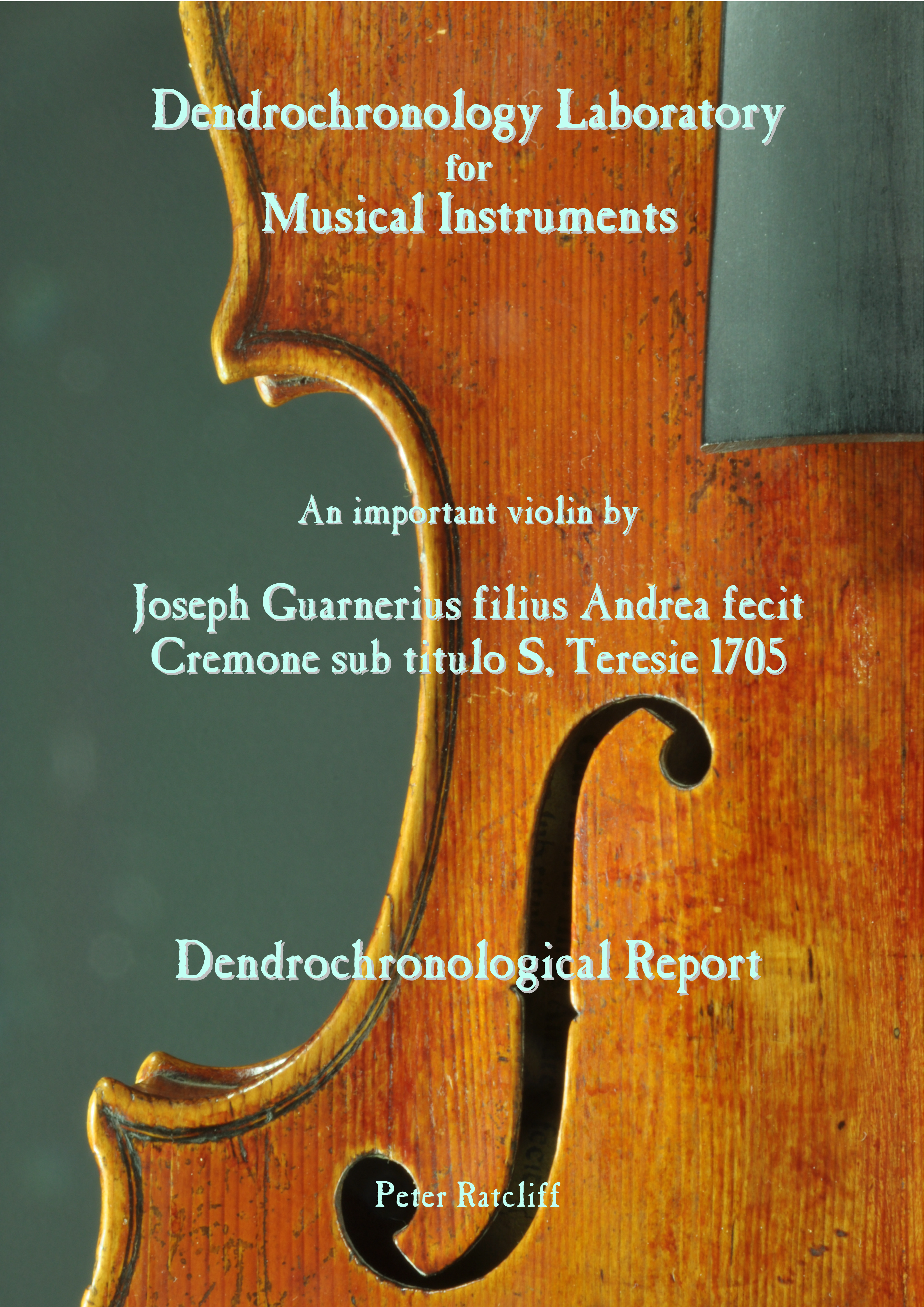


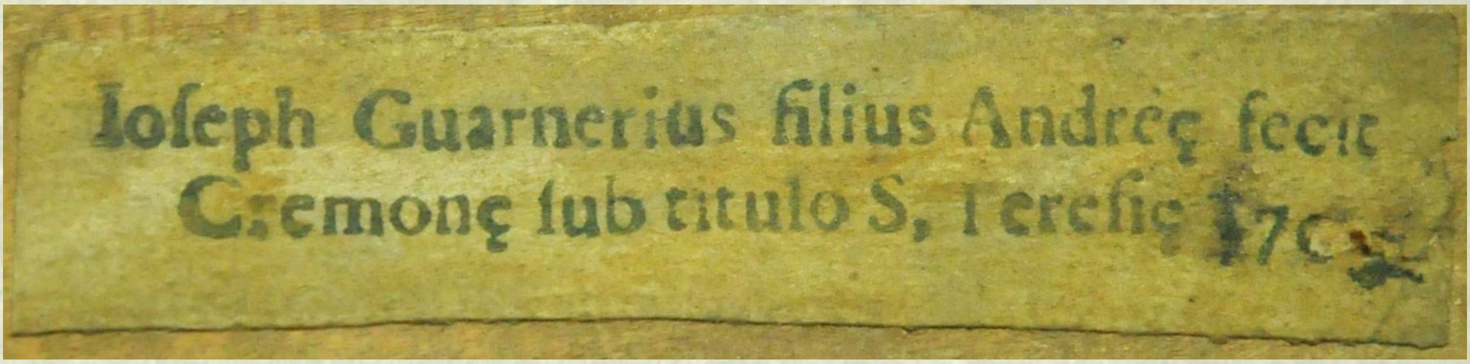
Dendrochronology Laboratory
for
Musical Instruments

An important violin by

Joseph Guarnerius filius Andrea fecit Cremone sub titulo S, Teresie 1705

Dendrochronological Report

Peter Ratcliff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Instrument Dendrochronological Investigations

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Tree-ring and Dendrochronological analysis of the belly of a violin by Giuseppe Guarneri, known as Giuseppe, Filius Andrea, Cremona, circa 1705

By Peter Ratcliff Higher Dip. Dist. Musical Instrument Technology

The violin uder study, a circa.1705 Giuseppe Guarneri, Filius Andrea, front and back views

Summary

Dendrochronology, the science of dating wood from the information contained in its tree rings, is now well established and widely used in the field of musical instruments. Information obtained following a successful test is second to none, and can yield very valuable and enlightening details, which can substantiate and strengthen traditional attributions, and equally, in some cases, demolish them.

Tree growth is influenced by many environmental and geophysical factors. Tree-rings register environmental and climatic data, in multiple aspects of their growth. The rate at which wood cells multiply and the changes in physical attributes of those cells determine the rings' characteristics. Within one year's growth, variations of density can be observed. In spruce, the earlier spring growth, normally of lighter shade is characterized by lower density than the darker, late-Summer growth, which comprises of more compacted and thicker walled cells. When cell growth stops at the end of the growing season, a concentric "ring" is formed below the bark, laying a visible and sharp boundary that becomes obvious when growth resumes in the following Spring. The varying distances between each ring are the results of the climatic and environmental conditions the growing tree found itself in, combined with its increasing development. These relative variations of year-to-year ring growth are the basis of dendrochronological cross-dating. Ring growth from separate trees may react slightly differently within a specific area, due to individual circumstances, but their relative ring-width sequences will mostly follow a similar pattern. Cross-dating identifies the similarities followed by the tree-rings of the sampled instrument and a dated reference database of the same and related species, positioning the sample at its appropriate temporal placing.

Various species lend themselves to dendrochronological dating. Conifers, on the whole display grain structure suitable for this process. On musical instruments, both of the bowed and plucked variety, including instruments of the violin family, guitars and keyboards, their harmonic tables are almost invariably manufactured with wood from conifers, mainly of spruce, fir or pine varieties. For strength, stability and acoustical reasons, the timber is processed in order to expose the radial plane. That way, tree-rings are positioned at an angle approaching 90 degrees from the main carved or flat surface. The resulting grain pattern of light growth interspaced by darker reed lines presents the ideal conditions for recording the tree-ring widths with minimal distortion. The varnish, usually applied to a highly finished wood surface, often highlights grain detail, allowing for enhanced accuracy in the measuring process.

Wood species used on other parts of musical instruments tend to be hardwoods. Traditionally, the use of maple, occasionally poplar and more infrequently beech forms the rest of the corpus for instruments of the violin family. These do not usually lend themselves to dendrochronological dating, although in the case of maple, grain similarity between backs of separate instruments, can sporadically be detected by statistical cross-matching or graphical comparison of their respective tree-ring patterns.

In the following report, we examine the results of cross-dating the wood from the belly of this violin, in order to identify the most significant and likely date of the latest growth ring present on its belly. In turn, this date will shed light on the earliest possible manufacturing date for this instrument.

In addition to merely stating dendrochronological results, this report will examine possible relationships between the wood on the belly of this violin and that of other instruments, taking in consideration the whole of the results in the context of violin-making procedures revealed by cross-matching in general.

Methodology

In recent years, with the rapidly increasing quality and achievable resolution of digital equipment, a growing number of dendrochronological tests on musical instruments have been based on tree-ring measurements gathered from photographic or scanned images. In most instances, these methods are equally as accurate as collecting data microscopically. As a distinct advantage, a digital image can be filed and stored for later use or further assessment if required.

In order to carry out the present analysis, high-resolution scans of the lower belly were taken. The maximum number of rings available is situated at the widest part of the body. The tree-ring measurements were therefore collected along a horizontal axis at the lower bouts of the front. Cropped areas (*Fig.1*) of this lower half were enlarged further and all tree-ring boundaries remained clearly distinguishable without consequential loss of sharpness, across the whole width of the bass and treble sides. The digital images were loaded on a specially created software module (*Fig.2*) to measure and record the distances between each ring boundary.

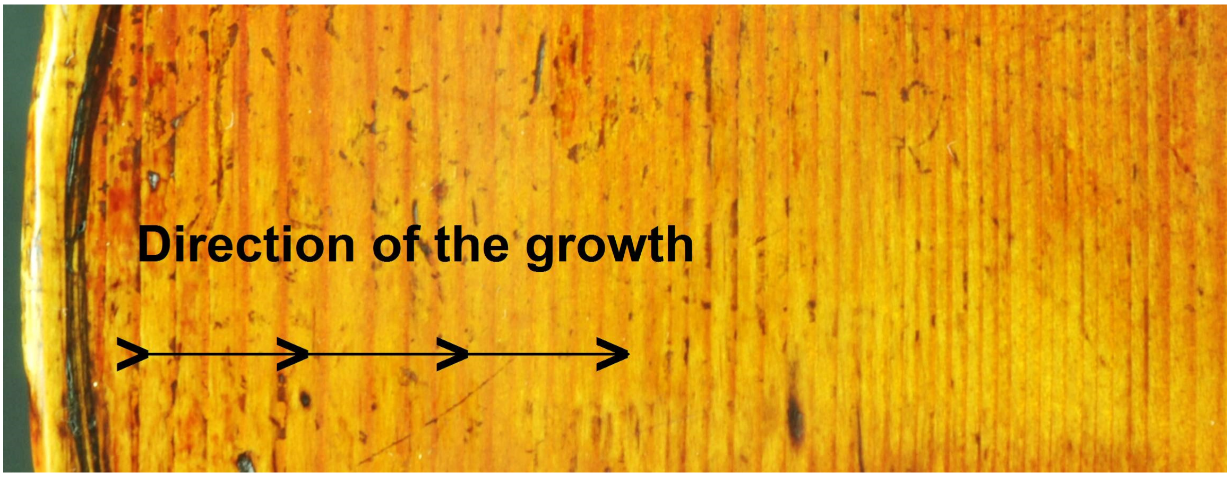


Fig.1 *A cropped part of the lower bass side of the violin where the tree-ring measurements were collected*

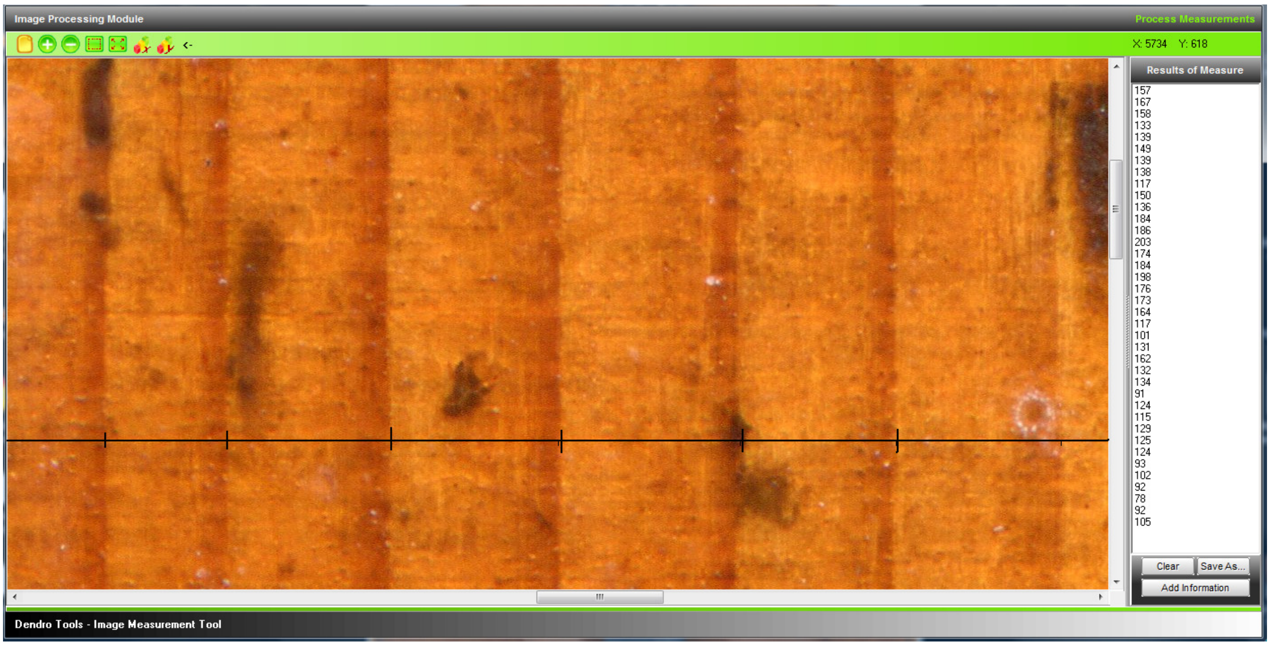


Fig.2 *Measurement processing module*

It was possible to measure every ring present on the two sections of the table and actually visible on the digital images, starting from within the purfling on the outer edges, right up to the last ones situated adjacent to either side of the centre joint. Whilst some rings may have been lost preparing and planing the gluing surfaces of the joint during the making process, their actual number remains speculative. It was not possible to see whether further rings were present underneath the fingerboard, but the alignment of the last visible growth rings in relation to the centre joint suggests very few, if any, extra rings are present.

The data resulting from the various measurements series are statistically cross-dated and analysed individually against a variety of master chronologies, both from published and private sources, including many generously supplied by the *International Tree Ring Databank* (ITRDB), together with a wide database of measurements taken from musical instruments, both from individual instruments and *instrument chronologies*, compiled from data from well correlated examples. Some instrument chronologies are *area specific*, and are the result of the amalgamation of well-correlated instrument data from specific towns or countries, whilst others can be from instruments made in separate countries, but with wood displaying strong visual and statistical relationship, suggesting similar *growing location*. As an integral part of the analytical process the sequences are visually compared with many of the instrument data and reference chronologies showing significant statistical results.

The cross-dating and other statistical tests, including the *Gleichläufigkeit* or GLK, and segmentation analysis when required are prepared using a specially written computer program (© P.Ratcliff) based on a routine devised by the Belfast CROS program (Baillie and Pilcher 1973). Indexation of data for graphical purposes is carried out with *CORINA* software (Cornell University) or with *COFECHA* (Grissino-Mayer) software suite. For checking purposes, some series were also analysed with the *TSAP Dendrochronological Software Suite* (RINNTECH®), an independent program in regular use by dendrochronologists, showing identical end results.

General conditions regarding the instrument under study

Prior to measuring, careful visual inspection of the table was carried out, in order to identify and locate possible repairs, to ensure the continuity and the accuracy of the sequence of measurements. No repairs that were identified were deemed to have disturbed the tree-ring sequences in any significant way.

The particular species of conifer used for this belly has not been identified positively, but appears to be, as is the case for many harmonic tables, made of *Norway spruce* (Picea Abies (L).Karsten). The exact nature of the species, however, remains speculative without a thorough study of the structure of the wood at microscopic level. The belly is made from two pieces, with a glued joint down the middle. Ring boundaries were carefully examined and the direction of tree growth was determined to be from the outer edges towards the centre joint on both halves of the table. As is customary in dendrochronology, measurements were therefore carried out following that direction. In order to reduce measurement error and average natural tree-ring variation within the piece, two sets of data were taken from each half at a slightly different level.

The latest growth ring present on the instrument is unlikely to have been formed in the same year as that of the felling of the tree or even the following year. Unlike certain species, the sapwood in Norway spruce is often indistinguishable from that of the earlier tree growth in seasoned or old timber. Furthermore, the number of sapwood rings in spruce varies greatly depending on the tree's growing location and other geophysical factors. This makes it impossible to estimate accurately the felling year based on the wood structure alone, hence the quest here for an earliest possible felling date, based on available information. The short period between a dendrochronological and manufacturing date occasionally witnessed suggests expedient wood transportation and minimal seasoning.

Results of the statistical cross dating tests

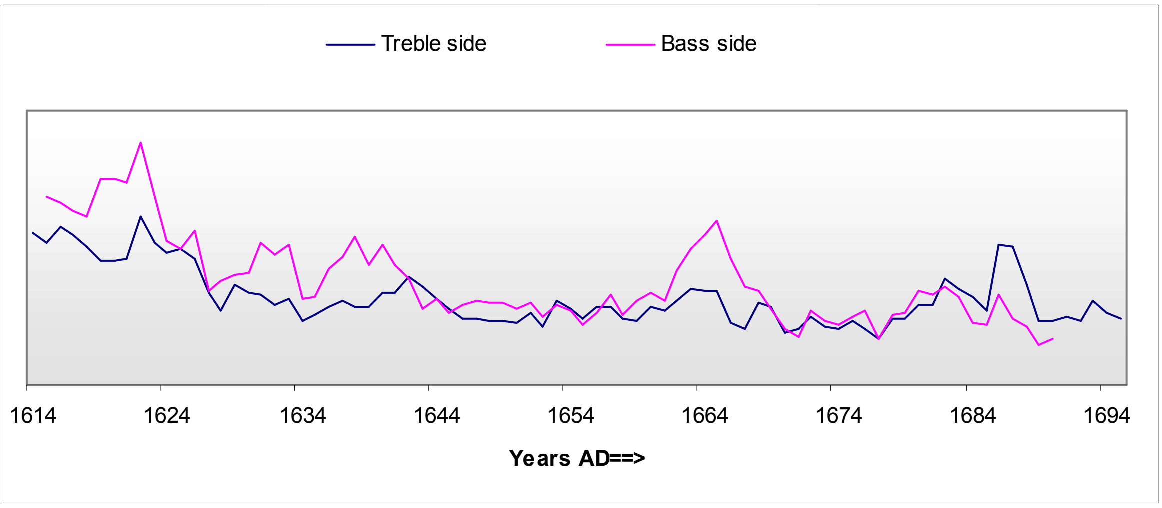
From each half were collected two complete sequences of tree-ring measurements. These were initially cross-dated independently and compared to each other, to ensure that no mistakes or omissions had been made during measuring. This is particularly important when repaired cracks are present or suspected, as some wood may have been removed during the repair process. The datasets were found to cross-date consistently at their relative dating position and were subsequently combined to form two final sequences, or curves, one for the *bass* and one for the *treble* side.

The resulting sequence for the bass side, of 76 measured rings, equivalent to 76 years of growth, most significantly matched reference and instrument chronologies at year **1690**. That of the treble side, of 82 rings, most significantly matched reference and Instrument chronologies at year **1695**.

These dates correspond to the year of growth of the latest growth rings measured on each half of the belly. As previously mentioned, these rings are situated just adjacent to the centre joint on both the bass and treble sides. In the plotted graph below, we can observie the way the two curves of the bass and treble sides follow each other. It is however unclear in view of this graph, whether the two halves originated within the same tree. The statistical correlation between the two, equivalent to a highly significant *t-value* of t=8.94 according to Baillie & Pilcher (1973), suggests a strong relationship but this level of correlation rarely indicates a "same tree" relationship. However, visible similarities suggest a similar response to climate and a nearby location likely for the growth of the two trees.

	Oldest ring	Youngest ring
Bass side	**1614**	**1690**
Treble side	**1613**	**1695**

Tree ring span of the two halves of the belly



Graph 1. *Graph comparing the ring widths of the two halves of the front of the 1705 G.Guarneri*

Tables of statistical cross-dating results

The tables below illustrate the statistical results obtained with the data from the bass and treble sides, compared to a database of individual instrument data and instrument chronologies. Results are displayed in decreasing order of significance.
Due to the overwhelming number of positive cross-dating results, only those achieving the most significant correlations feature in these tables.

Correlations with the bass side

Data corelating with BASS SIDE	t-value	dates	overlap	Glk
G Guarneri Filius Andrea y/hh/t	10.44	1614-1690	71	78.6
COUNTERPART TREBLE SIDE	8.94	1614-1690	76	70.0
P.A Testore viola b6068-2	8.19	1614-1690	76	62.0
Italian Instruments mixed chronology	7.29	1614-1690	76	60.0
Joseph Guarneri Filius Andrea y/t/b	6.49	1614-1690	52	71.6
1735 G.Guarneri Del Gesu' k/t	6.09	1614-1690	75	64.2
1718 A.Stradivari p758	5.99	1614-1690	59	67.2
Louis Panormo guitar pf1823	5.99	1614-1690	33	67.2
Jose Contreras (CR/t)	5.97	1614-1690	76	61.3
1768 G.B.Guadagnini ara/t	5.97	1614-1690	28	72.2
1708 A.Stradivari ad/t	5.96	1614-1690	76	66.7
Jose Contreras 1767 ap/b	5.93	1614-1690	76	62.7
Louis Panormo guitar p450	5.76	1614-1690	76	58.0
1721 A Stradivari bp /es	5.74	1614-1690	66	70.8
A Stradivari 1717 Tyrell treble	5.67	1614-1690	62	62.3
Venetian violin attributed to Sanctus Serafin ih/14	5.65	1614-1690	52	62.7
Pietro Guarneri Venice 1740	5.64	1614-1690	49	74.0
1717 A.Stradivari violin tr/b	5.64	1614-1690	66	67.7
Giorgio Bairhoff violin nor/b	5.62	1614-1690	35	67.6
Jose Contreras cello 1762 jpt/b	5.62	1614-1690	76	70.7
18th century Genoa attrib. Castello t67978	5.61	1614-1690	66	70.0
Attrib.to G.Guarneri Filius Andrea	5.6	1614-1690	76	70.0
1716 A.Stradivari bw/t	5.59	1614-1690	74	60.3
Attributed to Andrea Gisalberti af/	5.55	1614-1690	76	71.3
1712 A.Stradivari hr/t	5.53	1614-1690	73	58.3
Architectural timbers /northern Italy/ m1	5.49	1614-1690	76	63.3
Carlo Bergonzi violin tg/b	5.43	1614-1690	69	67.6
1769 Jose Contreras sat/b	5.32	1614-1690	76	57.3
Furnari Cremonese chr	5.31	1614-1690	76	68.7
G.Cappa cello bs4713	5.27	1614-1690	76	62.7
Lorenzo Storioni violin y/th/t	5.25	1614-1690	60	62.7
Violin composite A.Stradivari top. Lt130/ih	5.25	1614-1690	76	66.0
Domenico Montagnana violin eb/2013	5.2	1614-1690	55	55.6
Architectural timbers /northern Italy/ mess/1	5.18	1614-1690	56	59.1
1769 G.B. Guadagnini mer/t	5.16	1614-1690	48	72.3
Sanctus Serafin violin b060/m	5.15	1614-1690	76	56.0
1717 A.Stradivari violin at/m	5.14	1614-1690	59	68.1
Violin Mittenwald ca.1780, Klotz school fp/b	5.13	1614-1690	52	71.6
1715 A.Stradivari violin ti/b	5.12	1614-1690	60	63.6
René Lacote Guitar French p289/1pf	5.11	1614-1690	76	65.3
ca.1730/40 Venetian violin Guarneri workshop s00/t	5.09	1614-1690	76	59.3
1710 Antonio Stradivari J&AB131	5.07	1614-1690	76	60.7
1730 Guarneri Del Gesu' gv/t	5.04	1614-1690	72	66.2
Carlo Bergonzi violin tg/b	5.04	1614-1690	50	66.3
Attributed to Andrea Guarneri eb/j	5.03	1614-1690	76	69.3

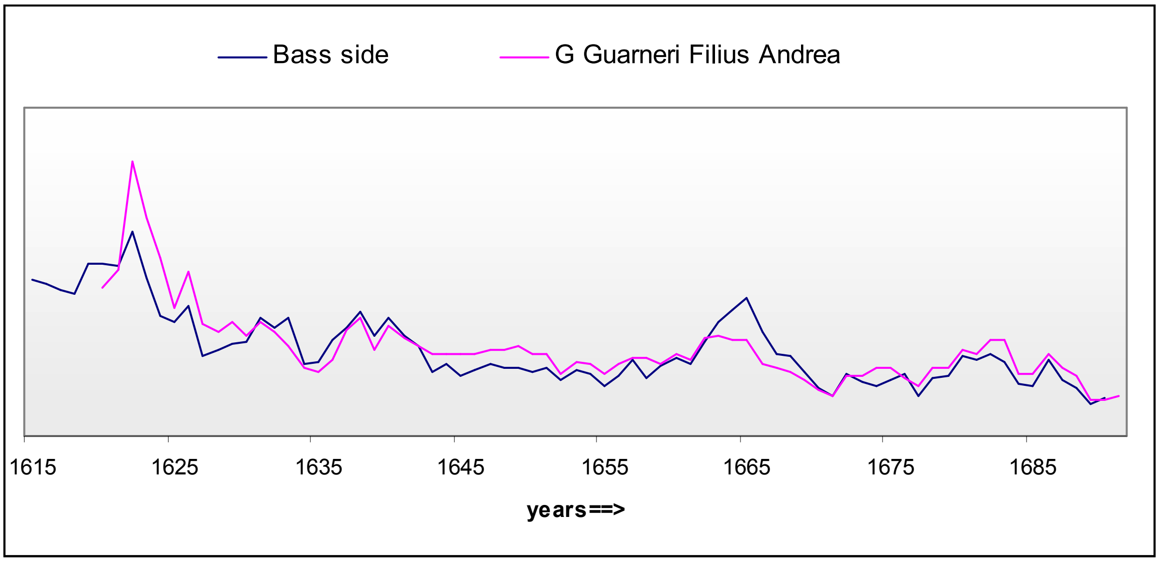
Correlations with the treble side

Data corelating with TREBLE SIDE	t-value	dates	overlap	Glk
Italian Instruments mixed chronology	9.2	1613-1695	82	64.8
COUNTERPART BASS SIDE	8.94	1613-1695	76	70.0
Attributed to Pietro Guarneri Venice AP5949 JC	8.55	1613-1695	56	65.5
G.B Guadagnini i4780m	8.12	1613-1695	63	66.9
G Guarneri Filius Andrea y/hh/t	7.57	1613-1695	72	72.5
1735 G.Guarneri Del Gesu' k/t	7.47	1613-1695	76	60.7
1769 Jose Contreras jm/t	7.21	1613-1695	48	64.9
c.1739 Camiillo Camilli p414.m	7.14	1613-1695	73	64.6
Joseph Guarneri Filius Andrea y/t/b	7.14	1613-1695	56	65.5
Joseph Gagliano l112/ih	7.14	1613-1695	74	63.0
1742 G.Guarneri Del Gesu ob/3978	7	1613-1695	69	60.3
Jose Contreras 1767 ap/t	6.96	1613-1695	82	63.0
1721 A Stradivari bp /es	6.88	1613-1695	71	62.9
Jose Contreras (CR/t)	6.83	1613-1695	82	61.1
Sanctus Serafin violin b060	6.82	1613-1695	82	51.9
1769 Jose Contreras cello sat/b	6.76	1613-1695	82	62.3
Domenico Montagnana eb2013	6.64	1613-1695	64	65.1
1715 A.Stradivari violin al/t	6.57	1613-1695	51	62.0
1734 A.Stradivari violin wm/t	6.48	1613-1695	77	61.8
1716 A.Stradivari violin bw	6.48	1613-1695	75	63.5
Michael Platner c1728/30 cello JJR	6.46	1613-1695	82	64.2
1744 Jose Contreras viola de gamba	6.4	1613-1695	64	66.7
1709 A.Stradivari violin y023/b	6.39	1613-1695	82	59.3
Attributed to Camillo Camillli schr/12	6.33	1613-1695	36	65.7
Violin/A.Stradivari table NMM	6.33	1613-1695	61	65.0
1717 A.Stradivari violin tr/b	6.31	1613-1695	72	59.2
1735 Carlo Bergonzi violin br/t	6.27	1613-1695	63	65.3
Violin Cremona ca.1730/35 vn/m	6.26	1613-1695	82	62.3
Violin composite A.Stradivari top. Lt130/ih	6.25	1613-1695	81	65.0
Top cello Contreras 1769 (Christina) tr	6.24	1613-1695	82	60.5
1709 A.Stradivari violin vt/b	6.2	1613-1695	81	64.4
Violin Mittenwald school c.1760	6.09	1613-1695	29	71.4
Gasparre Lorenzini violin ih/h000159	6.07	1613-1695	54	66.0
G.Guarneri Filius Andrea violin s027/ih	6.07	1613-1695	82	58.6
1717 A.Stradivari th/b	6.06	1613-1695	71	63.6
1767 Jose Contreras col/b	6.05	1613-1695	60	56.8
1777 Michele Deconet violin eb07/b	6.05	1613-1695	44	70.9
1711 A.Stradivari li/t	5.99	1613-1695	82	58.6
LP1751 Louis Panormo Guitar 1PF	5.98	1613-1695	82	72.2

Notes on the cross dating results

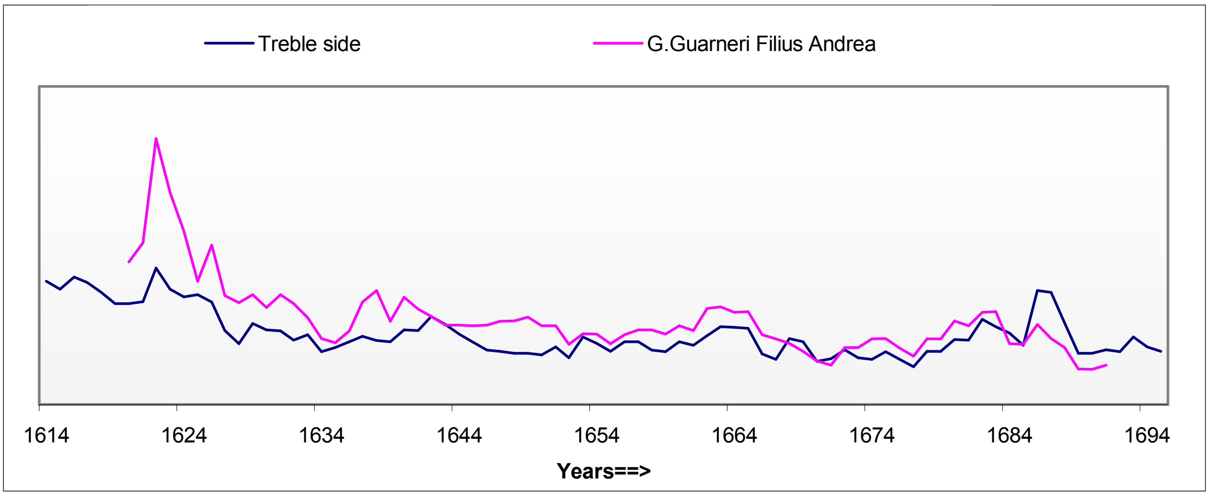
The database in use, leading to the above results is mixed and comprehensive. It contains data from instruments from all over Europe, irrespective of their country of making or period of manufacture as well as instrument chronologies. We note, however, the overwhelming presence of correlating data from instruments made in Italy in the output, suggesting a common source for the wood used in Italy at the time.
We also note the presence of several instruments by the Spanish maker *Jose Contreras* (b.1710, d.1775). Recent dendrochronological research in the production of Spanish eighteenth century makers, and in particular that of Jose Contreras, (in: *The Golden Age of Spanish Violin Making, Trito Edicion, Barcelona 2014*) has revealed that throughout his life, Contreras sourced his spruce tonewood from the same locations as those supplying the Italian market in that century. Tree-ring data from his violins therefore appear in the majority of cross-dating results from classical Italian violins.

Graphical comparison of correlating datasets is an essential and integral part of a dendrochronological analysis. The statistical results, here in the form of the *Student's t-value*, according to Baillie & Pilcher (1973), itself derived from the *Pearson's moment correlation coefficient*, highlight the better matching growth patterns. Subsequent graphical comparisons illustrate the relationship between these patterns.



Graph 2. *Graph comparing the ring widths of the bass side with those of the front of a violin, also by G.Guarneri Filius Andrea , which represents the highest correlation achieved with data from an instrument (t-value=10.44).*

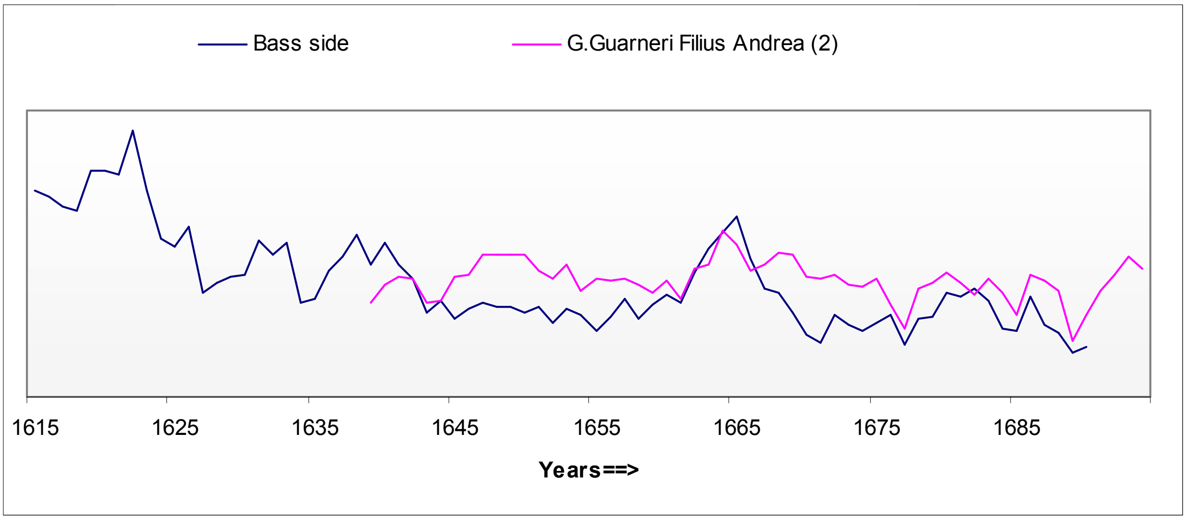
Interestingly, the visual similarity between the two curves in the above graph is more obvious between these two separate instruments than it appears to be between the two sides of the violin under study (*Graph 1*). Although the threshold for a same tree match is not reached in this instance, the notable correspondence of the tree-ring patterns could indicate the occurrence of wood from the same tree, albeit from a different location within the log. It is also worth noting that out of the entire database, with over 10,000 datasets, the most significant correlation happens to coincide with the soundboard wood from an instrument by the same maker. Comparing the treble side with the same data from the other violin by Guarneri Filius Andrea in the following graph, which also correlates significantly, although not to the same level as the bass side does, we can still see an appreciable similarity between the two.



Graph 3. *Graph comparing the ring widths of the treble side with those of the front of a violin, also by G.Guarneri Filius Andrea , achieving a significant (t-value=7.57).*

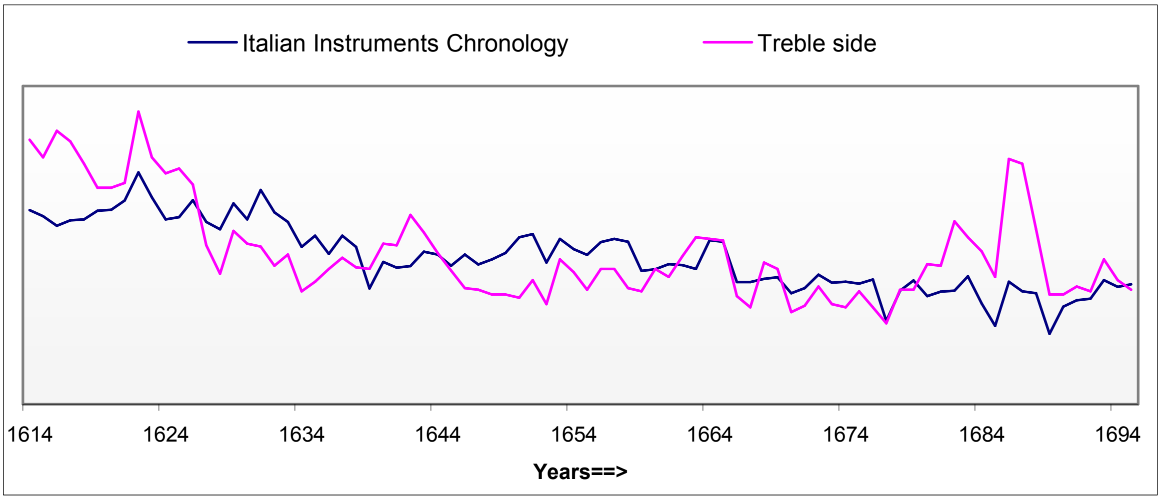
Research on instruments made in Italy in the 18th century, strongly suggests that some makers often purchased logs, or part of logs, rather than ready cut or split wedges. There are many instances, whereby the bellies of several instruments made in the same workshop, display such similarities between their tree-ring patterns that theses could only have originated within the same tree. We also come across "same tree matches" between instruments made in different locations in Italy, sometime hundreds of kilometres apart, strongly suggesting specific and reserved growing locations serving the Italian instrument making community. So far, as mentioned earlier, one exception to this rule is found with all instruments made by Jose Contreras in Spain, as all the cross-matching evidence points to a common source for the spruce he used shared with Italian makers.

Another significant correlation is seen in the results of the bass side, against data from yet another different violin by G.Guarneri Filius Andrea, although the two series of tree-rings overlap only over a portion of 52 years. The plotted data below shows some relationship between the two.



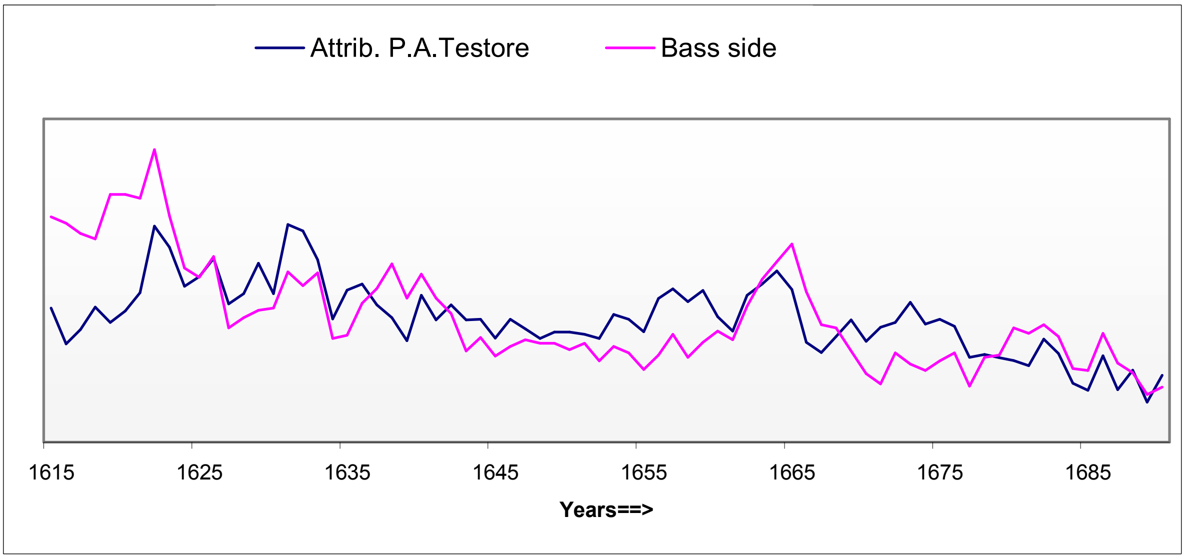
Graph 4. *Graph comparing the ring widths of the bass side with those of the front of another violin, also by G.Guarneri Filius Andrea , achieving a significant (t-value=6.49) over the overlapping section of 52 rings*

The graph below, represents the plotted data of the most significant correlation obtained with the treble side of the G.Guarneri Filius Andrea, against an *chronology* compiled with well correlated data from Italian instruments exclusively and achieves a highly significant *t-value* of 9.2



Graph 5. *Graph comparing the ring widths of the treble side alongside an Italian Instrument chronology*

Another significant correlation is represented below, against the bass side of the Guarneri Filius Andrea and was achieved against data from a viola, attributed to *Paolo Antonio Testore* of Milan. The plotted graph below represents the overlapping data of the two, as the viola ring sequence extends at either end of that of the Guarneri violin. A *t-value* of 8.19 is reached here and represents the second highest correlation obtained from the bass side data versus data from individual instruments.



Graph 6. *Graph comparing the ring widths of the bass side with those of the front of a Milanese viola attributed Paolo Antonio Testore*

A note on wood provenance

The precise growing location of the spruce tonewood used to make the belly of this violin by Giuseppe Guarneri, Filius Andrea is unclear. Cross-matching tests were undertaken against a variety of Alpine references but only reached low levels significance compared to the very significant results achieved with previously dated instrument data. A mixed Alpine reference chronology, although correlating at the dates mentioned, did not achieve significant enough levels to deduce a specific location for the growth of the trees.

Cross-dating tests were also carried out between the mean chronology (combined bass and treble side data) as the two sides obtained highly significant levels of correlation between each other (*t-value*=8.94). This indicates a close relationship between their respective trees, and therefore represents a more general response to the environment. The results, as well as containing far more instruments than the individual bass and treble series did, also identified several correlations with reclaimed architectural spruce beams from buildings erected in the late 17th and early 18th centuries in northern Italian valleys. Further sampling is required in order to try to establish more precisely the specific areas where spruce *tonewood* was harvested, and attempt to allocate these distinct locations to specific geographical areas of manufacture.

Our research, as well as that by other practitioners specialising in the dendrochronology of instruments, show strong inter-correlation between tonewood used in individual countries during specific periods. Generally, the spruce logs used by many Classical Italian makers, in town such as Cremona, Venice, Rome, Naples and Bologna, correlate statistically and graphically better between each other than they do with wood from instruments made outside Italy, in particular during the first half of the 18th century.

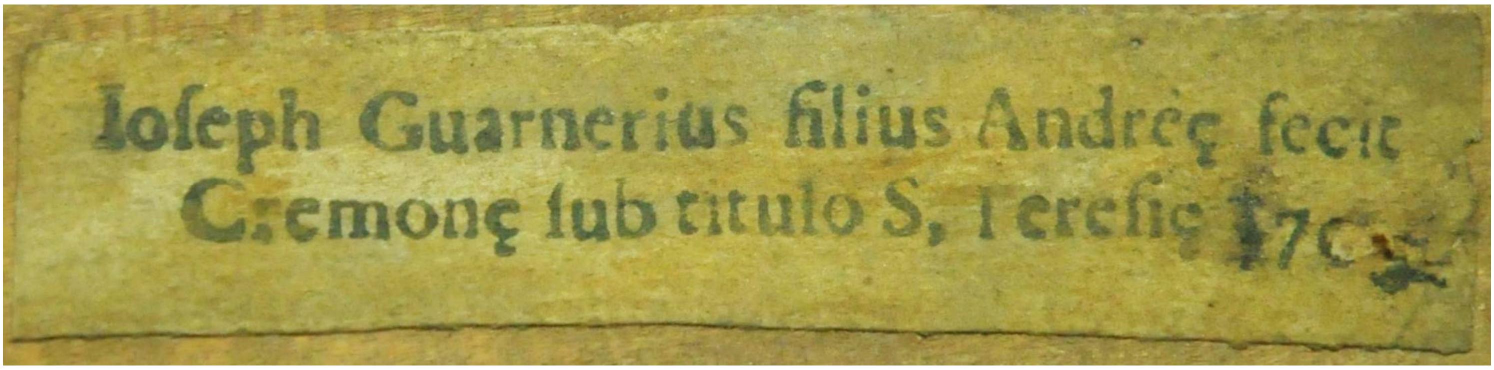
Conclusion

All the statistical tests, combined with the evaluation of many comparative graphs, have together determined that the *terminus post quem*, or the earliest possible felling date in the case of the tree used to make the front of this violin, is very soon after **1695.**

The difference between the “latest ring date” (1695) and the possible date of manufacture is naturally a matter of conjecture, and this instrument could indeed have been made at anytime after **1700.**

Following many dendrochronological tests on the spruce wood used by Italian makers in general, it has been found that the period between the latest ring date and the attributed date of manufacture varies greatly. In a few cases we encountered, this time span was occasionally shorter than 5 years, in most, a period 10 to 25 years elapsed between the dendrochronological date and the year of manufacture.

The results of this dendrochronological analysis therefore support an attributed manufacturing date of **circa 1705.**



Giuseppe Guarneri's label on the inside back of the violin

Appendix

Violin Dendrochronology explained

Dendrochronology, the science used to date wood, is becoming an important part of a thorough musical instrument appraisal. It has the ability to establish with great accuracy, the exact period in history when a tree, used in the making of the front of an instrument, was growing. The main purpose and the only certainty achieved from a successful analysis, is a date, pertaining to the last growth ring actually visible on the front of an instrument, which preferably should precede, by at least a few years, the death of the attributed maker.
There are a number of misconceptions, and inaccuracies concerning dendrochronology, and what it can and can't do. What it cannot ever do is ascertain the author of an instrument, nor confirm an attribution. It can, however, suggest historical links within one workshop, between makers, towns and countries. The more data that is accumulated, the more these links become apparent and are strengthened by each new instrument measured. Of course, there will always be a number of instruments that will not yield a result. In these cases, the reason is simply a lack of matching reference with which to compare them

Reference chronology data are a collection of sequences of measurements, many of which are published, carefully catalogued and their precise geographical location accurately documented. Many data (sequences of growth ring measurements) are collected from trees of known age (living trees), and from historical buildings, in many areas and forests. The reference chronologies are compiled from dozens of these sets of measurements mathematically combined together. By combining those sequences, the microclimatic effects of local variations are often reduced. Decreasing the effect of localised geophysical and weather related conditions, results in data containing information of a more general pattern than the one contained in a single tree sequence. Apart from these chronologies, references can also be obtained combining data from instruments generally accepted by experts to have been manufactured in a particular location and displaying particularly well matching growth patterns.
As the majority of instruments' harmonic tables were and are still made from spruce (Picea abies (L.)Karst), the dendrochronology analysis is mostly carried out against a database from that species. The reference may also contain data from other species of conifer, which are known to have occasionally been used, and therefore may help in the dating process.

T-values and GLK

When a set of measurements taken from a sample, in this case an instrument's harmonic table, is "compared" with a whole database of other sets of measurements, part of the method used involves advanced mathematical calculations. The result (or one of the results) is a statistical value known as *Student's t-value*. In practical terms, it highlights the degree of similarity between the sample and the reference database. The results of a statistical test will show some very low t-values, which will be ignored, and some higher ones, which will mostly be of significance. Together with these values, the dated part of the reference database, will also come up with a suggested date for the sample. The low significance t-value will often be accompanied by various spurious dates, whereas the higher ones should suggest the same dates.

The *t-value* is expressed as a number, ranging from nil to infinity, but in practical terms, a value of below 2.5 can be considered completely insignificant, and the highest one can hope for is probably about 18.
Other mathematical calculations are often applied to the measurements, revealing extra information as to the relationship between two or more samples. The *Gleichläufigkeit* or *GLK*, is a useful indicator of a possible relationship between samples. It represents the *percentage of parallel agreement* between tree rings of the sample and the reference. Compared to the previous year's growth, the width of a tree ring will either be wider, narrower or equal to it.

Every time this scenario is replicated in both sample and reference during the same period, the GLK score increases.
As well as the *t-value* and the *GLK*, graphical representations of the sequential measurements from the sample and relevant matching reference are produced in order to compare them visually. The graphs illustrated in the reports often compare two sequences, or “curves”. Each curve represents the plotted measurements of the sequential tree ring widths. After evaluating the various statistical results, together with an essential graphical comparison of the data, one can then make an educated assessment of the relationship between the sample and the reference chronologies.

If the wood used on a particular violin front grew in a situation prone to microclimates, or subject to much human interference, its growth pattern over the years may well be similar to the one from an adjacent tree. However. It will not necessarily have much in common with the growth pattern from a tree that grew fifty miles apart. Therefore, unless specific tree growth pattern information about that particular area is available, and is an integral part of the reference used, no positive results will be found. In the instance when no date is found, a strong and valid correlation may still be revealed against another instrument, as long as both trees that were used grew at close proximity to each other. The data collected from the two (or more) undated instruments can, when the quality of the match is good enough, be combined to form what is described as a floating chronology. This new chronology often loses the original individuality of the single sequence (which may have prevented dating) to become more closely associated with the general climatic pattern and in time reveal the correct dates of these samples.
The likelihood of trees from different locations and different time periods displaying similar growth patterns, in practical terms, doesn’t occur, at least not for a long enough period, which is why a minimum of sixty years growth is required in a sample to make an assessment and to avoid reaching the wrong conclusions. Most violin fronts have enough growth rings to perform an analysis. Occasionally however, a spurious match of good statistical significance is found against one reference chronology, but, as one of the principles of successful cross-dating is the repeatability of the correct results against several reference chronologies, the bogus date is normally quickly exposed, as the statistical likelihood of the wrong result being duplicated is negligible. Furthermore, a graphical comparison will almost certainly reveal that in fact, the two curves are not similar enough to have a temporal relationship. One good result is never enough to come to a conclusive date. That is why an extensive database is crucial to a comprehensive study and to reach a conclusive date. If any doubts remain a further test is often carried out, involving testing sections of the data independently.
On the whole, instruments fit into “*dendro” categories*, with wood origin appearing to be fairly specific according to period and country and with categories often merging or overlapping.

Written dendrochronological reports

A written report will normally contain, as well as a "most significantly matching" date, information on significantly matching reference chronologies and/or significantly matching instruments. “Significantly” in the case of dendrochronology results, means a match that exceeds a certain degree of statistical correlation, or in other words, two pieces of wood whose growth pattern match to a good enough level to conclude that their growth occurred simultaneously. So a detailed report may sometimes include “significant match” information, where the *t-value* exceeds 6 or 7, and graphical comparison charts of well matching sequences illustrating an obvious relationship. The dendrochronological dates are reached after careful evaluation of the statistical and graphical data obtained after analysis. If there are any doubts as to the accuracy of those dates, no date can be put forward and no report will be issued.
Occasionally, the statistical significance will be so high and the graphs of the data so similar between two samples, that same tree origin can be suggested. Of course this situation is often observed after comparing the two halves of one instrument. On different instruments however, this sort of match is very seldom met with, and when it does happen, it raises very interesting questions. But even a “same tree” match is no proof of authenticity; it is an exciting occurrence that invariably and rightly leads to speculation as to the possible historical reasons for this result. This however falls outside the remit of dendrochronology.

There is no such thing as a perfect match in dendrochronology. A perfect match would entail exactly matching growth ring widths over a given period. If a sequence of measurements taken from a sample at a given axis, is repeated one inch below that axis, it will yield different microscopic measurements (not different dates) simply because cell growth in wood is not perfectly uniform.

Confirming a specific manufacturing date following a test is not possible with dendrochronology. It can only confirm the likelihood of this date. However, the observations made and accumulated over hundreds of dendrochronological analyses can offer an insight into past practises, such as the seasoning of tonewoods, or the passing down of wood stock from generation to generation within a family of makers. What is important is that these observations, in order to be legitimate, should be collected from genuine and correctly dated instruments.

Sometime the structure of the wood can lead to speculation as to the felling date, but as the last ring isn't actually present, this is only conjecture.

Wood generally used for violins is highly selected, often from managed forests. It is normally straight grained, quarter sawn, without knots nor resin pockets. It is therefore ideal material for dendrochronology, because it is, as far as nature allowed, free from defects. Unlike wood samples collected for the reference chronologies, which may contain all sorts of growth anomalies due to countless reasons, instrument tonewood is chosen for its apparent even growth pattern. This pattern however is finely tuned and contains the best available information for dendrochronology dating purposes.

Conclusion

In the world of musical instruments, where expert opinions from a hundred years ago have been disproved by today's authorities, and may be reinstated by tomorrow's experts, Dendrochronology offers something quite unique which is not an opinion based on visual knowledge and experience, but a concrete and proven scientific method leading to an unbiased result.

Dendrochronology is another tool, often used when there is a doubt about an attribution. It can indeed upset a traditional provenance and can make for very uncomfortable reading in certain cases, yet presents a true scientific result, which can be demonstrated and verified, irrespective of all the stylistic attributes of the instrument.

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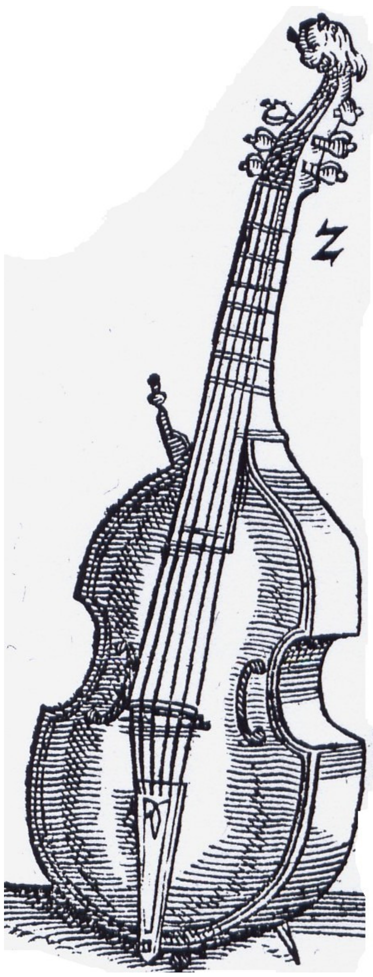
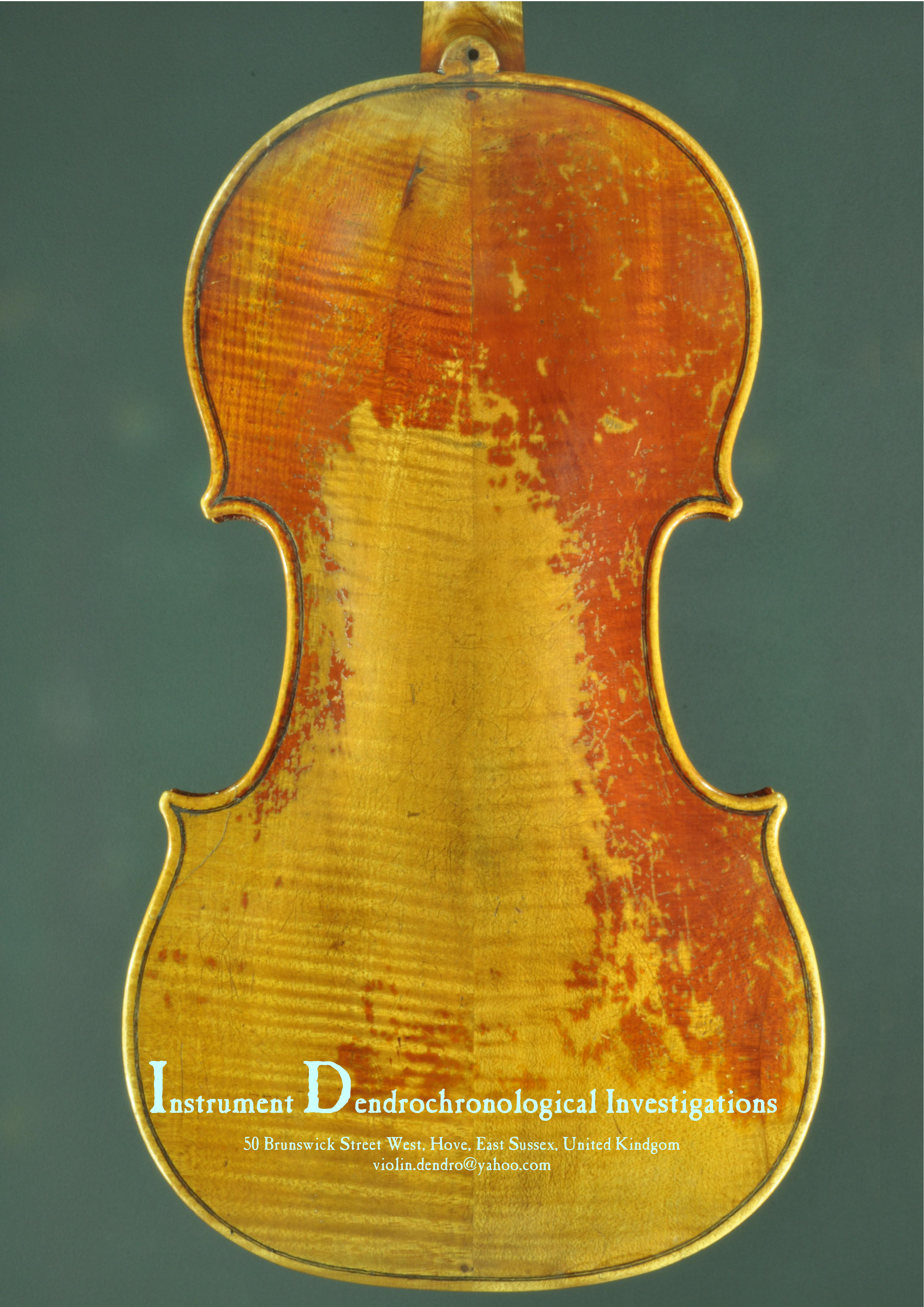



AGRI CREMONENSIS TYPVS.
BERGOMATIVM DITIONIS PARS.
CREMAE DITIONIS.
PARS
LAVDAE POMPE: AE DITIONIS PARS
PLACENTIAE DITIONIS CONFINIA.
OCCIDENS.
BRESCIA Venetorum ditionis
Cremona.
Piacenza.
Soncino.
Castelleone
Pizighiton arx
Ollio fiume.
Adda fluuius
Mozza fluuius
Po fiume
PADVS FLVVIVS.
Scala Milliarium Jtalicorum
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

SEPTENTRIO.
CREMAE DITIONIS DESCRIPTIO.
SEPTENTRIO.
Bressanensium confinia.
ORIENS.
MERIDIES
Mediolanensium confinia
diolanensium confinia.
CREMA
Serio flu.
Addua flu.
Lodi
Pandino
Lectori
Ne tabula hoc loco omnino vacua extaret, hoc Cremę territorium à quodam patrię studioso descriptum hic studiosis exhibere placuit.
MANTOA
S. Maria de Gratia
Curtaton.
Chastelluzzo
Asola, Venetorum ditionis.
Caneto, Mantuanorum ditionis
Marcaria, Ducis Mantuani
Borgo forte Ducis Mantuani.
Ollio flu.
Ollius flu.
Tor ollio
ORIENS.
PADVS FLVVIVS.
Casal maiore
Sabio
Guastalla Dñi Cęsaris Gonzage
Brisello, Ducis Ferrariensis.
Lenza flu.
Colorni, Dñi Frācisci Seuerini.
Parma flu.
Torsella, Parmensium ditionis.
Tarro flu.
PARMENSIVM DITIONIS PARS.
MERIDIES.
Antonius Campus pictor Cremonensis descripsit, 1579.
Cum Priuilegio.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