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An Investigation of Early Chinese Bronze Mirrors at the Harvard University Art Museums

Abstract

Mirrors have been used in China since ancient times for both practical and spiritual purposes. Thousands of examples of these early bronze mirrors have been excavated and can be found in collections worldwide. This study focuses on the Winthrop collection of Chinese bronze mirrors, which were donated to the Harvard University Art Museums in 1943. The collection consists of forty-four mirrors dating from the Zhou Dynasty's Spring and Autumn Period (771-476 B.C.) to the Tang Dynasty (618-906). There has been little previous scientific examination of these objects, and this paper presents the initial results of a survey to determine their composition, manufacturing technology, condition and the extent of previous restorations. The primary scientific methods employed include detailed examination with binocular microscopy and ultra-violet light, x-ray fluorescence (XRF), x-radiography, Raman spectroscopy, scanning electron microscopy (SEM) and Fourier transform infrared analysis (FTIR).

1. Introduction

In 1943, the Harvard University Art Museums (HUAM) received its largest single bequest of works of art from an alumnus, Grenville L. Winthrop. The approximately 3,700 objects included 19th century French, British and American paintings and drawings, Old Master paintings, decorative art, Peruvian gold and early Asian art. Winthrop acquired most of his Asian works of art from galleries in New York City, relying primarily on Yamanaka and Company and on C. T. Loo and Company (Mowry 1996). Winthrop collected ancient Chinese ritual bronze vessels, jades, ceremonial weapons, inlaid chariot fittings, silver vessels, early Buddhist sculpture and bronze bells and mirrors. The mirrors were primarily purchased during the 1930's, and their examination provided a unique opportunity to study the objects of one collector and to observe the aesthetic tastes of his generation.

2. Background

<u>2.1 Bronze in Ancient China</u>

Bronze casting technology has been known in China since at least 2750 B.C., which is the earliest known bronze object to date (Shoukang 1986). Bronze was a core component of the ancient Chinese world because it was cast to serve the principle affairs of the state: ritual and war. Control of bronze objects not only meant control of the instruments of war, but also access to heaven since bronze was the principle material for ritual objects (Chase 1991). Ancient China had all the resources required to make bronze within their borders including copper, tin and lead ores. For example, there are over 800 copper ore deposits in China with most of them producing copper in ancient times (Shoukang 1986). Craftsmen used different alloys for different types of objects indicating they had very good control of alloy composition and a clear understanding of their different properties.

2.2 Origin of Mirrors

Mirrors probably evolved out of circular reflecting disks associated with cultures to the north of the Shang and early Zhou states. Numerous undecorated disks have been discovered in burial tombs placed both on top of and next to the deceased. The earliest decorated mirror is only 9 cm in diameter and has a simple star decoration (*Fig. 1*). It was discovered in a tomb in modern day Qinghai province and dates to the Xia Dynasty (2100-1600 B.C.). By the eastern Zhou era (771-256 B.C.), mirrors attained the status of a unique object in the Chinese tradition with their form and decoration becoming distinctive among the other bronze objects of the period (O'Donoghue 1988).

Figure 1. Drawing of Earliest Mirror from Reflections and Reception: The Origins of the Mirror in Bronze Age China.

The earliest archaeological evidence for mirror production in China was found at Houma, a foundry site in Shanxi, where ceramic casting molds were discovered. The major period of production at Houma was 600 - 500 B.C., although foundries may have begun to appear earlier at the site (O'Donoghue 1988). Mirrors were initially produced in small numbers, but came to be a major production type during the late Zhou and Han Dynasties. To satisfy the demand of the court and court officials, government foundries were located in dynastic capitals or at times, secondary capitals. Regional centers were also active, especially those with copper mines in their vicinity and a sufficient urban development to ensure a high level of consumption as in Shaoxing, Yangzhou and Huzhou (Chou 2000).

Mirror production flourished from the Warring States period (475-206 B.C.) until the Tang dynasty (618-906). They were expensive luxury goods with only people from the privileged classes being able to afford them. It was during the Tang dynasty that private workshops, as opposed to government foundries, arose and spread probably due to the rising merchant class being able to afford mirrors (Chou 2000).

Bronze mirrors continued to be produced after the Tang dynasty, but not to the same extent. During the middle of the Qing dynasty (18^{th} c.), they began to be gradually replaced by glass mirrors, and an industry, which had continued for almost 4000 years, came to an end (Shoukang and Tangkun 1993).

2.3 Form of Mirrors

The majority of mirrors are round, but square and rectangular mirrors have also been produced. The back was decorated while the front was finely polished creating the reflective surface. The decorated side of the bronze was full of symbolism especially in the earlier mirrors. The Chinese believed that by using symbols representing the universe, it would be possible to acquire some of the universe's power to gain both strength and protection from evil. For example, round shapes represented Heaven, the Earth was square and small domes represented stars and constellations.

Cast inscriptions were added to the decoration of mirrors beginning around 200 B.C. during the Western Han period (Lawton 1982). The inscriptions, like incantations or prayers, were meant to attract supernatural powers and bring good fortune for the living or, if placed in tombs, to assist the dead by keeping evil spirits away (Bulling and Drew 1971).

The mirror could be held in the hand or grasped by a cord passed through the pierced knob on the back. The knobs are often simple domes, but can be decorative and some even take the form of an animal. Besides being hand held, it is also assumed that mirrors were placed on stands or frames, but very little evidence has survived to substantiate this claim. Images of mirror stands are found in numerous art sources including paintings and carved stone (Yang 1996). These stands were probably made of wood and did not survive, but a Han period bronze mirror and its gilt bronze stand have survived, as is seen in Figure 2.

Figure 2. Mirror with Stand, 1^{st} century A.D., 47cm High, Nelson-Atkins Museum of Art.

Occasionally, mirrors were made with handles. The earliest excavated ones date to 2000-300 B.C. and were discovered in tombs in Xinjiang, the westernmost provincial region of China (Mei 2000). They then do not seem to be found again until the Tang (618-906) or Song (960-1279) dynasties (Yang 1996). The handle appears to be a Western influenced addition and was never extensively used on Chinese mirrors.

This basic form of the mirror as a cast metal object with a highly polished reflective surface and a back with relief decoration remained unchanged throughout the approximately 4000 years of bronze mirror history in China. The overwhelming majority of these mirrors were made in a single cast and after polishing the surface, no other applied decoration was added. The following are some examples of the small minority of mirrors that vary from this norm.

2.3.1 Double Plate Mirrors

During the Zhou dynasty, two layer mirrors were produced, and HUAM has six of these rare mirrors in its collection. They were made in both square and circular form and are constructed of two pieces. One section has a raised rim allowing the second section to carefully fit into it. The front reflecting plate can be inserted into a slightly larger back or, vice versa. There are no rivets to join the pieces, and they seem to be held in place by friction and perhaps with the help of an adhesive. Some double plate mirrors, including one at Harvard, have their plates attached by cartouches that bridge the junction of the two pieces in numerous places as is seen in Figure 3.

Figure 3. Double plate Mirror with Cartouches, Zhou Dynasty, 14 cm Diameter, HUAM 1943.52.150

The mirrors were adorned with two types of decoration: turquoise inlay (*Fig. 4*) and circular metal inlays (*Fig. 5*). The small pieces of irregularly shaped turquoise were adhered into straight walled channels that appear to be cast. The adhesive on one mirror (1943.52.155), which was analyzed by FTIR, was a natural gum.

Figure 4. Detail Turquoise Inlay on Double Plate Mirror, Warring States Period, HUAM 1943.52.155

Figure 5: Detail Gold and Silver Circular Inlays on Double Plate Mirror, Warring States Period, HUAM 1943.52.151

The circular silver and gold inlays were composed of a thin layer of precious metal attached to a lead dome possibly by cold pressure welding. According to Jacobson, cold pressure welding was an early technique used during the Zhou dynasty before amalgam gilding was invented. The bronze surface may have been prepared chemically, then the metal sheet was applied to the surface by careful preheating and burnishing (Jacobson 1984). Another possibility is amalgam gilding because mercury was detected on three of the silver inlays on 1943.52.152. Mercury gilding with both silver and gold was used in China by the late 4th century B.C. The metal was dissolved in boiling mercury, the resulting paste smeared on an abraded surface and the piece was fired below 500˚C (Jacobson 1984). Once the metal inlays were manufactured, they were fitted into sockets in the bronze. There were no traces of adhesive in the sockets of missing inlays indicating they may be held in place by friction alone.

Figure 6. Gold Backed Mirror, Tang Dynasty, 16 cm Diameter, HUAM 1943.52.158.

2.3.2 Gold and Silver Backed Mirrors

During the Tang Dynasty, the decorated side of some mirrors was made of gold or silver sheet with repoussé designs (*Fig. 6*). The metal sheet was set into a recess in the bronze and may be held in place with adhesive. Adhesive visible at the gold bronze interface on one mirror (1943.52.159) was sampled and identified via FTIR as an animal glue and flour paste. It is not known for sure if this is the original adhesive because it could also be a later restoration. This type of mirror is often quite small (about five centimeters in diameter), but can range up to about sixteen centimeters in diameter. They were produced in small numbers, and due to their expense, they must have been a high status object.

Figure 7. Painted Mirror, Warring States Period, 22cm Diameter, HUAM 1943.52.156.

2.3.3 Painted Mirrors

Mirrors were also painted although few examples have survived intact making these mirrors extremely rare. Harvard has one example in its collection (*Fig. 7*) depicting numerous figures and horses against a red background. Analysis of the pigments was undertaken at the Fogg Museum in 1937 and showed that the red paint was cinnabar, the white was chalk, the brown was a mixture of cinnabar and charcoal black, the blue was azurite and the dark blue was smalt. The mirror was re-examined in 1956 and a new sample of the dark blue revealed there was indigo underneath the smalt.

2.4 Uses of Mirrors

Mirrors had many uses, which were both practical and spiritual. They entrapped reflections that had previously only been seen on the surface of still water. The same as today, this reflective surface was used as a vanity mirror. Early on, craftsman began the production of convex mirrors, which would reduce the size of the reflection so the face was seen in proportion. Mirrors were also used to start fires from the sun and may have been used to gather dew in their concave backs. Dew was valued for its purity and was used by Taoist priests for purposes of divination and worship (Hall 1935).

In addition to these practical uses, mirrors were valued for ritual purposes associated with the power of reflection. Chinese spirits, both good and bad, are supposed to throng the earth and plaque the living. Mirrors have the power to ward off evil since the form of any invisible spirit will become visible when reflected in the mirror. Taoist scholars are said to have worn a mirror hanging down their back so they could pursue their studies without fear of being harmed by the invisible spirits all around them (Rupert and Todd 1935). Nothing was considered more powerful in warding off these evil spirits than the threat of making them visible in the mirror.

Similarly, marriage mirrors were created for a bride to carry on her lap during the wedding procession and were later hung over the marriage bed to repel evil forces and ensure continuing good fortune for the couple. These mirrors have auspicious symbols chosen to express the idea of marital unity, especially pairs of animals. During the Tang dynasty, the phoenix represented a happy omen in marriage, and they were usually depicted on marriage mirrors of that time period (Cammann 1946). According to ancient tradition, the phoenix is monogamous and has a deep affection for its mate making it the perfect symbol to use on a marriage mirror.

Not only the living, but also the dead were protected by mirrors. In burial, mirrors were often placed face up on the breast of the deceased to protect them from evil spirits. Mirrors were also buried along side their owners with food, drink and the other prized and necessary possessions to ensure a comfortable eternity (Rupert and Todd 1935).

Mirrors have continued to be used over the years in China and can still be found in private homes, on shop fronts and on public buildings as protection against the spirits.

2.5 Molds

The earliest mirrors were made using direct, ceramic molds. They were made in two sections: one side was flat for the reflective side and the other side contained the decorative back. The decoration was created directly in the clay by carving and/or by the use of stamps. In general, this resulted in a crisp and two-dimensional design. The clay was fired and then used to produce only one mirror because the mold was broken to remove the cast bronze.

During the Han dynasty, soapstone molds were occasionally used. The advantage of using stone to cast bronze was that the foundry could reuse the mold multiple times. It is not known for certain if the molds were used to cast bronze, because they also could have been used to create a wax positive for lost wax casting. Lost wax casting was known in China from about the 5th century B.C. (Moy 2005), and although the date it was first used for mirrors is unknown, it appears to be the exclusive technique from the Tang Dynasty (618-906) onwards. Lost wax casting had two advantages over direct ceramic mold made mirrors. Numerous copies of a mirror can be produced from one mother mold, and there was much more design freedom because more three-dimensional and undercut shapes were possible.

2.6 Finishing

The front, reflective side of mirrors was highly polished and often burnished leaving no abrasive scratches. The finishing of the back, decorated side differed depending on the manufacturing technique (Chou 2000). In general, the finishing work on direct ceramic mold mirrors tended to be limited to polishing the raised, flat designs, chiseling concave linear design elements and the rotary abrasion of depressions, small domes and center knobs. The background was left as cast with no finishing work carried out on it (*Fig. 8*). In contrast, the designs on lost wax cast mirrors were more extensively finished with nearly all surfaces smoothed including the background (*Fig. 9*).

2.7 Composition

The composition of the bronze alloy to cast the mirrors was carefully chosen. The mirrors are composed of about 70% copper, 25% tin and 5% lead. As Chase (1991) points out, pure copper is difficult to cast because of its high melting point, and the fact that it absorbs gasses, especially oxygen, while molten. After the copper is poured and cools, gas bubbles form resulting in a very porous metal. The addition of tin not only lowers the melting point, but also acts as a deoxidizer helping to prevent porosity. As more tin is added, the color changes from red to yellow to silver and the hardness and brittleness increase. The addition of lead does not change the color, but up to three percent increases fluidity, helping the alloy

Figure 8. Manufactured by Direct Ceramic Mold, Six Dynasties, 3cm Wide, HUAM 1943.52.173.

Figure 9. Manufactured by Lost Wax Method, Tang Dynasty, 5cm Wide, HUAM 1943.52.162.

pour more easily during the casting process and any amount facilitates the ease of grinding and polishing. Lead does, however, decrease the tensile strength, and leaded bronzes cannot be hammered or they will break. The copper-tin-lead ternary alloy that was used was very hard and brittle, but the silver colored metal took a very good polish and was ideal for a reflective surface.

The mirrors, however, are also found with a lustrous black patina. The color difference is one of the most intriguing aspects of these bronzes. The question is whether the black color was intentional or was the result of a silver colored mirror being buried for hundreds of years. This issue has been widely studied, debated and is still not fully understood.

3. Analytical Techniques

The guiding principle in choosing the analytical techniques used to examine the mirrors was that they should be as far as possible non-destructive and preferably non-invasive. With this in mind, the following techniques were chosen:

3.1 Microscopic Examination

Low power binocular microscopy was used to examine the bronzes, and the resulting observations were recorded on a survey form for each object. Particular attention was paid to identifying traces of manufacture including any evidence for lost wax casting and any finishing work like polish marks, rotary abrasions and chisel marks. In addition, the different patinas and corrosion products were examined in depth.

3.2 Examination Under Ultraviolet Light

The mirrors were examined under ultraviolet light using a Spectroline Black Light Long Wave Ultraviolet Light Model B-100. The lamp was held approximately five inches from the mirrors and slowly moved across the entire surface looking for overpaint and adhesives from previous restorations.

3.3 X-radiography

X-radiography was used to help assess the condition of the mirrors and to see if any information could be gained about their manufacture. A LORAD mobile x-ray unit was used with a 3mm aluminum filter. The X-rays passed through the mirrors and were recorded on Kodak MX125 14” x 17” film in a cassette sandwiched between a 0.005 (top) and 0.010 (bottom) mil lead filters. The operating parameters were 160kV and 5mA for 3-8 minutes depending on the thickness of the mirror. The film was placed approximately 36 inches from the radiography unit.

3.4 Energy Dispersive X-ray Fluorescence (XRF)

XRF was used to characterize the elements present on the surface of the mirrors and restoration materials including solder and false corrosion products. An ArtTAX spectrometer with a molybdenum x-ray tube was used, and the collected data was analyzed with Roëntec software. The mirrors were placed approximately 1mm from the source and irradiated for 150s at 50kV and 600μA. The size of the area irradiated was approximately 70 microns.

3.5 Scanning Electron Microscopy (SEM)

SEM was used to examine metal cross-sections from two mirrors to obtain detailed information on the distribution of the metal phases and the extent of corrosion. Samples were run at The Museum of Fine Arts, Boston on a JEOL JSM-6460LV SEM instrument at 20kV in low vacuum mode at 35 Pascal.

3.6 Fourier Transform Infrared Analysis (FTIR)

FTIR was used to analyze various adhesives, both original and restoration, and some false corrosion products. A Nicolet 510 instrument coupled to a Spectra-tech IR-plan infrared microscope with a 32x objective was used for the FTIR analysis. The sample was compressed onto a diamond cell (2mm x 2mm) with a stainless steel roller and the sample area defined by double apertures contained in the microscope. An absorbance spectrum (4000-500 wavenumbers) was measured (resolution setting 8cm^{-1}) and subtracted against a blank background. The spectrum was compared with a database of artist's materials at the Straus Center for Conservation.

3.7 Raman Spectroscopy

Raman spectroscopy was used to identify the pigments used in false corrosion products. Samples were run at both the Massachusetts Institute of Technology and at Harvard University. A Kaiser Optical Systems Hololab 5000R Modular Research Raman Spectrometer with Microprobe was used at MIT at 514.5nm and 785nm while samples at Harvard University were run with a LabRam system at 632.8nm. Red lead or white lead standards were run during each session to verify the peaks positions. For each unknown, an initial 10-20s run was used to check for fluorescence, and then the samples were run for 100-500s depending on the strength of the Raman signal.

4. Results and Discussion

4.1 Corrosion

The first thing that stood out about these mirrors was the spectacular natural corrosion. Very few early bronzes survived without being buried. As a result, the typical archaeological corrosion products were found on the mirrors, the most common being tin oxides and copper carbonates. The tin oxide, which forms on the surface of these high tin bronzes, was a transparent, insoluble, passive layer that protected against further corrosion. This was why many of the mirrors had large areas of very well preserved metal. When the tin oxide layer was disrupted, the metal below corroded resulting mostly in cuprite, malachite, azurite and copper chlorides, but lead corrosion products were also present.

4.2 Redeposited Copper

Redeposited copper was also found on the surface of many of the mirrors. This can be the result of deliberate electrolytic treatment to reduce corrosion products. In fact, one of the mirrors was treated this way at the Fogg Museum in 1945, and the record notes that it left small patches of redeposited copper on the surface. However, electrolytic treatment is not the only way that redeposited copper ends up on the surface of archaeological bronzes. Researchers in China examined forty-five corroded bronze fragments excavated from Tianma-Qucun, Shanxi, a Zhou Dynasty site (1027 B.C. – 221 B.C.). Besides discovering redeposited copper in the structure of thirty-three metallographic samples, they found a few fragments with copper visible on the surface (Wong and Merkel 2001).

4.3 Textile Pseudomorphs

Many of the mirrors were buried inside or in direct contact with textiles leaving textile pseudomorphs in the corrosion layers (*Fig. 10*). These pseudomorphs yield information on early Chinese textiles when actual examples of weaving do not exist, and researchers have studied them identifying the fibers and thread counts.

Figure 10. Detail Textile Pseudomorph, 40x, HUAM 1943.52.162.

4.4 Metal Composition

XRF was used to characterize the elements present on the metal surface of the mirrors. Although this technique is not ideal for examining corroded metal surfaces, it did prove to be very useful as a quick alloy assessment. It verified that all the mirrors were composed of a leaded high tin bronze and not brass, which would indicate that the mirrors were of a later date than supposed. Numerous other elements were detected that migrated into the metal from the surrounding earth while the mirrors were buried including silicon, iron, calcium, potassium, manganese, chlorine and titanium. All of these were consistent with elements found in published soil analyses (Chase and Wang 1997) although the titanium could also have been introduced from a restoration material.

4.5 Metallographic Samples

Metallographic samples were taken from two black surface mirrors and examined by SEM. The first was a corroded surface sample with no bulk metal remaining (*Fig. 11*). The dark area at the top of the image was a layer of false corrosion products. Underneath this, the top edge of the metal was severely corroded and had only 18% copper left, with 67% tin, 7% lead and small amounts of iron, silicon, aluminum, phosphorus and arsenic. This agrees well with Shoukang and Tangkun (1993) findings of the top film of black mirrors containing 13% copper, 69% tin and small amounts of minerals. Shoukang and Tangkun did not report finding any lead, and much of the 7% found in 1943.52.171 may be present as corrosion products. Underneath the top layer, the altered zone was mineralized and contained numerous voids, which originally would have been filled with lead globules. The small amount of remaining lead appears bright white in the image with most of it located towards the bottom of the sample farther away from the surface. The altered zone was composed of 43% copper, 43% tin and 8% lead. Chase and Franklin (1979) report finding an average of 40% copper and 40% tin in the altered zone of black mirrors.

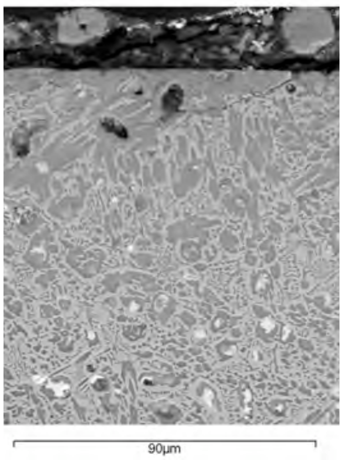

Figure 11. SEM Image of 1943.52.171.

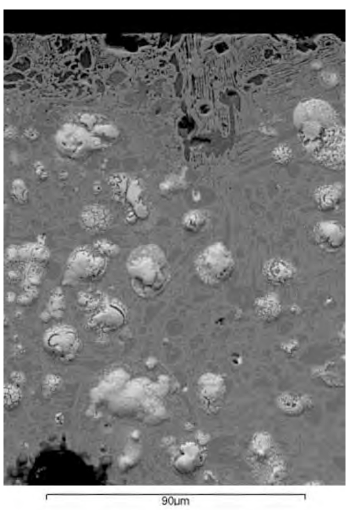

Figure 12. SEM Image of 1959.77.

In contrast, 1959.77 was a complete cross-section showing a corroded zone at the top followed by uncorroded core metal at the bottom (*Fig. 12*). In the uncorroded metal core, the bright white lead globules sit in the two-phase metallic structure with the lighter areas being the tin rich phase and the darker areas the copper rich phase. The core metal averaged 68% copper, 20% tin and 11% lead. In the corroded zone, almost all of the lead has been leached out leaving behind black voids. The copper rich phase has been mineralized to a darker, lower molecular weight product believed by most researchers to be tin oxide, which is consistent with the high tin content shown by SEM.

4.6 Restoration Materials

The majority of the mirrors were restored in the past, and the first technique used to identify restorations was x-radiography. It helped determine the mirrors' condition and the extent of solder repairs, which appear bright white in the x-radiograph as is seen in Figure 13. High tin bronzes are very brittle, and the majority of the mirrors suffered from cracks or breaks.

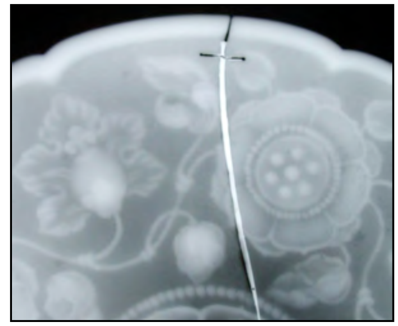

Figure 13. X-radiograph Detail Showing Solder and Staple Repair, HUAM 1943.52.169.

Cracks, break lines and other surface damage was often disguised with false corrosion products, and examination under ultraviolet light was instrumental in identifying their presence and location. An example is seen in Figure 14 where the medium adhering the false corrosion products fluoresced green. The bright orange was the natural fluoresce of yellow loess clay, although in this case it was adhered to give the false corrosion a more archaeological appearance. All of the examined mirrors except three (1943.52.154, 162 and 163) had false corrosion products adhered to the surface. While the majority of false corrosion was used to disguise losses or repairs, some was used to aesthetically enhance the mirror's appearance. The most outrageous was the reverse of 1943.52.174 (*Fig. 15*), which is almost a complete fabrication. The restorer adhered pieces of yellow clay in the middle of green and blue pigment. The mirror is broken into three pieces so some of this restoration was used to hide break lines, but the restorer went above and beyond on this mirror.

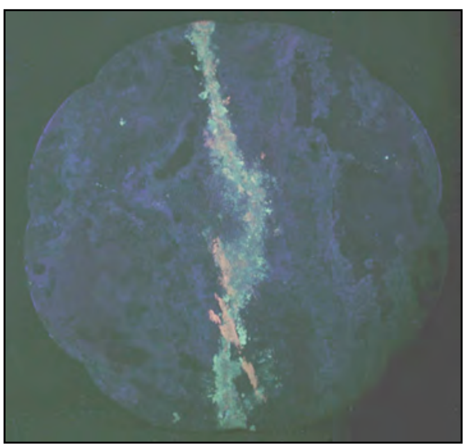

Figure 14. UV Light Image of False Corrosion Products Hiding a Break Line , Tang Dynasty, 27.4cm.

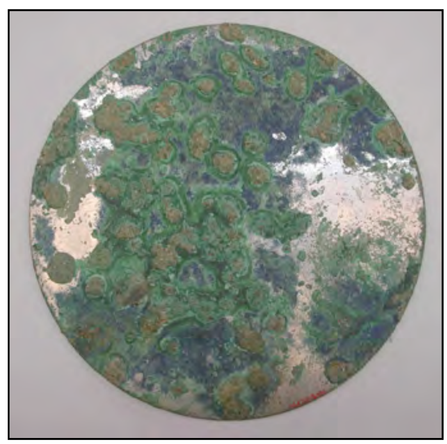

Figure 15. False Corrosion Products on Reverse of 1943.52.174, Han Dynasty, 13.9cm Diameter.

In addition to ultraviolet light, XRF was also very useful in identifying the false corrosion products because it revealed elements that were not consistent with natural corrosion. For example, discovering arsenic in an area of green corrosion probably indicates the use of emerald green pigment. This technique, in combination with Raman spectroscopy and FTIR, was employed to try and identify the colorants used in the false corrosion products. The majority of the blues were ground up azurite, but ultramarine and cobalt blue were also found. Greens were identified as ground up malachite and emerald green, vermilion and red earth were used in the reds and barite and lead carbonate in the whites.

Identifying the mediums used in the false corrosion products was challenging due to the difficulty in isolating small amounts of adhesive from the pigment. A sample from the front of one mirror (1943.52.159) was physically separated under magnification and the adhesive identified as wheat starch paste by FTIR. While analyzing false corrosion products to identify their colorants, FTIR also showed the presence of adhesives in some cases. A sample from one mirror contained animal glue and those from seven others had cellulose nitrate.

Other researchers have discovered false corrosion products on ancient Chinese bronzes. Gettens (1969) analyzed numerous objects at the Freer and found false corrosion products composed of ground malachite and azurite and pigments like emerald green, Prussian blue, artificial ultramarine and smalt. Zinc oxide, barite, cobalt and iron oxide were also found. Some had starch to bulk them and adhesives were identified as shellac, natural resin, animal glue and even real lacquer.

5. Conclusions

The initial results from this study have shed light on the Winthrop collection of ancient Chinese mirrors at the Harvard University Art Museums. The composition, manufacturing technologies, corrosion and restorations on the bronzes agreed well with the numerous published results on the topic. The Winthrop collection also allowed the unique opportunity to examine the objects of one collector and to observe the aesthetic tastes of his generation. The widespread use of false corrosion products on these bronzes to cover breaks and surface damage indicates a restoration practice driven by the collectors' preference for bronzes that appeared whole and were covered with archaeological corrosion.

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