ANNE-EMMANUELLE CEULEMANS, PHILÉMON BEGHIN,
PAUL FISETTE, FRANÇOIS GLINEUR, IONA THYS

Baroque Violas with Reduced Soundboxes: An Evaluation Method

In the history of musical instruments, the violin, understood as an instrument type of various sizes, holds a special place. While nineteenth-century instrument making underwent significant changes due to the development of techniques, the violin remained closely linked to traditional craftsmanship. The idea of progress that marked society hardly had an impact on it: in the collective imagination, the best violin was not the one that innovated, but the one that was in line with tradition.[1] Above all, luthiers and musicians worked in the belief that old stringed instruments necessarily sounded better than those of recent make, an idea expressed as early as in 1676 by Thomas Mace (1612/13–?1706).

> […] we chiefly *Value Old Instruments*, before *New*; for by *Experience*, they are found to be far the *Best*.
>
> The *Reasons* for which, I can no further *Dive* into, than to say; I Apprehend, that by *Extream Age*, the *Wood*, (and *Those Other Adjuncts*) *Glew*, *Parchment*, *Paper*, *Lynings of Cloath*, (as some use;) but above All, the *Vernish*; These are *All*, so very much (by *Time*) *Dryed*, *Lenefied*, *made Gentle*, *Rarified*, or (to say *Better*, even) *Ayrified*; so that *That Stiffness*, *Stubbornness*, or *Clunguiness*, which is *Natural* to *such Bodies*, are so *Debilitated*, and made *Playable*, that the *Pores* of the *Wood*, have a *more*, and *Free Liberty* to *Move*, *Stir*, or *Secretly Vibrate*; by which means the *Air*, (which is the *Life* of *All Things* both *Animate*, and *Inanimate*) has a more *Free*, and *Easie Recourse*, to *Pass*, and *Re-pass*, &c. whether I have hit upon the *Right Cause*, I know not; but sure I am, that *Age Adds Goodness to Instruments*.[2]

On closer inspection, however, the fidelity to the past displayed by nineteenth-century violin makers and musicians was far from absolute. Despite the admiration they aroused, Baroque violins were constantly revised and modified. The following pages deal with a type of alteration that affects a fair proportion of surviving instruments: the reduction of the body size. This modification is surprisingly neglected in musicological literature. However, in order to understand the morphology of the violin family in the Baroque period, it is essential to bear this parameter in mind, given the scarcity of instruments preserved in their original state.

A few recent studies on reduction procedures have served as a basis for the following research. In 2015, Karel Moens published an article that attempted to estimate the original size of the violins used at Versailles in the seventeenth and early eighteenth

[1] Exceptions are of course possible. Early nineteenth-century violin making in France for example was open to innovation; see Christina Linsenmeyer, 'Competing with Cremona: Violin Making. Innovation and Tradition in Paris (1802–1851)', PhD thesis, Washington University in St. Louis, 2011.

[2] Thomas Mace, *Musick's Monument*, part III (London: T. Ratcliffe & N. Thompson, 1676), pp.245–46.

centuries.[3] According to Marin Mersenne (1588–1648), this ensemble was composed of five members, called from high to low: *dessus*, *haute-contre*, *taille*, *quinte* and *basse*.[4] Mersenne did not give precise dimensions for these instruments, but he indicated their tuning (see Figure 1).[5] The *haute-contre*, *taille* and *quinte* shared the same tuning, but Mersenne insisted that they were 'of different sizes, although they [were] all in unison', which suggests that their timbre was probably different.[6] In 1701, Joseph Sauveur (1653–1716) described the same family, while mentioning possible variations from the tuning given by Mersenne.[7]

Karel Moens' study focuses on the middle members of the ensemble (the *haute-contre*, the *taille* and the *quinte*), and to each of these three types he relates instruments that have come down to us. Today, these instruments are often referred to as 'violas'. Moens' aim is, therefore, to show that they are not really violas, but models abandoned after the generalisation of the Italian-style quartet (two violins, a viola, a cello), both in orchestral writing and in chamber music.[8]

The soundbox of some of the instruments analysed by Karel Moens has been reduced in size, probably to meet the requirements in terms of virtuosity of late eighteenth- or nineteenth-century musicians. In this case, Moens tries to determine the original dimensions of the instruments, an innovative but challenging approach. His study is based on a thorough visual examination, founded on extensive experience, but not easy to objectify. For example, he publishes the following photograph of a French violin from the Museum Vleeshuis in Antwerp (Figure 2). The height of its body is currently 35.4cm, but according to Moens it would originally have been *c*38cm (the trimmed part is shown in grey). However, this estimate is difficult to substantiate.

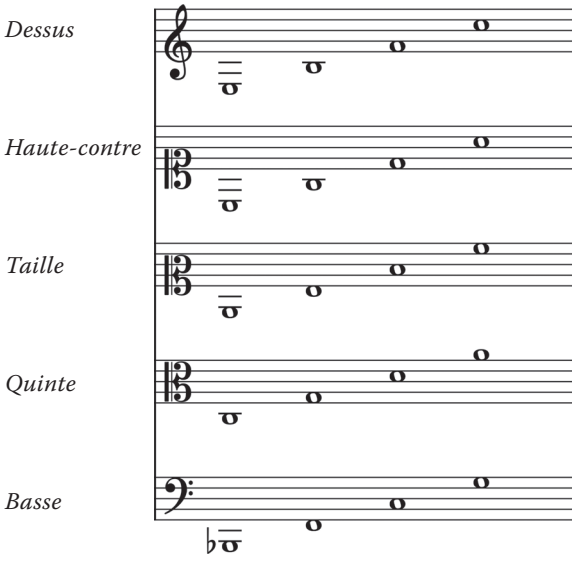

Figure 1. *Tuning of the French violin ensemble according to Marin Mersenne (clefs according to the usage of the Vingt-quatre violons du roi).*

Another methodological difficulty lies in the fact that, due to the small number of French violin-type instruments preserved in their original state, Moens bases his deductions on instruments of various origins, notably from the Southern Low Countries. It is not certain, however, that the musicians of this region always used instruments of French make or based on French models. Moreover, even in France, the best musicians often used instruments imported

[3] Karel Moens, 'Les voix médianes dans l'orchestre français sous le règne de Louis XIV: les instruments conservés comme source d'information', in Jean Duron and Florence Gétreau (eds.), *L'orchestre à cordes sous Louis XIV. Instruments, répertoires, singularités* (Paris: Vrin, 2015), pp.119–38.

[4] Marin Mersenne, *Harmonie universelle* (Paris: Sébastien Cramoisy, 1636–1637), *Livre quatriesme des instrumens à chordes*, pp.184–90.

[5] The few relative measures published in the *Harmonie universelle* are not reliable. See Anne-Emmanuelle Ceulemans, 'Mersenne et le violon', in Yves Balmer, Alban Framboisier, Fabien Guilloux and Catherine Massip (eds.), *Musiques – Images – Instruments. Mélanges en l'honneur de Florence Gétreau* (Turnhout: Brepols, 2019), pp.415–31.

[6] '[Elles] sont de differentes grandeurs, quoy qu'elles soient toutes à l'vnisson'. Mersenne (1636–1637), *Livre quatriesme des instrumens à chordes*, p.180. Mersenne does not explicitly cite the tuning of the middle parts, but it can be deduced from the *Fantaisie à 5* by Jean Henry (Henry le Jeune), published on pp.186–89. See Anne-Emmanuelle Ceulemans, *De la vièle médiévale au violon du XVIIe siècle. Étude terminologique, iconographique et théoriqu*e (Turnhout: Brepols, 2011), p.204.

[7] Joseph Sauveur, *Principes d'acoustique et de musique* (Paris: Académie royale des sciences, 1701), pp.37–38 and plate III.

[8] The earliest examples of this musical setting are not originally Italian, but it spread from Italy throughout Europe in the course of the eighteenth century. See Peter Holman, 'From Violin Band to Orchestra', in Jonathan Wainwright and Peter Holman (eds.), *From Renaissance to Baroque. Change in Instruments and Instrumental Music in the Seventeenth Century* (Aldershot: Ashgate, 2005), pp.241–57, at pp.245–46.

Figure 2. *Reduced violin (haute-contre) and assumed original size, France, first half of the eighteenth century (Antwerp, Museum Vleeshuis, inv. no. 1967.001.204), after Moens (2015), p.126, reproduced with the kind permission of Karel Moens and the Museum Vleeshuis.*

from Italy.[9] This observation makes the notion of a violin family specific to France and distinct from Italy questionable. Nevertheless, Moens' study remains pioneering in that it attempts to understand the history of this family bearing in mind the possible reductions in the instruments that have come down to us.

In the same collective book as Karel Moens, Anne Houssay offers a study devoted to a Cremonese instrument that she calls a *violetta*, attributed to Andrea Amati (before 1511–1577) and decorated with heraldic emblems.[10] The significance of this research lies in the description of the various adaptations made to the instrument: a reduction in both the height and width of the soundbox, as well as a bold reduction of the C-bouts, apparent from the insertion of pieces of maple in the upper corners of the back. The same technique will be found below, on an instrument from the Low Countries attributed to the Antwerp luthier Matthijs Hofmans (1622–1672).

In 2019, Alberto Giordano and Rudolf Hopfner illustrated the value of computed tomography (CT) scanning in visualizing the reduction of a viola by Nicolò (1596–1684) and Girolamo II Amati (1649–1740).[11] Their article, like that of Anne Houssay, concerns a single instrument. It is interesting for understanding the eventful history of a Cremonese viola, but does not aim to evaluate the original morphology of the violin family as a whole.

In 2020, five researchers from the Muséum d'Histoire Naturelle and the Musée de la Musique in Paris published an article that addresses the phenomenon of reduction in a rigorous manner, but whose methodology is unfortunately not transposable to a large corpus.[12] Their study focuses on two instruments by Andrea Amati, including the *violetta* already examined by Anne Houssay, renamed here 'tenor', and a violin from a private collection. Through an extensive study of the heraldic emblems on these instruments, it has been possible to determine with a high level of accuracy the amount of material removed from the tenor's back. This method is hardly applicable to other instruments, usually devoid of pictorial ornaments, but the article demonstrates the need to go beyond the simple visual observation of the instruments to quantify the reductions. While the missing width

[9] Norbert Dufourcq, 'Concerts parisiens et associations de 'symphonistes' dans les premières années du règne de Louis XIV', *Revue belge de musicologie–Belgisch tijdschrift voor muziekwetenschap* VIII/1 (1954), pp.46–57, at p.56; Bernard Bardet, *Les violons de la musique de la chambre du Roi sous Louis XIV* (Paris: Société française de musicologie, 2016), pp.20–21 and 400–408.

[10] Anne Houssay, 'Cordes filées et violons en Italie au XVIIe siècle: quelques cas d'instruments crémonais recoupés', in Duron and Gétreau (2015), pp.139–62, at pp.155–61. This instrument is preserved at the Musée de la Musique in Paris (inv. no. E. 1732).

[11] Alberto Giordano and Rudolf Hopfner, '1677 'Romanov' Nicolò Amati Viola. A Massive Achievement', *The Strad* 130/1556 (December 2019), pp.26–33.

[12] Marie Radepont, Jean-Philippe Échard, Matthias Ockermüller, Hortense de la Codre and Oulfa Belhadj, 'Revealing Lost 16th-century Royal Emblems on Two Andrea Amati's Violins Using XRF scanning', *Heritage Science* 8/112 (2020); available online at <doi.org/10.1186/s40494-020-00460-6>. On the authenticity problems of these instruments, see Jean-Philippe Échard, 'Les violons de Crémone à la cour des derniers Valois', in Luisa Capodieci and Oriane Beaufils (eds.), *La cour en fête* (Tours: Presses Universitaires François Rabelais, 2022), pp.221–35.

of the tenor was previously estimated at 2cm,[13] the heraldic study shows that the width of the instrument was actually reduced by approximately 4.59cm.

To date, no technique seems available for the large-scale analysis of reduced-size bowed instruments. This observation is the starting point for the present research. The Baroque repertoire is based on variable but poorly documented string ensembles. Historically informed performance has been restoring past playing styles for decades, while musicians have long since adopted instrumental models that are close to seventeenth- and eighteenth-century standards. However, it would be naive to think that the search for the sounds of early music has now achieved its goal. The morphology and dimensions of the violin family in the Baroque period remain little known and consequently, so is the timbre of the instruments and the sound balance between the different members.

The following pages present a tool that can facilitate the identification and evaluation of reduced bowed instruments. It is the result of a collaboration between the UCLouvain (Louvain-la-Neuve, Belgium) and the Brussels Musical Instruments Museum. The method has been tested on two violas from the Low Countries, but it is applicable to instruments of various origins.[14]

HISTORICAL FRAMEWORK

Without going into the details of a history of violin making that would go beyond the scope of this article, let us recall a few milestones useful to our analysis. From the sixteenth century onwards, the violin family was available in a range of instruments of different sizes.[15] The seventeenth century bears witness – through preserved instruments, treatises and scores – to a great diversity of sizes and an organological nomenclature that varies according to the author and the place. It is often impossible to determine with certainty the name that a musician or violin maker of the time would have given to an instrument that is preserved today as a 'violin', 'viola' or 'cello'. Conversely, it is equally difficult to know to which morphological type nouns such as *viola*, *violetta*, *tenore viola*, etc. refer. These names, which are found in many Baroque scores, may have been used for instruments of different sizes. Beyond the names, only the tessituras provide approximate indications of the required instrumental type.[16]

In the twentieth century, this diversity was virtually never considered in musicological research. Even today, scholars are inclined to reduce the multiplicity of early instruments to the categories familiar since the second half of the eighteenth century: violin, viola and cello. Yet, if we look at the problem in chronological terms rather than backwards, i.e. from today's point of view, the most intriguing phenomenon is perhaps not the diversity of the Baroque bowed instrumentarium, but rather the standardisation that occurred after 1750.

Several reasons can actually explain this development. Before the introduction and generalization of overspun strings, the low range of bowed instruments suffered from recurrent difficulties: the short vibrating length necessitated thick strings which inevitably presented problems of inharmonicity, so much so, for example, that composers required the lower string of the violin with obvious sparingness.[17] It is likely that the diversity of models observed in the Baroque period is the result, among other things, of constant compromises between, on the one hand, instruments that favour virtuosity in the high range to the detriment of the low range, and on the other hand, instruments designed to sound well in the low

[13] Houssay (2015), p.158.

[14] In the next stage of this project, the method described below will be applied to some 40 instruments from the Brussels Musical Instruments Museum, with the aim of detecting which ones have been reduced in size and determining their original dimensions.

[15] See, for example, Philibert Jambe de Fer, *Épitome musical* (Lyon: Michel Du Bois, 1556), p.61; Lodovico Zacconi, *Prattica di musica* (Venice: Girolamo Polo, 1592), fol. 218r–v.

[16] On the diversity of bowed ensembles in the Baroque period, see Holman (2005), pp.241–57; John Spitzer and Neal Zaslaw, *The Birth of the Orchestra: History of an Institution 1650–1815* (Oxford: Oxford University Press, 2005), pp.37–69, and several contributions in Duron and Gétreau (2015). On terminological muddles, see Stephen Bonta, 'Terminology for the Bass Violin in Seventeenth-Century Italy', *Journal of the American Musical Instrument Society* 4 (1978), pp.5–43; Marc Vanscheeuwijck, 'Violoncello and Other Bass Violins in Baroque Italy', in Dinko Fabris (ed.), *Gli esordi del violoncello a Napoli e in Europa* (Barletta: Casagna, 2020), pp.25–100.

[17] For Monteverdi, see David Boyden, 'Monteverdi's *violini piccoli alla francese and viole da brazzo*', *Annales musicologiques* 6 (1958–1963), pp.387–404, at pp.392–93. This also applies to the *Fasciculus dulcedinis* by Philippus Van Wichel (1678) discussed at the end of this article.

range, without however allowing great agility of the left hand. The increasing use of overspun strings in the eighteenth century would then constitute one of the standardisation factors.[18]

Other reasons explaining the standardisation of the violin family include the gradual stabilisation of performing pitch, the rise of orchestras and conservatories, and, in parallel, the adoption by composers of the Italian-style quartet, which by then involved only three clearly distinct instruments: the violin, the viola and the cello.[19]

This standardisation was accompanied by well-known morphological changes. The development of concert halls led to an increasing preference for the models of Antonio Stradivari (1644/9–1737) over those of the Amati family and Jacob Stainer (1619–1683). The latter, with their pronounced arching, are characterised by a softer tone that was difficult to reconcile with the changing musical life of the nineteenth century.[20]

An important modification concerns the neck, which had to meet the demands of ever-increasing virtuosity and the growing volume requirements of ever-larger concert halls. While Baroque necks were fitted more or less straight onto the soundbox, from the second half of the eighteenth century onwards they were tilted backwards. This change influenced the ergonomics of the instrument as well as its tone colour. It is coupled with a reduction in the angle of the strings on the bridge, which had to be raised. The neck was also slimmed down, while the fingerboard was lengthened, to enhance shifting.[21]

Under the influence of this new design, at the end of the eighteenth and in the nineteenth century, many early instruments were fitted with a new neck.[22] Usually, musicians and violin makers considered that replacing the neck did not alter the instrument in any way. For example, Francesco Galeazzi (1758–1819) wrote: 'The neck is a piece that is indifferent to the sound of the instrument, so the neck of a good violin can always be changed, if necessary, without risk of damage'.[23]

Galeazzi's argument is based on the fact that the neck is not involved in the sound generation or amplification within the resonance box. It is nonetheless misleading, since replacing the neck involves opening the soundbox to increase the size of the bass bar, an operation that obviously changes the sound.[24] In addition, when the body was opened, the soundboard was often (tacitly) made thinner to give more brilliance to the instrument, to make its sound louder and more penetrating, which could only move it further away from the Baroque sound ideal.[25]

The replacement of the neck and the thinning of the soundboard, however, were not the only changes

[18] Mimmo Peruffo, 'Italian Violin Strings in the Eighteenth and Nineteenth Centuries: Typologies, Manufacturing Techniques and Principles of Stringing', *Recercare* 9 (1997), pp.155–203, at p.159; Vanscheeuwijck (2020), p.64.

[19] On the history of pitch, see Bruce Haynes, *A History of Performing Pitch: the Story of "A"* (Lanham: The Scarecrow Press, 2002), especially pp.301–341. On the development of the orchestra, see Spitzer and Zaslaw (2005), especially pp.306–42.

[20] David D. Boyden, *The History of Violin Playing from its Origins to 1761 and its Relationship to the Violin and Violin Music* (London: Oxford University Press, 1965), pp.197, 447.

[21] Boyden (1965), p.197; Robin Stowell, *Violin Technique and Performance Practice in the Late Eighteenth and Early Nineteenth Centuries* (Cambridge: Cambridge University Press, 1990), pp.23–27; David D. Boyden, Peter Walls, Peter Holman, Karel Moens, Robin Stowell, Anthony Barnett, Matt Glaser, Alyn Shipton, Peter Cooke, Alastair Dick, and Chris Goertzen, 'Violin', *Grove Music Online*, 20 January 2001, last accessed on 3 May 2022; Stewart Pollens, 'Some Misconceptions about the Baroque Violin', *Performance Practice Review*, 14/1 (2009), available at the website <doi: 10.5642/perfpr.200914.01.06>.

[22] For a historical account, see Ignazio Alessandro Cozio di Salabue, *Carteggio*, trascrizione di Renzo Bacchetta (Milano: A. Cordani, 1950), pp.42 and 104–105 ('Darlo indietro alla moderna').

[23] 'Il Manico poi è un pezzo indifferente alla voce dell'instromento, onde ad un buon Violino si potrà sempre mutare il Manico, se ve n'è bisogno, senza pericolo di danneggiarlo'. Francesco Galeazzi, *Elementi teorico-pratici di musica*, 2nd edition (Ascoli: Franceso Cardi, 1817), p.61.

[24] On this subject, see Sébastien-André Sibire, *La Chélonomie, ou, Le parfait luthier* (Brussels: Weissenbruch, 1823), pp.128–29; J[ean] C[arl] Maugin, *Manuel du luthier* (Paris: Roret, 1834), pp.133–34 (note p.133 is wrongly paginated as p.135).

[25] For an overview of the most common modifications made to bowed instruments in the nineteenth century, see Florence Gétreau, 'Y a-t-il un état original de l'instrument ?', in Anne Penesco (ed.), *Du baroque à l'époque contemporaine: aspects des instruments à archet* (Paris: Champion, 1993), pp.27–41; Stewart Pollens, *Stradivari* (Cambridge: Cambridge University Press, 2011), pp.119–20 and 128–31.

made to early bowed instruments. Some of them were reduced in size. The archives of Count Ignazio Alessandro Cozio di Salabue (1755–1840), a collector of early violins, provide fairly detailed evidence of modifications made to violins from the seventeenth and first half of the eighteenth centuries.[26] Cozio describes the reduction of an instrument by Andrea Amati as follows:

> […] una viola che in sua origine era assai grande ed a cinque corde stata [crossed out word] ristretta dal fu [blank space, probably intended for an uncompleted first name] Mantegazza, e da esso fattavi il manico ed abbassata di fascie e ripostovi la catena e dallo stesso venduta al [crossed out words] fu sig. Don Paolo Campi di Milano. Il manico vecchio piu tosto voluminoso ma ben proporzionato lo ritiene ancora [crossed out words] il Mantegazza [crossed out words] figlio del sud*det*to.[27]

> […] a viola which was originally very large and with five strings, reduced by the late […] Mantegazza, and of which he remade the neck and lowered the ribs and replaced the bass bar, and sold by him to the late Don Paolo Campi of Milan. The former neck, which was quite large but well proportioned, can still be found at Mantegazza, the son of the previous.[28]

In the following pages, reduction methods will first be described according to the historical literature. Thereafter, procedures for the evaluation of resized instruments will be proposed.

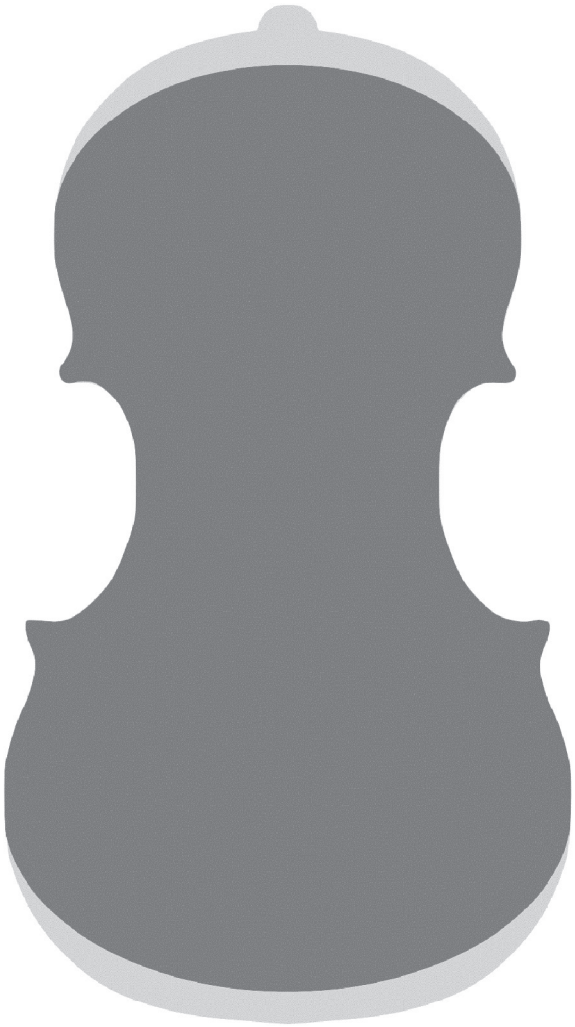

Figure 3. *Scheme for reducing the body length.*

WRITTEN EVIDENCE

In the second half of the eighteenth century, apart from their thick and short necks, two morphological characteristics of the Baroque violin family were recognized as detrimental to virtuosity: on the one hand, the excessive vibrating length of the strings, which required awkward distances between the fingers of the left hand, and on the other hand, the cumbersome dimensions of the upper bout, which hindered shifting.

Early written sources mention methods for reducing the length and width of the instrument

[26] On Ignazio Alessandro Cozio di Salabue, see Pollens (2011), pp.53–59 and passim. On the Cozio manuscripts as a whole, see *Documenti manoscritti del Fondo Ignazio Alessandro Cozio di Salabue, collezionista di strumenti ad arco*, <http://www.internetculturale.it/it/41/collezioni-digitali/29433/documenti-manoscritti-del-fondo-ignazio-alessandro-cozio-di-salabue-collezionista-di-strumenti-ad-arco>. The manuscripts are available online (<https://www.bibliocremona.it/patrimonio/biblioteca-digitale/risorse-elettroniche/fondo-cozio/>) and are transcribed in Cozio di Salabue (1950). Because of a number of inaccuracies in these transcriptions, mainly due to the messy handwriting, our transcriptions follow the readings of the original manuscripts. Only the punctuation and accentuation have been modernised.

[27] Cremona, Biblioteca Statale, Civico. Cozio, Cozio 1, 1816, fol. 21[ter]v. See also Cozio di Salabue (1950), p.22. According to Gianpaolo Gregori, *Archivio della Liuteria Cremonese* (<http://www.archiviodellaliuteriacremonese.it/strumenti/viola-tenore-ridotta_1.aspx?f=457893>), this instrument might correspond to the Amati tenor violin preserved at the Musée de la Musique in Paris (inv. no. E. 1732).

[28] A free translation is offered by Brandon Frazier, *Memoirs of a Violin Collector, Count Cozio di Salabue* (Gateway Press: Baltimore, 2007), p.12, which, however, deviates from the original in several instances.

body, which offer solutions to both problems. These methods can be combined, but they are rarely described together. Moreover, they are sometimes coupled with other modifications aimed at adjusting the shape of the C-bouts, which are hardly mentioned in lutherie treatises, but which can be found on some instruments.[29] The viola attributed to Matthijs Hofmans analysed below will illustrate these different possibilities.

REDUCTION OF BODY LENGTH

A first way to reduce the size of a soundbox is to cut a crescent of wood from its upper and sometimes lower bout, as shown in Figure 3.

The earliest description of this process can probably be found in a manuscript by Ignazio Cozio di Salabue, dated 1804–1807.

> Spicolire un istromento, retroissus.[30]
> Ella è cosa difficilissima a ciò far bene.
>
> Reducing an instrument, *retroissus*.
> It is a very difficult thing to do well.
>
> 1º Primo si osservi dare alla forma giusta voluta osservando però, se li CC sono longhi siccome questi non [crossed out word] si possono racorcire, bisogna racorcire meno l'inst*rument*o acciò non sia cotanto sproporzionato nella parte di mezze e così fra li due CC.
>
> 1. The intended right shape should be observed. However, consider that if the C-bouts are long, as they cannot be shortened, the instrument should be less reduced so that it is not too disproportionate in its central part and thus between the two C-bouts.
>
> 2º Bisogna anche fare osserva*zion*e alla long*hezz*a e posizione delle ff, per tagliarle di più nella parte inferiore se le ff fossero più elevate ed al contrario se più abbassate. Bisogna anche osservare alla curva, laquale portandosi troppo elevata ai bordi, non bisogna cotanto racorcirlo e restringerlo, però ordinariamente li instromenti che cadano a spiciolirsi sono li violoncelli e viole antiche eziandio de primarj autori Cremonesi o della loro scuola; e tali instromenti sono sproporzional*mente* più longhi dal centro delle ff in sù, e così conviene solo tagliarli nella parte superiore, la quale long*hezz*a se ivi apporta è disperz*ion*e di voce e magior incomodo nel suonarli, che al contrario sarà meglio lasciarli più longhi e larghi nella parte inferiore sia perché essa larg*hezz*a ivi dà voce più grave ed in magior quantità, e non è incomoda al suonatore.
>
> 2. The length and position of the f-holes should also be observed, so that more (wood) is removed from the lower part if the holes are placed high, and vice versa if they are placed low. The arching should also be observed. If it is too high at the edges, it should not be shortened or cut back too much. However, the instruments that usually lend themselves to reduction are the old cellos and violas, even those of the first Cremonese luthiers or their school. These instruments are disproportionately long from the centre of the f-holes to the top. It is therefore appropriate to reduce them only in the upper part, as this length leads to a dispersion of their sound and a great discomfort in playing. On the other hand, it will be better to leave them longer and wider in the lower part, because this width gives a lower and more sonorous tone, and does not hinder the musician.
>
> 3º Si taglia ora addiritura alle parti superiore ed inferiore senza tener conto delli bordi, siccome ora si fanno con migliore sucesso nuovi in solo quatro pezzi che si fanno passare a mezzo legno per la larg*hezz*a se de violini più di mezza oncia e se di altri strom*en*ti a proporzione; avvertendo che si rifarano [crossed out word] i bordi i*n* egual spezzore di prima.
>
> 3. Nowadays, the upper and lower parts are cut down without taking the edges into account, since only four new pieces are made today with greater success, with a halved joint, either, for violins, to a width of more than half an *oncia*, or, for other instruments, in a proportional manner, taking into account the fact that the edges will be remade to the same thickness as originally.

[29] The Amati tenor violin preserved at the Musée de la musique (inv. no. E. 1732) is a good example of a complex reduction. See Matthias Ockermüller, 'Documentation of the Parts Making up the Soundboard of E.1732', unpublished internal study, Paris, Musée de la Musique, December 2016.

[30] This word is hardly legible. The manuscript source resembles a dictionary of violin making, whose lemmas or subheadings are regularly accompanied by synonyms, sometimes in a foreign language. Did the author fashion the Latin word *retroissus* from the prefix *retro-* and a fanciful substantification of the verb *ire*?

> 4º La profilatura si fà dopo q*ues*ta asciugata l'incollatura che si fa tenere con molte viti.[31]
>
> 4. The purfling is done when the gluing is dry, which is secured by numerous clamps.[32]

Cozio was not himself a violin maker, but he was in regular contact with the Mantegazza family in Milan. His statements are therefore second-hand testimony, the reliability of which is not guaranteed.[33] However, despite some ambiguities, it is likely that his notes reflect common practices in early nineteenth-century Italy.

According to Cozio, the reduction of the soundbox applied mainly to cellos and violas, which means that it was rarely practised on violins. This is understandable: unless the instrument is unusually large, reducing the size of a violin could only result in an undersized object. On the other hand, the Baroque period was characterised by the multiplicity of medium and large bass instruments, which became unusable when the Italian-style quartet took over. Furthermore, Cozio points out the excessive size of the upper bout of Cremonese instruments, and therefore recommends that mainly this part should be reduced.[34]

Cozio's citation describes an apparently new reduction method, in which the original edges[35] are not retained. This process involves re-cutting them to exactly the right size. The new purfling must be inserted after the soundbox has been closed. This suggests that prior to the writing of the manuscript, resizing involved the preservation of the original edges and purfling, a technique that was still recommended a century later by Auguste Tolbecque (1830–1919). This luthier nevertheless attributes it to Parisian violin makers, including his own master, Victor Rambaux (1806–1871). He explains the technique as follows.

> A l'aide d'une fine scie de marqueteur, on commencera par détacher le bord avec son filet en allant du tasseau vers le coin et en ayant soin que ce bord reste attenant à la table à la partie où viendra se terminer en pointe le tracé de ce qui devra être enlevé à celle-ci. Après quoi on fera l'ablation de la portion de table qui doit disparaitre […].[36]
>
> With a fine marquetry saw, start by removing the edge with its purfling from the block to the corner, taking care that this edge remains attached to the soundboard at the point where the area of what is to be removed from it ends in a tip. Then the portion of the soundboard that is to be removed is excised.[37]
>
> Le bord qui a été conservé sera collé sur la table et maintenu avec un galon de fil faisant un certain nombre de fois le tour de la table, d'un bord à l'autre […]. Il faudra avoir soin de bien coller d'affleurement et de ne mettre que ce qu'il faut de colle en raison de l'impossibilité de laver les bavures qui se produiraient sans cela sous le passage du galon.
>
> Quand le recoupage d'un côté de la table sera terminé, on fera la même opération pour l'autre côté. Après que les bords auront été replacés, il faudra les soutenir en enlevant la moitié de leur épaisseur en dedans et en y appliquant des demi-bords qu'on collera sur toute la partie refaite du contour de la table, ce qui maintiendra solidement cet important travail.[38]
>
> The edge that has been retained will be glued to the soundboard and secured with a braid of yarn running a number of times around the soundboard, from edge to edge.[39] Care should be taken to glue flush and to apply only as much glue as is necessary because of the impossibility of washing out the smudges that would otherwise occur under the braid.

[31] Cremona, Biblioteca Statale, Civico. Cozio, Cozio 9: *Memorie per la costruzione e riadatamento degli strumenti da corda racolte da me diletante Ignazio Alessandro Cozio Salabue*, Milano, 1804–1807, fol. 46r. See also Cozio di Salabue (1950), pp.114–15.

[32] See also Ignazio Alessandro Cozio di Salabue, *Observations on the construction of stringed instruments and their adjustment 1804, 1805, 1809, 1810, 1816*, transl. by Andrew Dipper and David Woodrow (Taynton: Taynton Press, 1987), pp.59–60; Frazier (2007), p.77.

[33] Cozio di Salabue (1987), reviewed by Michael Fleming, *The Galpin Society Journal* 47 (1994), pp.194–97, at p.194.

[34] Nicolò Amati's viola analysed by Giordano and Hopfner (2019) is reduced in this way.

[35] We are defining the edge as the strip of wood outside the purfling of the soundboard and back.

[36] Auguste Tolbecque, *L'art du luthier* (Niort: L'auteur, 1903), p.244.

[37] Tolbecque illustrates this process with the help of a picture, the poor quality of which, however, does not allow for reproduction. See Tolbecque (1903), p.245, Figure 93 and <https://gallica.bnf.fr/ark:/12148/bpt6k3411724z/f273.item>.

[38] Tolbecque (1903), p.245.

[39] This is also illustrated with a picture. See Tolbecque (1903), p.245, Figure 94 and < https://gallica.bnf.fr/ark:/12148/bpt6k3411724z/f273.item>.

> When the reduction of one side of the soundboard is completed, the same operation is done on the other side. Once the edges have been replaced, they must be supported by removing half their thickness on the inside and applying half-rims which are glued to the whole of the reworked part of the soundboard's contour, thus holding this important work firmly in place.

Tolbecque adds that a heavy reduction can cause the channel that surrounds the arching to disappear, which must then be artificially reconstructed. To do this, he advises one to slightly hollow out the reverse side of the soundboard at the desired place, before gluing the doubling, i.e. a thin layer of wood to reinforce the reduced part. The new channel is shaped during the clamping process, by the pressure between the soundboard and the counterparts.[40] As we will see below, however, the channel is not always reconstructed.

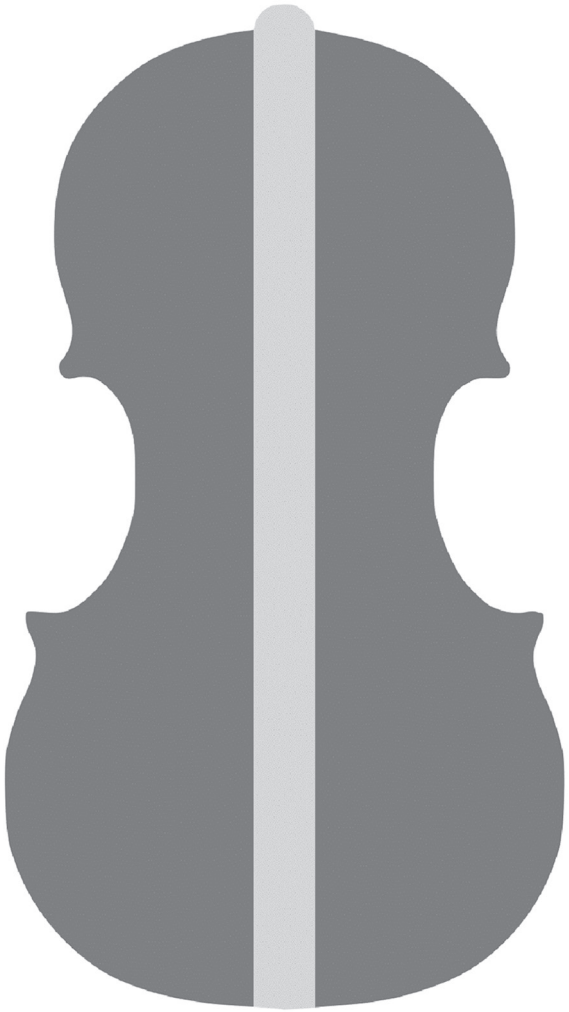

Figure 4. *Scheme for reducing the body width.*

REDUCTION OF THE BODY WIDTH

The process of reducing the width of the body is hardly explained in detail in eighteenth- and nineteenth-century sources. Cozio does not describe it, but in 1840 it is mentioned by Bernhard Romberg (1767–1841). It consists of removing a strip of wood along the central joint of the back and soundboard.[41] According to Romberg, this strip should be tapered, i.e. wider at the top than at the bottom of the body, because the width excess in the upper bout is usually greater than in the lower bout. In practice, width reductions seem more often to have been achieved by removing a strip of wood that is equally wide at the top and bottom of the body, as shown in Figure 4. Tolbecque, who briefly discusses width reduction, does not mention the tapered shape of the strip to be removed.[42] If the reduction is carried out as recommended by Romberg, the direction of the grain of the two parts of the spruce soundboard will no longer be parallel, but will form an easily identifiable angle (Figure 5).

HISTORICAL REFERENCES TO REDUCED VIOLINS

It is generally accepted that the reduction of early violin-type instruments to fit new standards of musical performance developed in the second half of the eighteenth century. Following Auguste Tolbecque, several authors cite the evidence of an inventory drawn up by Antonio Bartolomeo Bruni (1757–1821), which mentions a viola that was reduced by the Parisian luthier François Chatelain in 1782.[43]

Reductions are, however, documented from the middle of the eighteenth century onwards. In 1750, an advertisement published in the *Affiches de Lyon* offered 'An excellent *taille* violin, from Cremona, of which one would make a very good violin by cutting

[40] Tolbecque (1903), p.246.

[41] Bernhard Romberg, *Méthode de violoncelle, adoptée par le directeur du Conservatoire royal de Paris, à l'usage des classes de cet établissement* (Paris: H. Lemoine, [1840]), p.6; German version: *Violoncell Schule* (Berlin: Trautwein, [1840]), pp.4–5. The English translation, which dates from 1880, does not include the section on reduction.

[42] Tolbecque (1903), p.246.

[43] Antonio Bartolomeo Bruni, *Un inventaire sous la Terreur: état des instruments de musique relevé chez les émigrés et condamnés* (1757–1821) (Paris: Georges Chamerot, 1890), p.105.

Figure 5. *Appearance of the central joint of spruce in the case of a tapered reduction of the soundboard.*

it down, for sale'.[44] As seen above, the *taille* is one of the middle instruments of the French ensemble described by Mersenne and Sauveur. However, its dimensions are uncertain. The wording of the advertisement suggests that the instrument is small enough to be transformed into a violin. If this was not the case, it should have been reduced to a viola.[45] Nevertheless, this observation does not allow any generalisation: there is no proof that an instrument called a *taille* in 1750 is comparable to a *taille* of the time of Louis XIII or Louis XIV, and not even that the name *taille* refers to a standardised instrumental size at a given time.

The idea that violin-type instruments were reduced as early as the mid-eighteenth century is confirmed by a statement of Antonio Bagatella (1716–1806),[46] who in 1786 claimed to have reduced large quantities of instruments over the last 35 years in order to adapt them to the proportions of the violins of the brothers Antonio (*c*1540–1607) and Girolamo Amati (*c*1561–1630), which he considered ideal.[47]

Outside Italy, an example of early reduction concerns a viola from the Low Countries, whose label announces that it was 'Recoupé par hyacinthe / Lorret a gand 1761' (cut down by Hyacinthe Lorret in Ghent, 1761).[48] This instrument is in a private collection, but photographs published by Karel Moens show a particularly intrusive reduction, the channel having completely disappeared.

THE ANALYSIS OF REDUCED INSTRUMENTS

The first part of this article shows that the reduction of bowed instruments was a quite common practice as early as the eighteenth century, and that it continued into the twentieth century, since Tolbecque still found necessary to explain it in his treatise.[49] To understand the morphology of the violin family in the Baroque period, it is important to take these alterations into account.

Visual inspection can detect some reductions, in particular those in the height of the body, but misjudgements are always possible. In order to overcome the subjectivity of such an approach, we have developed a method that allows us to report on the reductions objectively and thus to validate or reject the visual analysis. A viola preserved in the Brussels Musical Instruments Museum, which has obviously undergone a major reduction, was used as a testing case. This instrument is attributed to the Antwerp violin maker Matthijs Hofmans (1622–

[44] 'Une Taille de Violon excellente, de Crémone, dont on ferait un fort bon violon en la recoupant, à vendre'. *Affiches de Lyon*, 16, 21 April 1750, p.127, also quoted by Bénédicte Hertz, 'Contribution à l'étude de l'effectif orchestral en province au XVIII[e] siècle: les parties intermédiaires dans le fonds musical lyonnais', in Duron and Gétreau (2015), pp.401–13, at p.404.

[45] In mid-eighteenth century France, the viola was commonly called *alto-viola* or *quinte*. The latter name no longer referred to the instrument of the quintet described by Mersenne, which disappeared around 1720. See Jérôme de la Gorce, 'L'évolution de l'orchestre à cinq parties et la suppression de la quinte de violon', in Duron and Gétreau (2015), pp.41–48, at p.47; Fabian Balthazart, 'La disparition de la partie de quinte de violon du motet à grand chœur à la chapelle royale de Versailles', *ibid*., pp.309–23; Françoise Escande, 'L'orchestre à cordes de l'Opéra après 1715', *ibid*., pp.325–43, at p.339.

[46] The dates of Bagatella's birth and death are given after Sauro Malagoli and Lorenzo Frignani, in Antonio Bagatella, *Regole per la costruzione de' violini, viole, violoncelli e violoni, II Edizione, Manoscritto del 1782 e 1[a] edizione del 1786 con tavole*, ed. by Sauro Malagoli, foreword by Sauro Malagoli and Lorenzo Frignani (Modena: LF Edizioni, 2010), pp.XIII–XVII.

[47] Bagatella (2010), pp.XLVII–XLVIII.

[48] Karel Moens, 'Zur frühen Geschichte der Geige in Brüssel', in Boje E. Hans Schmuhl and Ute Omonsky (eds.), *Musikalische Aufführungspraxis in nationalen Dialogen des 16. Jahrhunderts. II: Musikinstrumentenbau-Zentren im 16. Jahrhundert* (Augsburg: Wißner-Verlag, 2007), pp.153–66, at p.160.

[49] Jan Strick still witnessed reductions at the end of the twentieth century (personal communication, 2 December 2021).

Table 1. Dimensions (mm) of the viola attributed to Matthijs Hofmans and the viola signed by Johannes Cuypers.

	Hofmans MIM inv. no. 2846	Cuypers MIM inv. no. 2833
Full length (without end button)	686	659
Back (length)	417	405
Upper bout (back, max. width)	195	193
Waist (back, min. width)	140	127
Lower bout (back, max. width)	247	231
Vibrating string length (bridge between the f-hole notches)	382	370
Ribs (height)	34	34

1672) and entered the museum in 1908 (see Figure 6a in the colour section).[50] A label indicates that it was repaired by Charles-Claude-François Darche (1821–1874) in 1857, but it is not certain that this violin maker was responsible for its reduction.[51]

By way of comparison, we have selected an instrument dating from 1761, for which visual examination does not reveal the slightest trace of reduction: a viola by Johannes Theodorus Cuypers (1719–1806), a violin maker active in The Hague (see Figure 6b in the colour section).[52]

The main dimensions of these instruments are as shown in Table 1, above.

The reduction of the Hofmans viola can be seen from the symmetrically inserted pieces of wood at the top corners of the soundboard and the back (see Figure 7 in the colour section). Obviously, the C-bouts of this instrument were originally larger and were resized when the instrument was reduced.[53] This also explains the incisions in the middle of the C-bouts, which betray the point from which the edge of the soundboard and the back had to be cut to perform this operation.

Both violas were subjected to a hospital-based computed tomography scanning[54] and *in situ* photogrammetry. The resolution of medical CT scans is lower than that of industrial scanners, but they still reveal a significant amount of information that is invisible to the naked eye.[55] Photogrammetry is based on the correlation of photographs taken

[50] This instrument was part of the former collection of César Snoeck (1834–1898), which was donated to the Musical Instruments Museum by Louis Cavens (1850–1940). It has no label. Its attribution to Matthijs Hofmans is based on the *Catalogue de la collection d'instruments de musique flamands et néerlandais formée par C.C. Snoeck* (Gand: Imprimerie I. Vanderpoorten, 1903), p.17. It is possible that the instrument had a label in the nineteenth century, which was lost before it entered the museum. Jan Strick, however, considers it likely that it was made by the Brussels violin maker Gaspar Borbon (*c*1635–1710).

[51] The date 1914 has been added on the label by another, unidentified hand.

[52] This instrument has a label that indicates 'JOHANNES CUYPERS, / FECIT 'S HAGE Aº 1761'. Like the Hofmans viola, the Cuypers viola comes from the former César Snoeck collection.

[53] Karel Moens (2015), p.129 estimates the original length of the body to be 46cm. We have seen above that according to Cozio, the C-bouts could not be reduced. This technique may have developed after him.

[54] On the use of this technique for musical instruments, see Terry Borman and Berend Stoel, 'Review of the Uses of Computed Tomography for Analyzing Instruments of the Violin Family with a Focus on the Future', *Journal of the Violin Society of America. VSA Papers*, XXII/1 (Summer 2009), pp.239–50; and Frank P. Bär, Theobald Fuchs, Sebastian Kirsch et al, 'Three-Dimensional Computed Tomography Scanning of Musical Instruments', in Marco A. Pérez and Emanuele Marconi (eds.), *Wooden Musical Instruments. Different Forms of Knowledge. Book of End of WoodMusICK COST Action FP1302* (Paris: Cité de la musique – Philharmonie de Paris, 2018), pp.171–87. The instruments were scanned on 29 July 2017 at the Cliniques Universitaires Saint-Luc (Brussels). The equipment used was a Philips IQon Spectral CT scanner. The slice thickness is 0.67mm for the Hofmans viola with an overlap of 50% of the slices, and 0.9 mm for the Cuypers viola, also with an overlap of 50%.

[55] Andrea Zanrè and Rudolf Hopfner, 'New Light on an Uncut Diamond', *The Strad* 125/1494 (October 2014), pp.36–43, at p.39, point out that the margin of error for hospital CT scans is at best a few tenths of a millimetre, and therefore generally higher. Our own measurements on both the instruments and the CT scans did not show inaccuracies significantly larger than the resolution of the CT scans themselves. As Borman and Stoel have shown (2009, p.245), caliper measurements on instruments are also subject to frequent handling errors by the observer. For the present project, the data obtained are sufficiently accurate to allow reliable results.

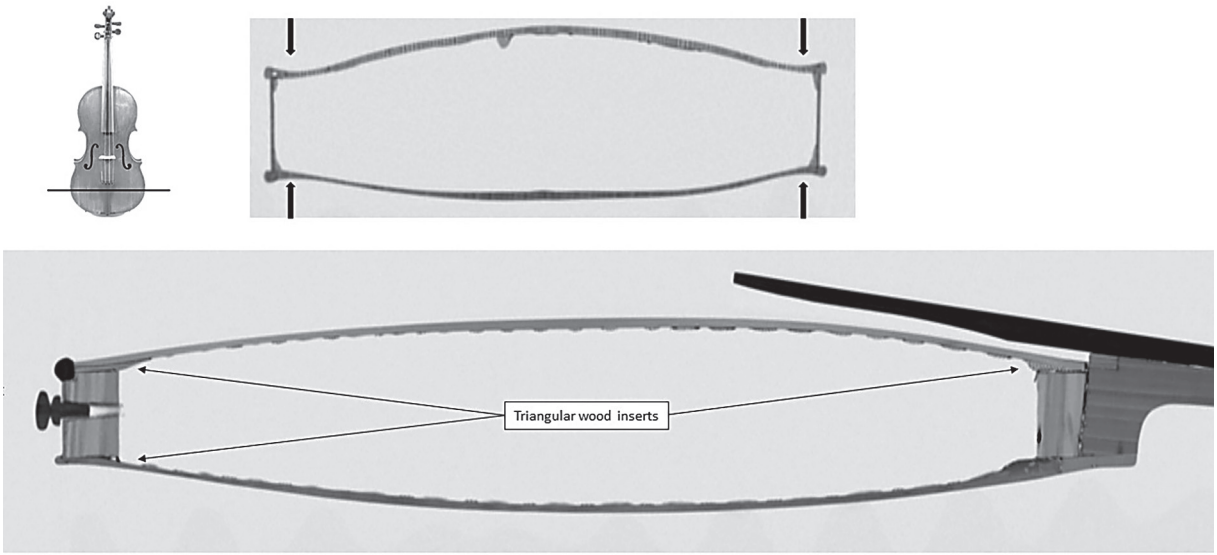

Figure 8. *Transverse and sagittal view of the viola attributed to Hofmans.*

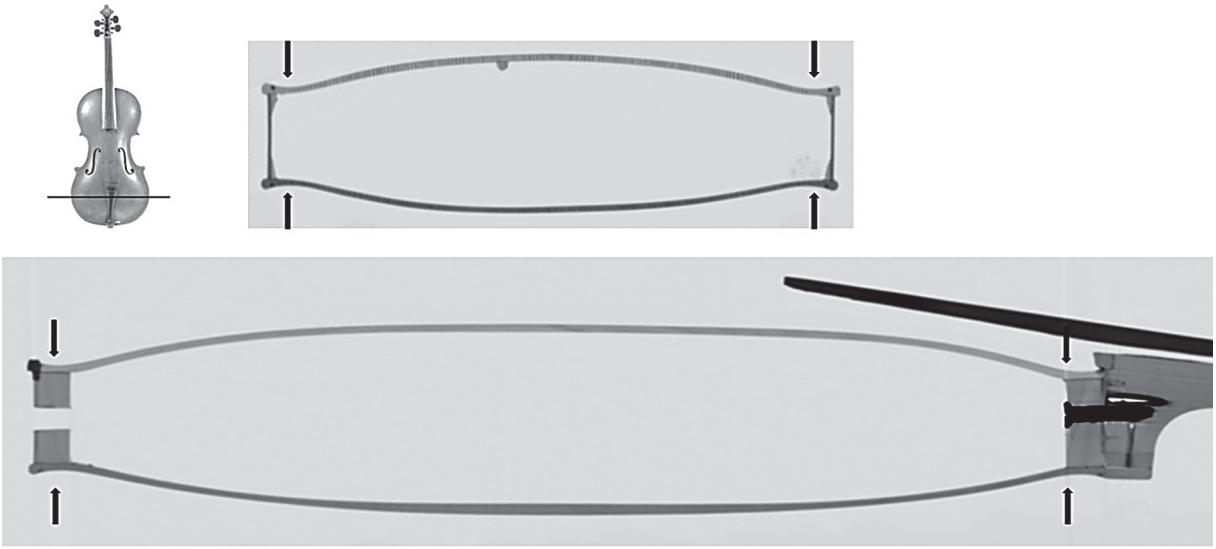

Figure 9. *Transverse and sagittal view of the viola by Cuypers.*

from different viewpoints and the automatic identification of homologous points from one photograph to the next. It allows the 3D modelling of objects in the form of meshes that correspond to their outer layer. One of its advantages is that it can be carried out with more limited human and technical resources than computed tomography scanning.[56]

The main challenge of photogrammetry is that the instruments are varnished and reflect light, which results in overexposure of the highlights that affects the accuracy of the 3D model. In order to minimise this problem, the violins were photographed in a light tent, with indirect lighting kept to a minimum. The instruments were set up on a turntable, with the pictures being taken from approximately the same

[56] Hospital CT scans involve the assistance of radiologists and technologists who, for obvious ethical reasons, work on a voluntary basis, outside the opening hours of their departments. For heritage objects preserved in museums, transport and insurance are challenges that are all the more critical when the instruments are old and fragile. In addition, some instruments have to be excluded because they carry pathogens. For industrial scanners, cost and geographical distance can be a major barrier. These problems are described in detail by Bär, Fuchs, Kirsch et al (2018), pp.173–75.

Figure 10. *Views of the CT scans: soundboard of the viola attributed to Hofmans at a thickness of 2.1cm and back at a thickness of 2.2cm.*

distance, but from different heights. The focal length of the camera used, a Nikon D850 with a 60mm lens, was adjusted slightly for each photo. To prepare the 3D model, *c*160–170 photographs per instrument were processed using Adobe Photoshop[57] to prepare a mask layer that hides all data outside the instrument. The masking and meshing were then carried out in the Agisoft Metashape software.[58] The original meshes are composed of about 1.8M nodes and about twice as many faces. In order to validate our analyses, we compared the mesh obtained by photogrammetry with a mesh generated from the medical DICOM files, with a satisfactory average error between them.[59]

VISUALISING LENGTH REDUCTION

Detection of a reduction in the length of the soundbox is achieved by analysing the channel surrounding the soundboard and back archings. In principle, this channel is carved at a constant distance from the edge. On a reduced instrument, however, the wood crescent taken at the top and possibly at the bottom of the body necessarily alters the channel, which may even disappear.

[57] <https://www.adobe.com/>.

[58] <https://www.agisoft.com/>.

[59] We found an average error for the soundboards equal to 0.29 mm for the Cuypers viola and 0.45 mm for the Hofmans viola. See Philémon Beghin, Anne-Emmanuelle Ceulemans, Paul Fisette, François Glineur, 'Validation of a photogrammetric approach for the study of ancient bowed instruments', preprint, <https://doi.org/10.48550/arXiv.2205.08745> (version 1). Note that this average error may vary according to the method of calculation.

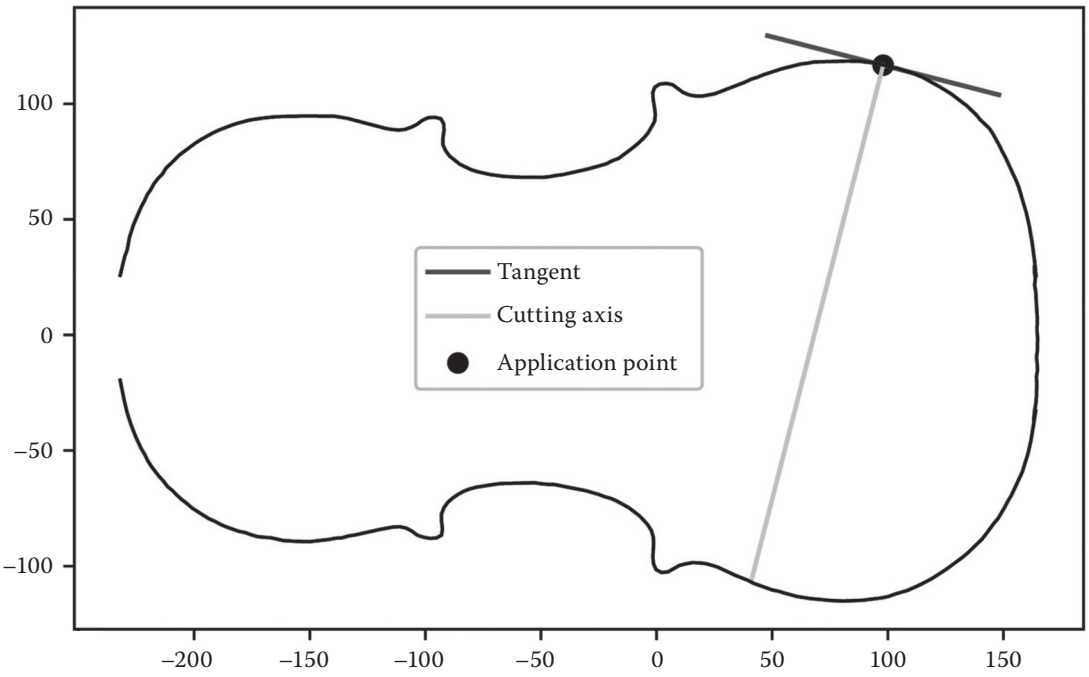

Figure 11. *Planar cuts in the mesh to detect the channel (scale: mm).*

The CT scans of the two reference instruments make it possible to show this phenomenon. The channel, indicated with black arrows, is visible on the transverse views of both instruments, but on the sagittal views it is only visible on the Cuypers viola (Figures 8 and 9).[60] It is absent on the viola attributed to Hofmans, which has been cut down in the upper and lower bouts. On this instrument, the reduction is compensated by the insertion of several triangular pieces of wood: one between the top block and the soundboard, and another between the bottom block and both the soundboard and the back. These pieces of wood were necessary to offer a surface large enough for gluing the ribs.[61]

The CT scans also suggest that the reduction of the Hofmans viola must have been more significant in the upper bout than in the lower bout. Figure 10 shows black streaks on the left and right of the neck, which correspond to large amounts of glue and especially an unidentified whitish paste inside the soundbox. They probably indicate a part of the instrument weakened by the removal of the upper part of the bout.

Thanks to an algorithmic tool developed at the École Polytechnique de Louvain (UCLouvain, Belgium), the channel pattern can be extracted in a purely objective manner, and visualised on the soundboard and on the back. This tool has been applied to the meshes produced by the CT scans[62] and to the photogrammetric meshes,[63] both of which yield similar results. The method consists in performing vertical planar cuts through the three-dimensional mesh, which are normal to the tangent at the application point on the edge (Figure 11).

[60] Figures 9–11 were made with the RadiAnt DICOM Viewer software (<https://www.radiantviewer.com/>). For a better visualisation, they are reproduced in negative.

[61] Since the Hofmans viola is built freeform, the presence of a platform cut into the back of the instrument at the level of the upper block ensures a sufficient gluing surface at this point, even after reduction. See Anne-Emmanuelle Ceulemans, 'The Violins of César Snoeck. Observations on the Origins of an Instrument Family', *Revue belge de musicologie–Belgisch tijdschrift voor muziekwetenschap*, forthcoming.

[62] Renaud Lothaire, 'Characterization of Violins: a Digital Tool at the Service of Organology', Master's thesis, Université catholique de Louvain, École polytechnique de Louvain, 2019, directed by Paul Fisette, François Glineur and Anne-Emmanuelle Ceulemans, pp.45–52.

[63] Philémon Beghin, 'A Digital Tool at the Service of Organology: Validation of a Photogrammetric Approach', Master's thesis, Université catholique de Louvain, École polytechnique de Louvain, 2021, directed by Anne-Emmanuelle Ceulemans, Paul Fisette, and François Glineur, pp.45–49.

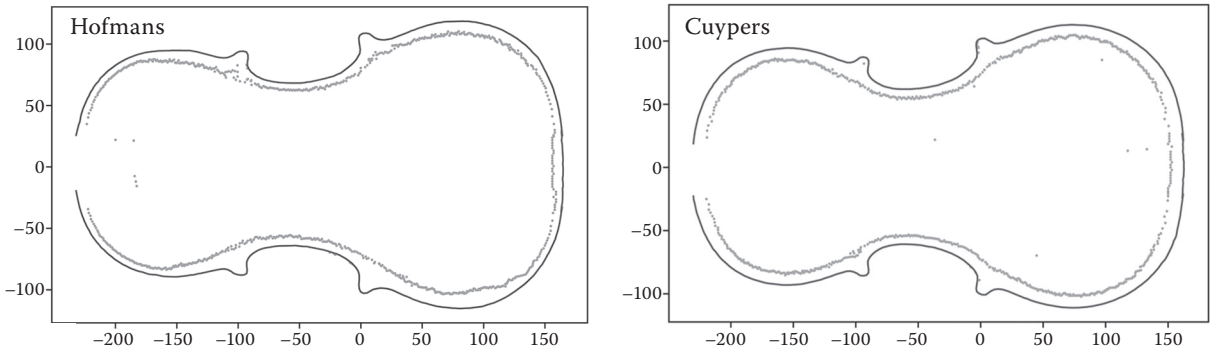

Figure 12. *Channel patterns of the soundboards: raw results based on the photogrammetric meshes (scales: mm).*

The lowest point near this edge corresponds to the bottom of the channel.

Figure 12 shows the raw data from this analysis based on the photogrammetric mesh of the soundboard of both the Hofmans (attr.) and the Cuypers viola. Note the apparent recess in the channel at the bottom of the Hofmans viola soundboard. This pattern is due to the lower nut, not to the actual channel which, as shown in Figure 8, has disappeared at this point.[64]

Figure 13 shows a version with the measurement data smoothed by means of splines.[65] It highlights the regularity of the channel on the viola by Cuypers, whereas on the instrument attributed to Hofmans, the channel nearly merges with the edge in some places at the top and bottom of the body. The advantage of this approach is to objectify the findings that a visual examination of the archings allows the observer to apprehend in a subjective way.

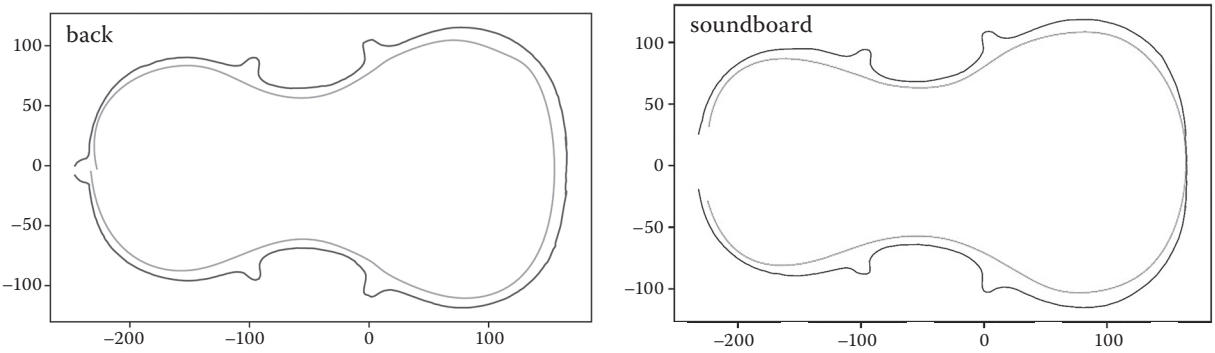

Figure 13a. *Hofmans (attr.), channel patterns: smoothed results by means of splines (scales: mm).*

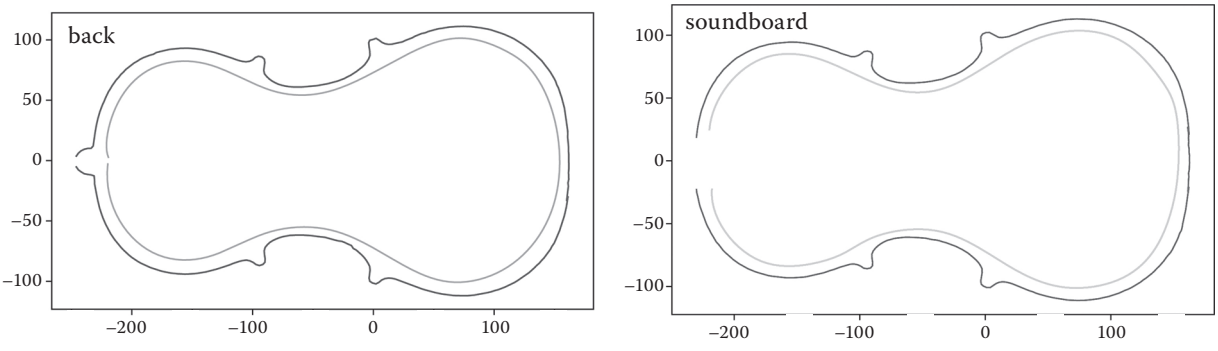

Figure 13b. *Cuypers, channel patterns: smoothed results by means of splines (scales: mm).*

[64] Figure 13 offers a more realistic view of the channel's path in this respect.

[65] A spline is a smooth curve defined by piecewise cubic polynomials.

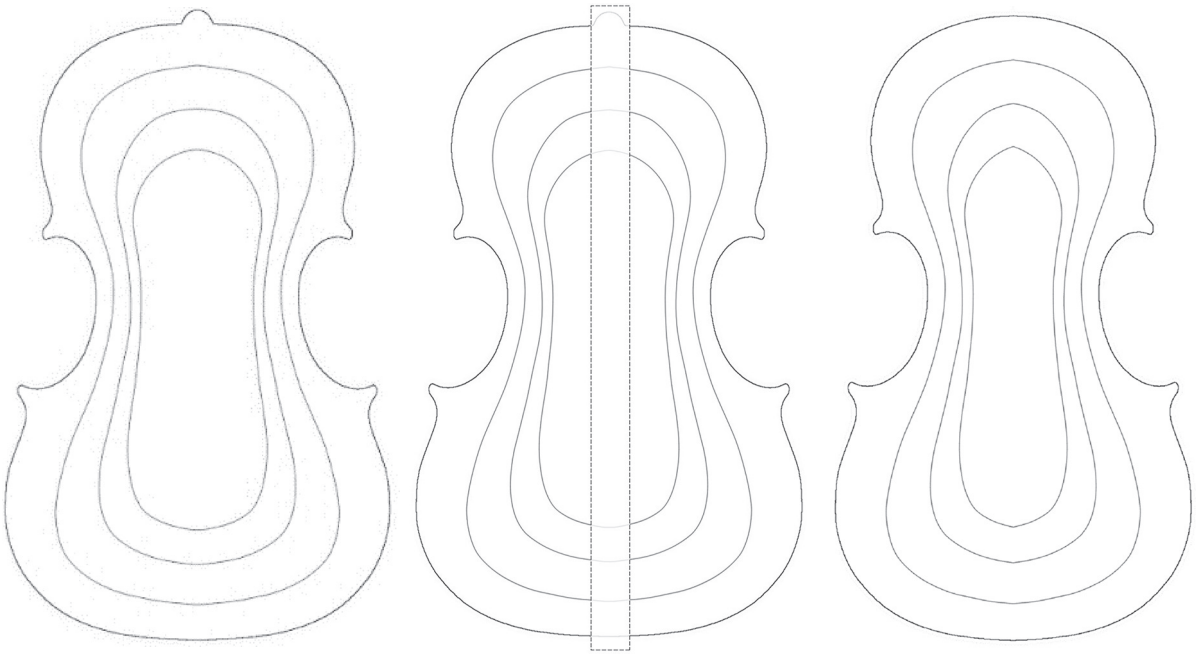

Figure 14. *Influence of a reduction of the body width on the contour lines.*

VISUALISING WIDTH REDUCTION

The width reduction of a soundbox is more difficult to detect with the naked eye than the reduction of its length. To highlight this kind of reduction, the contour lines of the archings are a great help. In our setting, contour lines consist of closed curves embedded within the surface of the soundboxes, and that stay at a constant distance from the plane of symmetry between the soundboard and back of the instrument. Figure 14 shows the theoretical influence of the removal of a wooden strip along the axis: whereas in the left-hand diagram, depicting an instrument before reduction, the contour lines are smooth all around the body, after the removal (central diagram), the curves become sharper in the upper and lower bouts, especially near the centre (right-hand diagram).

In reality, the archings of early bowed instruments are rarely as regular as the above figure suggests, because wood ages unevenly and stresses on the instrument alter its symmetry. Nevertheless, contour lines remain a useful source of information about the instrument's material history. Based on the photogrammetric meshes, we calculated the contour lines of the soundboard and the back of the Hofmans and Cuypers violas. As an example, the raw data for the Hofmans soundboard are shown in Figure 15 (colour section). The height differences are graduated every 2mm. Unsurprisingly, the scheme is disturbed by the fingerboard and the soundholes. However, it shows that the lower end of the soundboard is not level with the shoulders, an obvious consequence of the reduction of the soundbox.

By eliminating the fingerboard and the f-holes, we obtain Figures 16 and 17 (colour section), which reveal much more angular profiles on the Hofmans than on the Cuypers viola. It is clear that the Hofmans viola has been reduced in both height and width. This last reduction is not obvious to the naked eye. It may somehow be guessed by palpation of the archings, but it is difficult to put into words.

Figure 16, in the colour section, shows that the archings of the soundboard and back of the Hofmans viola are very different. This is sometimes a sign of an instrument that has been assembled from disparate parts. It is also possible that the back and the soundboard of an instrument are not reduced in the same way because of the soundholes, which exert strong constraints on the proportions of the latter. The bridge should be placed between the inner notches of the soundholes, whose location is therefore decisive for the vibrating string length. However, this length must also be in proportion to the neck.[66]

For the Hofmans viola, however, neither of these explanations seems valid. Both the back and the

[66] We thank Jan Strick for bringing this to our attention.

soundboard have identical wood inserts at the top corners. The edge and purfling incisions in the middle of the C-bouts are at the same height, suggesting a symmetrical reduction of both plates. The differences between the archings must therefore be explained in some other way, probably by the fact that from the beginning they were not identical and aged differently.[67] Clearly, the analyses proposed above do not explain all the particularities of reduced instruments. The tool we have developed is an aid, which should be combined with other approaches to understand the material history of the instruments. Nevertheless, this tool provides an innovative approach for the objective description of the alterations undergone by instruments of the violin family since the eighteenth century.

DISCUSSION AND CONCLUSION

Because of their three-dimensional nature, the archings of bowed instruments are difficult to describe and are much less studied in organological literature than the soundholes and body shapes, which are more easily reproduced through drawings or two-dimensional diagrams. However, the archings play a decisive role in the sound colour and we have seen that their analysis is useful in identifying the reductions undergone by Baroque instruments. In further research, the evaluation method illustrated above should lead to a more accurate assessment of the original dimensions of reduced instruments of the entire violin family. This information is essential for historically informed performance practice.

The case study of the two instruments examined above shows the issues at stake. While Cuypers' instrument is a true viola, built at a time when the Italian-style quartet was becoming established everywhere in Europe, the instrument attributed to Hofmans belongs to an earlier tradition. In an attempt to understand its use, by way of example, we can compare it with a more or less contemporary musical collection, the *Fasciculus dulcedinis* by Philippus Van Wichel (1614–1675), published posthumously in Antwerp in 1678. Van Wichel was a violinist at the Brussels Royal Chapel from 1637 to his death.[68]

His collection is composed for a violin family and uses the violin, soprano, alto and bass clefs. The headings of the middle parts associated with the soprano and alto clefs vary and the question arises whether these different names refer to distinct instrumental models. The tessituras are shown in Table 2.

Clef and range	Name of the part
	*Violino I* and *II*
	*Viol*[*ino*] *III*
	*Viola I*
	*Alto viol*[*a*]
	*Tenor viol*[*a*]
	*Basso viol*[*a*]

Table 2. *Ranges of the bowed instruments in Philippus Van Wichel, Fasciculus dulcedinis (1678).*

Although the morphology of Van Wichel's violin family is unknown, his music certainly involves a variety of sizes ranging from high to low. For example, the *tenor viola* and the *alto viola* share the same clef and have a similar overall range. In the *Sonata octava A 4*, both instruments are required, but the tenor viola part exploits the lower tessitura to a much greater extent than the *alto* part, and was perhaps intended for a larger instrument, similar to the original size of the Hofmans 'viola'. It seems unlikely, however, that the abovementioned part names and clefs refer to standardised instrumental morphologies. A more likely hypothesis is that they

[67] Cozio writes that the archings of the soundboard and back should ideally be identical (Cozio di Salabue (1950), p.93), but he acknowledges that this is rarely the case (ibid., p.91).

[68] *Fasciculus dulcedinis* (Antwerp: Lucas De Potter, 1678), RISM A/I W 994. About the composer and the collection, see Piet Stryckers, *Philippus Van Wichel (1614–1675), violist aan het hof te Brussel en zijn* Fasciculus dulcedinis, Master's thesis, Katholieke Universiteit Leuven, 1976.

point to range levels within the violin family, i.e. to a musical function within the harmonic texture rather than an instrumental model.[69]

A better knowledge of the morphological characteristics of the instruments with which Van Wichel and his contemporaries were familiar would allow a better-informed appraisal of their music. The long-term objective of our research is to enable a more accurate assessment of the original dimensions of reduced instruments by investigating a large corpus of instruments from the Southern Netherlands.

ACKNOWLEDGEMENTS

This article is the result of several collaborations and has benefited from the advice of many people. Prof. Emmanuel Coche, Prof. Etienne Danse (Cliniques Universitaires Saint-Luc, Brussels) and the technologists of the Pôle d'imaginerie médicale performed CT scans of several instruments from the Brussels Musical Instruments Museum, including the violas by Matthijs Hofmans and Johannes Theodorus Cuypers. Alain Vlassenbroek, Clinical Scientist at Philips Healthcare, Brussels, clarified the technical characteristics of the imaging provided by CT scanning. Two master students from the École polytechnique de Louvain (UCLouvain, Belgium) contributed to the past development of the analysis techniques: Laetitia Motte (*Conception d'un outil mathématique/informatique pour la classification d'instruments à archet*, 2017, directed by Paul Fisette and Anne-Emmanuelle Ceulemans), and Renaud Lothaire (2019). Jean-Philippe Échard (Musée de la musique, Paris) was responsible for the idea of studying the contour lines. Jan Strick (Maison Bernard, Brussels), Gauthier Louppe (École internationale de lutherie, Marche-en-Famenne) and Mirte Maes (Museum Vleeshuis, Antwerp) assisted us with their advice on violin making. Fañch Thoraval and Mattia Cavagna (UCLouvain) helped us to decipher the manuscripts of Ignazio Cozio di Salabue. Finally, Joris De Valck (Musical Instruments Museum, Brussels) gave us considerable logistical support. We would like to thank everyone for their help.

[69] This hypothesis is the subject of doctoral research by Manon Fauconnier, 'The Violin Family in the Southern Netherlands: A Cross-cutting Approach' (UCLouvain, Belgium).

Figure 6. *(a) Matthijs Hofmans (attr.), Viola, Antwerp, undated (second half of the seventeenth century), MIM inv. no. 2846; (b) Johannes Theodorus Cuypers, Viola, The Hague, 1761, MIM inv. no. 2833.*

Figure 7. *Viola attributed to Hofmans, corner inserts and incision of the C-bouts.*

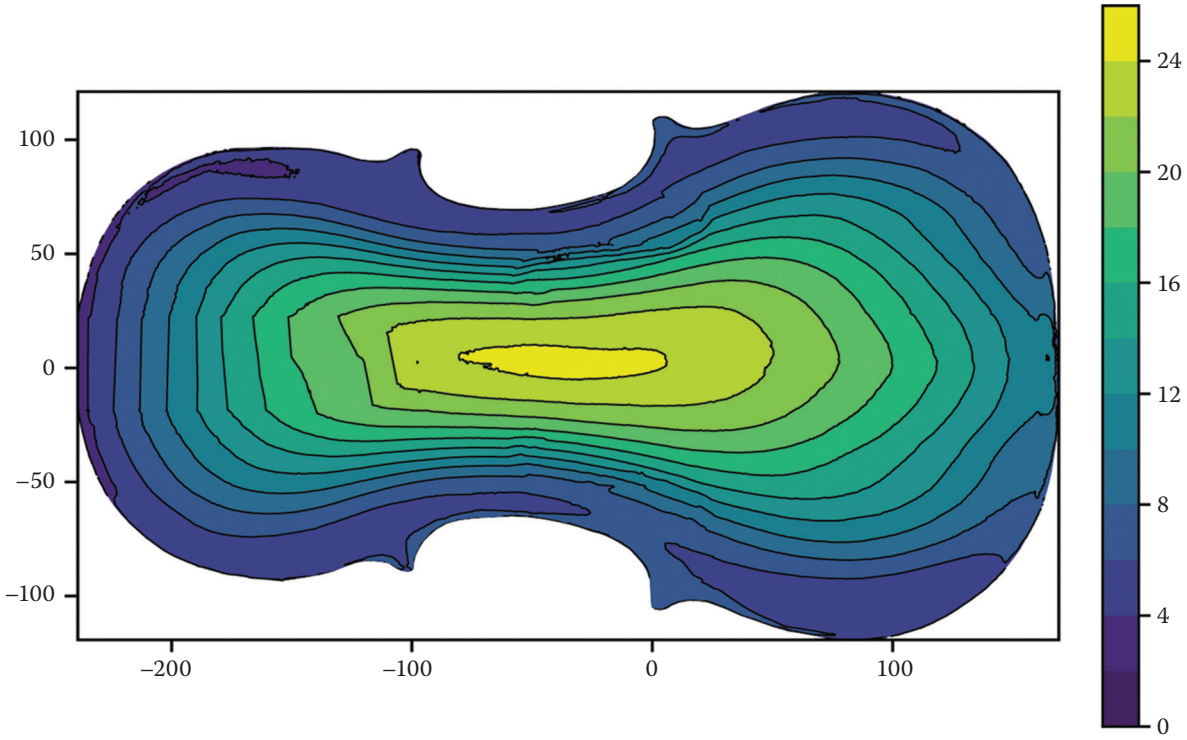

Figure 15. *Raw contour lines of the soundboard on the viola attributed to Hofmans (scale: mm).*

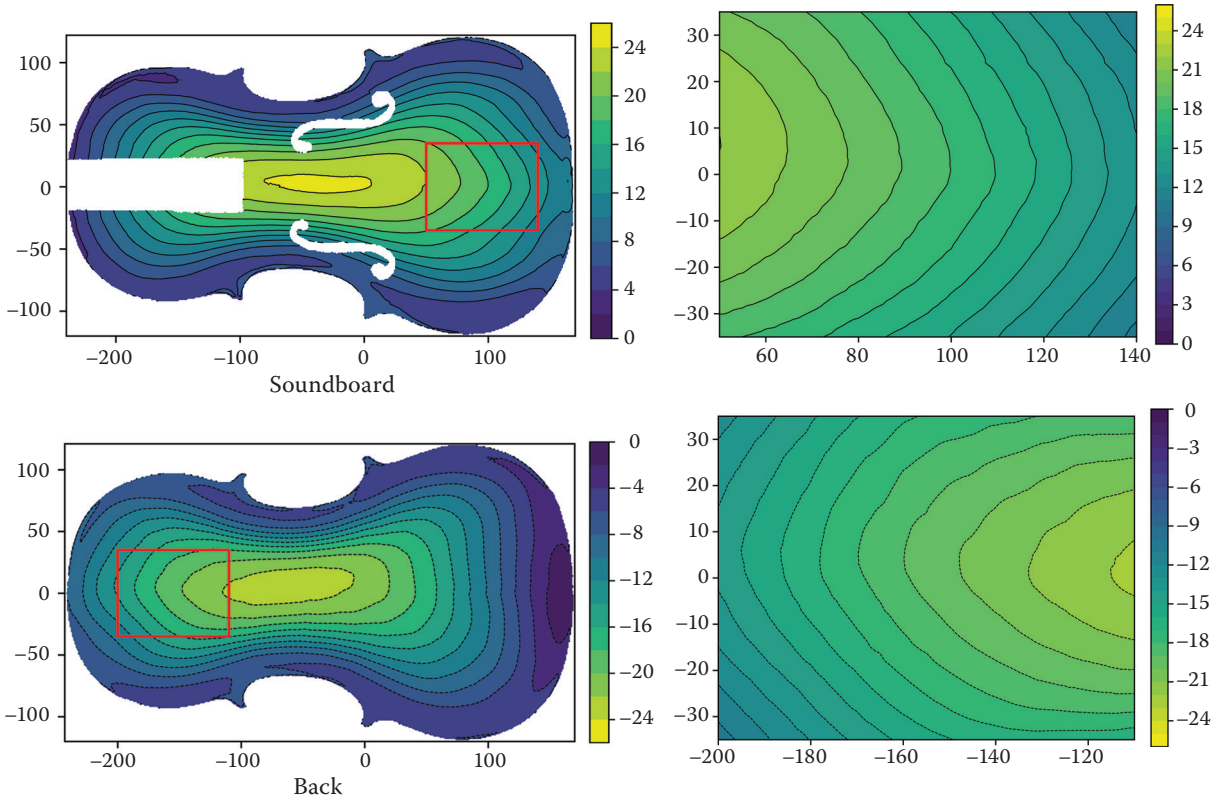

Figure 16. *Contour lines of the viola attributed to Hofmans: overview (L), and details (R) (scales: mm).*

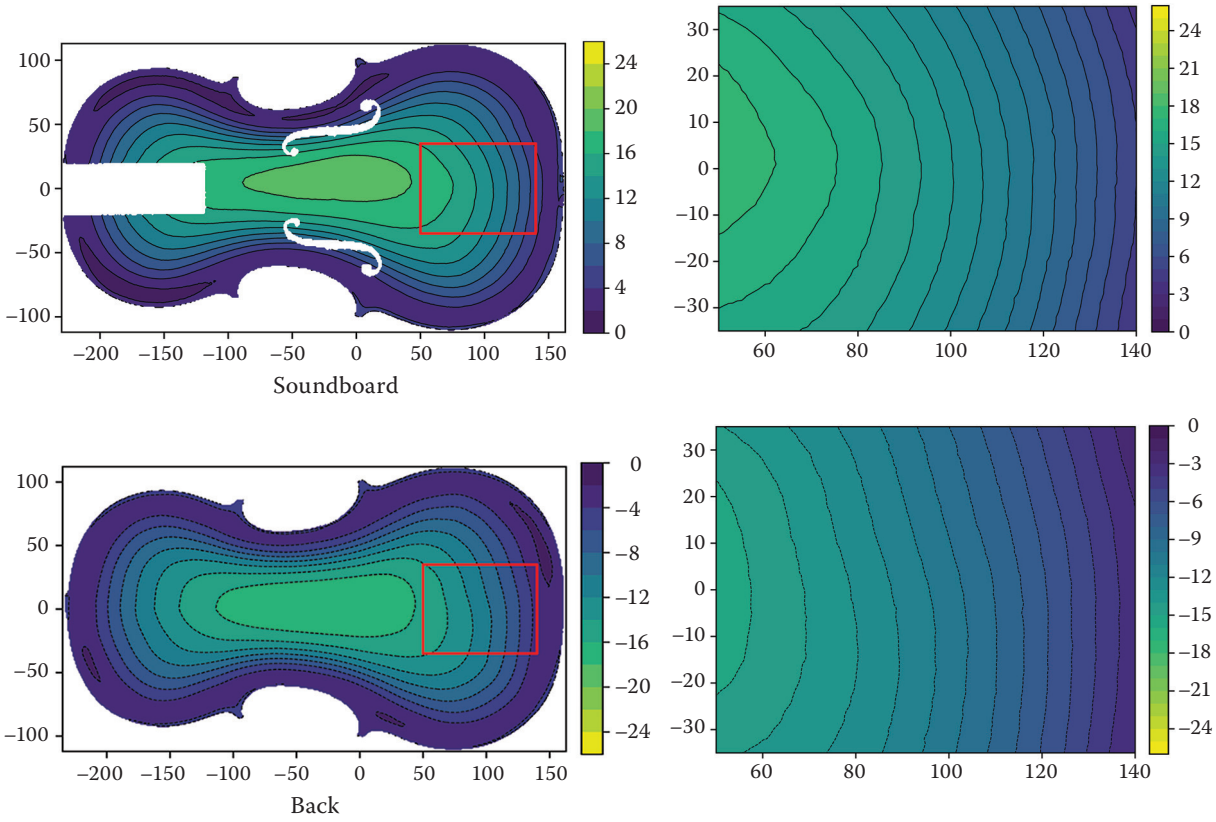

Figure 17. *Contour lines of the Cuypers viola: overview (L), and details (R) (scales: mm).*