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RADIOCARBON DATING OF LEGACY MUSIC INSTRUMENT COLLECTIONS: EXAMPLE OF TRADITIONAL INDIAN *VINA* FROM THE MUSÉE DE LA MUSIQUE, PARIS

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ABSTRACT. Although radiocarbon (^{14}C) dating is commonly used for archeological music instruments, little research has been conducted on modern instruments (16th–19th centuries). New technology, based on the Mini Carbon Dating System (MICADAS), enables some of the recurring challenges (e.g. sampling size) to be circumvented and paves the way for a new field of investigation. We here address the Indian instrumentarium, about which very little is known. We investigate the making and the restoration phases of two *vina*, a *kinnari vina* (E.1444), and a *rudra vina* or *bin* (E.997.24.1). By comparing ^{14}C measurements made on several samplings of elements of the instruments with museological information, we were able to specify a unique calibrated interval of ages [1666 AD–1690 AD] for the *kinnari vina*, with a restoration phase [1678 AD–1766 AD] for the upper nut. The *bin* is likely attributed to the [1650 AD–1683 AD] interval.

KEYWORDS: ^{14}C dating, modern musical instrument, small sample.

INTRODUCTION

Several challenges have to be met concerning the radiocarbon (^{14}C) dating of modern music instruments made between the 16th and 19th centuries. Dendrochronology cannot be carried out on modern music instruments as the tree-ring record is too short and ^{14}C dating may be a priori rejected for historical periods as a ^{14}C physical measurement may result in several equiprobable age ranges. Several samplings and independent expertise are then required to make a well-considered choice between these intervals. Owing to the new generation of ^{14}C dating instruments, a compact ^{14}C dating system such as the Mini Carbon Dating System (MICADAS) (Synal et al. 2007) allows some hundreds of micrograms of material to be sampled. For wood, the sample is thus as small as a pinhead. This new technology opens the door to multisampling without it being visible and without it affecting the instrument's playing quality. This might at least partly resolve issues of multi-interval calibration. Beyond the physical analysis, museum studies are another reliable means of investigation to attempt to find clues to the manufacturing period and history of the instrument. This approach involves the gathering of documents, the expertise of curators and restorers, and reports of scientific analyses used in cultural heritage institutions that are required for the study of instruments using ^{14}C dating. The interdisciplinary framework makes it possible to combine any *ante quem* or *post quem* information on the age of relics or music instruments. In this approach, we will draw on an ongoing project on modern music instruments involving radiocarbon dating specialists and museum experts. There are three challenges to be overcome: (1) the sample size, which will not extend beyond a few hundred micrograms, (2) the composite constitution of the instrument (varnishes, glues, restored parts), which requires specific and complex chemical protocols to extract the

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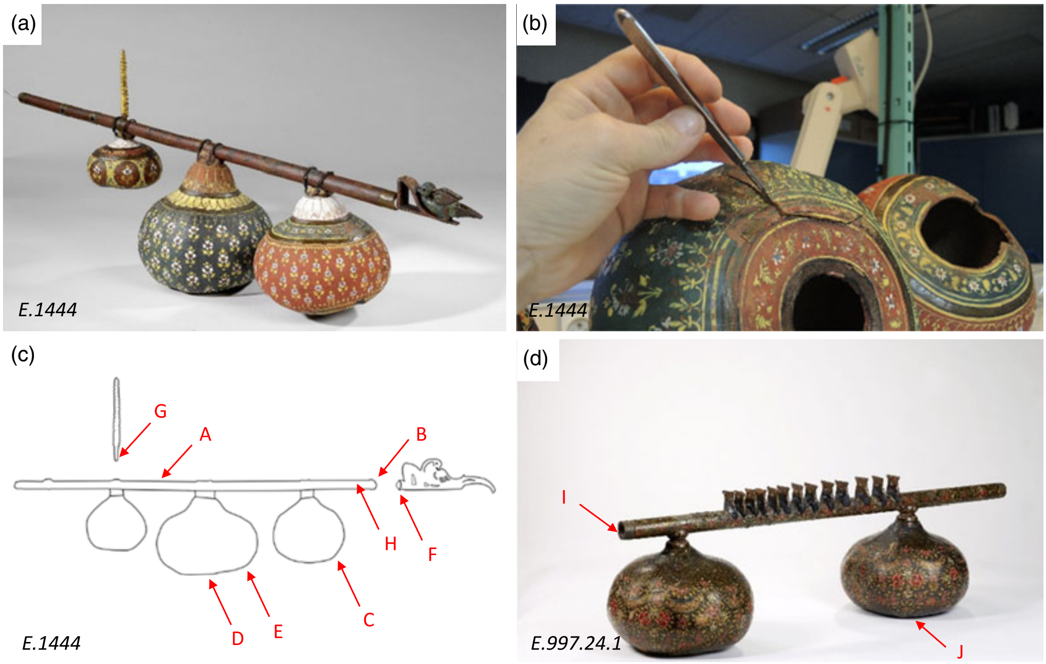

Figure 1 Indian *vina* from the museum collections and sampling locations: (a) *kinnari vina* E.1444, (b) close up of sampling in a crack from *kinnari vina* E.1444, (c) schematic view of the *kinnari vina* E.1444 and location of the 8 samples, (d) *bin* or *rudra vina* E.997.24.1 and sample locations. Pictures by Claude Germain (a, d) and Stéphane Vaiedelich (b) © Musée de la musique-Philharmonie de Paris.

carbon to be dated, and (3) the historical period which is not favorable to radiocarbon dating due to complex calibration curves. Our goal here is to date two amazingly well-preserved *vina* about which little information is available and possibly contribute to scientific knowledge about their origin and the history of their making.

MATERIAL AND METHOD

Material

Our study focuses on two *vina*, Indian stringed instruments belonging to the tube zither family and kept at the Musée de la musique in Paris. The first one is a *kinnari vina* (E.1444, Figure 1a,b). The second one is a *bin* (also called today *rudra vina*) (E.997.24.1, Figure 1d), which was played for centuries in North Indian princely courts. *Vina* are composed of a wooden tube onto which are fixed gourds which act as resonators. The conservation state of both *vina* is exceptional, although the constitutive and painted parts are very fragile and the storage conditions under the initial tropical climate were unfavorable, according to museum studies. Visual inspections under an optical microscope, endoscopic analysis, x-ray digital radiography, and XRF investigations were performed during museum studies and showed no visible evidence to suspect that certain parts had been replaced. None of the *vina* showed visible surface contamination. The decorations are original and it is very likely that gourds were chosen with care according to their acoustic properties (Bruguière et al. 2008).

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The *kinnari vina* (E.1444, Figure 1a,b) is made of three gourds (*Lagenaria siceraria*) fixed under a reed tube, made of *Arundo donax*, a species found in East and Southeast Asia. This makes this *kinnari vina* singular. A piece of wood from a *Dalbergia latifolia*, named "Indian rosewood," was carved in the form of a bird (a parrot) and inserted at the end of the tube. This part was used as a string holder and a bridge. The upper nut painted yellow with orpiment is made of *Artocarpus chama Buch*, a wood commonly called "terap" and found in Southeast Asia. An ancient iconography (Day 1891) presents a *kinnari vina* showing the same singular features without any decoration. The *kinnari vina* E.1444 entered the collections in 1892. It was sold to the museum by Gand and Bernardel, renowned Parisian violin makers and valuable music instrument dealers of the 19th century, who may have bought it in a public sale. The floral pattern of this *kinnari vina* is a motif found on 17th and 18th century artifacts produced in the region of Hyderabad (Andhra Pradesh) situated in Southeast India. According to the curator who relies on organological features and the painted patterns, this musical instrument could have been made in the 18th century.

The *bin* or *rudra vina* (E.997.24.1, Figure 1d) consists of two resonators made of gourds, a tube made of teak wood (*Tectona grandis*), and 13 wooden frets. The pegs and the string holder are missing. A mixture of beeswax and plant resin was traditionally used to stick the frets onto the tube. The highly sophisticated decoration of this *vina* comprises five successive layers: an undercoat of clay with iron oxides, a support of metallic sheet in tin, an organic layer with resin and paint layers. This *bin* was acquired by the museum in 1997. It is referenced as coming from Rajasthan, Northwest India, and it has been tentatively dated from the first half of the 17th century.

Method

Sampling

The ^{14}C activity was measured on 7 subsamples, representative of each of the constituent elements, of the *kinnari vina* (Figure 1c, Table 1) and on two subsamples of the *bin* (Figure 1d, Table 1). An eighth sample was taken on the *kinnari vina*: a black glue residue found inside the tube (Figure 1c, sample H). All the samples were of less than a few hundred micrograms of carbon. Samples taken from both *vina* belong to original components of the instruments. Each of them is devoid of any traces of varnish, painting, and wax and protected from other environmental contamination. They were taken in nonvisible areas inside the gourds or the tube, inside cracks, etc. (Figure 1b).

Treatment

As no visible surface contamination was highlighted through previous investigations and samples were extracted from hidden, uncolored parts of the instruments, a simple chemical treatment was enough to prepare the samples for ^{14}C dating.

The samples were treated with the classical AAA chemical pretreatment for wood and charcoal samples (Van Klinken and Hedges 1998). All chemicals were of ultrapure quality, and water was ultrapure (MilliQ grade). Chemical glasses were pre-combusted at 500ºC overnight prior to use and were preserved in Al foil (burnt at the same time). The procedure is as follows:

HCl 0.5M, ambient temperature, sample is rinsed until pH = 5

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NaOH 0.1M, ambient temperature, sample is rinsed with hot water until pH = 5 (80ºC)

HCl 0.5M, ambient temperature, sample is rinsed until pH = 5

Clean samples were transformed into CO_2 by flame-combustion with pure O_2. Evolved gases were passed through a trap kept at –80ºC (ethanol–dry ice mixture) and on Cu/Ag to get rid of water, O_2 excess and sulfur and nitrogen oxides. The amount of pure carbon was evaluated by a pressure transducer. Pure CO_2 was then flame-sealed, under vacuum, in one or several Pyrex tubes until measurement. No more than 140 µg of C were preserved per tube.

To control the impact of chemical treatment and of the combustion, we also ran "blank" and international standards (SIRI G—Scott et al. 2017). As a "blank," we used a $F^{14}C=0$ charcoal, known as "Afrique du Sud," from inside the Border cave (South Africa) in a Paleolithic level (Middle Stone Age) dated to more than 70 kya.

Physical Measurements

The mass spectrometer *ECHo*MICADAS (^{14}C AMS) was used to measure the ^{14}C activity of each sample (Synal et al. 2007; Tisnérat-Laborde et al. 2015). The gaseous samples (from 30 to 140 µgC) were directly injected into the MICADAS gas source through the gas ion source interface (GIS) (Ruff et al. 2010) by tube cracking. Ages were obtained from ^{14}C measurements using Bats software by comparing $^{14}C/^{12}C$ ratios with OXII standards (Wacker et al. 2010). Most of the samples provided several tubes of gas. All the tubes were separately measured, but results were statistically combined. The mean age of the sample then derives from the mean of the individual measurements, which pass the Chi^2 test, and is associated to the maximum between the Chi^2 reduced error and the standard deviation between the median of the individual measurements. Results are expressed in $F^{14}C$ as recommended by Reimer et al. (2004) and provided as ^{14}C ages (yr BP) following Stuiver and Polach's (1977) convention. Probability distributions of calibrated ^{14}C ages were

Table 1 List of samples from *kinnari vina* and *rudra vina* (refer to Figure 1 for locations).

Vina #	Sampling #	GifA #	Sampling description
Kinnari-vina E.1444	A	GifA18172	Inside the central part of the tube in the thickness of a crack
	B	GifA18173	Inside the end of the tube on the bird bridge side
	C	GifA18174	In the thickness of a broken part of the red gourd
	D	GifA18175	On the inner surface of the green gourd
	E	GifA18176	Inside a crack of the green gourd
	F	GifA18177	Part of the bird bridge that fits into the end of the tube
	G	GifA18179	Part of the upper nut that fits into the tube
	H	GifA18178	Black glue-like residue from inside the tube
Rudra-vina E.997.24.1	I	GifA17279	Inside the tube
	J	GifA17278	Under a gourd

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generated using OxCal v4.3.2 (Bronk Ramsey 2009) based on the IntCal13 calibration curve (Reimer et al. 2013). All data are provided in Tables 1 and 2.

RESULTS AND DISCUSSION

Vina resonators are made of gourds that are fast growing and quickly dried plants. The same is true for the reed used as the tube for the *kinnari vina*. This means that the ^{14}C dating will correspond to the year of manufacture to the nearest 1 to 3 years. The *rudra vina* tube, in contrast, is made of teak that is either a fast or a slow growing species depending on the environment. Examination of the tube revealed that it cannot have come from a branch but from a piece of turned wood. It comes from a beam that was drilled all along its length. We do not know *a priori* if it was extracted from the external part (the youngest part) or from the internal part (the oldest part) of the tree.

Kinnari Vina (E 1444)

^{14}C data obtained for each sample are shown in Table 2 and Figure 2. The F^{14}C data recorded for six samples (GifA18172 to GifA18177) were unexpectedly very similar: 0.983 ± 0.005 (GifA18172), 0.977 ± 0.005 (GifA18173), 0.977 ± 0.005 (GifA18174), 0.977 ± 0.006 (GifA18175), 0.977 ± 0.005 (GifA18176), 0.982 ± 0.007 (GifA18176), 0.977 ± 0.009 (GifA18177). Hence, they correspond respectively to similar ^{14}C dates: 135 ± 40 yr BP, 190 ± 40 yr BP, 190 ± 50 yr BP, 190 ± 45 yr BP, 150 ± 55 yr BP, 190 ± 75 yr BP. This result supports the conclusions of the museum studies that these pieces are original, and therefore correspond to the period when the instrument was made. The result for the upper nut (GifA18179) is an exception: 0.986 ± 0.005, i.e., a ^{14}C date of 115 ± 40 yr BP. Unlike the first investigations carried out in the laboratory of the Musée de la Musique, this piece does not seem to be original.

Combining the results of this series (7 samples) using the "combine" option of Bayesian modeling (Bronk Ramsey 2009) shows that the individual agreement index (A) for the upper nut sample (GifA18179) is 60.4% whereas it is between 90 and 125% for the other six samples. It was therefore decided to perform the Bayesian modelling without the nut, i.e. using only the six subsamples labeled GifA18172 to GifA18177 (Tables 1 and 2). The resulting equiprobable calendar ranges are (Figure 2, Table 2): [1666 AD–1690 AD] (17.8%), [1730 AD–1784 AD] (49.8%), [1796 AD–1810 AD] (9.9%) (the last one, [1926 AD– . . .] is outlier data due to the Suess effect). The three main ranges of calibrated dates are defined as the end of the 17th century and the 18th century.

As mentioned above, the upper nut may not be contemporaneous of the *vina* manufacture. It could be a replacement of the original nut that was probably lost or broken. This fragile part is subject to breakage and was likely changed during the period when the *vina* was played. The main probable ranges for the upper nut are: [1678 AD–1766 AD] (32.5%), [1772 AD–1778 AD] (1.0%), [1800 AD–1941 AD] (61.9%).

The instrument was acquired in 1892 and no restoration has been carried out since it entered the museum. Any replacement was thus done before. The use of terap in 19th-century Europe in cabinet making and instrument making is not attested and remains highly unlikely. European instrument makers of this era probably did not have the organological knowledge of traditional Indian instruments to accurately reproduce this part, either. It is very likely that the replacement was done while the instrument was still in India and was

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Table 2 Conventional, calibrated and modeled ^{14}C ages obtained for the kinnari vina E.1444. Statistical results of Bayesian modeling are shown in the last four columns: for all vina pieces first and for the original pieces of the vina thereafter. Individual agreement (Aind) and combined agreement (Acomb) are provided. Resulting modeling intervals are provided under the main part of the table.

identification				uncalibrated data							calibrated age [1]		statistical combination			
				individual measurement		Chi2-Test (5%)	mean value						model 1 (A->G) [2]		model 2 (A-> F) [3]	
Sample ID	**Fig.1 ID**	**GifA #**	**ECHo #**	**$F^{14}C$**	**±**		**$F^{14}C$**	**±**	**age BP [yr]**	**±**	**calibrated age (±1 s) [range in yr] (probability distribution)**	**calibrated age (±2 s) [range yr] (probability distribution)**	**A_{ind}**	**A_{comb}**	**A_{ind}**	**A_{comb}**
vina E1444 - P1 tube	A	GifA - 18172	ECHo - 2353	0.983 0.984	0.007 0.007	0.21/3.84	0.983	0.005	135	40	[1680 - 1700] (8.9%) [1703 - 1707] (1.6%) [1720 - 1764] (18.0%) [1801 - 1819] (7.8%) [1824 - 1825] (0.2%) [1833 - 1881] (20.8%) [1915 - 1939] (10.7%)	[1669 - 1781] (41.7%) [1798 - 1894] (38.2%) [1905 - 1946] (15.6%)	99.1		89.8	
vina E1444 - P2 tube	B	GifA - 18173	ECHo - 2354	0.9738 0.9797	0.0066 0.0070	0.37/3.84	0.977	0.005	190	40	[1663 - 1683] (13.6%) [1736 -1806] (43.4%) [1931 - 1933] (0.7%) [1935 - … [(10.5%)	[1645 - 1699] (22.7%) [1722 - 1817] (49.8%) [1834 - 1880] (6.6%) [1916 - … [(16.4%)	106.4		116.4	
vina E1444 - P3 red resonator	C	GifA - 18174	ECHo - 2355	0.9768	0.0062	-	0.977	0.006	190	50	[1653 - 1690] (16.7%) [1730 - 1810] (39.6%) [1926 - … [(11.9%)	[1644 - 1712] (22.7%) [1719 - 1830] (45.2%) [1831 - 1891] (11.9%) [1909 - … [(15.5%)	119.8		126.5	
vina E1444 - P4 green resonator	D	GifA - 18175	ECHo - 2356	0.9795 0.9739	0.0077 0.0076	0.28/3.84	0.977	0.005	190	45	[1660 - 1685] (14.0%) [1733 - 1808] (41.8%) [1929 - … [(12.4%)	[1645 - 1708] (22.8%) [1719 - 1821] (47.3%) [1822 - 1826] (0.4%) [1833 - 1886] (9.1%) [1914 - … [(15.8%)	113.5	109.4	121.9	142.1
vina E1444 - P5 green resonator	E	GifA18176	ECHo-2357	0.9816	0.0066	-	0.982	0.007	150	55	[1669 - 1698] (11.2%) [1724 - 1781] (22.8%) [1798 - 1816] (6.9%) [1835 - 1878] (15.8%) [1917 - 1946] (11.5%)	[1665 - 1788] (44.5%) [1790 - 1895] (34.6%) [1904 - … [(16.3%)	115.3		111.9	
vina E1444 - P6 bird bridge	F	GifA18177	ECHo-2358	0.9766	0.0088	-	0.977	0.009	190	75	[1647 - 1696] (16.8%) [1726 - 1814] (32.4%) [1837 - 1844] (2.0%) [1852 - 1869] (4.4%) [1872 - 1877] (1.1%) [1918 - … [(11.5%)	[1523 - 1575] (5.0%) [1629 - … [(90.4%)	127.1		131.2	
vina E1444 upper nut	G	GifA18179	ECHo-2360	0.9864 0.9855	0.0064 0.0073	0.01/3.84	0.986	0.005	115	40	[1690 - 1730] (19.3%) [1810 - 1892] (40.4%) [1908 - 1926] (8.5%)	[1678 - 1766] (32.5%) [1772 - 1778] (1.0%) [1800 - 1941] (61.9%)	60.3			
vina E1444 - P7 inner tube deposit	H	GifA18178	ECHo-2359	0.7973	0.0066	-	0.797	0.007	1820	65						
												resulting calibrated age (±2 s) [range yr] (probability distribution)	[1668 - 1693] (16.2%) [1728 - 1782] (49.7%) [1798 - 1812] (10.7%) [1920 - 1949] (18.7%)		[1666 - 1690] (17.8%) [1730 - 1784] (49.8%) [1796 - 1810] (9.9%) [1926 - …[(18.0%)	

[1] using OxCal4.3.2 (Bronk Ramsey 2009) based on IntCal13 (Reimer et al. 2013)
[2] Chi2-Test: T= 3.30/12.59 (5%)
[3] Chi2-Test: T=1.54/11.07 (5%)

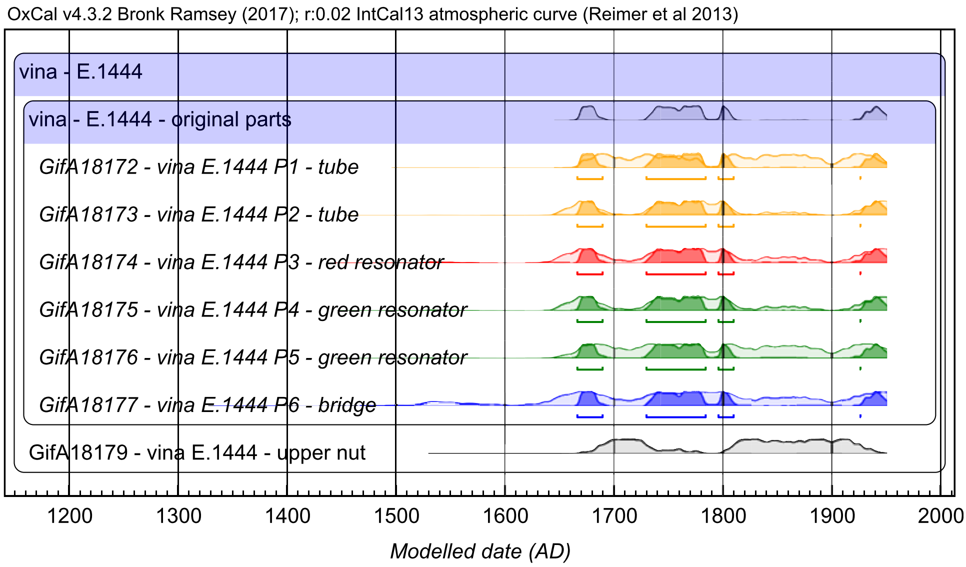

Figure 2 Calibrated ^{14}C ages of the *kinnari vina* E.1444. The upper probability distribution diagram, underlined in blue corresponds to the Bayesian modeling of the combination of the *vina*'s original parts. The probability distribution diagram of the restored piece (upper nut) is shown in the last line.

made by an Indian instrument maker. The only few slight traces of (musical) use on the upper nut seem to reveal that it was not played as much as the other parts of the *vina*. It is thus assumed that the nut was replaced during the [1678 AD–1766 AD] interval, towards the end of the musical use of the *vina*. Consequently, the instrument was made (age of the original pieces) during the [1666 AD–1690 AD] interval. It appears that the instrument is a little older than initially thought by the curator, who expected it to date from the 18th century.

Residue sampled in the *vina* tube shows quite different results, with F^{14}C equal to 0.797 ± 0.007, equivalent to an age of 1820 ± 65 BP (Table 2). Chemical characterization (chromatography, XRF . . .) of a new sample of the same black residue is in progress. It is known that bitumen-derived glue was used to maintain the tube when aligning elements and perforating holes. A balance equation between expected age (F^{14}C = 0.979, the modeled average of original pieces' F^{14}C) and a null ^{14}C content for a potential bitumen-derived component would result in a mixture containing about 20% of dead carbon in the resulting black residue, which is quite likely.

Rudra Vina **(E 997.24.1)**

^{14}C data obtained for each sample are shown in Table 3. Samples from the *vina* tube (GifA-17279) and the *vina* resonator (GifA-17280) provided very similar F^{14}C data: 0.976 ± 0.004 and 0.973 ± 0.005, respectively, equivalent to 195 ± 30 yr BP and 225 ± 40 yr BP, respectively. Calibrated ranges of dates of both samples are thus also very close (Table 3 and Figure 3) yielding three major ranges of dates, during the 17th century, the 18th century and associated to the Suess effect modern period. This concomitance of ages reveals that the tube was extracted from the external part of the tree and this allows Bayesian modeling to combine dating and reduce uncertainties.

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Table 3 Conventional, calibrated, and modeled ^{14}C ages obtained for the bin E.997.24.1. Statistical results of Bayesian modeling are shown in the last two columns. Individual agreement (A_{ind}) and combined agreement (A_{comb}) are provided. Resulting modeling intervals are provided under the main part of the table.

identification				uncalibrated data							calibrated age [1]		statistical combination [2]	
				individual measurement			mean value							
Sample ID	Fig.1 ID	GifA #	ECHo #	$F^{14}C$	±	Chi2-Test (5%)	$F^{14}C$	±	age BP [yr]	±	calibrated age (±1 sigma) [range in yr AD] (probability distribution)	calibrated age (±2 sigma) [range yr AD] (probability distribution)	A_{ind}	A_{comb}
vina E997.24.1 tube	I	GifA - 17279	ECHo - 1938	0.979 0.973 0.977	0.007 0.006 0.006	0.57/5.99	0.976	0.004	195	30	[1663 - 1681] (16.2%) [1739 - 1746] (4.9%) [1748 - 1751] (1.9%) [1763 - 1802] (33.5%) [1938 - 1950] (11.7%)	[1649 - 1691] (23.9%) [1729 - 1811] (54.8%) [1921 - 1923] (0.2%) [1925 - 1951] (16.6%)	111.7	
				0.972	0.007						[1644 - 1681] (29.8%)	[1524 - 1559] (4.1%) [1563 - 1571] (0.4%) [1631 - 1695] (34.5%)		120.7
vina E997.24.1 resonator	J	GifA - 17278	ECHo - 1939	0.973	0.007	0.007/3.84	0.973	0.005	225	40	[1740 - 1742] (1.0%) [1764 - 1801] (29.2%) [1939 - 1950] (8.3%)	[1727 - 1813] (43.4%) [1838 - 1842] (0.2%) [1854 - 1858] (0.2%) [1862 - 1867] (0.2%) [1920 - 1950] (12.2%)	116.9	
												resulting calibrated age (±2 s) [range yr] (probability distribution)	[1650 - 1683] (27.9%) [1736 - 1759] (9.4%) [1760 - 1805] (43.6%) [1935 - 1951] (14.5%)	

[1] using OxCal4.3.2 (Bronk Ramsey 2009) based on IntCal13 (Reimer et al. 2013)
[2] Chi2-Test:T= 0.30/3.84 (5%)

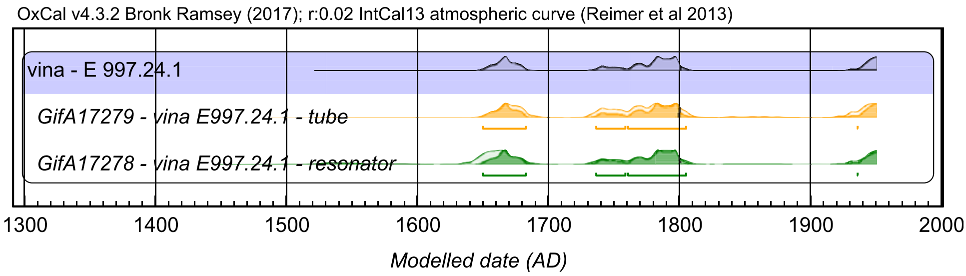

Figure 3 Calibrated ^{14}C ages for the two gaseous micro-samples from the *bin* or *rudra vina* E.997.24.1. The upper probability distribution diagram, underlined in blue, corresponds to the Bayesian modeling obtained by combination of bin ^{14}C results. (Please see electronic version for color figures.)

Bayesian modeling with OxCal (Bronk Ramsey 2009) reinforced the view that the two elements were associated at the same time and thus very likely correspond to the making of the instrument (Figure 3). Individual agreements, A, are 111.7% and 116.9%, respectively, resulting in a combined agreement factor of $A_{comb} = 120.7\%$. Modeling results in four equiprobable ranges of dates: [1650 AD–1683 AD] (28.1%), [1737 AD–1759 AD] (8.8%), and [1761 AD–1805 AD] (43.9%) and the last one ([1936 AD–…]) corresponding to the modern period that we ruled out.

According to the very accurate iconographical evidence and descriptions given in textual sources dating from the end of the 16th century and early 17th century, the curator speculated that the *vina* could have been made in the first half of the 17th century. The [1650 AD–1683 AD] interval is presumably that when the instrument was made. This interval is slightly more recent than expected.

CONCLUSION

Based on information from both geochronological analyses and museological resources, we were able to provide key elements on two *vina* from the Musée de la Musique The making of the *rudra vina* E.997.24.1 is now known and corresponds to [1650 AD–1683 AD]. The history of the *kinnari vina* E.1444 is now known: it was made during the [1666 AD–1690 AD] interval and its upper nut was changed before its arrival in France, likely during [1678 AD–1766 AD]. Furthermore, we have highlighted the use of bitumen-derived glue used to assemble and make the instrument.

To sum up, in this first combined museological-geochronological study performed on legacy musical instruments, we have shown that like analysis performed on archeological musical instruments, ^{14}C dating can be a powerful tool to inform not only on the creation of a musical instrument but also on its use.

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