Dendrochronologia 21/1 (2003) 41–45

http://www.urbanfischer.de/journals/dendro

DENDROCHRONOLOGIA

Short article

Stradivari, violins, tree rings, and the Maunder Minimum: a hypothesis

Lloyd Burckle[1], Henri D. Grissino-Mayer[2]

[1] Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York
[2] Laboratory of Tree-Ring Science, Department of Geography, University of Tennessee, Knoxville, Tennessee, USA

Summary
Instruments produced by the master violinmakers of the late 17th and early 18th centuries are reputed to have superior tonal qualities relative to more contemporary instruments. Many hypotheses have been proffered to explain this difference in sound quality, but all hypotheses were found wanting. We propose an alternative hypothesis based on the unique climate situation that existed between AD 1645–1715 known as the Maunder Minimum. This period of reduced solar activity was noted also for its lowered temperatures, which therefore caused reductions in tree growth rates. We hypothesize that the longer winters and cooler summers produced wood that had slower, more even growth, desirable properties for producing higher-quality sounding boards. During Stradivari's latter decades, he used spruce wood that had grown mostly during the Maunder Minimum. These lowered temperatures, combined with the environmental setting (i. e., topography, elevation, and soil conditions) of the forest stands from where the spruce wood was obtained, produced unique wood properties and superior sound quality. This combination of climate and environmental properties has not occurred since Stradivari's "Golden Period."

Keywords: Tree rings, Antonio Stradivari, Maunder Minimum, dendrochronology, violinmaking

Antonio Stradivari and the Violin

First developed in northern Italy ca. 1550 (Dilworth 1992), the violin received its distinctive sound with the emergence of the famous violin-making families of Amati, Stradivari, and Guarneri (Wechsberg 1973; Dilworth 1992) and later during the extensive restoration of their instruments that took place in the 19th century (Gough 2000). Of these, the most famous violinmaker was Antonio Stradivari. Born in 1644, he established his workshop in Cremona, Italy, and remained active there until his death in 1737 (Henley 1961). Stradivari made more than 1,100 instruments (Hill et al. 1902) – violins, guitars, violas, and cellos – of which more than 600 survive today (Doring 1945). Stradivari is responsible for crafting the most celebrated violin in the world, "The Messiah" (Dilworth 1992, 2001), in 1716. Recent controversy concerning its provenance, supposed stylistic inconsistencies, and its dendrochronological dating have spurred renewed interest in this

Address for correspondence:
Henri D. Grissino-Mayer, Laboratory of Tree-Ring Science, Department of Geography, University of Tennessee, Knoxville, Tennessee 37996 USA
Tel.: (8 65) 9 74-60 29, Fax: (8 65) 9 74-60 25
grissino@utk.edu

1125-7865/03/21/01-041 $ 15.00/0

remarkable violin (Pollens 1999; Topham, McCormick 2000; Grissino-Mayer et al. 2002, 2003 in press) and the authentication of instruments held individually and in collections (e. g. Topham 2002).

Wood Properties and Violinmaking

Considerable debate still occurs surrounding reasons why instruments made by the Cremonese artisans of the late 17th – early 18th centuries sound superior compared to modern instruments (although some even debate whether these older instruments truly sound superior). The popular belief is that the skills of the Cremonese violinmakers, combined with a "secret ingredient" (or undocumented technique), gave these instruments the rich sound so highly prized by professional musicians (Gough 2000). The nature of that "secret ingredient" has been the subject of debate for many years. Candidates include the development and use of a special varnish, chemical treatment of the sounding wood, "cooking" or drying the wood, storage time (i. e. wood seasoning), the use of very old wood from historic structures, and water leaching of supposedly harmful chemicals before seasoning.

These candidate explanations, however, were found wanting. Drying wood in ovens has never been documented as a technique used by violinmakers, much less the Cremonese makers, and was most likely unknown to these artisans (Peterlongo 1980). Seasoning of the wood also cannot be invoked as a possible explanation because considerable variability exists in the lengths of these seasoning periods, even among individual makers (Gough 2000). Instruments made by Stradivari have "seasoning" periods (as estimated by the interval of years between the outermost ring date and the label date) as short as seven years and as long as 31 years, for example (Topham, McCormick 2000). A "secret" varnish has yet to be demonstrated despite considerable scientific analyses that include ultraviolet photography, electron microscopy, ion backscattering, and x-ray investigations (Tove et al. 1980; Barlow, Woodhouse 1988, 1989; Gough 2000). In fact, varnish is more a protectant of the wood surface from water absorption rather than an acoustic enhancer (Schelleng 1968; Dilworth 1992). Similar negative findings discount any possibility of soaking in water or chemical treatment (Barlow et al. 1988; Gough 2000), although Rohloff (1940) suggests some violinmakers may have soaked their wood prior to construction to reduce acoustic damping. Finally, some have suggested that Stradivari used "cured" wood from more ancient castles or cathedrals (Wall 2002). This hypothesis is discounted because dendrochronological analyses on numerous instruments attributed to Stradivari demonstrated ages for the spruce wood that were contemporary with his lifetime (Topham, McCormick 2000; Topham 2002, Grissino-Mayer et al. 2003).

Violinmakers have always known that selection of the wood makes the difference in quality violins (Gough 2000). Maple (*Acer* spp.) is preferred for the back, ribs, and neck, while spruce (*Picea* spp.) is preferred for the top. These genera have superior acoustical and mechanical properties that have the least loss of energy through internal friction than other woods (Krüger, Rohloff 1938). For example, spruce cells are light, physiologically simple, hollow, and rigid, ideal properties for enhanced acoustic quality (Dilworth 1992). Stradivari and other eminent Italian violinmakers of the 17th and early 18th centuries had neighboring workshops in Cremona and likely used the nearby forests of the southern Italian Alps as their source for spruce wood (Topham, McCormick 2000; Grissino-Mayer et al. 2002, 2003 in press). A candidate location for this source is the well-known "Forest of the Violins" in the Parco Naturale Paneveggio in the eastern part of Trentino, Italy, known among violinmakers for its "fir trees of resonance" (Parco Naturale Paneveggio 2002; see also Peterlongo 1980).

Only trees that have grown at higher elevations on north-facing slopes (and perhaps in thin, nutrient-poor soils) have the slow growth and dense wood grain that help instill a superior tone and brilliance in violins (Peterlongo 1980). Indeed, wood grown under conditions that promote fast growth is likely to be less resonant and less able to stand up to the stresses it is subjected to as a violin (Gough 2000). This occurs because the percentage of earlywood (i. e. thin-walled, less dense cells) is greater relative to the percentage of latewood (i. e. thick-walled, denser cells) in trees growing under optimal environmental conditions. This fast-grown, less dense wood is therefore softer and more porous, giving the violin a dull, muffled sound that limits resonance.

Stradivari and the Maunder Minimum: A Hypothesis

Wood with high density, however, can be found in trees growing in a variety of habitats and environmental settings in numerous higher-elevation locations throughout the world. Hence, an explanation of superior sound quality based solely on wood properties is insufficient. Instead, could the superior sound quality be explained by a unique combination of wood properties, environmental characteristics, and macroclimatic properties? Could the wood used by the Cremonese makers have had unique physical characteristics that were perhaps time-specific? In other words, could the trees growing during the lifetime of Stradivari have experienced a unique set of environmental conditions that has not occurred since?

We propose that a major multi-decadal change in climate that affected tree growth rates contributed to an improved acoustic quality of musical instruments produced during the working lifetime of Stradivari. The climatic regime that gripped Europe and perhaps much of the world during the time of Stradivari supports this hypothesis. The well-known Maunder Minimum (AD 1645–1715) was a period characterized by a scarcity of sunspots and a reduction in the Sun's overall activity (Eddy 1975, 1976; Landsberg 1980; Esper et al. 2002). The low recorded sunspot numbers were a direct indication of less intense solar radiation and activity during this period (Suess 1979; Ribes, Nesmeribes 1993). It coincided with a sharp dip in temperatures during the Little Ice Age (LIA) and a period of very cold weather in western Europe. Estimates of the magnitude of cooling during the Maunder Minimum range from 1–2 °C (Shindell et al. 2001) compared to the 0.5°–1.5 °C range for the LIA overall (Rind, Overpeck 1993).

The Maunder Minimum is clearly seen in some tree-ring records from high-elevation forest stands in the European Alps. Grissino-Mayer et al. (2003 in press) developed a regional composite chronology from 16 individual high-elevation alpine chronologies (Fig. 1), representing information from several hundred trees from three different species (*Larix decidua* Mill. = European larch, *Picea abies* (L.) Karst. = Norway spruce, and *Pinus cembra* L. = Swiss stone pine) growing in five countries, extending from western France to southern Germany (ca. 600 km). Inter-chronology correlations (i. e., one alpine chronology correlated against a master chronology developed from the remaining 15) were all statistically significant ($p < 0.0001$), ranging from 0.49 to 0.74 (Grissino-Mayer et al. 2003 in press). These correlations indicate a strong regional climate signal.

The long period of reduced growth rates between ca. AD 1625–1720 is clearly indicated in the alpine tree-ring record developed from these 16 sites (Fig. 1). The duration of this period (ca. 95yr) is also unprecedented during the last 500yrs (although another period of reduced growth occurred between ca. AD 1810–1865) (Fig. 1). This period of reduced growth is contemporaneous with the Maunder Minimum (AD 1645–1715). In Europe, this 70yr period was wetter and colder during the summers and the latter part of the Maunder Minimum was one of the few periods when cold temperatures persisted for decades (Luterbacher et al. 1999, 2000). Furthermore, Briffa et al. (1999) have shown that this decadal-scale period of reduced temperatures likely began as early as the 1570s, also evident in the regional composite chronology (Fig. 1).

Interestingly, Stradivari was born one year before the beginning of the Maunder Minimum. His "Amati Period" (1666–1690), "Experimentation Period" (1690–1700), and "Golden Period" (1700–1720, when he fashioned perhaps the most prized and valued instruments, see Henley 1961) all coincided with the Maunder Minimum.

Long winters and cool summers produce wood that has slow, even growth, desirable properties for producing quality sounding boards. The violinmakers of Cremona during this period used the only wood available to them, i. e. from trees that grew during the Maunder Minimum. We suggest that the narrow tree rings that identify the Maunder Minimum in Europe played a role in the enhanced sound quality of instruments produced by the Cremona violinmakers. Narrow tree rings would not only strengthen the violin but would increase the wood's density. The onset of the Maunder Minimum at a time when the skills of the Cremonese violinmakers reached their zenith perhaps made the difference in the violin's tone and brilliance. Furthermore, the combination of elevation, topography, nutrient-poor soil properties, and a deterioration in climate was temporally unique – climate conditions with temperatures such as those that occurred during the Maunder

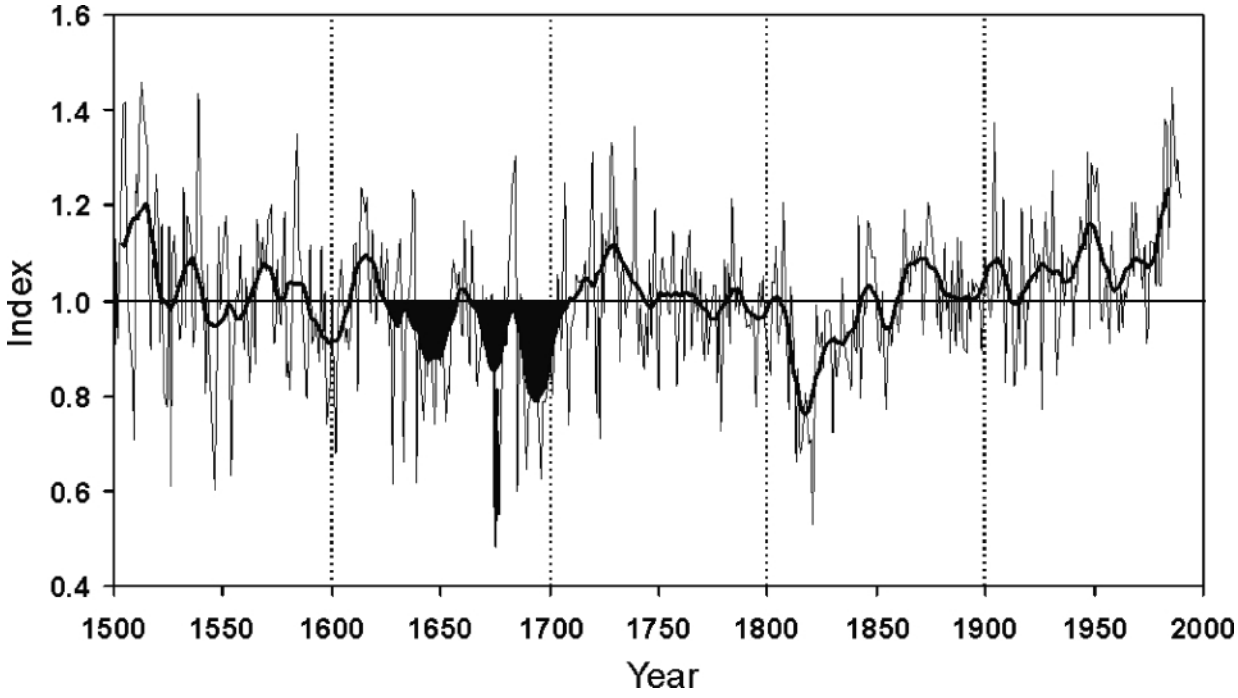

Figure 1. The standard tree-ring index chronology developed from 16 alpine chronologies in five central European countries (Grissino-Mayer et al. 2003 in press). The bold curve represents an 11yr moving average that accentuates the low-frequency trends. The Maunder Minimum is indicated in the shaded region between ca. AD 1620–1715.

Minimum simply can not and do not occur today in areas where the Cremonese makers likely obtained their wood.

Acknowledgements

Paul Sheppard (University of Arizona) and Malcolm Cleaveland (University of Arkansas) participated in the original research that investigated the authenticity of the famous "Messiah" violin attributed to Antonio Stradivari, and to them we are thankful for their insights on tree-ring dating of musical instruments. Paolo Cherubini, Swiss Federal Institute for Forest, Snow and Landscape Research, provided valuable insights on Paneveggio and the "Forest of the Violins." This is Lamont-Doherty Earth Observatory Contribution No. 6389.

References

Barlow CY, Edwards PP, Millward GR, Raphael RA, Rubio DJ, 1988. Wood treatment used in Cremonese instruments. Nature, 332: 313.

Barlow CY, Woodhouse J, 1988. Microscopy of wood finishes. Journal of the Catgut Acoustical Society, 1(1) (series II): 9–15.

Barlow CY, Woodhouse J, 1989. Of old wood and varnish: peering into the can of worms. Journal of the Catgut Acoustical Society, 1(4) (series II): 2–9.

Briffa KR, Jones PD, Vogel RB, Schweingruber FH, Baillie MGL, Shiyatov SG, Vaganov EA, 1999. European tree rings and climate in the 16th century. Climatic Change 43, 151–168.

Dilworth J, 1992. The violin and bow – origins and development. In Stowell J (ed), The Cambridge Companion to the Violin, Cambridge University Press, Cambridge: 1–29.

Dilworth J, 2001. Pure thrill – a work of genius. The Strad, 112: 838–845.

Doring EN, 1945. How Many Strads? Our Heritage from the Master. Bein and Fushi, Chicago.

Eddy JA, 1975. Maunder Minimum – when the sun lost its spots. EOS, Transactions of the American Geophysical Union, 56: 1055.

Eddy JA, 1976. Maunder Minimum. Science, 192: 1189–1202.

Esper J, Cook ER, Schweingruber FH, 2002. Low-frequency signals in long tree-ring chronologies for reconstructing past temperature variability. Science, 295: 2250–2252.

Gough C, 2000. Science and the Stradivarius. Physics World, 13: 27–33.

Grissino-Mayer HD, Cleaveland MK, Sheppard PR, 2002. A match for the "Messiah." The Strad, 113: 408–415.

Grissino-Mayer HD, Sheppard PR, Cleaveland MK, 2003. A dendroarchaeological re-examination of the "Messiah" violin and other instruments attributed to Antonio Stradivari. Journal of Archaeological Science, in press.

Henley W, 1961. Antonio Stradivari, Master Luthier, Cremona, Italy, 1644–1737: His Life and Instruments. Amati Publishing Ltd, Sussex.

Hill WH, Hill, AF, Hill AE, 1902. Antonio Stradivari: His Life and Work (1644–1737). WE Hill & Sons, London.

Krüger F, Rohloff E, 1938. Über die innere Reibung von Holz. Zeitschrift für Physik, 110: 58–68.

Landsberg HE, 1980. Variable solar emissions, the Maunder Minimum and climatic temperature-fluctuations. Archiv für Meteorologie und Geophysik, Serie B 28, 181–191.

Luterbacher J, Schmutz C, Gyalistras D, Xoplaki E, Wanner H, 1999. Reconstruction of monthly NAO and EU indices back to AD 1675. Geophysical Research Letters, 26: 2745–2748.

Luterbacher J, Rickli R, Tinguely C, Xoplaki E, Schupbach E, Dietrich D, Husler J, Ambuhl M, Pfister C, Beeli P, Dietrich U, Dannecker A, Davies TD, Jones PD, Slonosky V, Ogilvie AEJ, Maheras P, Kolyva-Machera F, Martin-Vide J, Barriendos M, Alcoforado MJ, Nunes MF, Jonsson T, Glaser R, Jacobeit J, Beck C, Philipp A, Beyer U, Kaas E, Schmith T, Barring L, Jonsson P, Racz L, Wanner H, 2000. Monthly mean pressure reconstruction for the late Maunder Minimum period (1675–1715) based on canonical correlation analysis. International Journal of Climatology, 20: 1049–1066.

Parco Naturale Paneveggio, 2002. Parco Naturale Paneveggio – Pale di San Martino, http://www.parks.it/parco.paneveggio.pale.s.martino/Epar.html.

Peterlongo P, 1980. The violin: the wood. The Strad, 90: 772–774.

Pollens S, 1999. Le Messie. Journal of the Violin Society of America, 16: 77–101.

Ribes JC, Nesmeribes E, 1993. The solar sunspot cycle in the Maunder Minimum AD 1645 to AD1715. Astronomy and Astrophysics, 276: 549–563.

Rind D, Overpeck J, 1993. Hypothesized causes of decade-to-century climate variability: climate model results. Quaternary Science Reviews, 12: 357–374.

Rohloff E, 1940. Über die innere Reibung und die Strahlungsdämpfung von Geigen. Annalen der Physik, Serie 5, 38: 177–198.

Schelleng JC, 1968. Acoustical effects of violin varnish. Journal of the Acoustical Society of America, 44: 1175–1183.

Shindell DT, Schmidt GA, Mann ME, Rind D, Waple A, 2001. Solar forcing of regional climate change during the Maunder Minimum. Science, 294: 2149–2152.

Suess ST, 1979. Solar-wind during the Maunder Minimum. Planetary and Space Science, 27: 1001–1013.

Topham J, 2002. A dendrochronological survey of musical instruments from the Hill Collection at the Ashmolean Museum in Oxford. Galpin Society Journal, 55: 244–268.

Topham J, McCormick D, 2000. A dendrochronological investigation of stringed instruments of the Cremonese School (1666–1757) including "The Messiah" violin attributed to Antonio Stradivari. Journal of Archaeological Science, 27: 183–192.

Tove PA, Sigurd D, Petersson S, 1980. Ion backscattering and x-ray investigations of violin varnish and wood. Nuclear Instruments and Methods, 168: 441–446.

Wall, D, 2002. The secret of the Stradivarius sound. Newsweek, October 28, 2002: 16.

Wechsberg J, 1973. The Glory of the Violin. Viking Press, New York.