

# Chinese Lacquered Cups of the Han Dynasty from the Collection of Noyon-Uul, the State Hermitage Museum: Complex Research Using the Methods of Art History and Natural Science

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**Abstract:** This investigation of unique Han Dynasty Chinese lacquerware eared cups in the collection of the State Hermitage Museum, Russia, combines an art historical approach with technological research concerning the paint. These Han *er bei* cups were found in the Xiongnu barrows discovered during the expedition of P. Kozlov (1863–1935) in the mountains of Noyon-uul in northern Mongolia. Using a comparative approach, we consider the characteristics of the paints and the technologies used in producing the colorings in the lacquer. The chemical composition and structure of the coatings were studied by optical microscopy, cross-section, Fourier Transform Infrared Spectrometry (FTIR), and X-ray analysis. The authors conclude that the multilayer coatings of the cups were made by a special technology using a natural material that is derived from the sap of the lacquer tree (*Rhus verniciflua*). The base material is a biopolymer of urushiol, a mixture of pyrocatechols contained in lacquer tree sap. The results show that these lacquerware samples from the Han Dynasty have tung oil as one of its components. This article shows the role of tung oil in the structures of the studied samples of *qi-lacquer*. We also present an integrated investigation of the lacquer cups from the Noyon-uul collection and a determination of the social position of the owners, their cultural and chronological attributions, and their dating.

**Key Words:** Han archaeology; Han *er bei* cup; Chinese *urushi*wares; Noyon-uul Barrows; *qi-lacquer*; tung oil as a modifier; FTIR and X-ray analysis

## 1. Introduction

### 1. 1. Early Chinese Lacquerware

Chinese lacquered objects are currently considered as one of the most important components of the dominant material culture of the Han Dynasty (206 BC–AD 220). The period 206 BC–AD 8 was the apogee of Han Chinese lacquer art.

It is well known that the lacquer used in ancient times in China as a protective, water-

proof coating material was made from the sap of the lacquer tree (Lat. *Rhus verniciflua*, Chin. 漆树, Eng. *qi-lacquer*, Jap. *urushi*). The natural zone of its growing was the southern provinces of China, and that was where the original distribution area of lacquered objects was, as well. The most ancient lacquered objects were brown in color. The ancient masters, in improving the cleaning techniques and the techniques for applying sap, tested and improved the properties of the coatings (Kapustina and Simonov 2000). By collecting the “sap of life” in copper vessels, the Chinese created a black

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lacquer (the product of a reaction with metals that caused the formation of chelate complexes of phenolic compounds in urushiol lacquer) with the best protective properties. The evaporation of excess water from the sap caused the lacquer to become harder. Stirring lacquer with an iron rod, in the same way, improved its properties, too.

The sacred functions of lacquer and ties of its color to Chinese philosophical principles have been discussed by scholars such as Novikova (2000: 33–37). There have been numerous experiments to explain how a red color (linked to the element of Fire) is obtained for lacquer. The main problem is that the sap itself wets practically no pigments. This problem was solved by mixing sap with vermilion that was previously rubbed with tung oil (*tong you* 桐油). The sacred functions of sap are known through poetic metaphors. For example, the color of fresh sap symbolized snow for the Chinese. A black layer of lacquer meant earth, and a red one (*tong qi* 彤漆) was connected with blood. In addition, the black color symbolized the North and Water, and red symbolized the South and Fire (Novikova 2000: 33–37). The combination of red and black layers of lacquer was considered favorable; in it, the forces of Fire and Water neutralized one another.

From start to finish, the whole process of lacquering strictly obeyed the system of the five elements. Earth gave birth to a tree that protected itself from damage by bleeding poisonous sap. During processing by human hands, sap became lacquer, and it had the elements of Earth and Fire. Lacquer hardened only in the presence of moisture (Water), and then it became fire-resistant and could withstand changes in temperature and humidity. Sunlight and dry air have negative effects on lacquer.

Extensive use of lacquer began from the end of the 5th century BC in southern China in the state of Chu 楚. Various items were covered with lacquer, and during this period, a variety of lacquer technologies were strictly regulated.

All operations were consolidating special treatises. Lacquer was an anticorrosive and antimicrobial insulating material. It extended the lives of objects not only made of metal and terracotta, but also of organic materials. Leather and all types of wooden objects were covered with lacquer, especially tables, chairs, containers, boxes, furniture, musical instruments, weapons, chariots, and coffins (Bonanni 2009). The Chinese were able to cultivate lacquer trees, and they planted varieties that could also be grown in the more northerly states. The number of trees and the harvested sap were strictly controlled and accounted for by special institutions. By the time of the Qin Dynasty (221–206 BC), lacquer was so widely used that there was a new technology for making lacquered vessels without the wooden base: in place of the wooden core, lacquered fiber ramie was used.

During the Han Dynasty, lacquer was also popular, as well as silk. Their products had intrinsic value, standing out mainly by design and quality. Sap is cannot be diluted with water, and the density of sap alone produces thick layers that take a long time to dry. Masters changed the working properties, appearance, and cost of compositions by adding into sap other organic materials, such as drying oils and modifiers (e.g., persimmon juice, shellac, animal glue, wood, starch, etc.). Qi-lacquer was diluted by oils, which for paint media most often was the oil of the tung tree.<sup>1</sup> The best strength and protective properties of the lacquer coverings were achieved by using an optimal amount of oil in the coatings. However, excess oil in the lacquer, while reducing its price, would also lead to the degradation of the coatings. The composition of lacquer was kept secret.

The manufacture of lacquered items was widespread in the Han Empire, especially in the South, where lacquer trees grew naturally. Plain silk and lacquerware of low quality (typically made by reducing the number of layers in the processing operations as well as the adherence

<sup>1</sup> Tung oil (modern product with the brand name “tung-oil”) is obtained from the nuts of the tung tree (*Vernicia fordii*). It belongs to the class of drying oils, as it contains 66%–82% unsaturated eleostearic acid. It dries faster than linseed oil, and tung oil coating is more durable. However, the durability of coatings based on it is not comparable to the resistance of coatings based on lacquer itself, and so based on this indicator they belong to different classes of coatings.

to processing methods and compositions, and which easily deteriorated due to the use of large quantities of cheap modifiers) were widespread among the common people. Colored silks and polychrome lacquerware (with red and black paint or inlaid with silver and gold) were very expensive and served as a marker of social status.

## 1.2. Archaeological Chinese Lacquer from the Xiongnu Barrows

The quantity and quality of lacquerware in archaeological contexts can be used to determine the wealth and social status of the owner or demonstrate his or her relationship with the Han imperial court. Archaeologists have found many lacquered objects in Han period tombs. Moreover, lacquer cups have been found as far north as north of Lake Baikal and as far west as Begram, Afghanistan (Louis 2006: 48–53). Findings of lacquered cups in such remote areas are explained as resultant from trade and economic relations of peoples along the Silk Road. Lacquered cups were found not only in Chinese burials, but also in ancient tombs in modern Korea, Mongolia and Transbaikalia. These were made beginning from the Eastern Zhou 周 Dynasty and ending in the Tang 唐 Dynasty (Rudenko 1962: 36, fig. 28; Lawton et al. 1987: 109; Liu et al. 2005: 358–363). Also, lacquer objects have been excavated in Mongolia and Transbaikalia in the barrows of the Asian Huns (Xiongnu). Among them are the finds from Noyon-uul.

The elite burials in the mountains of Noyon-uul in northern Mongolia are among the best-known archaeological monuments of the Xiongnu. They were excavated during last expedition (1923–1926) of Peter Kozlov (1863–1935), the famous Russian traveler and explorer of Asia. A total of eight barrows were excavated. A Mongolian-Tibetan expedition identified 212 barrows in all the cemeteries of Noyon-uul (Rudenko 1962: 8). The construction of the excavated barrows was similar in general. A barrow had a square mound with sides oriented to the cardinal points, and a square burial pit ranging in depth from 6 to 13 meters. At the bottom of the burial pit were dual chambers with a coffin in the inner chamber. The floor

was covered with carpets, and the walls were draped by silk fabrics. In the corridors were placed burial goods. The barrows of Noyon-uul date to the first century AD (Miniaev and Elikhna 2009: 21–31).

## 2. Objects of Research

### 2.1. Chinese Lacquer Eared Cups of the Han Dynasty in the Collection of the State Hermitage Museum. Provenance and Descriptions

Although fragments of various lacquered objects were preserved among the finds, the most widespread were cups of a special form. This type of elliptical cup with handles has a low rim, flat bottom, and two horizontal elongated handles with an oval form on the edges. They were colored by sap-based paints. The handles on these cups are complex and have a very distinctive profile, as they were always cut (or glued) at a slight angle. Therefore, such cups are said to have “wings” in the Chinese tradition (Chin. *er bei* 耳杯), or with “ears”. These cups were painted in red color on the interior. The exterior of the cups were decorated with red or orange geometric decorative ornaments on a black or brown background. The core for the lacquer cups was often cut from a piece of wood (Lubo-Lesnichenko 1969: 267).

The Chinese believed that not only the shape of the cups (with arms like a bird’s wings) could serve in the revival of the dead, but also the components used in their manufacture—cinnabar and lacquer sap—could, too. The cups were also to carry the dead to eternal life. Lacquer, in going into the ground, again becomes a tree; mercury (as an element in the cinnabar pigment) is capable of sublimation and can again become metal. The red layers are always repeatedly coated with a transparent black layer, and so the cycle of life and death is repeated over and over, too. Thus, the Chinese have applied philosophy to the painting.

Such lacquer cups were also used in the ancient Spring Festival. They were filled with wine and then were set afloat upon water. The person near who was floating on the water had to drink to the dregs. Related to using these cups, this holiday was sometimes called the “feast of birds”.

The cups were associated with the phoenix and as well as with two birds, represented by the handles. From the “mouths” they would “drink the sap of life”. That is why there were typically inscriptions on the cups with wishes for a “long life and many sons and grandsons”.

The cups were traditionally used for wine, as can be seen in scenes of feasting found in Han period tombs (Liu et al. 2005: 356). There were also cups, which, judging by the inscriptions, were designed for wine and food (Liu et al. 2005: 363). Not all cups had inscriptions (which are typically painted on the bottom or scratched into the lower side); in fact, most of the cups had no inscriptions.

In addition to lacquer, these eared cups could be made of stone, bone, mother of pearl, glass, crystal, jade, pottery, gilded bronze, or wood. In most cases, such cups belonged to the elite of society. Sometimes, bronze braziers were used as special supports for the cups in order to heat their contents. In some cases, legs were fastened to bronze cups, and these could be placed into special, deep trays. Sometimes a cup would be put on a small dish or sauceboat, and for some very solemn situations, the cups were put on a footed stand with a high or low leg, depending on the ceremony. These cups were used for fish and stews. There were images of fish, hens, or turtles inside the cups, and these were used in food offerings to the spirits of ancestors. One can see these on several stone reliefs in Han tombs (Liu et al. 2005: 354–359). Wooden lacquered cup were preserved in special lacquer ornamented containers into which they could seat seven pieces.

The expedition of P. Kozlov found only five lacquered Chinese *er bei* cups of wood at Noyon-uul (one in Barrow Number 6 and four in Barrow Number 23), along with two fragments of cup handles: one was found in Andreev’s Barrow (excavated in 1925), and the second piece in Barrow Number 12. The handles on cup MP-2301 were protected by

cover plates made of gilded bronze, i.e. it was a cup of “yellow ears” (Chin. *huang er* 黄耳). From the end of the Warring States period, and especially from the middle period of the Western Han Dynasty, lacquer objects for the imperial court began to be decorated on the edges and handles with cover plates of gilded bronze. Officials and private persons used cups with handles with cover plates of silver. Three cover plates for handles were found in the barrows of Noyon-uul, two in Barrow Number 6 and one in Barrow Number 12. Four lacquered cups were found in Barrow Number 23. One of the cups from this barrow was transferred to the Museum of History in Ulan Bator in 1927. Today, in the collection of finds from Noyon-uul stored in the Hermitage Museum, there are four cups (inventory numbers MR-2301, MR-2302, MR-2303, and MR-2304). In Mongolia, two cups from Noyon-uul now are stored in the History Museum in Ulan Bator, one from Barrow Number 23 and the second from the excavation of A. Simukov<sup>2</sup>. This cup was found by Simukov in 1927, and it is described as coming from “the lonely barrow in Tsurumte, which is lower than Kondratiev’s barrow” (Yusupova and Simukova 2007: 105).

The lacquered cup from Barrow Number 6 (MR-2301) has a maximum length of 161 mm. Its handles have protective overlays made of bronze, covered with gold. They were found separately and were saved in this form. On its surface there are historical inscriptions described below.

Cup MR-2302 has a maximum length of 130 mm. Other cups from Barrow Number 23 (MR-2303 and MR-2304) are identical in size and have a maximum length of 134 mm.

## 2.2. Cup Fragments

A fragment of a cup (MR-2551), found by G. Borovka<sup>3</sup> in Barrow Number 49, is black color

<sup>2</sup> From 2006–2011, a Mongolian-Russian expedition excavated six lacquered cups in Noyon-uul: five in Barrow Number 20th and one in Barrow Number 31st (Polosmak et al. 2011: 122, 140). They were given to museums in Mongolia.

<sup>3</sup> G. Borovka (1894–1941), an archaeologist at the State Hermitage Museum, was sent by the request of S. Oldenburg, Academy of Sciences of the USSR, to the excavations of burials in Noyon-uul only in September 1924. He wanted to “dig up at least one barrow”. In the summer of 1926 his dream came true: he dug out Barrow Number 49, located in Sudzunkte.

on the sides and has no painting. It is round in shape and has a leg. Now there is no leg, leg was broken. It is made of a durable material.

Another fragment of *er bei* cup handle (MR-2412; dimensions 27 mm×37 mm; Figure 1; Plate VI, 1) is covered with red lacquer. It was fitted with a bronze cover plate and was found in Andreevsky's Barrow. The fragment was found in the ground under the decking. Its condition is satisfactory, and it was broken into three parts, which allowed a determination of its manufacturing technology. Its design, such as a geometric pattern on the handle, is very close to the cup that was found by A. Simukov (Brent 2005: 51) and to two cups from Barrow Number 20 (Polosmak et al. 2011: 121–122). Presumably, this cup fragment can be dated to the first years BC.



Figure 1. A fragment of the handle of a cup (Inv. Number MR-2412) from Andreev's Barrow, Noyon-uul, Mongolia, held in the State Hermitage Museum.

Also in Barrow Number 12 at Noyon-uul, excavated by S. Teploukhov and G. Borovka, 36 fragments of lacquer ware were found, according to the inventory record. They were discovered in the corners and eastern parts of the inner chamber. One of the fragments was published (see Pirazzoli-t' Serstevens 2009: 36–41, fig. A-14). Most of them belong to a lacquered box, of which a schematic reconstruction was done by Umehara (1960: 33, fig. 18). This lacquer box was dated 16–2 BC. Among the fragments is one which is part of a handle (Figure 2; Plate VI: 2; size 4.7 cm×1.5 cm×0.8 cm); the old expeditionary number 12–338 remained on it, confirming its origin from Barrow Number 12 and its location along

with fragments of boxes. On the surface of the handle is a specific rim for attaching a bronze cover plate, which was also found in the inner chamber of Barrow Number 12. It is stored in the State Hermitage Museum and is a perfect fit for this fragment of a *huang er* 黄耳 handle.



Figure 2. Fragment of the handle of a cup from Barrow Number 12, Noyon-uul, Mongolia, held in the State Hermitage Museum.

### 3. Research Methods

A comprehensive investigation of lacquer and paint objects from the Noyon-uul collection was completed during a 2012–2013 investigation of archaeological finds of lacquered objects found in the Altai region that was done by the Department of Scientific and Technical Review (DSTR) of the State Hermitage Museum (Tishkin et al. 2008: 196–200).

Qi-lacquer can be confidently identified by the methods of analytical chemistry (Kamiya and Miyakoshi 2001: 865–874; McSharry et al. 2007: 29–40). The markers of lacquer and modifiers of lacquers (such as vegetable oils) are known. Fourier Transform Infrared Spectrometry is often used in the identification of coatings: this technique compares the spectrum of the unknown lacquer with the spectra of attributed materials (Silverstein et al. 1998; Urushi 1985).

For this article, the chemical composition and structure of the coatings of the finds from Noyon-uul (16–2 BCE—the end of the first century AD) were determined using a comprehensive approach. Coatings were investigated by analytical methods using microscopy, infrared spectroscopy, and X-ray by the Department of Scientific and Technical Review of the State Hermitage Museum. Infrared

spectra were taken, and photographic images were produced by X-ray fluorescence analysis of the coatings (taken from different sides of the cups and separate layers).<sup>4</sup>

All infrared spectra were taken in a scanning Fourier Transform Infrared Spectrometer, model Shimadzu FTIR-8400S, with a highly heat stabilized DLATGS detector in the spectral range 7800–350  $\text{cm}^{-1}$ ; samples were prepared as KBr pellets. The structure of varnishes and paints was analyzed using an ArtTAX (Brüker) instrument with the help of roentgen-fluorescent analysis of the surface. Conditions of conducting: voltage of 50 kV, current strength of 700  $\mu\text{A}$ , accumulation time spectrum 40 $^{\circ}\text{C}$ . Since the analysis was done on paint, a composite material containing inorganic (pigments and other) and organic (binder) parts, the discussion is qualitative in nature.

In addition, to clarify the composition of the paints, experiments were conducted on the modification of fresh sap with tung oil. The lacquer formulations in this study were dried in a hydrostat. The properties of these coatings on a variety of metal substrates were studied using infrared spectra and X-ray fluorescence analysis, etc. Their soaking in different environments was defined, and the influence of ultraviolet radiation on their properties was checked. This experimental work on the modification of lacquer with tung oil and others oils was done in 2000 at the Department of Chemical Technology of Organic Coatings at the St. Petersburg Institute of Technology under the leadership of O. Novikova.

Lastly, the structure of the coating layers was studied by viewing microsection cross-section samples under a microscope. To determine the composition of the binders (Figure 3; Plate VII: 1; Figure 4; Plate VII: 2), micro-chemical studies using reagents (20% solution of KOH, Ponceau S, Amidoblack, Sudan Black B, Lugol) are done. Whether or not the reagents cause a reaction (such as saponification, changes in coloring, etc.) is observed under the microscope. This research, along with differential-thermal analysis and

other studies are still underway, and the results will be reported later.



Figure 3. Fragment of a bowl from Barrow Number 49, Inv. Number MR-2551, as viewed under the microscope.

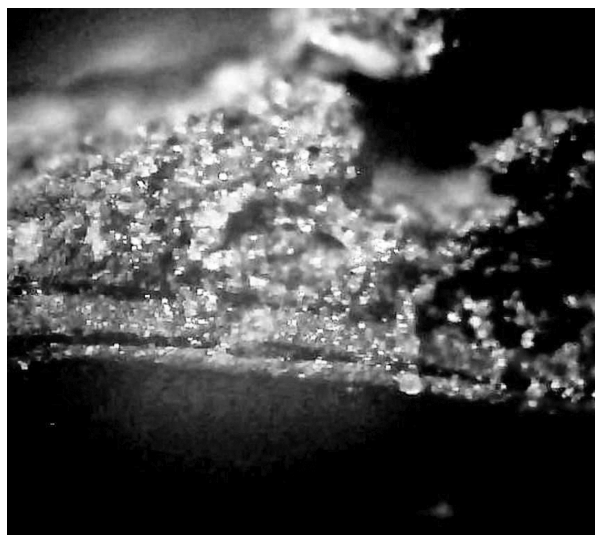


Figure 4. Fragment the structure of the paint coating of the cup from the barrow number 6, Inv. Number MR-2301, recording under the microscope.

## 4. Investigations. Results and Discussion

### 4.1. Construction of *Er Bei* Cups

*Er bei* cups from Noyon-uul in the collection of the State Hermitage Museum have the oval shape of a typical Chinese cup used in the ancient Spring Festival that was filled with wine

<sup>4</sup> Chemical and microscopic study of the spectra and decryption was completed by O. Novikova, Ph.D., Senior Research Associate of the Laboratory of Physics and Chemistry, Department of Scientific and Technical Review of the State Hermitage Museum. X-ray fluorescence analysis was completed by S. Khavrin, Assistant Manager, Department of Scientific and Technical Review of the State Hermitage Museum. The sensitivity of the method is within 0.05%–0.5%.

and floated on water. Following another name for this holiday, they are sometimes called “celebration of birds” cups. They were carved from a whole piece of dried wood. Handles were carved separately and glued to the body of the cup, such as we find for MR-2301 (Lubo-Lesnichenko 1969: 268). Then coatings were applied to the wooden blank to produce the final lacquered object; these coatings primarily performed a protective function for the wooden base. (The results of the technological and chemical investigations of the paint layers follow below.)

The paints on the cups (as well as very strong glue that joined the handles to the sides of cups) have well withstood the test of time, but there is still some damage typically seen on the cups. This damage is often similar, due to the specific shape and construction of the cups. It should be

noted, however, that the damage to the coatings is not at the weakest part (the curved area) of the wooden base. Deformations were not seen on the problem areas at the sides of the cups. The greatest damage to the wood occurred at the side adjacent to the zones of attachment for the handles (Figure 5: 1; Plate VIII: 1). In some cases, the deformations caused only a warping of the lacquered covering, while in others they were so great that they led to a complete loss. There are cases that show disruptions in the wooden cups (National Museum of Mongolian History, unnumbered) or complete separation of the sides of the cups and handles. On the cup from Barrow Number 6 (MR-2301, the view from the top or the bottom), there is a strong shift of the wooden base and the handles away from each other, and this resulted in the complete loss of the paint layer.



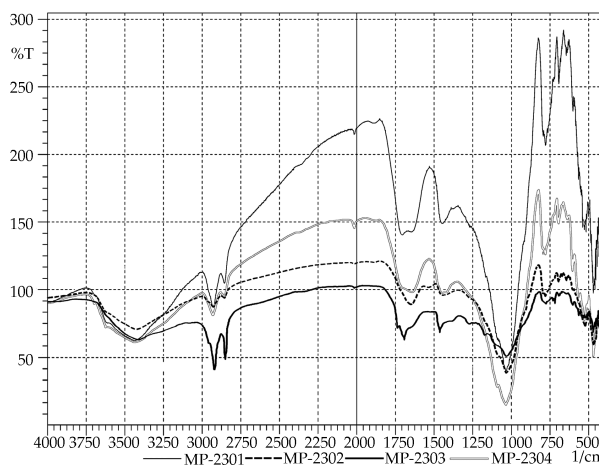
1



3



2



4

Figure 5. Han Dynasty lacquer cups from Barrows Number 6 and Number 23 at Noyon-uul, Mongolia, held in the State Hermitage Museum.

1, 2. Cup from Barrow Number 6, Inv. Number MR-2301; 3. Cup from Barrow Number 23, Inv. Number MR-2302; 4. IR spectra of four cups, Inv. Numbers MR-2301-2304.

Damage happened due to internal tension in the base (the amount of damage depends on the

type of wood). Due to the heterogeneity and curvilinear anisotropy of wood fibers, damage

can appear even with uniform drying. A hygroscopic moisture gradient appears along the cross-section of the material resultant from when the objects were in a burial and this increases the tension in the wood. Then, due to the growth of the asymmetry of its distribution in a product, the shape of the cross-section of the wooden core changes, resulting in the emergence of cross-warping and cracking along the fiber layers (Figure 5: 4).

Why the masters of China are for centuries repeated the wooden form of *er bei* cups and its multilayer coatings that originally seemingly were doomed to fail against the test of time? Yes, from a chemical point of view, the lacquer cups have withstood a strenuous durability test, being buried in the ground for twenty centuries with varying temperatures and humidity. This shows excellent protective properties (adhesion, physical and mechanical). Modern special paints are hardly able to withstand this amount of tensile strain.

We assume that the manufacture of these lacquer cups was based in deep philosophical analogy. For example, the shape of the cup was similar to a metal vessel used from antiquity to the present day in China to collect raw lacquer. Also, lacquer's name itself symbolizes the fullness of vitality and spirit. Handles on the cup served an important function in collecting sap and were thus not only for decorative purposes and to protect them. In the treatise, "The Discourses on Salt and Iron", they were called poetically "silver mouth in yellow ear." One of them would be deeply wedged in the cut on the trunk of the tree, and the handle would securely suspend the vessel, so as not to allow a single drop of the precious liquid to fall to the ground.<sup>5</sup> After it was filled, the cup could be pulled out from the trunk with force by holding the other handle.

## 4.2. The Results of Historical and Art Studies

### 4.2.1. Painted decor cups

The lacquered cup from Barrow Number 6 (MR-

2301) is decorated with figures of phoenixes and red spiral motifs drawn on a dark brown lacquer background (Figure 5: 1, 2; Plate VIII: 1, 2). Another figure of a bird was engraved on a bronze cover plate on the handle. The inscription on the side of the edge of the cup bottoms was translated by O. Hummel and S. Umehara (Umehara 1960: 29). In addition, the cup has been studied by M. Pirazzoli-t' Serstevens. In her opinion, it was made in a private workshop, and it was a copy of the imperial style of manufacture (Pirazzoli-t' Serstevens 2009: 36–41). The inscription was carved and consists of seventeen characters. According to the inscription, the cup was made in 2 BC. At the bottom of the cup there are characters Shanglin 上林, written in red paint, which indicates the name of the Han Imperial Palace Gardens.

Stylistically the cup that was found by Simukov (noted above) is an example of mass production in the imperial workshop in Sigong County in the state of Shu (Sichuan Province). The inscription on the cup consists of sixty characters. It also is dated 2 BC. Fifty lacquered cups from Sichuan are well known. Among them there is a cup of fine quality, despite the fact that it is a product of mass production. The inscription on it mentions that it was suitable for use by the emperor.

The best preservation of lacquer layers is found on cup MP-2303, which has loss of paint layers only on the outside of the bottom. In the center of the bottom there is a small area of "wrinkle" in the lacquer (approx. 10 mm). The cup part of MR-2302 shows a loss of the paint layer on the base on the outer side of the oval part, on the bottom, and on the rim of the handle (Figure 5: 3; Plate VIII: 3). The greatest loss and warping of the lacquer layers is observed on surfaces close to the handles. The cup MR-2304 displays the maximum amount of loss of the lacquer layer in the same areas; this has occurred due to the imbalance of the cup's wood base. These three cups do not have inscriptions and exhibit a more simplified pattern of lacquerware created in the Eastern Han (AD 25–220). F. Louis (Louis 2006: 50) analyzed similar designs on cups from the burial in Wang

<sup>5</sup> The oval shape of the cup (versus a round shape, for example) allows the attachment of a handle of greater length to the cup and thus can increase the structural strength and, at the same time, be able to collect a larger volume of sap. Known lacquer cups with handles, from the time of the state of Chu, have a concave outer edge pens cups inwards. This design allows even better attachment of the cup to the tree.

Shu in Korea and came to the conclusion that the cups were made after AD 69. In the archived inventories from the burial, there is no clear information where the cups were found (only somewhere to the north of the coffin). They are an example of the production of lacquered objects of wide use and for trade, and they were not intended as gifts that the court of the Emperor gave to the Khans of the Asian Huns.

#### 4.2.2. Ornaments and Inscriptions

On the lacquered *er bei* cups that were found in the barrows of Noyon-uul, there are two types of ornaments, but of course many more ornaments are known. The most widespread of the cups have two types of ornaments, and these are on the cups from the collections from Noyon-uul, kept at the State Hermitage Museum. The first type was made in a workshop in Western Sichuan approximately between 44 and 20 BC (Pirazzoli-*t'* Serstevens 2009: 36–41). This ornament is a combination of straight lines, swirls, and concentric circles, with figurines of phoenixes opposed to each other. The second and simpler one is a composition of curls and circles. Probably, this is a simplified version of the “cloud” ornament.

All cups with inscriptions from Noyon-uul belong to the period of the Western Han (206 BC–AD 9). The inscriptions contain a description of the process of lacquering (上漆) and the names of lacquerers (漆工). The character relating to the binder for paints and lacquers means the sap of the lacquer tree. The inscriptions on the cups differ about their places of manufacture (Chistyakova 2009: 59–68). So, one of the cups from Barrow Number 20 is dated 9 BC according to the inscription (excavations 2006–2011). It was made in the imperial workshop of Kaogong 考工 (city of Chang'an). A few years later, the cup from Barrow Number 6 (MR-2301) was made in a private workshop.

A cup fragment (MR-2551; Figure 6; Plate VI: 1; dimensions approximately 100mm×80 mm) is less than half of the cup, round in shape, and dark brown color with inclusions of stripes of dark layers. Barrow Number 49, from which it came, can be dated to the second half of the first century AD (Miniaev and Elikhna 2009: 27). At

the bottom of cup MR-2551 there are traces of a thin circular leg. The fragment has a gracefully curved edge, so we know the bowl had a more complex form (with a rim and an extension to the bottom), which distinguishes it from *dou* 豆 pedestaled serving stands.<sup>6</sup> A bowl that was made of similar material to the leg, but different in form, was found by Chinese archaeologists in 2012 in a cemetery dating back to the Qin 秦 Dynasty (221–206 BC).



Figure 6. Bowl from Barrow Number 49, Inv. Number MR-2551, from Noyon-uul, Mongolia, held in the State Hermitage Museum.

The design on the fragment of the *er bei* cup handle MR-2412 includes a geometric pattern that is very close in appearance to that on the cup that was found by A. Simukov (Brent 2005: 51) and to the two cups from Barrow Number 20 (Polosmak et al. 2011: 121, 122). Presumably, this fragment of a cup can be dated to the first years BC.

The shape and cross-section of the handle from Barrow Number 12 (old expeditionary number 12–338; Figure 2) are typical for *huang er* 黄耳 cup. On the surface of the handle there is a specially shaped rim for attaching a bronze cover plate. The bronze cover plate that was also found in the inner chamber of Barrow Number 12 and that is now stored in the State Hermitage Museum is a perfect fit for this handle fragment. On two sides of handle there

<sup>6</sup> *Dou* 豆 have been described as bowl with lid for meat, and were used in rituals to sacrifice fresh spring onions.

remained fine decorative painting. The background was painted in dark brown, and the pattern was made with black paint. The edge of the handle is encircled with a red contour. A kind of “cloud” ornament was drawn on the bottom side of the handle. Such ornamentation is typical for the Han Dynasty. In general, the carefully executed decoration on the handle is indicative of it being produced relatively early, so we can assume a date for the cup that is earlier than the one from Barrow Number 23.

#### 4.3. Natural Science Research Methods Results

Experiments in modifying the sap of the lacquer tree with a small amount of tung oil have shown that the addition of 5%–7% oil to lacquer. Increases the degree of polymerization and can improve the mechanical properties (gloss, hardness, etc.). The addition of oil beyond this amount leads to the drastic deterioration of the physical and mechanical properties of the coatings, which are based on urushiols from the sap of the lacquer tree.

Infrared spectra of samples taken from different parts of the cups (such as the background and painting) are in good accordance with the infrared spectra of Chinese lacquers, as well as the infrared spectra of a Japanese lacquer in the British Museum available in the Infrared & Raman Users Group (IRUG) database. Infrared spectra of all the colors on the cups are similar to the characteristic spectra of paint and lacquer from other artifacts from Barrows Numbers 6, 12, and 23 at Noyon-uul held in the collections of the State Hermitage Museum, including wheel spokes, rosettes, legs, boxes, etc.

To date, analysis has produced infrared spectra for forty samples. In the spectra there are three sharp stripes at 1450–1650  $\text{cm}^{-1}$ . These are characteristic for aromatic combinations. They were accompanied by a weaker absorption around 1000–1200  $\text{cm}^{-1}$  and the characteristic CH plane deformation vibrations at about 670–900  $\text{cm}^{-1}$ . Absorption stripes of groups –C–N, –O–C=O are present, and they are for specific polymers and the urushiol group –C–O and for polysaccharides of plants and wood. Absorption at 670–900  $\text{cm}^{-1}$  and/or there being overtone composite frequencies in the range 1660–2000  $\text{cm}^{-1}$  for different types of

lacquer tree SAPS indicate a clear difference in the number and position of substituents on the benzene ring of the pyrocatechols.

The spectra resulting from the known, experimental urushi-oil lacquers allowed the calibration of the IR spectra on the oil content in the studied archaeological lacquers. In the composition of the coatings of the studied lacquers we noted the presence of small amounts of tung oil (the so-called “wooden” oil). Each pigmented layer of paint (chin. *tong qi*) is a mixture of binder-based lacquer, and these layers were applied to a layer of transparent black *qi-lacquer*. The safety of the adhesive bond between the layers is very high. In the first step in manufacturing paint, vermilion was mixed into the oil, and then the resulting mixture was added to the lacquer sap.

According to the infrared spectra covering various parts of the cups MR-2302 and MR-2303, these two cups are identical. Also similar are the composition of paint on the interior and exterior of MP-2301 and the exterior of cups MR-2301 and MR-2304 (Figure 5: 4). There are some differences from the spectra of samples from the cup handle MR-2412 from Andre-evsky's Barrow. We note in the compositions of the coatings of the cups from Barrow Number 23 the presence of proteins containing an amide group (there is a small dash in the absorption in the areas 1534  $\text{cm}^{-1}$ , 1524  $\text{cm}^{-1}$ , 1519  $\text{cm}^{-1}$ ). Their amount is less than in the compositions used for coating the exteriors of these items. These cups are different (compared with a cup from Barrow Number 6) because of the presence of a larger amount of tung oil in the paints. In Table 1 you can see the absorption band of plant varnishes and oils.

The elemental analysis data are given in Table 2. It is revealed that sulfur is present in the black lacquer layers on all four cups; there is low calcium content, and the intensity content of potassium exceeds 2.5–5 times. The black layer of cups MR-2301 and MP-2404 have small amounts of copper. In the black lacquer on all cups there is a considerable amount of iron, as well as traces of titanium and manganese. The ratio Fe / Mn is close for the lacquer of cups MR-2302 and MR-2303 (ration of 30/1), and it increases in lacquer of cup MR-2304 (ration of 70/1). Sap for coloring the cups was prepared in vessels that had slightly different iron content.

The comparison of the red layers of cups shows that each has a marked difference in the degree of pigmentation: high for MP-2301 and less for the other colors of cups (the colored layers are also thinner). Note that the red layers of cups

MP-2302 and MP-2303 contain the same amount of HgS, and in the paint from MR-2304, the content of HgS is less. What is special to the paint coverings of the objects from Noyon-uul is the presence in their samples of titanium ions.

**Table 1. Characteristic absorption bands of analysis lacquer cups from Noyon-uul**

Position strips, cm <sup>-1</sup>	Attribution absorption bands
1740–1709 (av.)	C=O stretching vibrations non-conjugated ketones, compounds containing carbonyl and ester groups. Characteristic for the oxidation products lacquer
1675–1655 (int.)+	C=O stretching vibrations in the para-substituted aromatic ketones
1640–1620 (int.)	C=C-valence phenolic ring
1534–1514 (sl.)++	amides glicoproteins, nitrogen components of lacquer
1430–1417 (av.) +++	C–C-valence aromatic skeletal fluctuations combined with C–H-asymmetric plane by deformation oscillations in metilol groups
1375–1365 (sl.)	aliphatic C–H-symmetric deformation fluctuations in the methyl group; planar deformation O–H fluctuations in phenols
1280–1266 (sl.)	skeletal fluctuations bisphenol ring and C–Ar–O–C valence asymmetric oscillation phenolic ring
1240–1221 (sl.)	stretching vibrations in phenols and esters of lacquer
1166 (shoulder) (av.)	aromatic C–H-plane deformation fluctuations and stretching of C–O fluctuations in the ester groups (conjugated) aromatic C–H-plane deformation
1086–1080 (shoulder) (av.)	stretching vibrations of C–O in the secondary alcohols and asymmetric C–O–C in aliphatic ethers
993–982 (sl.)	-HC=HC-out-of-plane deformation vibrations
858–853 (shoulder) (sl.)	C–H-out-of-plane deformation vibrations phenolic ring (1, 2, 3, 4) and (1, 2, 3, 5) substitutes bisphenols and dibensofuranes

Note: + intensive; ++ slow the intensity of the bands absorption; +++ average.

Stratigraphic investigation of the paint layers shows that, in general, the four cups were made with a similar technology. The safety of the adhesive bond between all layers of paints is very high. Warping of the base caused the destruction of the conglomerate in the weakest layer, which was a coating composed of a mixture of qi-lacquer with animal glue, powder from wood sawdust, and charcoal. Between the layers of coating there is a textile (apparently from vegetable fibers of hemp or ramie), soaked in lacquer. A layer of lacquer is on the textile layer, and above it is a colorful conglomerate consisting of alternating layers of a transparent black lacquer and finely ground red paint<sup>7</sup>. Moreover,

two layers of pigmented *tong qi* (a mixture of qi-lacquer with ground cinnabar mixed with tung oil) are painted upon each other, alternating with thinner layers of black qi-lacquer (mixed with charcoal). This is consistent with the rules of the treatise, *Huainan zi* 淮南子 (II c. BC), which states that “the master can paint <object> only red on black <layer>, but not in the reverse order” (LuboLesnichenko 1969: 267). The outer surface of the cups, which is shiny and without of cracks, is covered by thin layer of tinted (*imprimatur*), transparent and durable lacquer (probably of animal origin, possibly based on casein). Since lacquer has a yellowish color; the general color of the background of the cups is brown.<sup>8</sup>

<sup>7</sup> We emphasize that this technique (two layers of red alternating with two layers of black) was found on all four cups and handles of cups from Noyon-uul, and we do not consider the second layer of vermilion on them the result of the restoration of the old product.

<sup>8</sup> Some suggest that the brown background of the painted lacquer objects is a stylization of the color of bronze vessels.

**Table 2. The results of the roentgen-fluorescent analysis on the lacquer cups from Noyon-uul**

Inv. No.	Layer color	S	K	Ca	Ti	Mn	Fe	Cu	Hg	Another
MP-2301	Black	low content	+	++	low content	low content	+++	low content	low content	
	Red	low content	low content	++	low content	low content	++	—	+	
	Red (bottom)	low content	low content	low content	—	—	+	—	+++	
MP-2302	Black	low content	low content	+	+	low content	++	—	—	
	Red	low content	—	+	—	low content	++	—	++	
MP-2303	Black	low content	low content	+	low content	—	++	—	—	
	Red	low content	low content	low content	low content	—	+	—	++	
	Brown	low content	+	+	+	low content	++	—	—	
MP-2304	Black	low content	low content	+	low content	low content	++	low content	low content	
	Red	low content	low content	+	low content	low content	++	low content	++	
MP-2412	Black	—	low content	+	low content	—	+++	++	++	
	Red	—	—	low content	—	—	low content	++	+++	
MP-2551	Black	low content	low content	+	++	low content	+++	++	—	Zn ++, As ++, Cl +

There is a small technological difference between the coatings on the cups. The coating on the outside of cup MR-2301 is thicker than the coating on the inside. This is not observed on cups from Barrow Number of 23, which have inner and outer layers of the same thickness and composition. Some cups with thin paint layers have a brown layer of lacquer (or even of animal glue, e.g. MR-2304) instead of a layer of black lacquer present, the fabric is not soaked in lacquer but rather in glue, and the red layers contain a lot of tung oil. That is to say, the three cups MR-2302, MR-2303, and MR-2304

were produced using technology that was easier and cheaper than in the case of cup MR-2301. The result is obvious: some of these cups have the worst preservation of the paint layers.

Tung oil is also used in the coatings of the cup from Barrow Number 6, but in a much smaller (and thus more optimal) concentration. Its colorful conglomerates were virtually destroyed in the 20% alkali (but its layers did not swell). It is not so for the other painted cups. Alkali causes swelling of glue inside the paint and lacquer layers. On cup MR-2304, moreover, the

layers immediately swelled and the outer layers are easily removed by a needle (red and black layers), and there is more tung oil in the paint of these layers than in the paints of cups MP-2302 and MP-2303. However, the swelling is reversible. If the samples in alkali do not have the mechanical force of a needle applied to them, after drying, the colorful conglomerate of all the samples retains its unity. This lets us recall the Chinese proverb that describes a strong friendship as being as strong as the link between the layers of glue and lacquer, or *jiao qi* (胶漆, glue and lacquer).

Microscopy of the layers of the coating of the handle of cup MR-2412 from Andreevsky's Barrow shows that the technology of its color is the same, but a little easier. Below the layer of imprimatur on the black lacquer layer (an application of animal glue), there is laid only one layer of red paint with vermilion. A coating with wood fibers and a lot of particles of charcoal was put across the grain of the wood that was strengthened with black lacquer. X-ray fluorescence analysis showed that both top layers contain ions of copper; the copper content is very high, but sulfur and manganese are missing. Apparently, the sap for the lacquer in this cup came from another area of China. Its gilded bronze cover plate is close in composition to traditional Chinese bronzes.

According to infrared spectra and X-ray fluorescence analysis, bowl MR-2551 from Barrow Number 49 is a highly filled composite mixture consisting of a binder—a natural polymer containing a significant amount of arsenic, zinc, iron and copper—and a filler, namely wood fibers. The blocked biopolymer that is based on the pyrocatechol urushiol features a high degree of similarities in physical and mechanical properties (such as hardness, heat resistance, etc.) to those of synthetic materials of the phenol series developed in the twentieth century, such as thermosets and polycondensation products of phenol with modifiers (such as bakelite or resite): these similarities can be attributed to the natural precursors of the synthetic materials.<sup>9</sup> The chemical composition and the features of edge

chippings of the fragment indicate the method of its manufacture. Apparently, the cup on the leg was created by molding it stage by stage into complex forms that were deleted one after another after the drying of lacquer mixture. The place where the leg attaches to the bottom, due to its small diameter and (presumably) its length, was one of the weakest points in the construction of the bowl. Therefore, because it had been buried in the ground and remained there, the bowl has reached our times in a fragmented form. New data from differential thermal analysis confirm these conclusions and suggest even more refined compositions for varnish materials on the cups from Noyon-uul; this will be described in a future article.

## 5. Conclusions

Physico-chemical investigations of cups from Barrows Number 6 and Number 23 at Noyon-uul held in the collections of the State Hermitage Museum identified their method of manufacture and the composition of paints, as well as confirmed their dating. The paint on the cups derives from urushiol present in the sap of the Chinese lacquer tree. The earlier cup MR-2301 was manufactured in compliance with ideal technology, while the manufacture of the other three cups is marked by changes and disorder. We see dilution of the lacquer paints used in coloring the cups with greater amounts of tung oil and less expensive components (such as cinnabar and lacquer). These cups were objects of mass production. The composition of the paints on cups MP-2302 and MP-2303 are almost identical. A cup from Barrow Number 6 was made with a greater understanding of chemistry and processing technology of lacquering, showing great care and refinement. Important characteristics for attributing these objects to specific places of production can include not only the coatings of cups, but the dimensions and thickness of the piece, including the handles. For example, the earlier cup MR-2101 has a thinner handle with greater length than that on cup MR-2102. Aggregate data from the investigation of the coatings on the fragment of

<sup>9</sup> However, phenol-formaldehyde lacquers (phormophénoliques) are inferior in physico-chemical properties to lacquers based on urushiol.

the handle from Barrow Number 12, as well as the size of its bronze cover plate, show that it could support the cup to which it was attached in the tradition of painted cup MR-2301, although the rest of the cup body was not found and it was probably destroyed.<sup>10</sup>

Comparison of the chemical properties and other data from the coatings for all four cups with LCP of the handle of the cup MR-2412 allows us to attribute it to a group of objects, as it has been painted with Chinese lacquer from a different place of origin. Its size and the remains of gilding on the bronze cover plate allow us to (tentatively) infer that it was not a mass produced item.

Bowl MR-2551 from Barrow Number 49 was created by using qi-lacquer that was applied in a different way, namely as a composite binder material with wood sawdust. Thus, in the collection of the State Hermitage Museum, these are a unique set of Chinese lacquerware from the Han era from the barrows of the Xiongnu that no other Russian museums possess.

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<sup>10</sup> However, it could be earlier, as its infrared spectra are very similar to the spectra of the samples from the coatings of the box. Perhaps this handle can be dated to the same time period as the fragments of the box, i.e. 16 to 2 BC (Pirazzoli-t' Serstevens 2009: 36–41).

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