

# The Story of the “Qiuilai” Gin Unraveled by Radiocarbon Dating, Material Characterization and Chinese Written Sources

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## Research Article

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# Abstract

An ancient table zither *qin*, an emblematic stringed instrument of traditional Chinese music, has been rediscovered in the museum collection of the Conservatoire National des Arts et Métiers (inv.4224, CNAM collection), Paris. This instrument named "Qiulai" *qin*, whose origin is poorly documented, can claim to be one of the oldest *qin* preserved in European collections; its state of conservation is exceptional. A thorough examination was carried out based on an innovative approach combining museum expertise, material characterization analyses (optical microscopy, VIS/IR/UV imaging, X-ray fluorescence, SEM-EDS, Raman) and advanced radiocarbon dating technology (*ECHoMICADAS*). Our results highlight the great coherence with the traditional manufacturing practices mentioned in early Qing dynasty *qin* treatises and poems, in particular the collection of materials with highly symbolic meanings referring to the *qin* sound, nature and the universe. They also confirm the antiquity of the "Qiulai" *qin* in Europe by indicating that it was most likely made in a small interval of about 30 years at the turn of the 18th century.

## 1. Introduction And Research Aims

The *qin* or *guqin* ("old *qin*") is a seven-stringed Chinese table zither regarded as one of the oldest chordophones in China. Based on surviving early written sources and archeological findings, the instrument is attested since the Zhou dynasty (11th-5th century B.C.) and its definitive organological features were established during the Western Jin dynasty (265–316) [1]. Its construction appears simple but allows a wide variety of sounds, from deep bass to crystal-clear high-pitched notes, and finger strokes that can be or gentle or violent. This highly esteemed and mainly solo instrument connotes the refinement and sophistication of the literati, the Chinese scholarly elite, along with the practice of poetry, painting, calligraphy and chess [2]. The *qin* is considered as one of the objects that best epitomizes Chinese thought [1].

Beyond the elaborate sound images it produces, the *qin* is also revered as a refined artwork, whose shape is imbued with a strong symbolic meaning. The different parts of the instrument refer to the dragon, the phoenix, the sky and the earth. The making of a *qin* corresponds to an ideal such as a concentration of the harmony of nature, the energetic flow (*qi*), and all the forces of the Universe [1]. The materials selected are therefore invested with deep meaning, such as timber from temples that is impregnated with chanting, or from trees growing near water cascades, or in calm and secluded places, etc. Great value is attributed to the numerous cracks (*duanwen*) on the surface lacquer layer which are considered as a sign of "antiquity", one of the virtues embodied by the *qin* [3, 4].

The ten-year Cultural Revolution (1966–1976) in China had important consequences on the arts, including on the teaching and practice of *qin* and listening to this instrument [5]. Like other symbols strongly associated with the elites of the Old Empire, efforts were made to "target for destruction" multi-century *guqin* [6]. Nowadays, modern *qin* makers, recognized as the heirs of this ancestral tradition, perform their work with the remaining knowledge that survived the cultural compliance policy under Mao Zedong [7]. Considering its long history, its numerous cultural and symbolic associations and its crucial role in the shaping of Chinese culture, the *qin* – along with its musical repertoire – was included in 2008 in the UNESCO list of Intangible Cultural Heritage of Humanity.

To our knowledge, the *qin* rediscovered in 2012 in the collections of the Conservatoire National des Arts et Métiers (CNAM, Paris) is the oldest *qin* known in European museum collections. In view of the evidence in favour of its authenticity, its value is considerable. Research combining a series of scientific techniques and early written sources remains relatively inaccessible and can only be found in Chinese scientific literature or well-informed Chinese expert circles [8]. Likewise, while the literature on Chinese lacquers is abundant [9–12], few scientific reports are available on the material characterization of early *qin* lacquers [8, 13]. However, information related to the making of *qin* appears in the numerous poems praising the instrument and in ancient treatises that shed light on the origin and use of materials [14].

This article combines visual examination of the instrument by *qin* experts, material characterization analyses and advanced radiocarbon dating technology in an interdisciplinary framework. We will demonstrate that the scientific investigations on the different parts of the *qin* from the CNAM collection are consistent with the practices of *qin* craftsmanship depicted in the

following seventeenth and eighteenth-century written sources: the *Yuguzhai Qinpu* "Abiding with Antiquity" written c.1860 by Zhu Fengjie which is a very popular late Qing dynasty *qin* handbook [3] and the *Qinfang* "Twenty Four Flavours of *qin*" which is an early treatise written c.1641 by Xu Shangying [4].

## 2. Description Of The "qiulai" Qin

### 2.1. An exceptional Chinese zither in European collections

The *qin* under study is a Chinese table zither owned by the Conservatoire National des Arts et Métiers (CNAM, inv. n° 04224) and currently on loan to the Musée de la musique since 2015 (inv. n° D.04224) (Fig. 1). This *qin* is composed of a soundboard apparently made from a single block of wood, without a bottom, with a system of bridges, peg pool, a nut, two feet to attach seven silk strings, respectively on and under the forehead, the end (tail) and below the soundboard of the *qin* [15]. Thirteen round studs or emblems (*hui*) of mother-of-pearl are aligned to mark harmonic positions. The upper and lower parts of the *qin* symbolize the sky and the earth; two pillars under the soundboard in a circular and a crescent moon shape are called respectively the pillars of "Heaven" and "Earth" (Fig. 2).

This *qin* was rediscovered in 2012 during the "récolement" of the musical instruments of the CNAM acoustic collection. Philippe Bruguère, the former Curator of non-European collections at the Musée de la Musique, suspected its old age. The Musical Instrument Museums Online database (MIMO) was queried to compare this instrument with other *qin* listed in partner museums, as well as for *qin* from private collections [16]. The *qin* has exceptionally rare features with a leaf banana shape known as *jiaoye* 蕉 style and the absence of a bottom. The shape and the carved date situate its manufacturing period during the 17th or 18th century in China. For comparison, the "Gumeihua" *qin* with a similar shape in China (Forbidden City) was made during the Ming 朝 dynasty (1368–1644) and once belonged to the collection of the Emperor Qianlong 朝 (1735–1796) [17]. The rediscovered *qin* is assumed to be one of the oldest *qin* kept in European museum collections.

Despite previous studies based on the CNAM archives and inventories, its provenance remains mysterious. The CNAM was created in 1794 following decrees issued during the French Revolution to promote national industry. The researchers of the CNAM gathered the following clues [18]:

i- the presence of musical instruments is attested since 1814 at the CNAM with the installation of the early "Cabinet de physique de M. Charles" who was elected as a physicist to the Académie des Sciences in 1785 [19].

ii- the *qin* n°4224 is clearly mentioned in the inventories edited in 1849 at the Conservatoire for the creation of the acoustics gallery in 1851–1852.

iii- objects with inventory numbers around 4000 were presumably kept at the Académie des Sciences prior to their transfer to the Conservatoire. The Académie des Sciences was initially created in 1666 as an informal scholarly circle and kept collections of objects for scientific studies and education. Some objects were taken from these collections to complete the collection of the Conservatoire after the French Revolution.

### 2.2. Inscriptions and translations

The inscriptions engraved on the back side of the *qin* are reported in Fig. 2. First, they refer to the name of the instrument "Qiulai" 秋籁 meaning "Autumnal resonances" (Fig. 2.a). The following inscriptions in carved Manchu reproduce an extract from the famous poem "Qinzan" 琴讚 "In praise of the *qin*" written by Li Bai 李白 (701–762) (except the first verse and some slight modifications in red (Fig. 2.b). The bottom part of the inscriptions includes information on the making of the instrument (Fig. 2.c) and Tang Kai's seal (Fig. 2.d). Tang Kai 唐楷 was a well-known court zither player and zither maker, as well as a *qin* collector during the reigns of the Chinese emperors Yonzheng 朝 (1722–1735) and Qianlong 朝 (1735–1796) of the Qing 朝 Dynasty (1636–1912) [17]. The inscription Songtao 松涛 "gusts of wind in the pines" refers to the nickname of Tang Kai whose complete *hao* (i.e. pseudonym) is Longwan *cun sou* Songtao 松涛 "the so-called old man of the gusting wind in the pines of Longwan". According to the carved inscriptions (Fig. 2.c), the making of the *qin* is dated 1712, which is consistent with the

period of activity of Tang Kai. This maker is known to have owned seven ancient *qin* 琴 with similar inscriptions and the same seal as the "Qiulai" *qin* [20]. However, no early written sources mentioned this "Qiulai" 琴 *qin* in his collection, even though the name is common for a musical instrument.

## 2.3. Material composition

### Wood

The monoxyloous wooden body of the "Qiulai" *qin* is made of the light porous brown resinous species from the *Taxus* genus belonging to the *Taxaceae* family. The forehead of the *qin* has been carved in hardwood teak, i.e. *Tectona grandis* from the *Lamiaceae* family.

Based on the legacy of the surviving written sources and the practices of modern makers, the commonly mentioned wood species for each part of the instrument are as follows [14]:

i- for the soundboard: *tong* 桐 tree, *wutong* 梧桐, *paotong* 泡桐, *qingtong* 青桐, etc. translatable by sterculia or paulownia; or spruce 杉, or cedar *shan* 杉 or "cloud fir wood" *yunshan* 云杉.

ii- for the back side: *zi* 梓 or *qiu* 楸 trees, i.e. catalpa; or *qi* 漆 tree i.e. *Rhus verniciflua* or lacquer tree.

iii- for the foot: *wu* 乌 tree, i.e. black ebony.

The *Taxus* wood is not a conventional wood used in the making of *qin* since the Chinese literature and tradition mainly cite the *tong* 桐 tree as the foremost wood used [3, 14, 22].

### Coating

The wooden body of the "Qiulai" *qin* is completely covered with black and red coatings, providing a strong impression of the homogeneity and cohesion sought by the *qin* maker [4]. We will choose the term "lacquer" in the following due to the traditional use of raw tree lacquer as organic binder. Traditionally, the lacquer ash layer *huitai* 灰胎 is applied on the wood support as the preparation layer. It is usually described as a miscellaneous mixture of *Rhus verniciflua* lacquer, deer bone powder, deer antler, pig's blood, brick, lime, mother-of-pearl, gypsum, gold, silver, jade, agate, coral, shells, etc. The lacquer was applied in several layers to give the finishing veneer. Great value is attributed to ancient *guqin* whose lacquer layer is marked by numerous cracks named *duanwen* 断纹. Surprisingly, the lacquered surface of the "Qiulai" *qin* has no cracks.

### Silk

The strings that were found knotted around the feet and the bridge prior to their changes in 2018 are made of silk (Fig. 3). The silk came traditionally from insect cocoons named *jiacan* 柞蚕 or domestic silkworm in Chinese and the species used is *Bombyx mori*. A coating of dirt, glue or wax on the surface of the strings is visible, ranging from off-white to brown-black. Early recipes suggest the use of fish glue, wax or boiled rice for the impregnation of boiled silk strings that helps hold the fibers together and influences the sound [3].

## 3. Methods

### 3.1. Sampling

Micro-sampling was performed on the *qin* for radiocarbon dating. The size of the samples ranged from 0.2 to 1.4 mg on discrete parts of the back of the body of the *qin* in order to respect the aesthetic integrity of the object (Fig. 3).

### 3.2. Material characterization analyses

#### 3.2.1. Optical and digital microscopy

First, the stratigraphy of the lacquers was observed in-situ under visible (VIS), infrared (IR) and ultraviolet (UV) rays using VIS/IR/UV imaging on a Dino-Lite with DinoCapture 2.0 software. Then, a chip of the coating, which comprises the complete stratigraphy from the surface to the wood support, was investigated using light microscopy (Zeiss Axio Scope.A1 Vario) and digital microscopy (3D Keyence-VHX).

### 3.2.2. X-Ray fluorescence

A preliminary investigation was done using X-ray fluorescence spectrometry (XRF) Jetstream M6 from Bruker with a rhodium anode in the X-ray tube at 50 kV and 200  $\mu$ A with a 100  $\mu$ m-thick beryllium window. The beam diameter was 450  $\mu$ m. The target was placed horizontally at a working distance of 2 mm. The spectra recording time was 200 s, with a maximum count rate of 96 kcps. Data were processed with the Esprit software developed by Bruker [23].

### 3.2.3. MEB-EDS

The coating sample was embedded in a polyester resin ESCIL-SODY 33, pre-polished with SiC papers, to obtain a transversal section. Analyses were then performed using Scanning Electron Microscopy with Energy Dispersive X-ray spectroscopy (SEM-EDS) with the JEOL-JSM IT 300 instrument (mode 'HighVacuum', WD = 10mm, an energy beam of 20keV, mode BED-C) and an X-ray microanalyzer X-MaxN (Oxford). The results were processed with Aztec software (Oxford).

### 3.2.4. Raman

Two different Raman instruments were used. The microspectroscope Raman confocal INVIA Renishaw with a laser source of 532 nm was used for the black layer of the transversal section of the coating (see 4.1.1.). The microspectroscope Raman with a laser source of 785 nm from BWTek was used for the red layer of the transversal section of the coating (see 4.1.1.). The systems were equipped with an optical microscope (confocal mode, focus x50).

## 3.3. <sup>14</sup>C analyses

### 3.3.1. Sub-sampling of the coating

Q1, Q2, Q3 and Q4, were sampled using a cleaned chisel (Fig. 3). The multi-layer lacquer sample Q5 (see 4.1.1) required a more elaborate mechanical treatment using microchisels (0.125 mm, 0.25 mm and 0.5 mm, Fig. 4) in order to produce separate <sup>14</sup>C measurements on: 1-the wooden support, 2-the black preparation layer and 3-the reddish finishing lacquer (Fig. 4). Solvents, commonly used by restorers to separate layers, were excluded because they induce carbon contamination. The black lacquer sub-sample Q5-2 was isolated from the wooden sub-sample Q5-1 using a microchisel on sample Q5 under binocular microscope (Fig. 4.a). The reddish lacquer layer sub-sample Q5-3 was collected in-situ using microchisels under binocular microscope after removal of a light brown film of dust by scraping with a microchisel (Fig. 4.b).

### 3.3.2. Chemical pretreatment for <sup>14</sup>C dating

The wooden and silk samples were treated with the classical AAA chemical protocol suitable for wood and charcoal [24] as follows: i- HCl 0.5M (room temperature) and rinsing with ultrapure water until pH = 5, ii- NaOH 0.1M (room temperature) and hot rinsing (80°C) until pH = 5, and iii- HCl 0.5M (room temperature) rinsing until pH = 5. As dust was expected to be the potential lacquer contamination, Q5-2 and Q5-3 underwent acid treatment with HCl 0.5M, at ambient temperature and rinsing until pH = 5.

Chemical glasses and protective aluminium foils were previously baked out at 450°C during 6 hours, making them carbon-free. All chemicals were of ultrapure quality, and water was ultrapure (MilliQ grade).

To control the impact of chemical treatment and of the combustion, we also ran in-house "blank" (AfSud, a 70 kyr charcoal from Border Cave, South Africa) and international standards (wood - SIRI G at 378  $\pm$  39 BP [25]).

### 3.3.3. CO<sub>2</sub> conversion and physical measurement

The mass spectrometer *ECHoMICADAS* was used to measure the  $^{14}\text{C}$  activity of each sample [26, 27]. All the samples (from 40 to 160  $\mu\text{gC}$ ) were directly injected into an elemental analyser (EA) coupled with the MICADAS gas source through the gas ion source interface (GIS) [28]. The red lacquer sample Q5-3 was an exception and was injected as a gas into the MICADAS gas source through the GIS by tube cracking [29].  $\text{CO}_2$  was obtained off-line by combustion under pure  $\text{O}_2$ .

Ages were obtained from  $^{14}\text{C}$  measurements using Bats software by comparing  $^{14}\text{C}/^{12}\text{C}$  ratios with OXII standards [30]. Most of the samples provided several measurements, but results were statistically combined. The mean age of the sample then derives from the mean of the individual measurements, which pass the  $\text{Chi}^2$  test, and is associated to the maximum between the  $\text{Chi}^2$  reduced error and the standard deviation between the median of the individual measurements. Results are expressed in  $F^{14}\text{C}$  as recommended by Reimer et al. [31] and provided as  $^{14}\text{C}$  ages (BP) following Stuiver and Polach's convention [32]. Probability distributions of calibrated  $^{14}\text{C}$  ages were generated using OxCal v4.3.2 [33] based on the IntCal20 calibration curve [34].

## 4. Results

### 4.1. Material characterization

#### 4.1.1. General description of the lacquer layers

The optical microscopy revealed that the lacquer of the *qin* comprises two successive layers: (a) a heterogeneous black layer of around 1 mm with greenish grains applied on the wooden support, (b) a homogeneous reddish surface layer of 35  $\mu\text{m}$  lightly covered with a dust deposit (Fig. 5.A). According to measurements using XRF, the two layers comprise mainly iron and copper inorganic elements.

#### 4.1.2. The black lacquer

This layer is black under visible (VIS) and infrared (IR) rays using VIS/IR/UV imaging. Hence, it contains a black pigment absorbing VIS and IR rays, which cannot be iron oxide since it reflects IR rays. We deduced that the pigment is most likely a carbon black: soot, charcoal, stone black, ivory black, vine black or bone black. Respectively using SEM-EDS and Raman spectroscopy, the matrix was identified as being mainly constituted of a filler made of bone black ( $\text{Ca}_3(\text{PO}_4)_2$ ) with coarse-grained malachite ( $\text{CuCO}_3(\text{OH})_2$ ) (Fig. 5). SEM-EDS analyses also detected lime  $\text{CaCO}_3$ , silica  $\text{SiO}_2$ , earths ( $\text{Fe}_2\text{O}_3$ ,  $\text{MnO}_2$ ), ochres ( $\text{FeOOH}$ ,  $\text{Fe}_2\text{O}_3$ ) with potassium and magnesium aluminosilicates, traces of cinnabar ( $\text{HgS}$ ) and a lead-based white pigment (Pb, C, O), possibly cerusite or hydrocerusite (Fig. 5.B).

#### 4.1.3. The red finishing lacquer

This layer is red under visible (VIS) and slightly reflective under infrared (IR) rays using VIS/IR/UV imaging. Since XRF analyses applied on the sample Q5 mainly detected Cu and Fe, we first surmised that the red pigment could be an iron oxide. However, using SEM-EDS and Raman spectroscopy (Fig. 5), the red layer was identified as being mainly constituted of a mercury sulfide ( $\text{HgS}$ ) most likely from the mineral named cinnabar (Fig. 5.C).

### 4.2. $^{14}\text{C}$ dating results

The sample Q5-2 on the ash lacquer was thick enough to perform four measurements using radiocarbon dating (Table 1, Fig. 6.a.). The heterogeneity of these measurements with a weak  $A_{\text{comb}}$  of 5.4% is consistent with the composition of the lacquer ash layer as a mixture of several solids. The  $^{14}\text{C}$  dating mean value obtained [69AD – 245AD] is incompatible with the historical information gathered on the "Qiulai" *qin*.

The wooden samples Q1, Q2, Q3 and Q5-1 yielded similar  $^{14}\text{C}$  results. The combination of the results using the "combine" option of Bayesian modelling [33] gave a high agreement index  $A_{\text{comb}}=114.1\%$ . It can be concluded that the wood pieces

chosen for the manufacturing of the *qin* are contemporary. The tree or trees used grew and were cut during the [1458AD – 1528AD] or [1552AD – 1634AD] intervals (Table 1, Fig. 6.b.).

The silk string sample Q4 and the red lacquer sample Q5-3 present similar  $^{14}\text{C}$  results (Table 1). The combination of these measurements, acknowledged by a high  $A_{\text{comb}}$  value of 110.9%, highlighted that the silk strings and the red lacquer are contemporaneous, which might provide the last period of lacquering and changing of the strings on the *qin*. Considering that the presence of the *qin* in the CNAM collections is attested since 1849 (*terminus ante quem* in the Bayesian analysis), this probable last maintenance in playable condition might be included in the following intervals: [1659AD – 1699AD] (25.0%), [1721AD – 1814AD] (66.6%) or [1834AD – 1848AD] (3.8%) (Fig. 6.c).

Table 1

Conventional, calibrated and modelled  $^{14}\text{C}$  ages obtained for the "Qiulai" *qin* using OxCal4.3.2 [33] based on IntCal20 [34]. Statistical results of Bayesian modelling are shown in the last four columns.

Identification		Laboratory reference		Uncalibrated data				Calibrated data	Statistical modelling
Samples	ID	GifA #	ECHo #	Number of measurements	$^{14}\text{C}$ activity ( $F^{14}\text{C} \pm 1 \sigma$ )	age $^{14}\text{C} \pm 1 \sigma$ (year BP)	Chi 2	Age range with IntCal20 (calAD) (95.4%)	Resulting calibrated date [range yr AD] (95.4%)
qin_foot back side	Q1	GifA19208	ECHo 2833	2	0.967 $\pm$ 0.005	265 $\pm$ 40	1.39/3.84	1493–1603 (43.6%) 1608–1679 (38.2%) 1742–1752 (1.2%) 1764–1799 (10.7%) 1941 - ... (1.7%)	$\chi^2$ -Test: df = 3 T = 1.010(5% 7.815) Agreement n = 4 Acomb = 114.1%(An = 35.4%) [1458–1528] (46.0%) [1552–1634] (49.5%)
qin_pillar	Q2	GifA19209	ECHo 2834	2	0.957 $\pm$ 0.006	355 $\pm$ 45	1.15/3.84	1456–1640 (95.4%)	
qin_foot	Q3	GifA19210	ECHo 2835	2	0.955 $\pm$ 0.005	375 $\pm$ 45	0.06/3.84	1446–1530 (49.2%) 1538–1636 (46.2%)	
qin_wood under lacquer layers	Q5-1	GifA20230	ECHo 3480	1	0.950 $\pm$ 0.011	410 $\pm$ 90		1323–1356 (2.8%) 1392–1661 (92.5%) 1789–1792 (0.2%)	

Identification		Laboratory reference		Uncalibrated data			Calibrated data	Statistical modelling	
qin_silk string	Q4	GifA19211	ECHO 2836	2	0.980	160	0.27/3.84	1660–1699 (17.8%)	$\chi^2$ -Test: df = 1 T = 0.248(5% 3.841)  Agreement n = 2 Acomb = 110.9%(An = 50.0%)  [1660–1699] (17.8%)  [1722–1814] (47.4%)
					± 0.005	± 40		1722–1814 (47.4%)	
								1835–1883 (10.1%)	
								1883–1889 (0.7%)	
								1909 - ... (19.4%)	
qin_red lacquer	Q5-3	GifA20363	ECHO 3738	1	0.976	200		1643–1710 (22.5%)	[1835–1883] (10.1%)  [1883–1889] (0.7%)  [1909AD - ...] (19.4%)
					± 0.007	± 50		1720–1820 (43.6%)	
								1820–1824 (0.4%)	
								1832–1892 (12.1%)	
								1906 - ... (17.0%)	
qin_black lacquer	Q5-2	GifA20231.1	ECHO 3481.1	4	0.801	1780	16.96/7.82	30–528 (95.4%)	
		GifA20231.2			± 0.008	± 80			
		GifA20231.3	ECHO 3481.2		0.811	1690		215–559 (95.4%)	
		GifA20231.4	ECHO 3481.3		± 0.008	± 80		-383–26 (95.4%)	
			ECHO 3481.4		0.768	2130			
					± 0.008	± 80		-35–565 (95.4%)	
		0.793							
		± 0.008							

## 5. Discussion

### 5.1. Characterization of the wooden body

The radiocarbon results are consistent with a traditional practice of reusing a symbolic wood when making a *qin*, as explained in "Abiding with Antiquity", c.1860 [3]. The radiocarbon dating results provide a significant hiatus, that could reach several centuries, between the dating of the wood in the [1458–1528] or [1552–1634] intervals and the dating of the silk string and red finishing lacquer in the [1659–1699], [1721–1814] or [1834–1848A] intervals (Fig. 6). The hiatus is relevant to the Chinese tradition which symbolically associates the material quality of "a very old paulownia wood" with the quality of the sound. This

virtue of "antiquity" is cited in the "Twenty-Four Flavours of *qin*", ca. 1641, and detailed in the introduction by Goormaghtigh, as part of the aesthetic canons [4]. Such a music appreciation is still controversially present in the modern practice of carving *qin* in a wood that has been stored for more than a hundred years [35]. However, the storage of wood through several generations of *qin* makers is not attested in the past.

The dating hiatus between the wood on the one hand and the red lacquer and string on the other cannot be due to the sun-drying of a multi-century old tree trunk. The wood used to make the *qin* should be porous, light, even and smooth without the knots or distended and twisted fibers caused by the influence of the sun or the wind on the growth of the wood, as mentioned in early written sources. Therefore, secondary branches are preferentially selected according to an appropriate age and height [22]. The Tang period poems (618–690, 705–907) studied by You [14] confirm the preference for secondary branches rather than the trunk, except in the case of a tree less than a decade old.

"As for the material that should be used, it should be from younger branches; that is, branches that are close to the top of the trunk. If the *tong* is not old, then its young branches will certainly not be big. Choose wood far away from the ground, with the top blown by wind and dried by sun. It should be moistened by frost and dew with plenty of pure air. Furthermore, it is good if the material is facing southeast, (because) "the Great Brightness (the sun) is born in the east".

The *Book of Odes* states: "The *wutong* grows there on those slopes and faces the sun" [3]

The interpretation of the  $^{14}\text{C}$  results as due to the reuse of wood is reinforced by the fact that the "Qiulai" *qin* is not made from a conventional paulownia species, but from a porous resinous wood from the *Taxus* family. Considering that the changes in Li Bai's poem carved on the back side are a subtle and skilful adaptation to this particular *qin*, the replacement of the sinogram *tong* 桐 for paulownia by *bai* 柏 for resinous woods of cedar or cypress may be linked to this manufacturing choice. Other wood species than paulownia can be used, especially old building timbers:

"As for good quality in old materials, (...) one cannot be certain that it will be *tong* wood. Some other kinds of wood are also all right. The wood is useable as long as it is light and porous, crisp and smooth. (...) As for beams, pillars, and router rafters, the ancients used *tong* for some of these. But it has to have survived for a couple of hundred years. If at an old monastery or temple on a high precipice or cliff, or by a waterfall, or stream shore in high, spacious and quiet regions, absolutely cut off from the cacophony of the everyday world, there one can find good material for the *qin*. Naturally it will have a special sound. "[3]

As a testimony of this practice during the 19th century, the wood of the "Yun He" 雲和 *qin* kept at the Musical Instruments Museum, Brussels (Coll. MIM, n° inv. 0760) has been identified as originating from Jing Hui 敬惠 Temple in the Guangzhou province (Canton) thanks to ink inscriptions on the back side [36]. This unfulfilled epigraph also indicates that the *qin* was built by the maker Li Menggeng 李孟庚 whose life is poorly known, but who partly coincides with the reign of Daoguang 道光 (1820–1850). The entry of this *qin* in the MIM collections is dated between 1881 and 1886 according to the inventories.

The  $^{14}\text{C}$  results for the wood of the "Qiulai" *qin* are consistent with a long tradition in *qin* making that consists in reusing old wood with a highly symbolic and spiritual value, whether during the period of activity of Tang Kai or in the early 19th century before the recorded presence of the *qin* in the CNAM collection in 1849.

## 5.2. Composition of the lacquer ash layer

The radiocarbon dating and material characterization of the "Qiulai" *qin* lacquer ash layer revealed a mixture of two major solid ingredients, bone black and malachite, consistent with the use of powdered deer antler and crushed stones mentioned in the *Qinfang* c.1641 and the *Yuguzhai Qinpu* c.1860 [3, 4]. The lacquer ash layer is located between the wood body dated from [1458–1528] or [1552–1634] and the red lacquer dated from [1659–1699], [1721–1814] or [1834–1848]. However, the heterogeneous  $^{14}\text{C}$  results on this layer are not compatible with the expected period of the making of the *qin*. Based on the material analyses, the age obtained might be due to the mixing of carbon from ingredients contemporary with the lacquering of the *qin* ( $F^{14}\text{C} = 0.976 \pm 0.007$ , value of the red lacquer) with 20% of geological carbonates from malachite residues ( $F^{14}\text{C} = 0$ ) remaining after acid etching during the chemical pretreatment of the sub-sample Q5-2.

The detection of carbon and phosphorous in the lacquer ash layer of the "Qiulai" *qin* does not differentiate deer antler ash from deer or another animal bone ash. Li et al. [13] also reported that the detection of  $\text{Ca}_3(\text{PO}_4)_2$  merely indicates the presence of bone ash regarding the "Yu Quan" *qin* from the Yuan Dynasty. However, traditional recipes comprising the raw sap of the lacquer tree and the ash of deer antlers *lujiao shuang* 鹿角霜 are mostly cited [14, 37]. According to the *Yuguzhai Qinpu* c.1860, "Whenever others put on the powder and lacquer they use a cattle horn comb (...). The powder; that is, deer horn *shuang*, (...) should be ground fine."

The detection of the coarse grains of malachite is suggestive of the *qin* makers' practice of occasionally adding fragments of metal or stone to the lacquer ash layer in accordance with the symbolism of the carillon and lithophone so as to obtain the ideal acoustic properties, as discussed by Goormaghtigh [4] based on the following citation in the *Qinfang* c.1641: "The fingers struck the strings as if they drummed metal or stone, without any interference from the neighboring strings. It is in this search for limpidity that one goes beyond all sounds. ". Chang [38] mentioned that the highly estimated lacquer of *qin* made in the Tang Dynasty (618–690, 705–907) corresponded to the Asian lacquer technology consisting in adding scraps of metallic or stone fillers. A mixture, commonly named "eight precious ash" lacquer *baobaohui* 八宝灰 by *qin* makers, is made of fragments of gold, copper, bronze, porcelain, silver, mother-of-pearl, malachite, pearl, jade, agate, coral or seashells [8].

Powdered deer antler and crushed stones are not ingredients inherent to the *qin* but can be found in Asian lacquers [39]. For example, a lacquered tray from the Ming period (1368–1644) presents surface "snake-belly cracks" as for *qin* from the same period, which could be due to the use of similar compounds such as powdered deer antler, bone, horn, ash, sandstone, or ceramics [40]. Our results are consistent with the traditional composition of the lacquer ash layer of *qin*; however, due to the long tradition spread over several dynasties, a more accurate attribution is not possible.

### 5.3. The silk string and the red lacquer dating

The analyses revealed that the remaining silk string and the red lacquer are contemporaneous, meaning that the last lacquering and maintenance in playable condition occurred in China during the Qing dynasty (1644–1912) since the radiocarbon dating yielded the [1659–1699], [1721–1814] or [1834–1848] intervals. According to our investigations, three hypotheses are currently available for the attribution of the period when the "Qiulai" *qin* that entered the CNAM collection before 1849 was built: i- it was collected, dated and signed by Tang Kai in 1712, ii- it was made by Tang Kai in 1712, or iii- it is a well-informed late 18th-19th century copy using an old wood carved in China.

The absence of typical cracks *duanwen* 断纹 on the red lacquer is surprising. Cracks may begin to appear a hundred years after the making, and the shape of the cracks can be used for the relative dating of the *qin*. Re-lacquering or restoration of the "Qiulai" *qin* by successive owners can be considered during the [1721–1814] or [1834–1848] intervals, as such practices have already been observed on other ancient *qin*. For example, the "Mingfeng" 鸣凤 *qin* is known to have been recut and re-lacquered by Tang Kai [20]. The cracks on the "Xianren you" *qin* from the Song period (1127–1279) have been wiped out by restoration [41]. However, the cracks are not necessarily proof of antiquity even if this is the reason why Chinese connoisseurs estimate them. Like the "Qiulai" *qin*, the "Yun He" *qin* that entered the MIM collection c.1880 presents no surface cracks either.

The "Qiulai" *qin* shows 18th-century features, and material characterization analyses as well as  $^{14}\text{C}$  results are consistent with the traditional practices of the *qin* makers from this period as described in written sources [3, 4]. The authenticity of this *qin* is credible. Indeed, the Qing dynasty period was rich in cultural exchanges between China and France under the Ancient Regime. French sinophilia during the 18th Century Enlightenment is also well-known under the reign of Qianlong (1735–1796). China's tolerance toward Christianity allowed the establishment of Jesuits whose exchanges with the Académie Royale des Sciences provided information on Chinese techniques of the time. For example, the Jesuit Pierre Nicolas Le Chéron d'Incarville (1706–1757) sent a memoir to the Académie in 1760 mentioning the use of resin tree and calcined deer bones in black Chinese lacquers [42]. The sending and the studying of *qin* in the eighteenth century in France is attested. For example, the Jesuit priest Joseph-Marie Amiot (1718–1793) sent a *guqin* to M. Bertin for his cabinet of curiosities [43], as reported in his correspondence with the Académie des Sciences [44]: "The first is a *Kin* with seven strings, unlike those of today (...). It is made of a single piece of wood".

If the "Qiulai" *qin* was made by Tang Kai and kept its original lacquer, then it was manufactured in the [1659–1699] interval, since the  $^{14}\text{C}$  dating results on the red lacquer provide intervals that do not include the date of 1712 carved on the back side of the *qin*. The carving of inscriptions on a guqin traditionally took place after the instrument had been made and even played for several years.

## 6. Conclusions

The most significant findings that emerge from this study are that the *qin* rediscovered in the CNAM collection has exceptional characteristics that are consistent with current knowledge about eighteenth-century *qin* manufacture: the shape, Tang Kai's seal and pseudonym, the multi-layered lacquer composition, and the wood and lacquer dating. While interdisciplinary investigations on early Chinese zithers are seldom used, our results were achieved thanks to the combination of material characterization techniques, advanced radiocarbon dating technology and museum expertise confronted with early Qing dynasty written sources. This research project constituted a unique opportunity to study one of the most remarkable *qin* kept in Europe.

## Declarations

### Availability of data and materials

All data generated or analyzed during this study are included in this published article. Raw data (including spectra) are available upon request from the authors.

### Competing interests

The authors declare that they have no competing interests.

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### Authors' contributions

MGD and SV designed the study with input from CH and AGM. CF was responsible for the loan of the object and agreed with the way the study was conducted. MGD, AGM, SV, CF are responsible for the historical and scientific documentation of the instrument. Radiocarbon and statistical analysis were performed by CH and MGD. TF prepared cross sections and performed material characterization on samples. TF and WN discussed the results and interpreted them in the context of radiocarbon dating. The global interpretation was the result of a collective thinking of all authors. MGD wrote the manuscript with input from all co-authors. All authors read and approved the final manuscript.

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## Figures



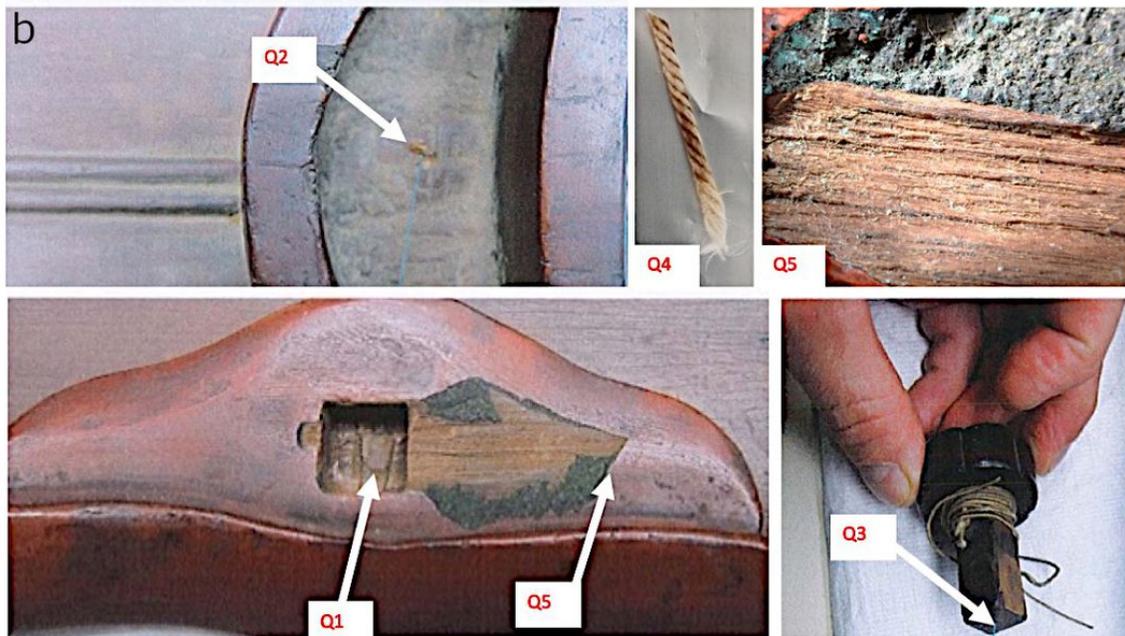
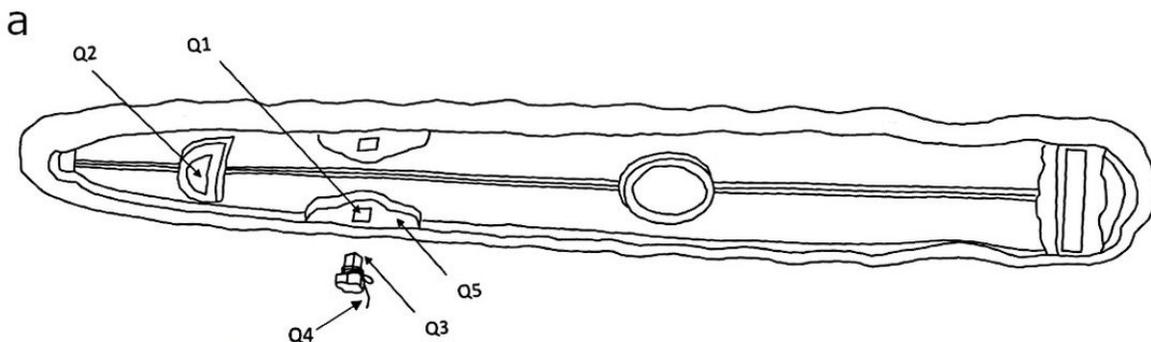
Figure 1

The Chinese zither or qin from the CNAM collection (inv. n°04224). The silk strings were strung in 2018 at the Musée de la musique, Paris. Pictures by Claude Germain © Musée de la musique, Cité de la musique – Philharmonie de Paris.

	Original inscriptions	Translations
	a) 秋籟。	Autumnal resonances <sup>1</sup>
	b) 峰阳孤桐，石笋天骨。 盛京赤柏  根老冰泉，叶苦霜月。 枝茂  斫为绿绮，徽声焕发。 微音  秋风入松，万古奇绝。 清	Upon the craggy slopes near the peak, <u>the solitary paulownia</u> <sup>2</sup> <u>crimson cypress of Shengjing</u> Hoists itself upon the rock like some celestial skeleton  Its venerable roots appear as streams stilled by frost  And <u>its fragile leaves</u> as though iced by the moon <u>its lush branches</u>  Its wood is carved to produce the most exquisite instrument, Whence <u>the notes</u> exuding from its emblems <sup>3</sup> sparkle as they spread, <u>delicate sounds</u>  Resonating like the autumn wind that passes through the pines: <u>A wonder</u> that will remain forever unequaled! <u>crystal-clear</u>
	c) 大清康熙五十一年歲次， 王辰春龍灣村叟松濤斫  橫琴山廬藏	51st year of the Kangxi era of the great Qing <sup>4</sup>  The old man Songtao carved the instrument in the village of Longwan in spring 1712 <sup>5</sup>  Hoarded in the hermitage of Hengqinshan («horizontal qin mountain»)
	d) 	Tang Kai's seal 

Figure 2

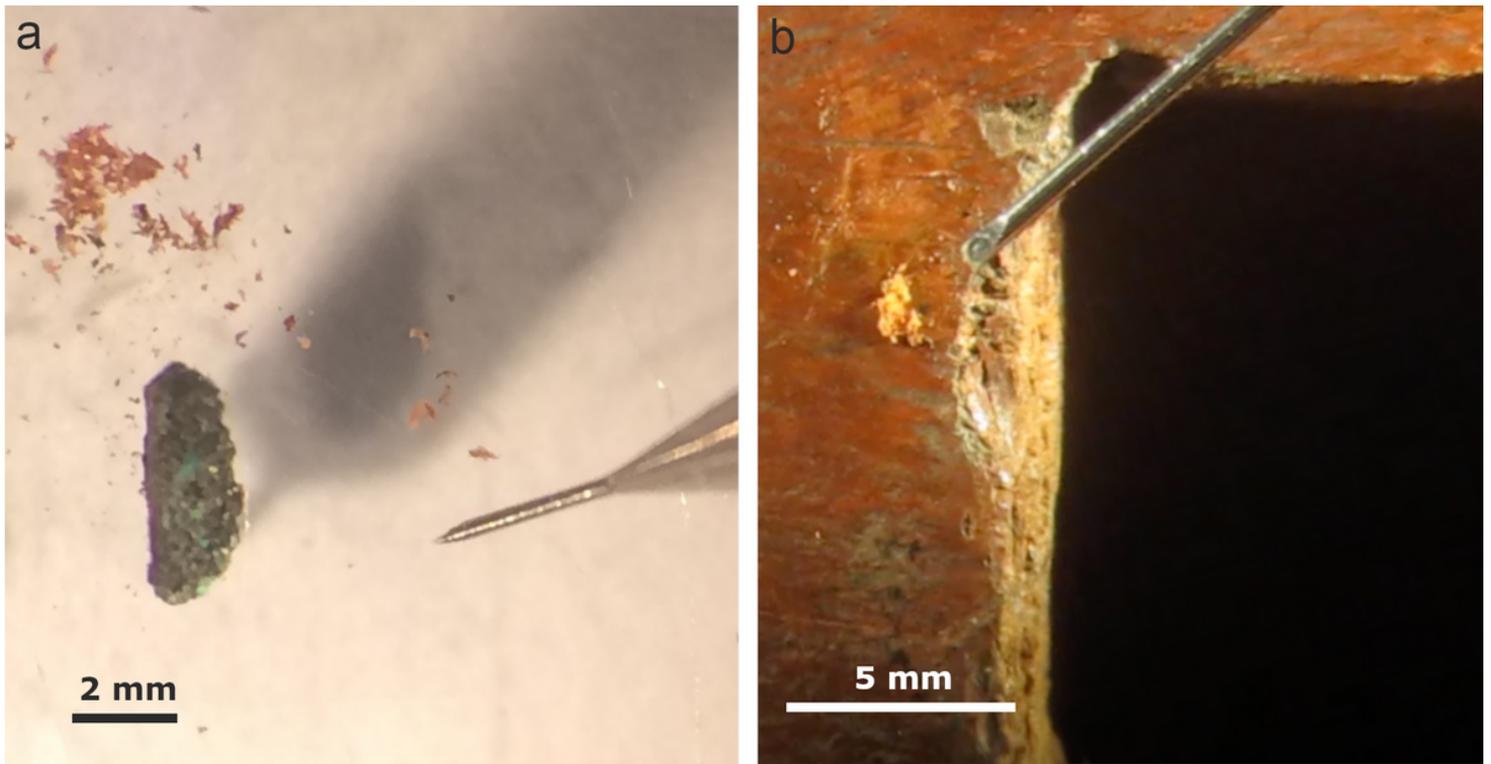
Pictures of the front and back sides of the qin. The inscriptions carved on the back side of the qin and their transcriptions: a) the name of the qin: 1lai is a polycalamus flute of the yue type with three holes. The qin tends to reproduce the soft and nostalgic sounds of this "antique" flute suggesting an autumnal atmosphere b) "In praise of the qin", Li Bai's poem (translation by Lucie Rault): the original text is in black, the modified passages carved in the qin are in red and under the corresponding sonograms. 2 tong (in original version) translated by paulownia or wutong [21]. 3 hui studs that mark harmonic positions, c) information on the making of the qin: 4 dated from 1712 according to the era mentioned under the Qing Dynasty, 5 dated from the spring of the year renchen, which is the name of the sexagesimal year corresponding to 1712 (according to the cyclic calendar), d) zoom in of Tang Kai's seal.



Sample	Location	Material composition
Q1	Bottom of the foot pool	wood
Q2	Pillar – back of the qin	wood
Q3	Foot	wood
Q4	String	silk
Q5	Coating crack near the foot pool	Coating stratigraphy

Figure 3

Location of the samples on the qin: a) schematic view of the qin and location of the five samples, b) pictures of the sampling location by Stéphane Vaiedelich © Musée de la musique, Cité de la musique - Philharmonie de Paris, c) description of samples Q1 to Q5.

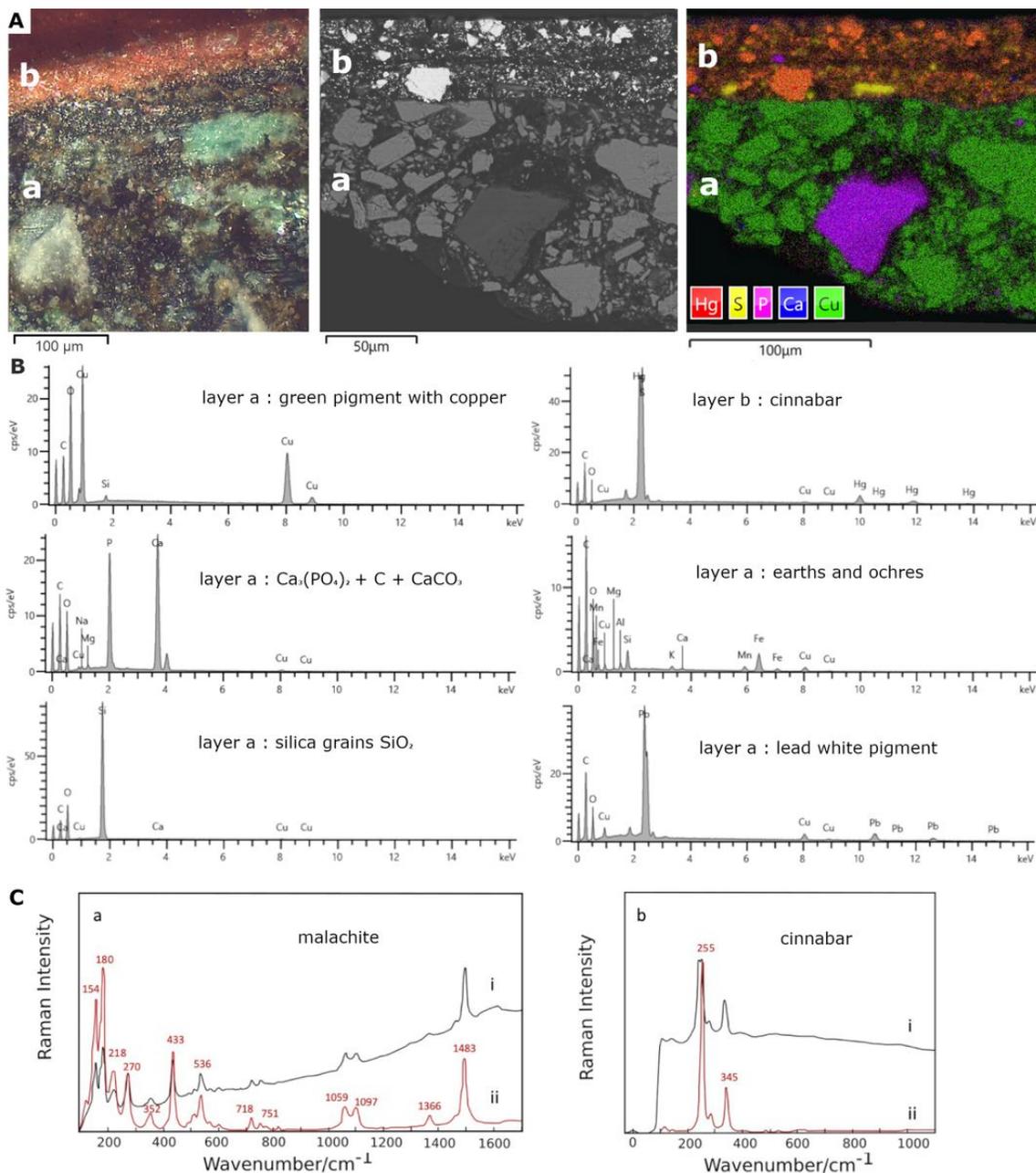


C

Sub-sample	Description of the layers
Q5-1	Wood under the black lacquer
Q5-2	Black lacquer
Q5-3	Reddish lacquer

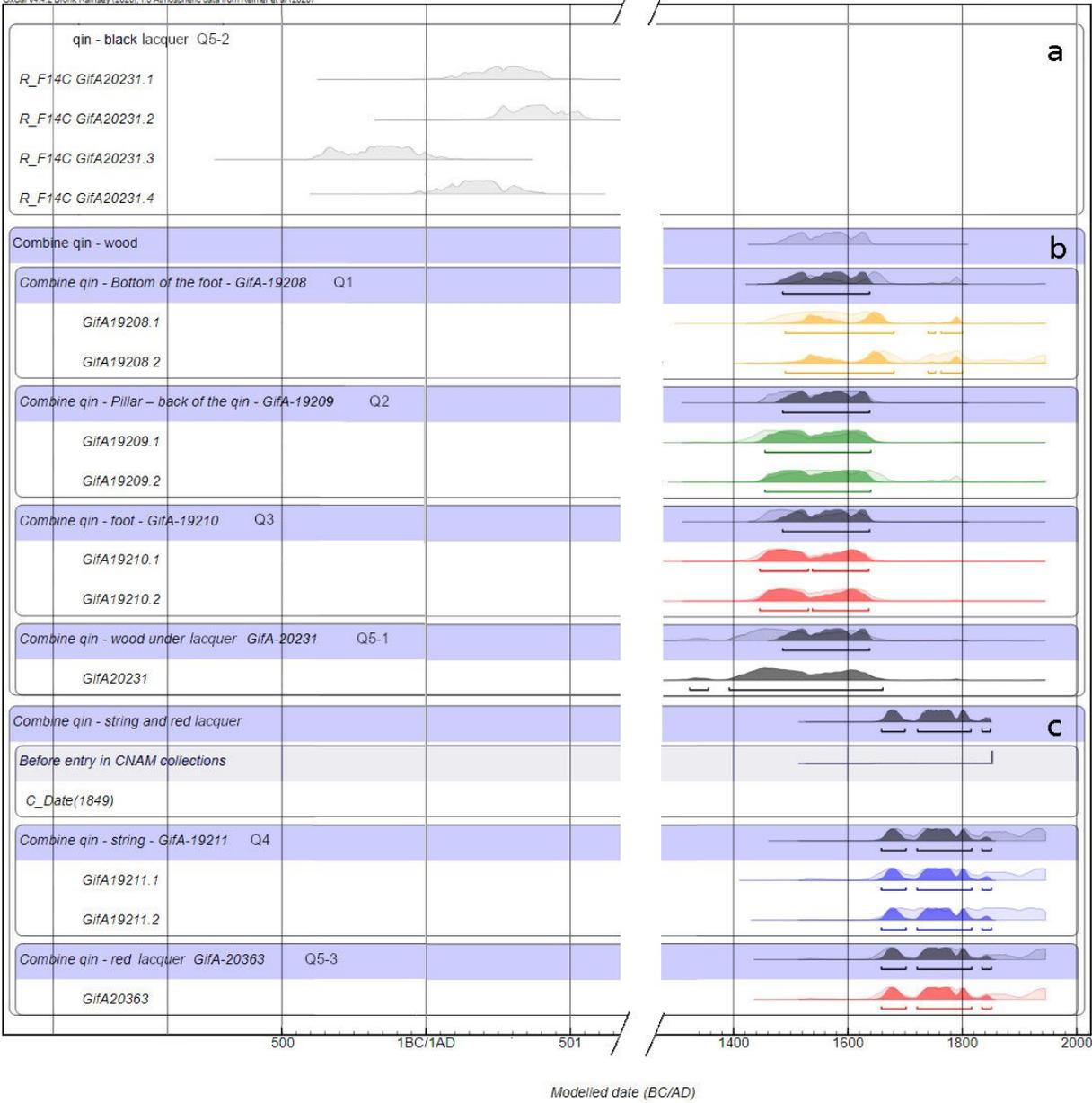
Figure 4

Separation of the lacquer layers of the qin under binocular microscope using microchisels. a) separation of the black lacquer Q5-2 from the wood support Q5-1, b) sampling of 1.3mg of red lacquer Q5-3. Pictures by Marie-Gabrielle Durier © Musée de la musique, Cité de la musique - Philharmonie de Paris, c) description of the sub-samples Q5-1 to Q5-3



**Figure 5**

A) (from the left to the right) Image taken by optical microscopy of the two successive layers of the coating of the qin. Pictures by Marie-Gabrielle Durier © Musée de la musique, Cité de la musique - Philharmonie de Paris; SEM image of the transversal section of the coating of the qin; cartography EDS with the distribution of the main elements in the two lacquer layers of the transversal section. B) The upper spectrum on the right correspond to the homogeneous red lacquer (b), and the following spectra to the heterogeneous black layer (a) and were obtained using SEM-EDS. Analyses and images produced by Tiphaine Fabris © Laboratoire de Recherche des Monuments Historiques, Champs-sur-Marne. C) Raman spectra for the identification of mineral pigments a) in the black lacquer; (i) several coarse green grains showing the presence of malachite; (ii) malachite reference spectra in red, b) in the finishing lacquer (i) some red grains showing the presence of cinnabar in black; (ii) cinnabar reference spectra. Analyses performed by Didier Brissaud © Laboratoire de Recherche des Monuments Historiques, Champs-sur-Marne.



**Figure 6**

Calibrated 14C ages of the "Qiuilai" qin. The probability distribution diagrams of: a) sub-samples of the black lacquer Q5-2; b) wooden samples of the back side of the foot Q1, the pillar Q2, the foot Q3 and the wood support under the lacquer Q5-1 with their respective Bayesian modeling combination in black, and the upper diagram in blue of the combination of all wooden parts; c) sub-sample of the upper lacquer in red Q5-3 and sub-samples of the silk string in blue Q4 with their respective Bayesian modeling combination in black, and the upper diagram in black of the combination of the red lacquer and the silk string parts taking into account the event of the entry of the qin in the CNAM collection prior to 1849.