Path through

What secrets lie beneath the surface of violins by the great 'del Gesù'? Here, **Jeffrey S. Loen**, **Terry M. Borman** and **Alvin Thomas King** use the latest techniques to reveal the hidden contours of wood density

ABOVE mapping the graduations of an instrument such as the c.1730 'Kreisler' 'del Gesù' can begin to yield its acoustical secrets

the woods

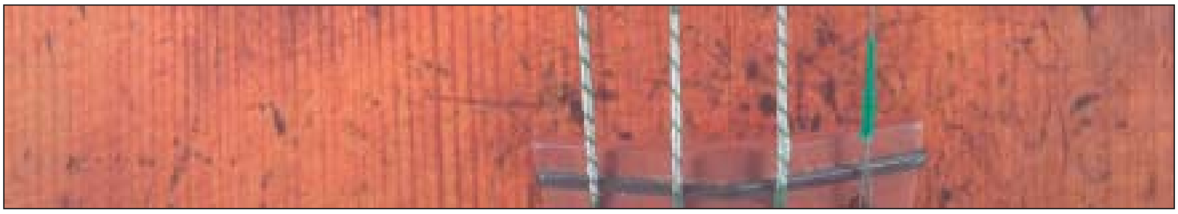


Figure 1 photographs of spruce grain in two 1735 'del Gesù' tops

Familiar iconic images of old Italian violins show only the outside surfaces of remarkable three-dimensional creations. We naturally wonder – what lies beneath the surface of a great Guarneri 'del Gesù'? Is the wood light or heavy? How do the graduations pinch and swell beneath the smoothly modelled arching and the 270-year-old patina?

In our research, we have used two methods of revealing hidden features: CT scans and thickness calipers. Our CT scans show changes in shape and wood density. The separate colour contour thickness graduation maps make it possible to compare plate structures of different instruments visually and intuitively.

Thinking about wood thickness as shown in maps is becoming familiar to violin makers. However, thickness without density means nothing to the working luthier. A 'light' piece of spruce will need to be thicker than a 'heavy' one. In addition, a material with uniform density, such as willow or carbon fibre, does not begin to approximate the acoustical properties of spruce. In our opinion, the characteristics of spruce (ie soft spring growth and hard fall growth) contribute significantly to the acoustical properties and strengths of individual logs. For that matter, individual sections of logs on a steep hillside will develop differences in the uphill part compared with the downhill section. See Figure 1 for two examples of spruce grain in 'del Gesù' top plates.

CT SCANS

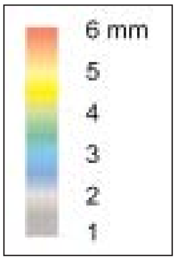
We have been investigating dimensions, design and wood density using computed tomography imaging technology, commonly known as CT scans. In CT imaging, X-rays projected through an object are received on a processing plate or receptor array. The difference between the amount of energy sent and received is referred to as 'attenuation'. Denser objects 'absorb' more of the energy transmitted and appear lighter, whereas less dense objects appear darker. The scale used is the Hounsfield Unit (HU) whereby -1000 represents the attenuation of air and zero represents the attenuation of water. This is easily converted to the standard format for density, which is the ratio of an object's mass to volume (air = zero; water = 1.0g/cm^3).

CT has advantages over standard study techniques, which often involve handling and disassembling of instruments. It is non-invasive, rapid and accurate. A typical CT scan of a violin involves removing the instrument from its case, placing it on a padded support in the machine for two minutes and then returning it to its case. In that time, the machine acquires as many as 1,500 'profiles' through the instrument. These images can be displayed as transverse or longitudinal profiles, or as three-dimensional models (see figure 2, overleaf).

The transverse CT profile shows the alternating light–dark spring–fall wood-grain structure in the spruce top, and the more homogenous nature of the maple ribs and back. We have measured the density of each grain line (see densitometer graph, figure 3). These densities have then been averaged to arrive at a mean spring and fall growth, and a spring–fall ratio has been calculated. For the 1735 Guarneri top shown in figure 1, the spring–fall ratio is 1:1.275 ▸

Photo opposite: Stewart Pollens, courtesy of Peter Biddulph/Giuseppe Guarneri 'del Gesù'; all other images courtesy of the authors

Figure 4 colour bar used in wood thickness graduation maps



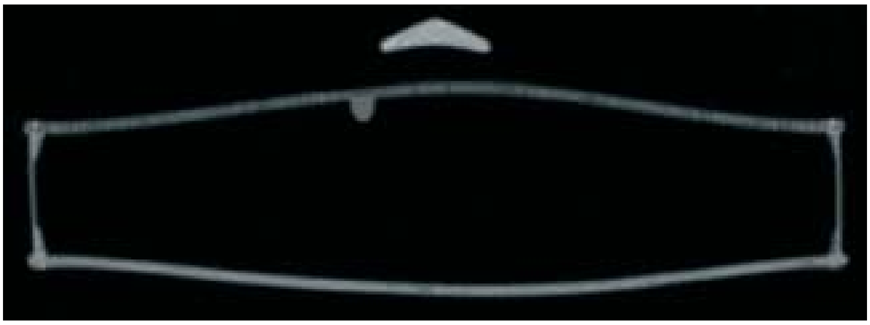


Figure 2 transverse CT profile of a 1735 Guarneri 'del Gesù' at the widest section of the lower bout. Note end of bass-bar (within body) and part of tailpiece (above body)

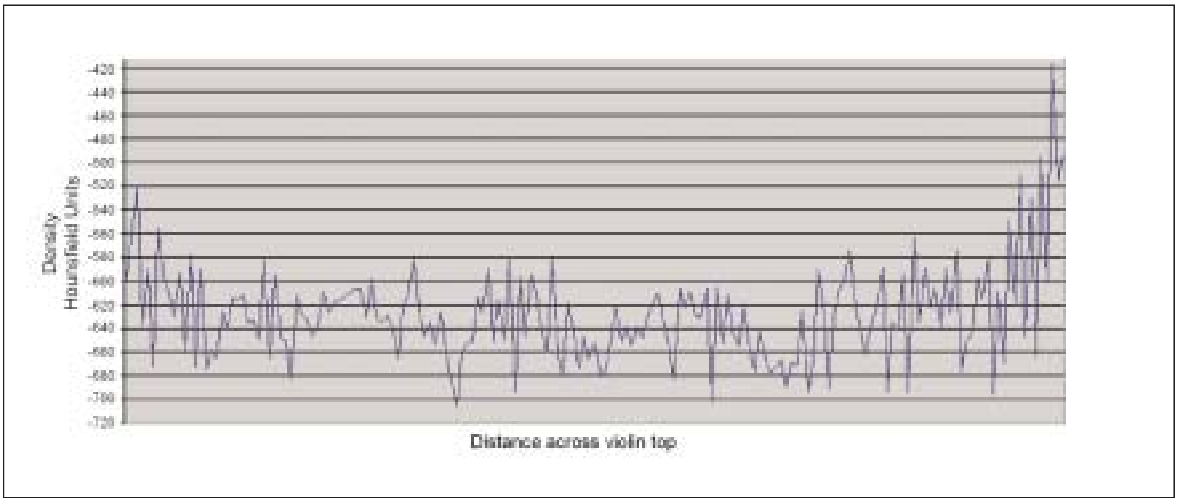


Figure 3 CT densitometer graph for the 1735 'del Gesù' top shown in the CT scan image in figure 2. Peaks represent harder fall growth and troughs represent softer spring growth. Higher densities at the two extremities are due to purfling, glue infiltration and an edge underlay on the right-hand side

and the overall density is -633 HU or 0.368g/cm^3. Hence, the fall wood is almost 30 per cent denser than the spring wood, although the overall density is relatively light. Another scanned Guarneri top, also from 1735, has a lower spring–fall ratio of 1:1.241 and a heavier overall density of -619 HU or 0.382g/cm^3. In comparison, a 1736 Stradivari violin top shows a spring–fall ratio of 1:1.153 and an overall density of -574 HU or 0.427g/cm^3, which is relatively heavy.

We believe that these preliminary data are simply an affirmation of the ancient technique of testing wood by dragging one's thumbnail perpendicular to the cross-grain of spruce: winter grains create a washboard effect depending on their hardness, spacing, width and relationship to summer growth. This technique also gives an idea of general density. Developing this sort of feel with fingers contributes greatly to a luthier's choice of wood, and approximates the results of CT densitometry. Further CT work will compare the wood choices of classical makers in other areas to these baseline examples as well as wood chosen by modern makers.

THICKNESS MAPS

We have compiled over 4,500 thickness measurements from 46 violins made by 'del Gesù'. Eight instruments, all outstanding examples, are shown here (see figures 5 and 6 overleaf). Thickness values were measured using magnetic thickness gauges. Data compiled from various sources (violin shops, Strad posters and museums) were systematically contoured and coloured using a computerised geographic information system (see our article on Stradivari's plate thicknesses in The Strad, December 2002, for details of how these maps are produced). Note that the maps are based on the instruments' current condition and we do not know if thicknesses are original. We're also unable to say whether the maps depict original wood or multiple layers, as in patches. The resulting maps, coloured in an intuitive way (hot colours for thick, cold colours for thin; see figure 4 for a colour bar) allow us to compare the overall structures of the plates. Positions of data points are shown by black dots, although values are omitted in order to emphasise structural patterns. All plates are viewed from the outside.

The earliest violin depicted, made in 1728, shows zones of minimum thickness between the f-holes. The centre-of-back ▸

thickness is slightly lower than the centre of the plate, and the thickness pattern is somewhat square.

The 1730 'Szymon Goldberg' violin again shows a zone of minimum thickness between the f-holes, but both the top and back plates are more variable than the 1728 violin. The centre-of-back thickness is irregular and suggests a linear pattern.

The top plate of the c.1730 'Kreisler' violin is thinner in the central areas than near the edges, block platforms and f-hole exteriors. A zone of minimum thickness sweeps diagonally through the f-hole region, from the upper left to the lower right. The back, like the top, has a highly asymmetrical thickness pattern. The back plate shows a rather small central thickness zone running parallel to the centreline.

The 1734 violin again shows a diagonal zone of minimum thickness that passes through the f-hole region (a soundpost patch has increased the thickness near the right f-hole) although this time from the upper right to the lower left. The back plate is strongly asymmetrical, including the position of the centre-of-back thickness, which is shifted significantly to the bass side.

The c.1739–40 violin has a rather uniformly graduated top. The back plate has a prominent oval zone of greater thickness centred near the halfway point.

The 1742 'Alard' violin has a uniformly graduated top plate. The back plate is rather symmetrical and the centre of thickness is near the halfway point.

The 1742 'Lord Wilton' violin is graduated quite uniformly, except for one slightly thicker value between the upper f-holes. This top plate is rather thin in the centre and attains maximum values just inside the linings of the upper bouts. The back plate shows a large triangular zone of increased thickness. The centre of thickness seems to be higher than the halfway point.

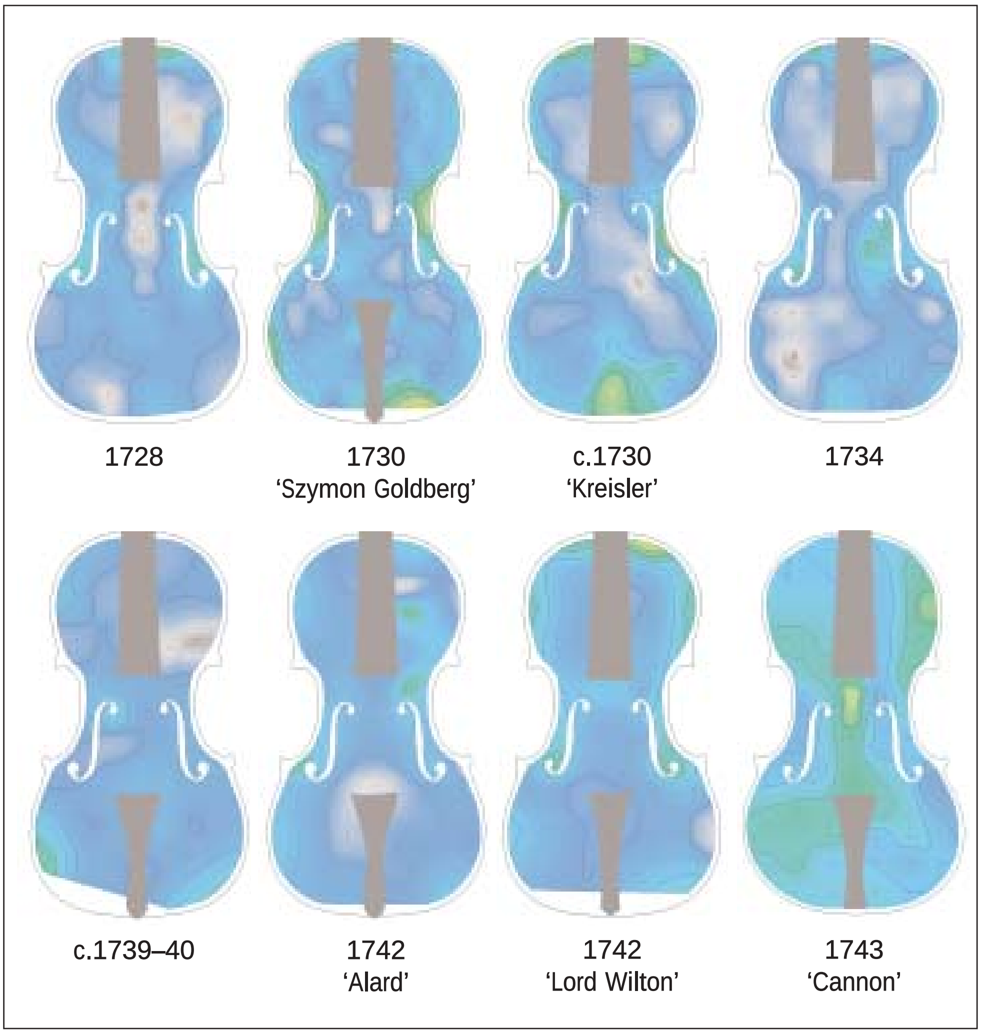
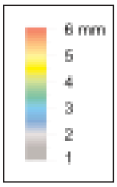


Figure 5 graduation contour maps for top plates of eight violins. Positions of data points are shown by black dots, although values are omitted in order to emphasise structural patterns. All plates are viewed from the outside. See colour bar below for reference

Paganini's 1743 'Cannon' is thought to be in a nearly unmodified condition. The top plate is especially thick between the f-holes and the back plate is extremely robust throughout its length. Regrettably, data do not agree from the three times that the 'Cannon' has been measured. Candi collected measurements along the centre-lines of the top and back plates in 1937, using a caliper on free plates (see 'The Cannon and Typical Features of Guarneri's Instruments' from *Paganini's Violin* by Alberto Giordano, 1995). Candi documented a thicker top plate (max. 4.3mm) and a thinner back plate (max. 5.4mm), compared with more recent attempts (top plate 3.4mm; back plate 6.2mm). We have no explanation for these differences. A definitive measurement is needed, in which sufficient data points are collected using a well-calibrated gauge, before we can make firm conclusions about the thickness of the 'Cannon'.

Looking at these, and other maps in the database, we can make generalisations about how these violins compare with other Cremonese masters and master-level work of modern violin makers. Firstly, most plates are slightly thinner than modern makers are taught to use. Secondly, the range between thick and thin is greater than we are often led to believe is 'acceptable'. Finally, plates are quite irregular by today's standards, showing considerable pinching ▸



and swelling. Such variable patterns are typical of other Cremonese makers (including Stradivari).

Top plates mostly have a membrane-like structure, a few of which are slightly thicker in the centre between the f-holes, chief among these being the 'Cannon'; although most are thinner in the centre than at the edges. Thicknesses are commonly in the 2.2–2.9mm range, although outside margins of f-holes and block platforms typically are 3.0–3.5mm. The variability of adjacent values is moderate, often showing changes of 0.2–0.6mm within distances of 20–30mm. Spots as thin as 1.5mm occur in several cases, especially in early work before 1730, although the usual minimum values on top plates are 2.1–2.3mm. Several violins have known or suspected breast patches (a restoration technique used to correct and strengthen extensively repaired areas), which could also have been executed because the plate was judged as too thin in the centre.

Back plates all have a concentric structure, with a strong central zone of greater thickness. Maximum thickness values in the central zone range from 3.5–6.5mm (average 4.8mm), and the shape of the central zone is variable, including round, oval, rectangular, triangular and linear patterns. The upper and lower bouts tend to be of uniform thickness in the range 2.0–3.0mm, although thin spots in the range 1.4–2.0mm are common, particularly near edges.

We will never know the original character of most of the violins by 'del Gesù' (with the likely exception of the 'Cannon'). One could speculate that they were originally all like the 'Cannon'. However, it is just as possible that the 'Cannon' was one of few violins that were made exceptionally thick, which might explain Paganini's trouble finding similar Guarneris during the early 1800s. Perhaps the most surprising aspect of these maps is that there is so much variation, and yet sound quality is consistently high.

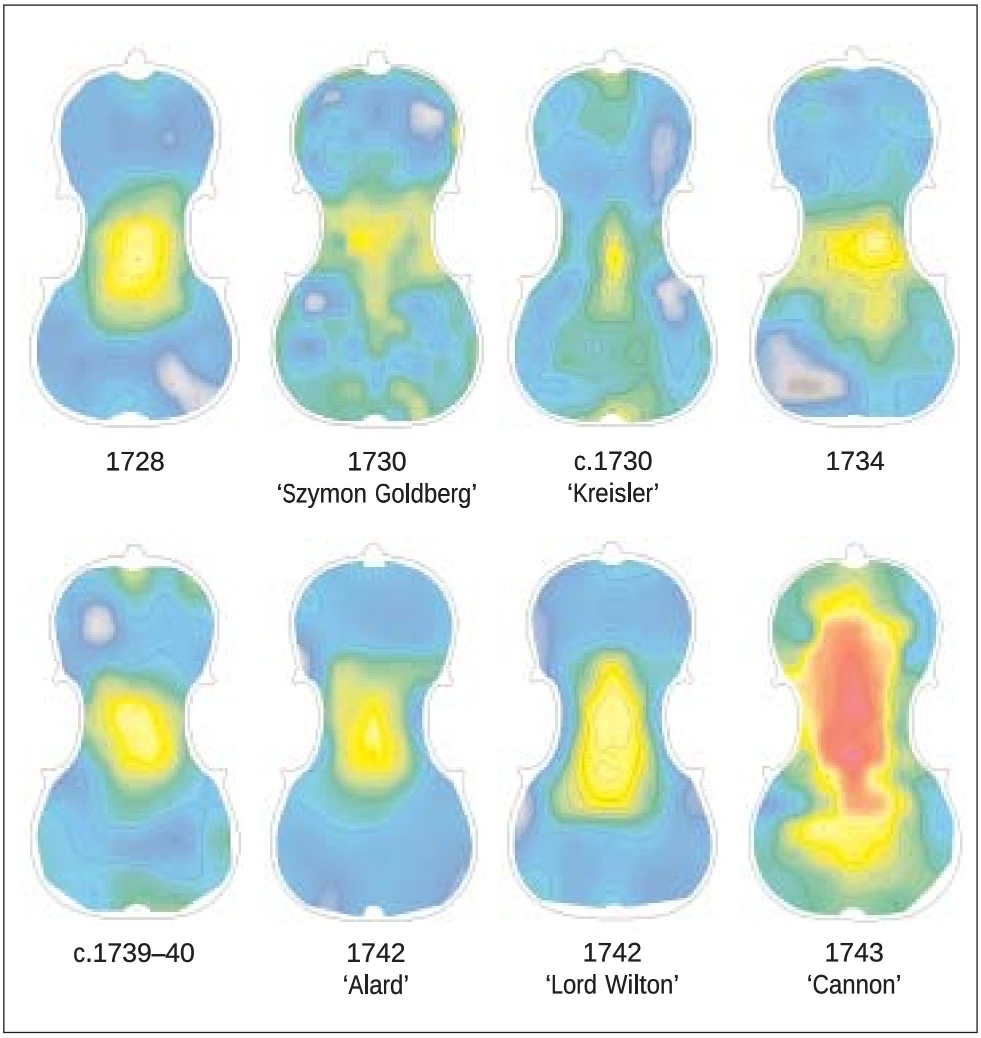


Figure 6 graduation contour maps for back plates of eight violins. See colour bar below for reference

This lack of correlation between thickness patterns and sound quality suggests to us that thickness graduations do not play as great a role as we thought relative to acoustical performance.

In conclusion, plate graduations appear to be highly variable in the violins of 'del Gesù'. Substantial thickness variations and numerous graduation patterns occur, and yet they retain their high level of performance; this despite possibly extensive modifications over the years. We think that perhaps the most significant observations come from the CT densitometry scans, although we need to scan more instruments to arrive at definitive conclusions. We believe that we are one step closer to getting inside the mind of perhaps the greatest violin maker of all time, by taking into account the densities of the wood that he chose and getting a feel for his preferential spring–fall ratios. S

The c.1730 'Kreisler' and the 1742 'Alard' violins appear in The Strad calendar 2006, available from www.thestrad.com or by calling +44 (0)1371 810433.

Thanks to Dr Ronald Glass and the faculty and staff of the Mount Sinai School of Medicine; and Angie Ackerman and Scott Carlson at the McKay-Dee Hospital Center for help with CT scans. CT scanners used were Siemens Somatom Sensation 16. Thanks also to Gregg Alf, Gary Frisch, Gary Sturm and Peter Westerlund for help with graduation data. Data for The Strad posters of the 1742 'Alard', the 1742 'Lord Wilton' and the 1743 'Cannon' were compiled by John Dilworth and Roger Hargrave.