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A Significant Japanese Coffer: A Multi-disciplinary Approach to Examining Late Sixteenth- Early Seventeenth-Century Export Urushi Ware

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ABSTRACT
A significant coffer in the Royal Swedish collection, inventory number HGK 406, is examined. The aim is to confirm or add new data concerning its age, provenance, and components of manufacture. The scientific analyses include microscopy of cross and thin sections, wood species identification, scanning electron microscopy with energy-dispersive X-ray spectroscopy, X-ray fluorescence microscopy, pyrolysis-gas chromatography-mass spectrometry, strontium isotope ratio measurement, and radiocarbon dating. To a lesser degree, the investigation also includes excerpting and examining historical documents. The results show that the body wood is Thujopsis dolabrata BUN 1248, a strong indication for a Japanese origin of the coffer. The urushi coating is made with sap harvested in Japan from the species Toxicodendron vernicifluum. The decorations include gold powder, red iron oxide, and cinnabar pigments. Radiocarbon dating supports dating of the coffer, also based on its style, as late sixteenth or early seventeenth century. While all the results may not stand alone, the study shows that a methodology with a multidisciplinary approach can produce new knowledge, as well as support or reject hypotheses arrived at from other kinds of sources.

Introduction
Conservation as a discipline has evolved over the last century, from the skilful restoration of tangible objects considered of specific value to a profession in its own right. Conservation may contribute to the development of new knowledge by bridging interdisciplinary gaps. This study illustrates one way of contributing to the body of knowledge already published about a so-called namban shikki coffer, and perhaps also to clarifying its context. Furthermore, re-examining artefacts with a known biography by scientific means not previously at hand can produce quantitative and qualitative data to serve as reference aids for other artefacts.

The Gripsholm coffer and its context
The unique and extraordinary Gripsholm coffer (hereafter ‘the coffer’), with inventory number HGK406, is in the custody of the Swedish Royal collection. For a long time, it has been displayed at the Gripsholm Castle, Mariefred. It measures w. 131 cm, d. 55 cm, h. 65 cm. According to data in the most recent inventory, it was made in Japan, with a body from cedar coated with Chinese lacquer, and dated to 1580–1600 (Nyman 2014). The outer sides of the front, short sides, and domed lid have decorations in pearl shell, as well as motifs made with metal powders of assorted colours and densities, in so-called hira maki-e technique (flat relief). The motifs are rural landscapes, vernacular buildings, trees, flowers, wild animals, birds, and Asian-looking human figures. On the rear side, the decoration is different, with foliage in a scattered pattern. Inside, the lid is decorated only in various metal powders, and the motif is a less elaborated waterscape with bushes, boats, and birds. Its engraved and contoured metal mountings include fittings on all corners, two lockers on the front, four hinges on the rear, and a handle on each short side. On handling, it is surprisingly light-weight, given its size, a fact that may be explained by its thin-walled body. The coffer is quite well preserved, despite its assumed age, but this good state of preservation is to be expected considering its assumed limited practical use over the passage of time and cool and dark display environment. Visible signs of deterioration include scratches, cracking along joints in the wood body, slight warping, detached and partly lost coating and pearl shell, as well as some tarnishing of the solid and powdered metals. The surfaces inside are shinier than the outside (see Figures 1–2).

Its present condition may also reflect that this coffer probably never played any functional role in the Swedish royal household. From the Gripsholm 1699 inventory deed, it is clear that many other coffers of more modest design were used, and, at the same time, that the coffer in this study remains unrecorded (RA 1699, folio 1, 2). Why the coffer is missing in the 1699 inventory is out of the realm of the authors to...
explain. However, the Drottningholm inventory of 1777 records a Japanese coffer with brass fittings together with a green 'saffiano' leather cover (see Figure 3) (RA 1777, folio 36). This entry is interpreted as the coffer. The inventory does not give any hint as to why some coffers had covers, and others did not, but it is known that upholstery furniture often had protective covers (Brunskog and Nilsson 2013, 169–180). Moreover, the inventories indicate that movable assets were relocated between the royal residences when necessary.

The Swedish king Gustav II Adolf was presented with the coffer by the States-General of the Netherlands (Dutch: *Staten generaal*) at an official audience in June 1616 (Strömbohm 1937, 116; Vahlne, Alm, and Fogelmarck 1986, 26). Such state visits were part of the management of international affairs. The visits were either by courtesy in order to maintain respectful and friendly relations between nations or to resolve conflicts. The gift from the consignee—the federal body of political and juridical power—may be interpreted as a reassurance of mutual benefit in the future.

During the seventeenth century, Asian lacquerware, as well as other extravagant and exotic artefacts from East Asia, was traded in high numbers by the European East India companies. A century earlier, in 1498, the Portuguese explorer Vasco da Gama made the first sea voyage from Europe to India, via the southernmost tip of Africa. The mission was driven by a desire to find a direct route to the places where spices were plentiful and cheap. If spices were the driving force, followed by tea, silk, and ceramics, the export and import of Asian lacquerware might be understood as a by-product. During the seventeenth century, Portuguese and Dutch great ships sailed along the route via Macao to Nagasaki and Kyoto in Japan (Impey and Jörg 2004, 27; Nagashima 2008, 34–35). Luxury goods from the East were in demand, and some Asian lacquerwares were, as stated above, even used as official gifts in cross-cultural and diplomatic contacts. Inter-Asian trade also involved *urushi* ware (Clulow and Tristart 2018, 58, 73, 79). Nagashima has traced information that merchants of the Dutch Verenigde Oostindische Compagnie (VOC) traded *urushi* from Japan to India (2008, 34–35, 324). Another indication of the same phenomenon appears in Swedish marine lieutenant Nils Matsson’s travel diary, published in 1667 (Matsson Kiöping and Eriksson 1667, folio 22–23).

Indeed, coffers are among the earliest categories of artefacts exported from Japan. Thus, the Gripsholm coffer is a typical representative of its time and place. At the same time, it is unique and assumed to be one of the oldest Japanese artefacts still extant overseas. As far as is known, only two other similar, large coffers remain in Europe. One is in the Vatican Museums in Rome, a gift from Hasekura Tsunenaga.
to Pope Paul V in 1615 (Koyama 2013, quoted in Kobayashi and Yoshida 2017, 16). Another is in Madrid, Spain (Impey and Jörg 2004, 147). The latter coffer was recorded in a monastery in 1582 and has been passed down ever since. Other large coffers are in Japanese museums or private collections, while smaller chests of a similar design are found in private collections in the Czech Republic (Nagashima 2008, 38, 91, 95—99) and in museums throughout Europe.

The immediate aim of the study and the methodology

The existing written material about the coffer tells about its provenance and about different styles of Japanese urushi arts and crafts, but also discusses intercontinental trade, early globalisation, political, military, and socio-economic circuits. The aim of this study is to add data to this biography, dealing with its age, provenance, and physical and chemical character. Such information is essential to the long-term preservation of the coffer, as well as acting as reference material for other Asian lacquerware of a more uncertain age, provenance, or composition. The present investigation may either validate previous results or propose an understanding in contrast with assumptions arrived at from other sources of information. An object’s physicality can be investigated through both human expertise and technological devices. The methodology includes materials analyses, applied in similar case studies and proven to be successful, such as optical, chemical, and physical standard analysis methods. In this way, conservation methods can restore what has been lost, and reconnect objects with their prior contexts. The methodology also includes a careful and close reading of old manuscripts and documents, housed in libraries and archives, that were contemporary with the coffer. With increasing frequency, documents have become available digitally. In the past, many records were largely inaccessible (physically or otherwise) to researchers or available for reading only on-site, and restricted for security reasons and by limited opening hours.

Provenance derived from style or wood species

As mentioned above, categories of objects and styles of decorations on Asian lacquerware have been associated with periods in time, but also with the places of manufacture (Yamazaki 2001, Fig 1; Impey and Jörg 2004, 7; Nagashima 2008, 36; Kobayashi and Yoshida 2017, 8; The Wonders of Urushi 2017, 187–189). To derive provenance from style always lends itself to a broad scope of interpretation. Even when scholarly research shows that a particular style prevailed in a specific area, there is always the risk for atypical exceptions, deviating from the primary trend. Moreover, styles have emerged independently from each other or have been transferred from place to place. In short, trends and traditions have been in constant flux, fashions ephemeral, and information and hearsay unrooted.

An alternative and complementary way to trace provenance and place of manufacture of Asian lacquerware is to identify the wood species in the bodies and substrates. Because wood is a material that is available almost everywhere, it is unnecessary to transport. Thus, the results of wood identification can produce more valid information than e.g. style. Wood is generally obtained close to the place of manufacture because it is also bulky and impractical to transport over long distances. And, some species grow only in particular habitats. For example, asunaro (Thujopsis dolabrata BUN 1248), in the cypress family, also called hiba or false arborvitae, is native to Japan. T. dolabrata is endemic to the four main islands: Hokkaido, Honshu, Kyushu, and Shikoku (Katsuki and Farjon 2013; Noshiro 2017, 25—26). Meanwhile, the suggested type of wood, cedar, registered in the catalogue, is unspecific. Many common names include the word cedar; for example, Japanese cedar (Cryptomeria japonica) has its native habitat in Japan, with old trees scattered in Honshu, Shikoku, and Yakushima. It has been extensively used over at least the last millennium. The timber was valued for its durability as a construction material and in furniture making. Due to its typical sweet fragrance, it was also used for incense (Thomas, Katsuki, and Farjon 2013a). The Chinese incense-cedar is another common name (Calocedrus macrolepis Kurz), a species with habitat in many east Asian countries (Thomas, Liao, and Yang 2013b). Because many conifers emit characteristic vapours, other wood species may be mistaken for cedar if they too have a striking fragrance.

Provenance derived from the chemical composition in the polymer

The general term ‘Asian’ lacquerware covers products that have coatings made with sap from one of three wood species that grow in Far East Asia, mainly in Korea, Japan, continental China, Taiwan, north Vietnam, Myanmar, Thailand, and Laos. (However, chemically and physically they have little in common with Western types of coatings, that also are called lacquer, except for the glossy surfaces.) Depending on the species, either Toxicodendron vernicifluum, Toxicodendron succedanea, or Gluta usitata, they produce a slightly different sap. In this paper for lack of a better word that covers all three types of Asian catechol-containing saps, they are named according to their respective main lipid component when appropriate. Coatings of an assumed Japanese origin are called urushi, and the corresponding Chinese coatings

In Korea, continental China, and Japan, the so-called true lacquer tree, T. vernicifluum, is the prime sap-producing species. The chemical compound urushiol is the marker for this sap. The second wood species, T. succedanea, grows in the south of China, Taiwan, and north Vietnam, and produces a sap rich in laccol. The third wood species, Gluta ustata, grows mainly in Thailand, Myanmar (Burma), and Laos, and produces sap containing thitsiol (Thein 2000, 85). Despite their differences in chemical composition, these saps are used in the same manner and harden with the help of enzymes catalysed by moisture and heat. The presence and proportion of different sap components are possible to identify a posteriori, and thus indirectly also the botanical and geographical origin of the sap (Lu and Miyakoshi 2015, 25–62). Pyrolysis gas chromatography-mass spectrometry is a versatile tool for analysis of the chemical composition of polymerised coatings.

Historically, saps were traded in large quantities between many regions and countries in Far East Asia (Kitano et al. 2008, 37–52; Honda et al. 2010, 897–901). For example, during the Momoyama period (from the late sixteenth to the early seventeenth century) the demand in Japan for black urushi exceeded domestic production. Through the investigation of archaeologically excavated objects in Kyoto, the import of shengqi from China, Thailand, and Cambodia has been verified (Kitano et al. 2009, 37–52). Therefore, the detection of a specific chemical component in Asian coatings on antiquities is not conclusive evidence for that artefact having been manufactured in the location where the sap was harvested. However, it is likely that the most substantial volume of the sap harvested in a particular region was used primarily to supply local demand. Japanese urushi ware is known for being made predominately with locally available sap, but also sap from Vietnam (Lu, Honda, and Miyakoshi 2012, 237, 270–278).

As a consequence, sap composition might be an indication of the provenance of coated artefacts with an unknown origin. However, hypotheses generally need to be underpinned with other data. In this study, even if the wood body of the coffers proves to be grown in Japan, the coating may well be made with imported raw material.

A strontium isotope ratio measurement (87Sr/86Sr) is another alternative to indicating the geographical origin of catechol saps, and thus, by extension, indirectly the place of manufacture and provenance of an Asian lacquerware. The Japanese archipelago is geologically younger than continental Asia. Calcium (Ca), one of the sixteen elements essential for the growth of plants, enters plants as they draw water to be delivered to tissues. Strontium (Sr) is a homologous element of calcium; therefore, trees absorb strontium at the same time that they draw water. Strontium has four stable isotopes with different weights. One of them is also generated by beta decay of rubidium (87Rb) with a half-life of 48.8 billion years. Since primary rocks in different locations were formed during different geological eras, each soil exhibits a distinct 87Sr/86Sr ratio (Yoshida 2012, 13–27; 2017, 251–252). As previously reported, shengqi films from different provinces in China have ratios determined from 0.712 to 0.718 (see Figure 7), and from Wunju, Korea, a ratio at 0.7145. Urushi films made from Japanese sap are expected to fall under the threshold 0.710 (Lu et al. 2015, 84–88).

**Dating based on documentary sources, styles of namban shikki, or radiocarbon analysis**

The manufacture of the coffers must predate its presentation in June 1616, referred to above, by at least several months, if not years. The coffers was assumed to be Japanese, but then later Chinese. Still later, Strömbom assumed it was made in the Netherlands around 1600 (1937, 116). Recently, the coffer again was considered to be Japanese. Sea voyages between Europe and Far East Asia commonly lasted a year or more (Gethe 1746–1749, M280-1). Impey and Jörg claim that the first vessels dispatched by the Dutch trading company VOC arrived at Kyushu in 1609 (2004, 22). If the coffer was in the cargo of the VOC’s first vessel, it could not have arrived in Europe earlier than 1610. Before that year, Portuguese merchants probably provided Asian lacquerware to the Dutch (Impey and Jörg 2004, 27). Like other namban artefacts from the late sixteenth and early seventeenth centuries, the coffer has typical features of the first decorative style favoured by the Catholic communities in Europe. The exterior design is considered typical of the namban shikki style. These often display a combination of flat gold makie and pearl shell in a dense design contrasting with a monochrome black surface (Strässer 1997, 13–15; Murose 2000, 149; Yamazaki 2001, Fig. 1; Impey and Jörg 2004, 77–78; Nagashima 2008, 34–36; Kobayashi and Yoshida 2017, 8; The Wonders of Urushi 2017, 187–189).

Radiocarbon (14C) dating in general, and thus also the dating of urushiol, laccol, and thitsiol coatings, uses the fact that radioactive carbon is continuously created in the atmosphere by the interaction of cosmic irradiation with nitrogen. Hence, all growing plants take up carbon dioxide as well as its radioactive isotope during the photosynthesis
process. Although this process ends as plants die or are harvested, the radioactive decay continues, with a half-life of about 5,730 years. In dating, from the measured ratio between stable and radioactive carbon dioxide, the period since the take-up ended is estimated. An urushiol, laccol, or thitsiol coating specimen may contain other material, such as paper fibres, textile fabric, and wood. These are considered to be contaminants, since they contain unwanted carbon. Therefore, for the dating of coatings, all irrelevant constituents must be removed from the actual coating before analysis. The measured result for \(^{14}\text{C}\) is distributed statistically according to a bell curve, with the most frequent value as the mean value. There is a probability of \(\frac{3}{2}\) that the data is covered within two standard deviations (2\(\sigma\)) below and above that mean value. Within one standard deviation (1\(\sigma\)) the probability is \(\frac{3}{8}\) that the data is covered (Ozaki 2012, 29–42).

Calibration curves are used to convert the age before the present (BP, with 1950 as year zero) of a given specimen to estimate its calendar year common era (cal CE). The production of radiocarbon has not varied much through time, but the effect of variation is compensated for by calibration curves calculated by dating materials of precisely known age. The best samples are tree rings, but annually laminated sediments have also produced excellent results. The calculated age is often presented as a time range with one standard deviation (1\(\sigma\)). The data predicts a probability of 68% that the actual age of the specimen will fall within that time frame. With two standard deviations (2\(\sigma\)), 95% of the data lies within the time frame. Nevertheless, the age of any Asian coating specimen may not be precisely the same as the age of the coating or the artefact. Saps might be used long after they were harvested. And artefacts may be much younger than some of their components because Asian lacquerware is known to have been dismantled and re-used, even decades later (Brunskog and Miyakoshi 2020).

### Experimental

#### Sampling

From the outside of the coffer, three small specimens were sampled, HGK406 Nos. 1–2, of black coating with gold decoration, and No. 3 ditto including wood. In addition, from the inside, several larger fragments (f) already detached and containing monochrome black coating were taken mainly for radiocarbon dating and strontium isotope ratio measurement, which require a minimum specimen size of c.30 mg each. The specimens are detailed in Table 1.

#### Instrumentation

**Preparation of cross and thin sections and light microscopy (LM)**

Specimen No. 2 intended for microscopy was embedded in epoxy resin, any air bubbles evacuated under vacuum, and was left to cure overnight. After subsequent grinding and polishing, the reverse side was glued to a microscope glass slide (Matsunami Glass Ind. Ltd.), using the same medium, and left to cure overnight. Thin sections were cut to about 1–2 mm in thickness, using a diamond saw (South Bay Technology, Low-Speed Diamond Wheel Saw, model 650). Grinding was done stepwise automatically (Buehler AutoMet 250 Ecomet grinder polisher) for three minutes on each paper, using 400, 600, and 2400 mesh silicon carbide waterproof papers. The subsequent polishing used suspensions (Sankei aqra diamond suspension 3 microns, or Ultra-High-Purity Deagglom Alumina Suspen 0.05 \(\mu\)m), for about one minute. The final step in polishing was done manually to avoid excessive material loss, and to reach a final thickness of around 10–15 \(\mu\)m. Observation of sections used an ECLIPSE LV100N POL microscope, Nikon Co. Ltd, equipped with a digital camera. Sections were observed in both transmitted and reflected light, in dark field, and under crossed polarisers, magnification 5–20x as appropriate. The observation of fibres was done with a digital microscope gauged with magnification 500–1000x, using a VHX-1000 instrument with a wide-range zoom lens system VH-Z100R instrument (Keyence Corporation, Japan).

**Wood species identification**

From the small wood splint in specimen No. 3, thin tissues were cut with a razor. All the three principal directions of the wood were observed for tree species distinction with an Olympus optical microscope model BX51.

**Scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX)**

Specimen No. 1 intended for SEM-EDX was first prepared as a cross section. The embedding medium was Epofix cold mounting epoxy resin, mixed with a hardener, supplied by Struers. The epoxy cured overnight. Subsequent grinding and polishing were done on a manual Struers Labpol-5, using waterproof silicon carbide grinding papers of grit 220, 320, 500,
800, 1200, 2400, and 4000 stepwise, a few minutes on each grit. Before analysis, the sections were documented and images captured with a Nikon SMZ1000 (Japan) stereomicroscope, using, Plan Apo 1x lens, oculars C-W 10xA/22, with an attached DinoEye eyepiece camera AM4023CT/R4, 1.3 megapixel resolution.

SEM-EDX analysis used a LEO 1455VP (Zeiss) scanning electron microscope, with a tungsten filament. The SEM was equipped with an EDS (Oxford instruments) with INCA 400 software. Images were collected and point analyses of elements were performed in variable pressure (VP) vacuum mode, EHT 15 kV and probe 300–470 pA, as well as the mapping of elements over larger areas.

**X-ray fluorescence microscopy (XRF)**

X-ray fluorescence microscopy analysis was done at normal atmospheric pressure utilising X-ray irradiation (current 50 kV and 1.0 mA) in the microscope (Horiba Scientific XGT-5200 Analytical X-ray Microscope) with high spatial resolution, from 1.2 mm down to 10 µm.

**Pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS)**

Direct Py-GC-MS measurements were performed with a vertical micro furnace pyrolyser PY-2020ID (Frontier Lab, Japan), a HP 6890 gas chromatograph, and an HPG 5972A (Hewlett-Packard, Ltd.) mass spectrometer. A stainless-steel capillary column (diameter 0.25 mm × 30 m) coated with 0.25 µm of Ultra Alloy PY-1 (100% methyl silicone) was used for the separation. A platinum cup with the sample (0.05 mg), was first kept on top of the pyrolyser at near ambient temperature; after that, the sample introduced into the furnace at 500°C. The oven was programmed to provide a constant temperature increase of 12°C per min from 40°C to 300°C. The flow rate of the helium gas was 1 ml min⁻¹. The injector had a split of 50:1. The MS ionisation energy was 70 eV (EI-mode). All pyrolysis products were identified by mass spectrometry at ionisation energy at 70 eV (EI-mode). Data were analysed with Agilent MSD Chemstation software and all pyrolysis products were identified from an interpretation of their mass spectra (Idei et al. 2018, 1–5; Takahashi et al. 2018). The results are presented as extracted ion chromatograms (EIC).

**Strontium isotope ratio measurement (87Sr/86Sr)**

A multiple collector-inductively coupled plasma-mass spectrometer (MC-ICP-MS) together with a Quadruple ICP-MS, was used to measure the isotope ratio for strontium. The application in this study used the lower ratio in Japanese soils, compared with the ratio in Chinese soils with a threshold of <0.711 (Lu et al. 2015, 84–88; Yoshida 2017, 251–252; 2012, 13–27).

**Radiocarbon dating (14C)**

The Paleo Labo company, Gifu Prefecture, Japan, assisted in the radiocarbon analysis. It was done by direct atom counting following the accelerator mass spectrometry (AMS) protocol (Tuniz et al. 1998). A Compact-AMS instrument, National Electrostatics Corp. (NEC), 1.5SDH, USA, was used. The machine was equipped with a dual ion source sequential injector, which allows measurements of low-activity carbon samples with masses 12, 13, and 14 for dating. The acceleration voltage was set at 500 kV. The precision is ±50 years, or, with careful tuning, even better. Calibration of the curve was according to the literature (Bronk Ramsey 2009; Reimer et al. 2013). All the dates are in conventional radiocarbon years BP or CE unless otherwise stated.

**Results and discussion**

**Provenance derived from identification of wood and sap analysis**

A very shallow banded surface structure of the wood body was perceived on the surfaces when touched or viewed in raking light. The pattern was easy to observe with the naked eye on surfaces without coating, such as in uncoated areas, but also relatively easy to see through the thin coating inside the coffers. The annual rings appeared broad and measured several millimetres in width.

The wood species was determined based on the morphological features in the three principal directions (see Figure 5) to *T. dolabrata* BUN 1248 (Jap: *asunaro*). The structure is typical of a conifer wood with distinct boundaries between the annual rings, in combination with a gradual shift from earlywood to latewood (Noshiro 2018). The bulk of fibres consists of axial tracheid cells with many narrow rays in the perpendicular. The *asunaro* is a relatively sizeable evergreen tree, reaching up to 40 m tall and 1.5 m in diameter. Such large timber allows for processing into large planks and boards as well. Traditionally, *asunaro* was planted around temples and in gardens, and the timber was and still is appreciated for its resistance to mould and pleasant scent. The wood choice for the body might be understood as desirable because of the frequent use of large coffers at the time of interest, and in the following centuries, at least in Europe, in stately homes, vernacular residences, and clerical buildings. Coffers and chests commonly were used to store items such as flat textiles, costumes, and clothing. Textiles, in general, represented an essential part of any household’s assets. Since they were time-consuming to make, they were used and reused for as long as possible. They circulated in second-hand markets, and were finally repurposed as rags, an essential fibre resource for making paper pulp. Textiles were stored...
for later use, between seasons and important events, since they would require protection from mould and pests. *Asunaro* was an appropriate choice of wood since it could have inhibited mould growth and insects, and, at the same time, conferred a pleasant fragrance to stored items.

The original function of the coffer in question remains unknown, albeit its size and components of construction do not contradict an intended practical use as a wardrobe or a luxury container for preserving valuable assets, in its literal sense. The coffer could also function as conspicuous consumption. As shown in Figure 2, Figure 4, and Figure 5, the earlywood growth zone is wide compared with the latewood. The wide spring zone might partly explain the light weight of the coffer. And the thin dimensions of the body also contribute to its lightness.

The direct Py-GC-MS analysis shows that the coating contains the marker compounds for urushiol. Figure 6a shows the extracted ion chromatogram (EIC) at m/z=108. The 3-heptylphenol (MW = 192) in peak C7 and 3-pentadecylphenol (MW = 304) in peak C15 were detected based on their mass spectrometry. The blue triangle marks the area of the most abundant members of the catechol family. The peak C15 indicates the member with the highest number of carbon atoms in the side chain. Compared with a standard *urushi* sample, it can be concluded that the coating on the coffer was made from sap yielded by *T. vernicifluum* trees.

The detection of fatty acids (see Figure 6b) in EIC at m/z=60, is interpreted as a drying oil, an additive in Asian coating technology usually used to increase the lustre and elasticity of coating films. As stated in other scholarly research on Asian antiquities, linseed and perilla oils can be expected in mixture with urushiol (Webb 2000, 26; Castro Henriques 2011; Khanjian, Schilling, and Heginbotham n.d.; Heginbotham and Schilling 2011, p. h; Honda et al. 2015, 44; Kaji 2018). The peaks C16 and C18 indicate detection of the fatty acids palmitic acid (MW = 256) and stearic acid (MW = 284), respectively and the peaks (C6–C9) mark pyrolysis products for other related saturated fatty acids. In contrast to unsaturated fatty acids, saturated fatty acids (such as palmitic and stearic acids) are considered to remain in the coating film without being oxidised. It is believed that they are thermally decomposed by Py-GC-MS analysis and thus possible to detect (Honda 2017, 60). Fresh linseed oil contains three different fatty acids: linolenic, linoleic, and oleic acid. The two former are polyunsaturated, and the latter is monounsaturated. Mixed in an *urushi* coating, linolenic and linoleic acids polymerise together with the urushiol polymers. When exposed to air and oxygen, the oleic acid is subjected to oxidative cleavage in which the C=C bond brakes, and azelaic acid is formed. A previous study detected azelaic acid along with palmitic, stearic, and saturated acids with a low carbon number i.e. C6–C9, albeit suberic acid was not (Brunskog and Miyakoshi 2020, Figure 18). Palmitic and stearic acids have also been detected along with C6–C9 at m/z=60 without the simultaneous detection of either azelaic or suberic acids (Honda et al. 2016; Sung et al. 2016; Idei et al. 2018). Future research needs to explain that. Another complicating circumstance is reported by Heginbotham and Schilling (2011, p. h). The palmitic and stearic (P/S) ratios are an unreliable method to identify oil. In the pyrolysis of samples from the coffer, azelaic and suberic acids remained undetected. In conclusion, we assume that the coating contains oil, but the source for that oil remains unknown.

Pyrolysis data cannot differentiate between the Chinese, Japanese, or Korean territories for the sap harvest. In addition, pyrene was detected at m/z 202, a type of pyrolysis product confirming carbon black (soot). The soot layer probably also explains the blue–green shine, marked as (c) in Figure 9, of the thin section captured under polarised light and perpendicular polarisers.

**Figure 4.** Microscopy of the specimen HGBK06-3, before preparation, captured in dark field, reflected light (left), and in ultraviolet light (right), 50x. Tracheid vessels in the wood are visible and some of the ray cells (more brown in hue) in the perpendicular. The lower part of the specimen with black coating displays a typical low UV fluorescence (Photo: M. Brunskog 2015).

**Figure 5.** The three principle directions of the wood in specimen HGK406-3: cross-grain (left), radial (middle), and tangential (right). Note that the radial direction (the bar equals 20 µm) is captured at a higher magnification. The cross-grain and tangential direction images have bars that equal 100 µm (Photo: by courtesy Dr Noshiro, 2019).
The strontium isotope data clarified that the sap-producing trees grew in Japan. In this case, it might seem superfluous since the wood species is a strong indicator of the place of manufacture. As discussed above, timber was less frequently transported, compared with the large volumes of saps, which were traded across borders and overseas. However, given the opportunity of enough coating fragments, it was decided to trace whether the coffe was manufactured only with locally obtained sap or with imported sap. The 87Sr/86Sr isotope ratio of the HGK406 specimen is 0.7056, which is lower than the threshold 0.710, suggesting that the coffe was made with sap tapped from a lacquer tree grown on the Japanese mainland (see Figure 7). For comparison, other measurements are also plotted in the same figure. These represent urushi saps collected from the island Hokkaido in the north, to the Okayama Prefecture on the main western island Honshu, with a ratio in the range of 0.705 to c. 0.709, and saps from different provinces in China, all in the range of 0.712 and above. It was concluded that the specimen of the coffe falls within the Japanese cluster.

Thus, it is possible to confirm that the coffe was made in Japan with locally obtained wood and sap. The results dispute the aforementioned previous hypotheses claimed by Strömbom. The strontium result disputes that the coffe was made in Holland or that it is Chinese, as the catalogue suggests, at least in the sense that the sap came from China. Rather, the coffe is an entirely Japanese product.

**Age derived from coating analysis**

The radiocarbon dating of the coating shows a 94.4% probability of the sample falling within the time frame 1482─1638 (2σ) and a 35.6% probability of falling within the time frame 1556─1602 (1σ) (see Figure 8). The peak (red) represents the measurement of the specimen with a mean value of 335+−19 BP. Converted to CE this leads to the period 1664─1702. For natural reasons, documentary evidence of 1616 as the year when the coffe was bestowed to the king refutes that period, as long as it is the same coffe. There is nothing in the sampling procedure or in the preparation of analysis that explains this inconsistency in dates. The areas below (grey) illustrate the conversion into the calendar year. They correspond to the areas that overlap between the BP peak and the calibration curve (blue). The total timeframe of 156 years is wide since the calibration curve is almost horizontal in the area that corresponds to the
peak. However, in combination with the document-
ary evidence of the coffer, bestowed to the Swedish
king in June 1616, the most reasonable time frame
is reduced to 1552−1602. In combination with its
decorative style, which is associated with the last
two decades of the sixteenth century, the frame
can be limited to the period late 1570s−1602. This
date coincides with the aforementioned similar
coffer in Spain, manufactured before 1582. Thus,
radiocarbon dating does not dispute earlier hypoth-
eses concerning the age of the coffer, except for the
hypothesis claimed by Strömbom. It is older than
what he assumed a century ago. The sap itself –
processed before the making of the coating – may
be older than the completion of the coffer, but, if
so, probably only by a few years.

![Diagram](image1)

**Figure 7.** Saps from Japan (red square), the coffer (black square), and from China (red dot). Abbreviations used: HKD Hokkaido,
IWP Iwate Prefecture, FKP Fukushima Prefecture, IPB Ibaraki Prefecture, KTP Kyoto Prefecture, OTP Okayama Prefecture in Japan,
Shanxi, Jianshi of Hubei, Guizhou, and Sichuan Provinces in China.

![Diagram](image2)

**Figure 8.** The $^{14}$C dating of specimen HGK406-f. The red peak represents the measurement of the specimen. The grey area depicts
the overlapping between the red peak and blue curve, and shows a 94.4% probability of the sample falling within the timeframe
1482−1638 (2σ covers 9/10 of the data) and a 35.6% probability within the timeframe 1556−1602 (1σ covers 2/3 of the data).
Components in the strata of the coating

The faces of the coffer show a thin and in some areas almost transparent coating. On close inspection, the decorations seem less sophisticated and similar to many other namban style objects. Artefacts made for the domestic market were usually made to satisfy fastidious consumers. The idea behind the coffer was perhaps quantity rather than quality. The cross and thin sections show a four-layer structure with a light brown ground with a single layer (d) made from an inorganic material (see Figure 9). Under perpendicular polarisers, this layer displays some particles with birefringent properties. The layer is most likely an earth pigment. The next thin, black, and opaque layer (c) is interpreted as soot, a typical pigment for black coatings made before the mid-eighteenth century (Lu and Miyakoshi 2015, 268). On top, is another monolayer (b) of a clear urushi coating. As shown in Figures 4 and 8, the coating is rather thin, displaying a characteristic colour, semitransparency, and clear interface of urushi. The clear urushi is almost of the same thickness as the ground layer. It looks homogeneous in colour and texture, even under different lighting conditions. If there were numerous applications, it is not obvious in cross section. Under polarised transmitted light and crossed polarisers a bluish shine is visible at the interface between layer c and b, which might be explained by the presence of soot. The layer (a) is interpreted as the outermost surface and decoration layer. The limited thickness of the specimen and the small number of layers – and hence also the total coating thickness – explains why the wood structure is visible through the coating, especially inside the coffer.

The overall impression of the coating structure is that it corresponds to a simplified process of the manufacture reported by other scholars. Sometimes, it is claimed that artisans practiced ways to hasten the manufacture of export Asian lacquerwares, in which the ground and coating layers were modified compared with the traditional structure that was intended for a domestic consumer with an expected demand of higher quality (Webb 2000, 38; Petisca et al. 2016, S3-89).

In addition to the characterisation of the urushiol, laccol, and thitsiol coatings by microscopy, pyrolysis, and strontium analyses, SEM-EDX and XRF have also supplied data on the composition of the ground. The inorganic component, shown as layer d in Figure 9, also visible in Figure 11, contains iron. XRF analysis supports that iron (Fe) is present in the ground and the coating but from these data, it is not possible to differentiate which stratum is responsible for the signal. Other detected compounds are silicon (Si), calcium (Ca), aluminium (Al), and potassium (K) which all indicate a mineral substance, probably in the ground layer (see Figure 10). Also, in the decoration strata, iron is present and interpreted as the pigment iron oxide. The pigment is well-known and
Iron oxide was much cheaper than cinnabar and used in the monochrome tomato-red surface, or as in this case, can be blended with a clear grade sap to render a coating layer, also gold (Au) was detected (shown in red), mixed with mercury (Hg) in the upper zone closest to the surface (shown in blue).

Figure 11. Mapping of elements using SEM-EDX (left), and the same cross section in VIS reflected light (right). This detected iron (Fe) in high concentration in the ground and in lower concentration in the actual coating layer (shown in green). In the coating layer, also gold (Au) was detected (shown in red), mixed with mercury (Hg) in the upper zone closest to the surface (shown in blue).

A frequently used pigment in the makie technique. SEM-EDX has also detected mercury (Hg), which is interpreted as the pigment cinnabar (mercury sulphide), another red pigment traditionally associated with catechol-type coatings (see Figure 11). Cinnabar can be blended with a clear grade sap to render a monochrome tomato-red surface, or as in this case, used in the makie technique. Red iron oxide and cinnabar were probably mixed and used simultaneously. Iron oxide was much cheaper than cinnabar and could be used as an extender. The lighter, more yellowish red hue of cinnabar was more appreciated than the brownish-red and considered to be higher quality compared with iron oxide.

Conclusion

The Gripsholm coffer is significant because it is still extant and in quite good condition, after more than four centuries, and because it has the capacity to remind beholders of some remarkable historical events. It is associated with European rulers and with the early and increasingly important export trade from Japan to the Occident. In addition, it has the potential to reveal other and competing historical narratives. Recognition of its narrative potential may include artisan’s willingness to adjust to shifting demand, and levels of know-how and manual skills, or the lack thereof. Other possible histories may concern the variety of materials, tools, and processes of Asian lacquerware manufacture. On a closer look using scientific methods, we conclude that it was made in Japan, from locally cut wood. The thin dimensions of the body, the width of the boards made from single members, the tight joints, and the almost intact shape without much warping indicate a skilled woodcutter and quality-sensitive joiner. The urushi sap was a domestically supplied product. Artisans were sometimes inclined to simplify the making of urushi ware for exportation; even if the coating structure on the coffer is less elaborate than many other Japanese urushi ware, it still required a suitable level of competence to make without flaws.

The craftsmen also exposed themselves to a toxic material that can cause severe allergic reactions. The production of the pearl shell and the pigments also required training and experience. The cinnabar and gold components in the decoration can be interpreted as signs of rather high quality. Therefore, the woodwork, coating, and decoration of the coffer provide testimony of the skills and efforts by all the various craft persons involved in its making. The continuous care of the coffer was outside the scope of this study, but this result can inform conservators concerning the importance of exposure to a stable environment, with low light levels, cool temperatures, and limited handling. By extension, the results of this study can support decisions concerning its future care.

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