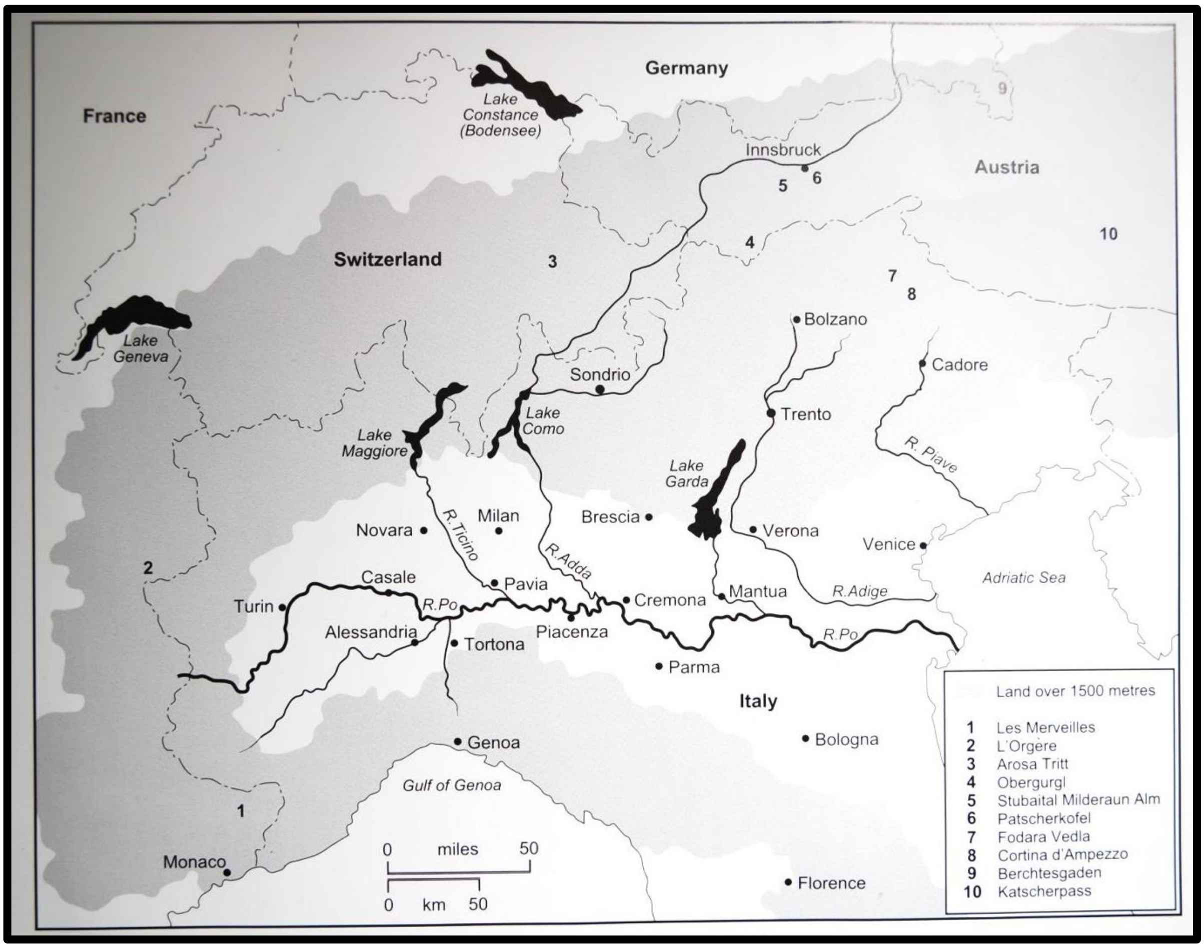

Supplementary figures relating to the Antonio Stradivari *Archinto* viola (1696).
All year-dates are sourced from ITRDB BRIT051 data.

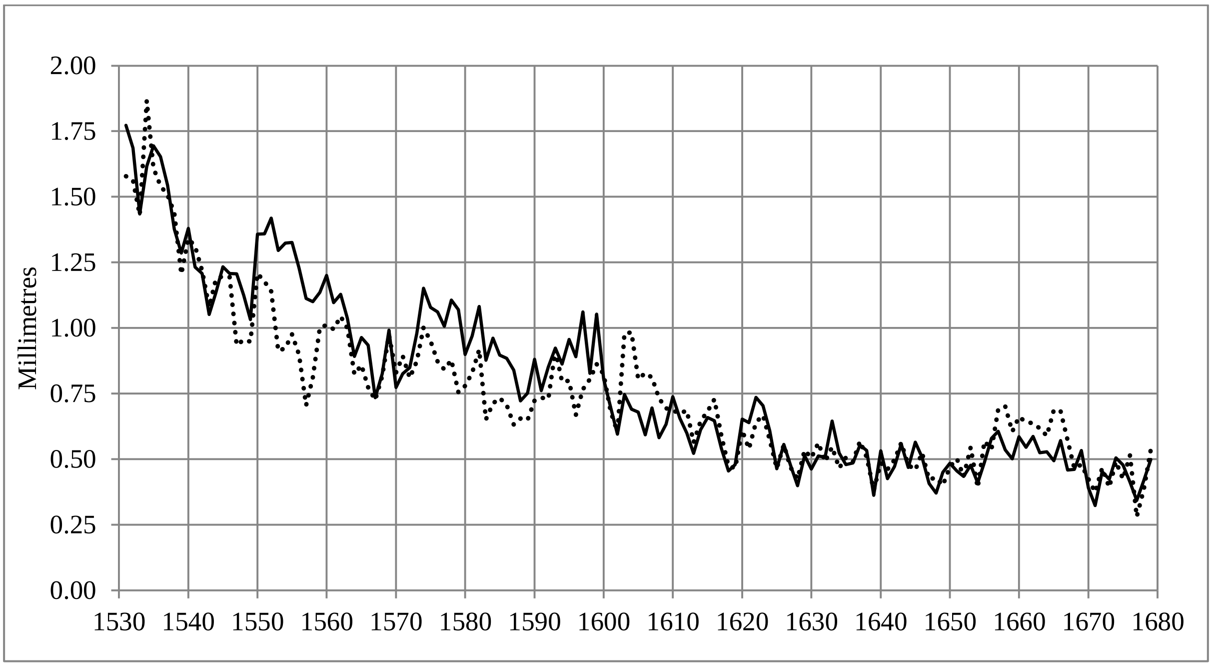

Figure 30: *Archinto* viola, raw measurements. Treble is solid line, bass is dotted. Common years are 1531-1679. Data from ITRDB BRIT051.rwl. The two front-plate half widths were likely taken from the same log of spruce.

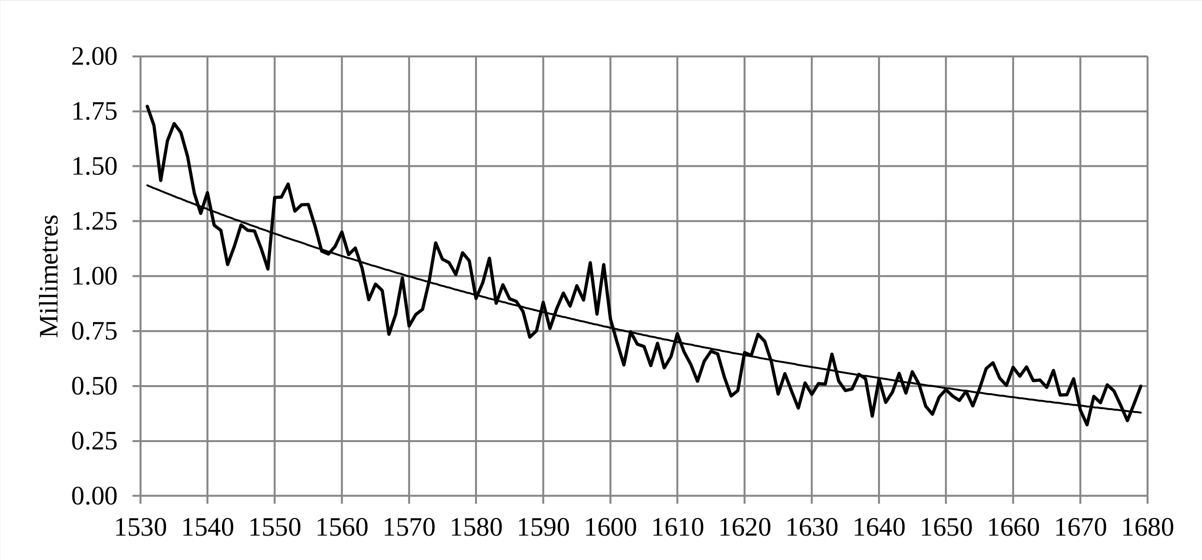

Figure 31: *Archinto* viola, treble-side raw measurements with added negative exponential trendline.

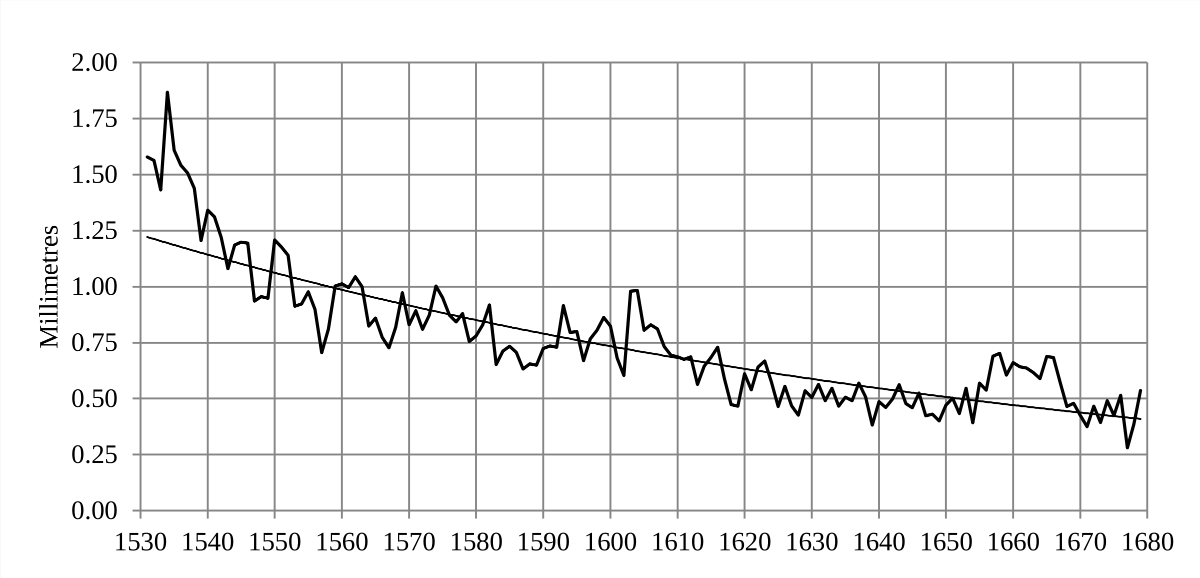

Figure 32: *Archinto* viola, bass-side raw measurements with added negative exponential trendline.

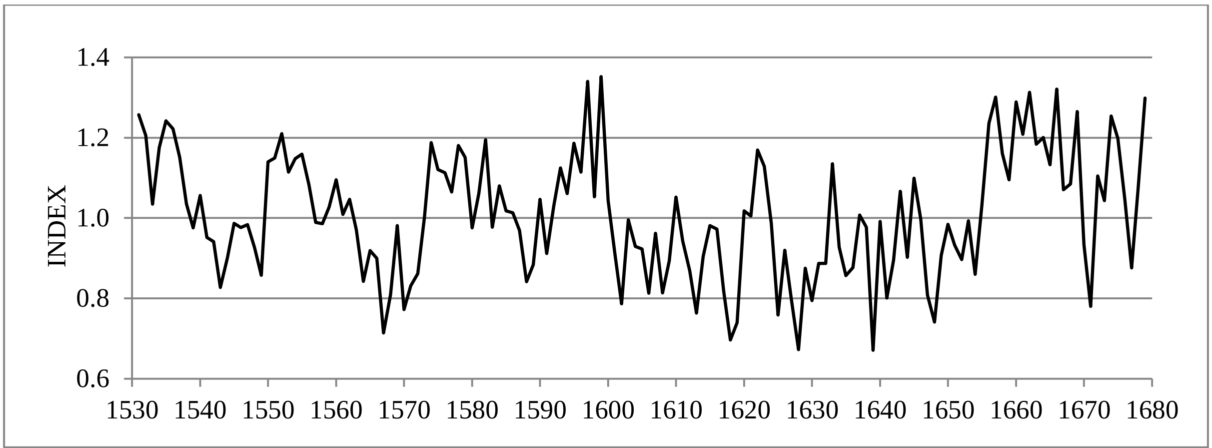

Figure 33: *Archinto* viola, treble-side standard-index chronology, derived from Figure 31.

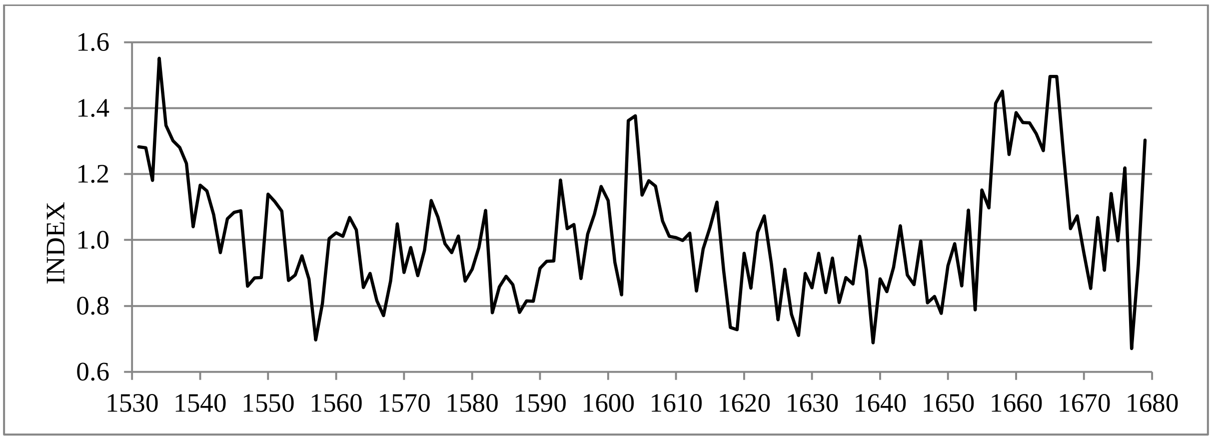

Figure 34: *Archinto* viola, bass-side standard-index chronology, derived from Figure 32.

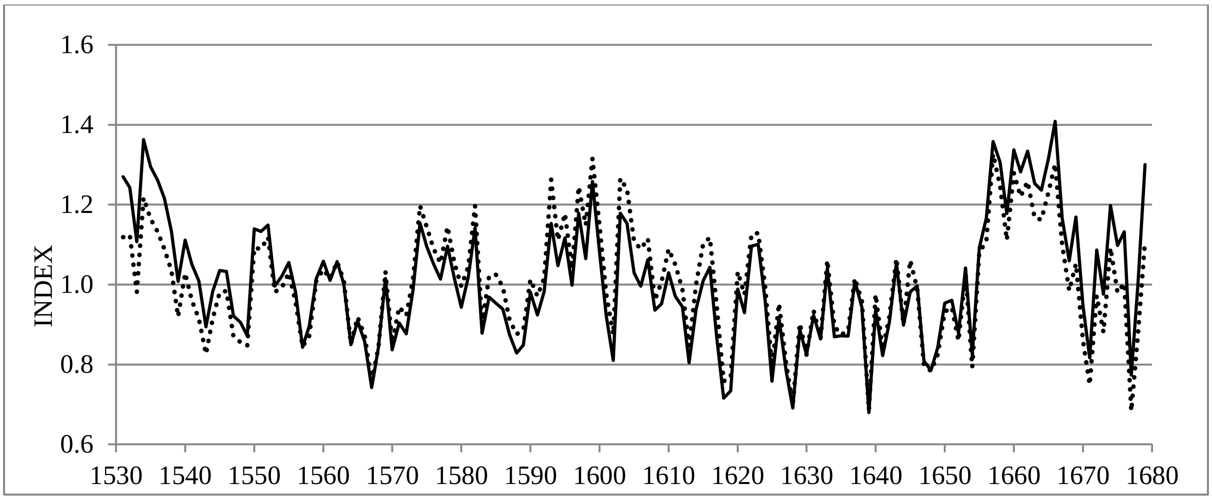

Figure 35: *Archinto* viola, the present author's standard-index chronology (Figures 33 and 34 averaged), solid line. *Archinto* viola, ITRDB BRIT 051.crn, standard-index chronology, dotted.

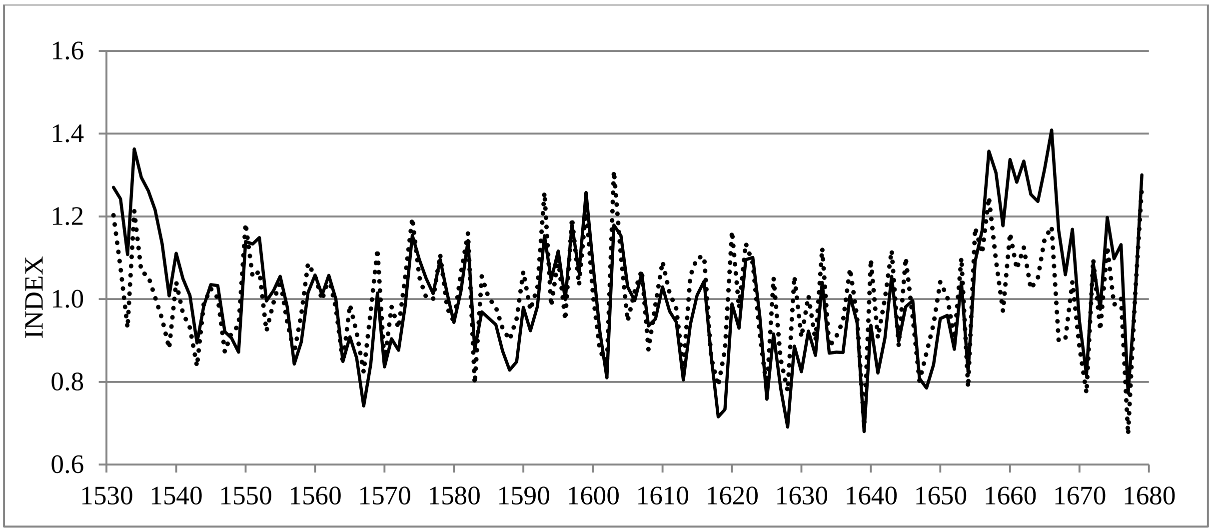

Figure 36: *Archinto* viola, author's standard-index chronology (as Figure 35), solid line. *Archinto* viola, ITRDB BRIT 051r.crn, residual chronology, dotted.

For a graphical comparison between the residual chronology from the *Archinto* viola and the residual chronology from the *Messiah* violin see Figure 26.