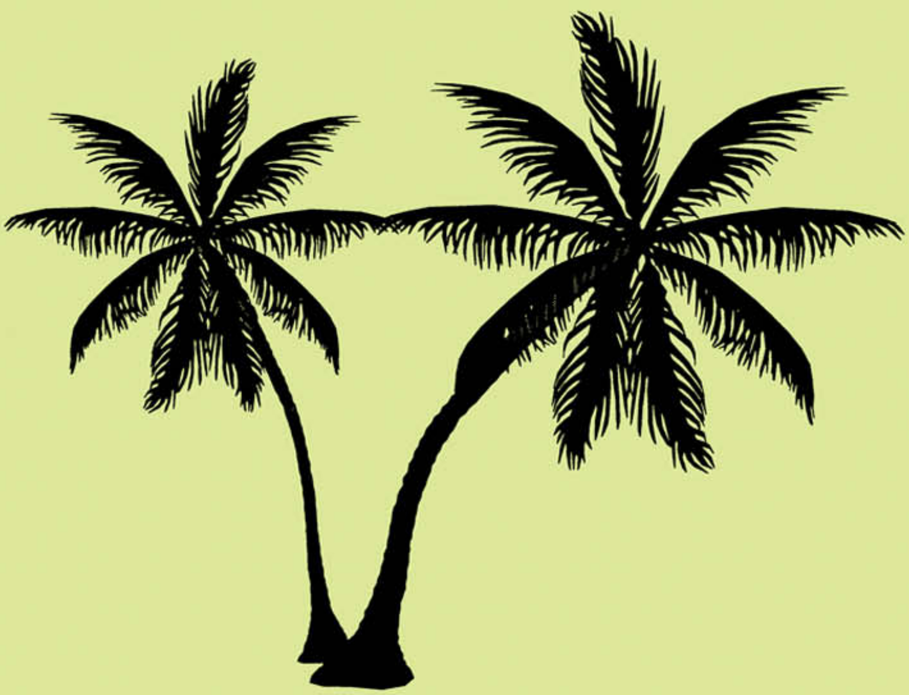
Objects Specialty Group Postprints

Volume Five

1997



American Institute for Conservation of
Historic and Artistic Works

Objects Specialty Group Postprints

Volume Five

1997

Compiled by Virginia Greene and Ingrid Neuman

Proceedings of the Objects Specialty Group Session
June 13, 1997
25th Annual Meeting

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FOREWORD

This is the fifth volume of *Postprints* published by the Objects Specialty Group (OSG), and includes all of the papers presented at the OSG session, June 13, 1997, at the AIC meeting in San Diego, California. It is hoped that this volume will be of interest both to those who were there and those who were not able to attend the annual meeting. Ideally, this publication will serve as a departure point both for further discussion with the individual authors and as a base line against which to measure our progress in the field of objects conservation. The papers were minimally edited for format, punctuation and English usage - there was no peer-review process and readers will notice great differences in individual style. Authors are encouraged to submit their work to peer-reviewed publications such as the *Journal of the American Insitute for Conservation*. The authors retain all reproduction rights to their text and images.

The themes selected for this year's focus - *Inherent Vice* and *Revisiting Old Treatments* - were pinpointed as two ideas which had yet to be discussed after reviewing topics from the previous ten years of OSG meetings. *Inherent Vice* is certainly a concept and a reality confronted by objects conservators on a regular basis. Objects which exhibit "inherent vice" can often benefit from improved environmental, exhibit and/or storage conditions. In this regard, the selection of inherent vice dovetails well with the preventative conservation approach that has become a major part of our efforts. The three papers by Patricia Leavengood and John Twilley, Mary Clerkin Higgins and Lisa Kronthal cover three radically different types of objects - a large outdoor stone sculpture, a glass/stone/shell mosaic panel and donkey skin puppets - all with problems relating to inherent vice (and in the last two cases, additional problems from previous treatments).

The majority of the papers focused on *Revisiting Old Treatments*, which offered an opportunity for the OSG to examine the effects of past treatments (with 20/20 hindsight, of course) and to apply the information gained from this review to the future care and conservation of artifacts. It was a time to seriously reexamine and reflect on the choices conservators have made in the past and to redirect or rethink the choices we will make in the future. The materials are again varied: ceramics (including the special problems of field conservation), stone, metal, leather and skins.

On behalf of the OSG, I would like to extend my sincere gratitude to Virginia Greene for her dedication to producing this volume of papers from which we will all benefit. I would also like to thank all the speakers for a job well done and for sharing their insights and honest evaluation of treatments with their colleagues. This attention to detail, and ability to reflect on and learn from the past, will help us as we continue to improve the field of objects conservation.

Ingrid A. Neuman
OSG Chair

ISAMU NOGUCHI'S "BLACK SUN": INVESTIGATION OF A CRACKING PHENOMENON

Patricia Leavengood, John Twilley and Thomas Van Halm

Abstract

The monumental sculpture by Isamu Noguchi entitled "Black Sun" was carved in Mure, Japan from a single 30-ton block of stone quarried from the Tijuca formation in Brazil. The finished piece, a polished torus shape nine feet in diameter and weighing 12 tons, was installed on an outdoor viewing plaza in front of the Seattle Art Museum in 1969. Small hairline cracks in a radial pattern were noticed on the west face of the sculpture during the 1980's. In 1992 the cracks were mapped and measured; by 1994 a definite increase in the width and length of some of the cracks was verified. A core sample and acetate peel samples were taken and analysed. The stone was characterized mineralogically as a black gabbro. The core sample was examined petrographically for evidence of weathering or mineral transformations that might be associated with the crack development. The results disclosed nothing of this sort and suggested that the cracking is a purely physical phenomenon related to stresses in the stone. A program of thermal monitoring was established and measurements were taken over a one year period. A computer model of the sculpture was constructed and the collected data was used to plot expected thermal tension stresses in the sculpture due to temperature differentials. The computer modelling indicated thermal stress patterns consistent with the cracking pattern on the sculpture.

To prevent water penetration into the cracks and the development of secondary deterioration phenomena a fill material of Acryloid B72 bulked with microballoons was applied in January 1995 and has been monitored for loss and shrinkage since. To date the cracks appear to have stabilized, which might indicate a state of thermodynamic stasis has been reached. Sheltering of outdoor stone sculptures during severe winter weather when the exhibit is closed has been undertaken at the Noguchi Foundation in New York. However, permanent shading of "Black Sun" to minimize cyclical solar heating has been deemed to be aesthetically unacceptable. Considering the size and weight of the sculpture, as well as its site specificity, movement of the piece to another location is not feasible. Constant monitoring and maintenance of the fill material is the recommended treatment for the present.

1. Introduction

When Isamu Noguchi created the monumental "Black Sun" in 1969 he was at the height of his career and enjoying an intensely productive and creative period. A major retrospective of his work had been held at the Whitney Museum in New York in 1968. His sculptures were internationally known, and he had recently completed and installed major pieces for Chase

Manhattan in New York, the Israel Museum in Tel Aviv, Beinecke Library at Yale University, and the city of Spoleto, Italy. In 1968 the Japanese-American artist was commissioned jointly by the Municipal Arts Commission of Seattle and the National Foundation for Arts and Humanities to create a large-scale sculpture for installation in a public space in Seattle (Figure 1a). The sculpture was one of three major works by various artists commissioned for public spaces in the United States by the fledgling National Foundation for Arts and Humanities, under a new program designed to provide the nation's cities with publicly-accessible high quality artworks.

To create "Black Sun" Noguchi purchased a 30-ton block of black gabbro (often mis-identified in catalogues of Noguchi's work as "granite"), directly from a quarry in Brazil and had it shipped to his studio compound in the city of Mure, on the island of Shikoku, Japan. Noguchi had recently begun to work with a young Japanese stone carver, Masatoshi Izumi. "Black Sun" was the first monumental sculpture Izumi had ever carved, but it was followed by many significant works during a long and fruitful collaboration with Noguchi (Ashton 1992). When completed in the summer of 1969 the sculpture, a highly polished, torus-shaped piece approximately 9 feet in diameter and weighing 12 tons, was shipped from Japan to Seattle, Washington where it was installed in Volunteer Park in front of the Seattle Art Museum. Noguchi saw "Black Sun" as a companion piece to the 1964 white marble "Sun", a major element in the Beinecke Library sunken garden installation. It fulfilled Noguchi's desire that a "Sun" sculpture be on each coast of the United States.

A condition survey of the city's public art in 1991 documented on "Black Sun" a hairline crack which seemed to section the sculpture radially in the top north quadrant and which was intersected by an almost complete circular crack extending around the center of the west face (Figure 1b). These cracks had not been visible as late as 1986, when Mr. Izumi visited Seattle and closely examined "Black Sun", which he deemed at the time to be in excellent condition. Over the course of two years, between 1991 -1993, the cracks in the sculpture were monitored. In 1994 it was clear that the cracks were growing, both in length and in width. At this time most of the cracking could no longer be described as "hairline".

Through the Isamu Noguchi Foundation in New York contact was made with Masatoshi Izumi, who provided valuable information about the carving of "Black Sun". Samples were obtained of the residual stone, which had remained outdoors at the Noguchi compound in Mure. Izumi recalled that the stone had been extremely fine-grained and non-stratified, with no internal flaws or irregularities, and very "pleasing" to carve. The stone removed from the central hole of "Black Sun" was used to carve an interior column capital for one of the buildings in the Mure studio complex. According to Izumi, no other Noguchi sculptures were ever carved from Brazilian gabbro (Izumi 1993).

2. Examination

The rock mass from which Black Sun was cut is of highly uniform composition. There are a couple of very faint lines passing through the sculpture which represent a slight increase in one mineral phase along a thin plane. These are in no way related to the developing system of cracks. The grainsize of the stone is remarkably uniform and free of phenocrysts throughout.

In September 1993 the fracture features of Black Sun were examined and samples taken of the stone at surface points where fracturing was evident. A core sample was extracted to a depth of roughly 2 cm at a point on the upper surface where a crack extended over the top from one side to the other. Additional samples were collected from those few locations where weathering products were noted on the surface by the use of cellulose acetate peels. The cracking occurs in both radial and circumferential directions at very widely spaced intervals. It does not seem related to any drainage pattern. Over most of their lengths the cracks never divide. Detached chips are rare and very small. Typically, a subtle darkening within the stone follows the cracks over their entire lengths. Apart from the very small amount of white mineral matter which appears to have leached from the crack, the only observed evidence of chemical breakdown of any minerals is very occasional rust-like spots where individual iron-rich grains have decomposed. An alternative explanation for the whitish matter along the cracks is that moisture held in the crack causes dust to adhere in that region.

The sculpture has maintained a significant degree of its polished finish. Where the surface has most roughened (the lower inside of the hole) this seems to be the effect of mechanical wear on the soft minerals (biotite) caused by visitors climbing or sitting in the opening.

3. Origin of the stone

Neither the Noguchi Foundation nor the City of Seattle possesses any documentation on the source of the stone beyond its Brazilian origin. No bill of sale that would relate it to a specific quarry or geological formation has been found to date. A proximal location has been determined based upon what is known of the Brazilian stone industry in the 1960s. This question is of more than academic interest. Other outdoor installations of the same stone in buildings or sculptures would be the best potential sources for comparative information that could serve to separate the effects of insolation, freezing, rainfall and biodeterioration. Therefore, considerable effort was invested in determining whether Noguchi used the same stone in any other sculpture. Review of a number of Noguchi's catalogues and books on his work reveals very few "black granite" sculptures which are not ascribed to some other source and no others described as Brazilian. One indoor example of a Noguchi water basin/table which appears to be the same, or very similar, stone was examined in a private collection and found not to be affected by any deterioration.

The excess material removed from Black Sun is apparently all still in Mure, Japan. A fragment provided by Noguchi's stonecutter, Mr. Izumi, exhibits all the traits of a stone rich in iron minerals and biotite. Its exposure over the past 25 years to the coastal weathering conditions of Japan has lead to a considerable degree of surface roughening, deterioration of iron minerals, and patina formation. The major difference leading to the premature development of these effects, which are not yet seen on Black Sun, is the lack of surface finishing on the fragment. Polishing removed unstable surface material from Black Sun and reduced the surface area to a minimum. This can greatly slow the weathering process and is an argument in favor of maintaining a polished surface on Black Sun once the cracking problem is dealt with.

A literature search was conducted for the purpose of identifying sites where the stone was in use and any relevant geological literature on typology and weathering (Pires et. al. 1982, Purves 1973). Lamego depicts the geological features of the Tijuca peak region to the southwest of Rio and reproduces a sectional geological diagram passing through this locality from which it is clear that a variety of intrusive igneous rocks are available (Lamego 1938). Ramos and Barbosa have published petrographic views of a few plutonic rocks from the area including a granite from the Tijuca Forest (Ramos and Barbosa 1965). In the 1960s there was only one igneous rock being exploited in the area of Rio de Janeiro which came from the Tijuca, a pre-Cambrian formation which includes the extreme escarpments which typify the landscape around the city. The areas being quarried were reportedly above the city and are closed today due to increased urbanization. Sources indicate that the quarrying at this time consisted of collecting exposed rock from the escarpments (Dromens 1993). The name Tijuca also refers to a forest area and national park, so only an approximate location is clear at this time.

A thesis by Odin, contemporaneous with the execution of the sculpture, referred to the use of this stone at the Occidental Center in Los Angeles (Odin 1971). Ultimately the same, or visually nearly identical stone was noted to be in use on two public buildings in California. These installations are comprised of thin panels of cladding. They are roughly the same age as Black Sun and are free of cracking and distortions with the exception of minor impacts near ground level.

4. Characterization of the stone and its weathering state

4.1 Sampling

A core sample was drilled in such as way as to intercept one of the cracks for the dual purpose of providing a petrographic thin section to characterize the stone and a look at the microstructure associated with the cracking. Features which could occur at this crack which could be expected to be diagnostic of the problem include chemical transformation of unstable minerals, expansion of foliose minerals such as micas, deposition of slightly soluble minerals leached from the deeper rock and so on. Secondary phenomena which could be indicative of the onset of more rapid deterioration that were to be searched for include: colonization by microorganisms; disaggregation of individual mineral grains near the surface; and crack widening due to freeze-thaw cycling. Despite the immense size of the sculpture, its highly finished surface required that sampling be kept to a minimum in order to be unobtrusive.

4.2 Instrumental analysis

Characterization of the mineralogy of the stone started with the segregation of visually distinct minerals for X-ray diffraction analysis. It had been noted during the core drilling that one of the unique features of this stone is a high content of magnetic minerals. The black magnetic fraction was analyzed by X-ray diffraction and confirmed to be magnetite. A non-magnetic black foliose mineral phase was separated for analysis. This was determined by X-ray diffraction to be an iron-rich biotite, siderophyllite, represented in the ICDD standards by pattern 25-1355. A third phase analyzed consisted of grey translucent crystals. These were found to be high-calcian albite corresponding closely to ICDD standard 20-548. Deviations from this standard include additional peaks due to incomplete separation of the albite and peak shifts due to the existence of a complete solid-solution series in the plagioclase feldspars running from purely sodium varieties to purely calcium ones. A much smaller fraction of clear colorless grains were analyzed and determined to be quartz.

Each of the segregated samples analyzed by X-ray diffraction was also analyzed by X-ray fluorescence to determine its compliment of major elements. Elements detected in this analysis, conducted in air rather than vacuum, is limited to elements above atomic number 16 (sulfur). In addition to the elements whose presence may be inferred from the X-ray diffraction results, titanium was found to be abundant in the dark material, suggesting the presence of ilmenite.

The detachment of the core also produced three fragments from approximately 1.5cm beneath the surface. The faces of these fragments which met at the crack being investigated were covered with a very uniform grey powder of fine mineral matter. All of the above XRD determinations were made using a Siemens D500, theta/2-theta goniometer diffractometer with a cobalt X-ray tube calibrated against NIST silicon. The grey powder lining the face of the crack was available in much smaller quantities and was analyzed by the Gandolfi camera powder method. The results suggest that most of what is present is merely small particles of the main minerals in the stone. An unmatched line at 7-angstroms is significant as it indicates the presence of a clay. This clay, if it is not infiltrating the crack from outside (which seems unlikely), is probably the result of feldspar weathering. Testing of the grey powder by Fourier Transform Infrared Spectroscopy yielded little more information. The spectrum was dominated by silicate and hydroxyl absorptions. The lack of sharp characteristic hydroxyl absorptions for clay or mica is probably due to their states of disorganization, being in an intermediate stage of weathering. The infrared spectrum also discloses the presence of a little carbonate in the fissure, indicating that by this depth (about 1.5cm beneath the surface) any acidic precipitation has already been neutralized. It is significant that no gypsum was to be found within the crack. At least at the point sampled near the top of the sculpture, there are no soluble minerals undergoing recrystallization in the crack and thereby causing it to widen. It is further significant that no brown or red coloration is occurring within the crack. Considering the enormous amount of iron in this stone, it is notable that this element does not, as yet, appear to be involved in any significant weathering phenomenon such as the oxidation of pyrrhotite or pyrite.

Taken together, the results of the analysis of white surface residues and of these constituents of the crack suggest that the slight amount of chemical weathering takes the form of feldspar decomposition with the excess calcium being released in the form of gypsum, most of which is being carried away by moisture.

Surface peel replicas were taken from areas where deterioration residues were apparent on the sculpture surface. White powdery residues collecting along either side of a crack margin were determined to be gypsum by X-ray diffraction. Previous studies carried out on the 15th century Chinese marble sculptures of the Seattle Art Museum at this same location have shown that gypsum is a prevalent weathering product when calcium is available in the stone (Twilley 1986). This occurrence is indicative of a small degree of leaching of calcium from the plagioclase feldspars in the rock by the action of sulfuric acid in precipitation.

4.3 Petrographic analysis

A petrographic thin-section prepared from a plane perpendicular to that of the crack was examined in order to find any incipient mineral transformations and to examine the physical form of the fracturing. This section was embedded under vacuum and prepared scrupulously avoiding any water so as to retain all soluble minerals which might be present. The thin section is also necessary to characterize the texture and mineral interrelationships that are the diagnostic basis for the classification of igneous rocks.

Figures 2 and 3 show the majority of the thin section in plane polarized light rotated 90 degrees with respect to each other. In these views the highly twinned birefringent mineral grains are the high calcium albite. Siderophyllite varies dramatically from pale to dark between the two views, becoming indistinguishable from the opaque minerals at extinction. A number of additional grains are clear but nearly full of fine opaque particles.

The most important observation made from this petrographic section is that the crack is a transgranular tensile fracture. That is to say that the crack passes, indiscriminantly, through the minerals of all types rather than following the boundaries between them. The stresses on the stone are greater than the tensile strength of the intact minerals of which it is made. Furthermore, no indications of any significant weathering proceeding into the minerals exist along the edges of the crack. At this location virtually no loss of mineral grains from the sculpture's surface along the crack has yet occurred. No mineral transformations are apparent at the outer surface either. Biotite (siderophyllite) has not yet begun to expand or exfoliate.

The most notable compositional feature of this rock is its high content of ore minerals. These arelargely responsible, along with the iron-saturated biotite, for the black color of the stone and take many forms. Figure 4, in reflected light at 400x, shows one common form of iron-titanium oxide assemblage surrounding a sphere of magnetite which itself surrounds a bit of brassy colored pyrrhotite (magnetic, i.e. mixed valence, iron sulfide). This striped grain type, often in the form of chevron-like twins, is a common feature of the stone. It consists of ilmenite and another more iron-rich iron-titanium oxide. Another region rich in opaques contains euhedral crystals of magnetite and ilmenite along with a trace of pyrrhotite, intermingled with quartz and pyroxenes. The entire assemblage is surrounded by siderophyllite (Figure 5, 100x in reflected light). Pyrrhotite was also found surrounded by calcium silicate (pyroxene), itself surrounded by high-calcium albite in an apparent exsolution series. The generally low pyroxene content of the stone is a determining factor in its classification.

Transmitted light views such as Figure 6 (50x) disclose the reason for the grey "clouding" of the plagioclase. The interiors of these grains are filled with needles of opaque ore minerals. Zoning of the plagioclase is apparent in the absence of these inclusions near the grain boundaries. Figure 6 also discloses the disposition of quartz in this rock. The quartz, mostly a dark grey in this view, exists primarily in the form of doubly terminated hexagonal prisms. A cluster of these may be seen in the center of the frame, standing upright and reduced to stubby hexagonal posts by the grinding of the thin section. These occur inside both biotite and albite grains. Quartz also occurs in areas full of small crystals of magnetite such as the spotty (as opposed to "streaked") areas of Figure 7 at 50x. Densely oriented needles of ore minerals fill another unidentified silicate mineral, probably olivine, in this view. Hornblende completes the list of commonly encountered minerals in this rock. Locally, areas of myrmekitic texture were observed.

5. Petrological classification

Based upon what has been learned from this one petrographic section one cannot apply a strictly quantitative criterion to its classification. The grain size (averaging about 2 mm) is large enough that the total number of grains in the sample is too few. However, it clearly is an intrusive igneous rock close to a gabbro in composition. Its very high level of ore minerals puts it slightly outside the usual classification schemes which, in any case, vary slightly from country to country and school to school. It has been suggested that the surface quarrying above Rio de Janeiro involving this formation resulted in the exploitation of a pyroxene tonalite (Dromens 1993). However, the level of pyroxene found seems too low for this category, as does the content of quartz. The actual content of dark minerals is lower than might be expected from the appearance of the sculpture and places this stone in an intermediate or "mesocratic" category as regards its content of mafic materials.

6. Implications for weathering and deterioration

The unfinished fragments of the sculpture returned from Mure, Japan, are quite instructive in that they exhibit the onset of deterioration typical for the minerals of this stone which remain unaffected up until now in "Black Sun". The high concentration of iron minerals, particularly those which incorporate ferrous iron and the small proportion incorporating sulfur, may be expected to begin to release iron which will gradually alter the color of the surface to a warmer, brown shade (Schiavon 1993). Biotite typically weathers to chlorite. The plagioclase feldspars, the biotite and the hornblende may all, in time, begin a transformation into clays (Rogers and Holland 1979). The byproducts, alkali cations for the most part, may be expected to leach out, being carried away as salts or semi-soluble minerals such as gypsum.

Perhaps the most serious potential effect of weathering is the tendency for biotites (in this case siderophyllite) to exfoliate (Bustin and Matthews 1979). This will be observed as an increase in surface roughening and it will greatly increase the vulnerability of the sculpture to all other forms of weathering. At present very little of this has occurred with the exception of the lower inside surface where handling and climbing have dislodged grains of stone. The high degree of surface finishing given by the artist, and the corresponding removal of damaged stone left from the shaping operations, has been the single most beneficial factor in preserving the sculpture. By thus minimizing the surface area, chemical and physical erosion have been kept to a minimum. Two conclusions of Bustin and Matthews' study are relevant: that the degree of alteration increased with the amount of biotite in the rock, and that coarser grained rock tends to disintegrate more readily due to easier crack propagation.

Furthermore, in a study conducted in Baja California on the causes of the disintegration ofboulders (a scale to which Black Sun may certainly be compared), Conca and Rossmann determined that the less weather-resistant biotites were the iron-rich type as are present in "Black Sun". They found that "these high-Fe layers appear highly etched and indicate that they are dissolving at a much faster rate than the low-Fe layers" (Conca and Rossman 1985). They also note that other authors have observed iron-rich hornblende to be completely dissolved leaving the rest of the hornblende unchanged. Conca and Rossmann have explained the phenomenon underlying the development of caverns inside boulder-sized tonalite monoliths. A situation slightly different than the more common "case-hardening" of the exterior occurs, which they term "core softening".

It is remarkable that there is no evidence for the colonization of the crack studied here by microorganisms (Frankel 1977). Microorganisms are prolific at this site and have been found to be aggressively colonizing both the exterior of the Seattle Asian Art Museum building and the marble sculptures formerly displayed there. There are three possible reasons for this disparity. The dark stone may be too warm or too dry, on average, for the species found on the lighter colored stones to flourish. There may also be inhibitory metallic elements which are toxic to these organisms in "Black Sun", as chromium, cobalt, copper and arsenic (among others) often accompany the iron oxides and sulfides minerals found here. The only study of igneous rock weathering in Rio de Janeiro which was found involved a stone of a different type (Smith and Magee 1990).

7. Thermal fracturing

In light of the information provided by the petrographic analysis and literature search, the following potential causes of fracturing on this scale considered were: 1) the release of unconfined tectonic stresses; 2) volume expansion of mineral phases undergoing alteration; 3) fabrication damage; and 4) thermal stress. Tectonic stresses seem unlikely to manifest themselves in patterns conforming to the sculpted shape of the object, as has occurred with "Black Sun" and its circular crack pattern. Volume expansion of mineral phases is not occuring according to the analytical data. Fabrication damage was ruled out on the basis of observation and Masatoshi Izumi's testimony as to the ease of carving "Black Sun" and lack of untoward incident during the process, as well as eye-witness accounts of the faultless installation process. Therefore, the focus was placed on thermal stress.

Attention has been drawn to the obvious temperature rise which this stone experiences in the sun and the potential for crack propagation which thermal cycling would pose. As yet no evidence of thermal expansion problems in building panels of the same, or similar, stone has been observed. However, the much greater thickness of "Black Sun", and its toroidal shape, may be crucial to the manner in which cracking occurs. Insolation has been periodically raised and, in varying degrees, dismissed as a prime cause of rock weathering (Rice 1976). It was very clear in the present case that, given the absence of significant mineralogical weathering in the sculpture, an investigation of a physical cause for the cracking should be initiated. In the interim, overall treatment with a water-repellent or consolidant was excluded until the role of thermal expansion and contraction could be better understood, as such surface treatment could have a serious impact upon this property. However, the prevention of chip losses from along the cracks and the exclusion of water and ice from the cracks was essential. For this purpose a reversible fill of the cracks was carried out.

8. Thermal monitoring

In order to test the hypothesis that thermal stresses could be the cause of cracking on "Black Sun", a program of twice-weekly temperature measurements was undertaken during the months of January through December, 1995. An infrared thermometer was chosen for these measurements to assure that they were not influenced by faulty contact with a temperature probe or by the temperature of the probe itself. The emissivity value for the Raytek infrared thermometer was set to 0.83 after verification in the laboratory on the stone sample. The measurements were taken at approximately 9:00 a.m. and 4:30 p.m., on 8 pre-selected sites on the sculpture. Four sites on the east face and four on the west, at approximately the cardinal points on an interior circle halfway between the inner and outer circumferences, were monitored. The collected data revealed expected temperature gradients between the east and west faces of the sculpture. A clear warm morning following a cool night would typically show a rapid thermal gain on the east face, occasionally with as much as a 50 degree F difference between the east and west face. The thermal gain on the west face towards the end of a warm day was more dramatic, where temperature differentials between the two faces were measured as high as 87 degrees. Due to the height of the sculpture it was not possible to measure the temperature on the top plane, where it is surmised the greatest thermal gain would occur. The temperature measurements at the four sites on each face typically varied only by a degree or two.

9. Stress modeling

To analyze the thermal stresses on the sculpture it was necessary to create a computer model of "Black Sun" using what is known as a finite element modeling program. The theoretical basis for this program was developed during the late 1960's, but it was not until the 1980's that personal computers were powerful enough to utilize finite element programs. The software programs currently available are used primarily by specialized structural engineers who study the complex stresses in solid bodies such as engine parts. The software program used to create the model of "Black Sun" is "Stardyne", a multi-purpose finite element program supported by Research Engineers of Yorba Linda, California.

The model of the sculpture is created as in a computer-aided drafting, or CAD system. The model is composed of thousands of brick-like blocks called finite elements. The eight corners of each block are known as "nodes" (Figure 8). Each node has six degrees of freedom, meaning it has six directions (three linear and three rotational) in which it may move given a thermal stimulus. Thus for each block, or finite element, 48 equations are formulated by the computer in order to evaluate the six degrees of freedom possible for each of the eight nodes given a particular stress load (in this case a patricular temperature). The equations for each finite element are compiled into a matrix of equations for the entire model. The variable in each equation is the temperature experienced by each node. For the purposes of the computer model, a gradient of 100 degrees F was programmed under four different conditions: from top to bottom of the model, east to west, south to north, and outside ring to inside ring. The other factors in the equations, which remain constant, are Young's Modulus, Poisson's Ratio, and the coefficient of thermal expansion. These statistics were derived from Touloukian, Judd and Roy (1981) and are as follows:

Young's Modulus	E = 6,300,000 psi
Coefficient of Thermal Expansion	a = .000006 in/in/deg F
Poisson's Ratio	v = .2

Stress levels are calculated for each of the finite elements based on these equations. Stresses typically occur in a material where temperature-induced expansion is blocked by external or internal restraint. Tension stress occurs in a cooler material that is being pulled by adjacent hotter material; compression stress occurs in the hotter material which is being constrained by the adjacent cooler material. In curved bodies, such as a torus, radial tension stresses will occur when the (for example) hotter outer portion of the torus pulls away from the cooler inner portion. These radial stresses occur in a direction normal to the temperature-induced tension/compression stresses.

9.1 Results

Stresses are measured in pounds per square inch. The computer program calculates the maximum principal stress for each finite element. Maximum principal stress is the highest stress level experienced by the element, regardless of the direction of the stress (up, down, in, out or any angle in between). The maximum principal stresses are plotted on the model using coded colors to correspond to specific psi stress levels. It was found that in the simulated situations of a temperature gradient from south to north, and from top to bottom of the model, (the sun to the south and high in the sky) (Figures 9, 10) the maximum principal stress varied between 709.3 psi to 957.9 psi. Note that the tension stresses in the psi range of 543 to 709 under these conditions follow the actual cracking pattern on the sculpture. The ultimate tensile strength of the stone has been estimated at 1000 psi. However, this number does not take into account the fatigue of the stone induced by cyclical thermal stress, which effectively lowers the ultimate tensile strength.

The other loading conditions (east to west and outer ring to inner ring) applied to the model indicated clearly that the stresses due to a radial gradient are much more significant than those occuring due to a gradient through the thickness of the stone. This would indicate that while large temperature differentials between the east and west faces of the sculpture were recorded during the monitoring program, the temperature differential (and hence stress tension) between the outside, especially the top of the sculpture, and the interior and lower part of the sculpture is considerably greater.

9.2 Model limitations

The following limitations of the computer model should be noted:

The temperature gradients used were only a very rough approximation of the actual temperature distributions that may occur. However, the 100° F total difference in temperature is very reasonable based on actual measurements. The model is a linear static model while the fracturing of stone under cyclic dynamic thermal stresses is a non-linear dynamic process. Cyclical loading experiments have demonstrated that fatigue phenomena are an important factor in lowering the ultimate strength of stone. These have not been considered in the present model and can be expected to have played a significant role with "Black Sun". It is also important to note that after a crack is initiated it tends to propagate. This is due to the high stress concentration that occurs at the tip of the crack.

The tensile breaking strength for the stone is estimated to be 1000 psi. Unfortunately no material existed upon which to directly measure this parameter. The estimate is based upon experimental values measured on stones in current commericial use which are loosely referred to as "black granites". While some contain comparable levels of feldspar and magnetite, they often contain considerably more pyroxene or fall into the catagory of a monzanite. None of them contains the levels of biotite observed in "Black Sun". The extremely easy basal cleavage of this mineral makes it likely that the bulk tensile strength of a stone will decrease in proportion to an increase in this mineral. Therefore, the estimate of 1000 psi has been made which is approximately 30% below values typically encountered in other types.

10. Conclusion

The magnitude of the thermal stresses revealed by the computer model indicate that thermal factors probably have contributed significantly to the cracks found in "Black Sun". Because of its massive size and its site specificity, removal of the sculpture to another environment was not considered. In order to prevent water penetration into the cracks and the development of secondary deterioration phenomena, a fill material of Acryloid B72 bulked with microballoons was applied and is monitored for loss and shrinkage. To date the cracks appear to have stabilized,which might indicate that a state of thermodynamic stasis has been reached. However, monitoring of the cracks continues on a regular basis.

Acknowledgments

The authors wish to express their thanks to Jeff Matthews and Dagaverto Dromens for their information relating to the stone industry of the 1960s in Brazil, and to Dr. Pekka Ihainen, of the University of Tampere, Finland, for helpful discussions regarding the thermal performance of plutonic rock types. We are also grateful to Carlos Contreras of the Seattle Art Museum, for his faithful monitoring of the sculpture and accumulation of thermal data, to the structural engineering firm of Chalker, Putman, Collins and Scott for their timely support, and to the Isamu Noguchi Foundation for making possible a visit to Mure, Japan and communication with Masatoshi Izumi.

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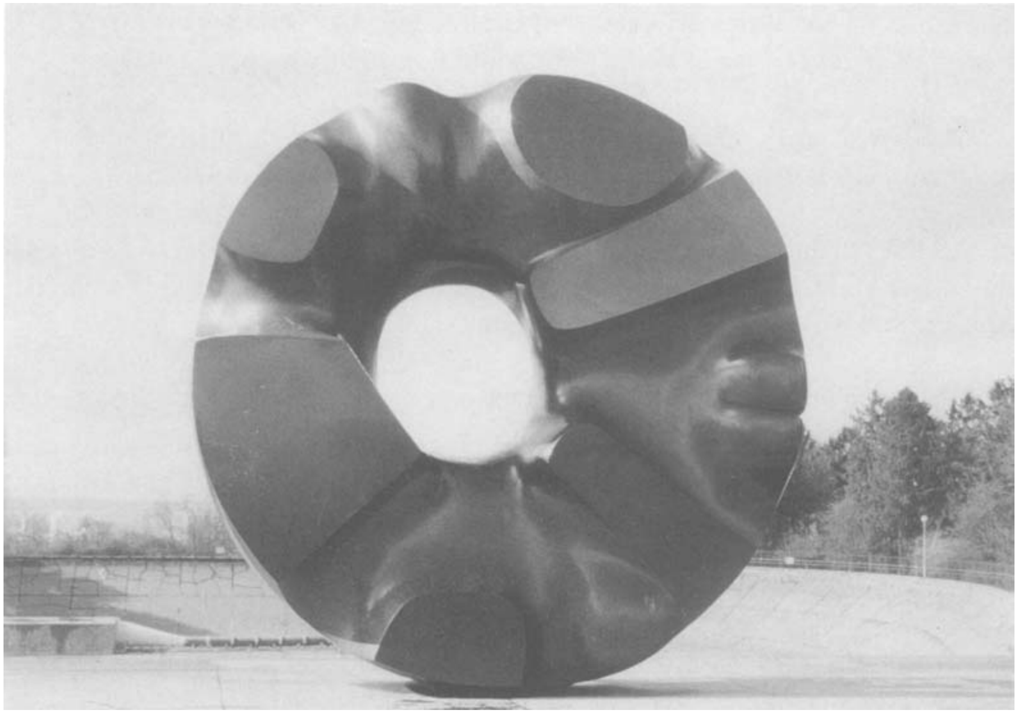

Figure 1a. *Black Sun* on exhibit in Seattle.

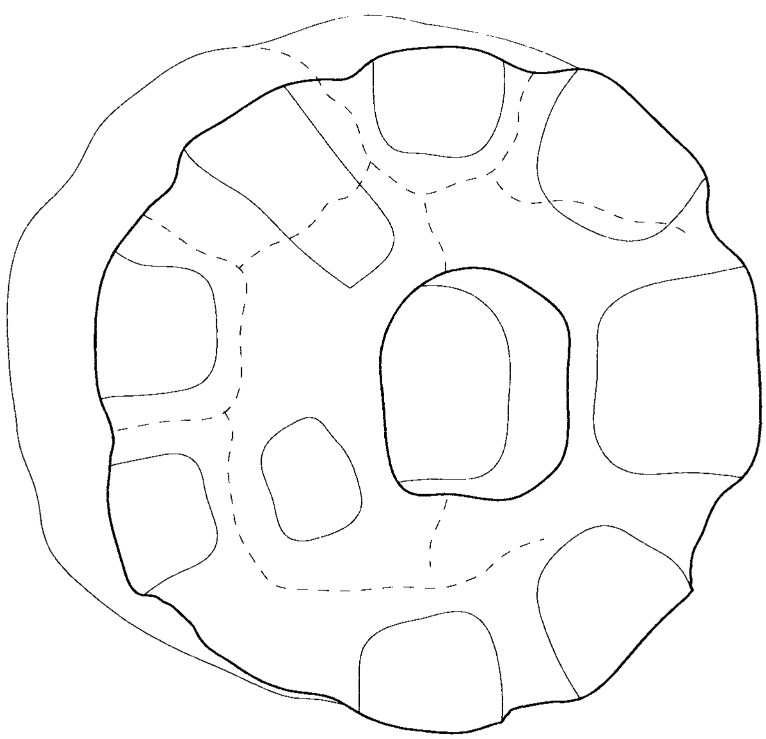

Figure 1b. Drawing showing the cracks in the stone.

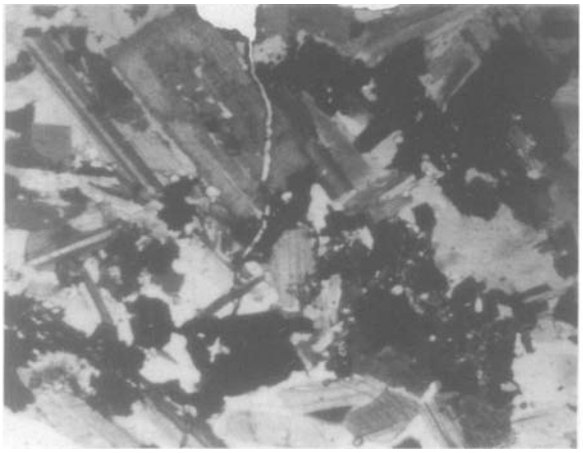

Figure 2, 10x, transmitted, polarized light

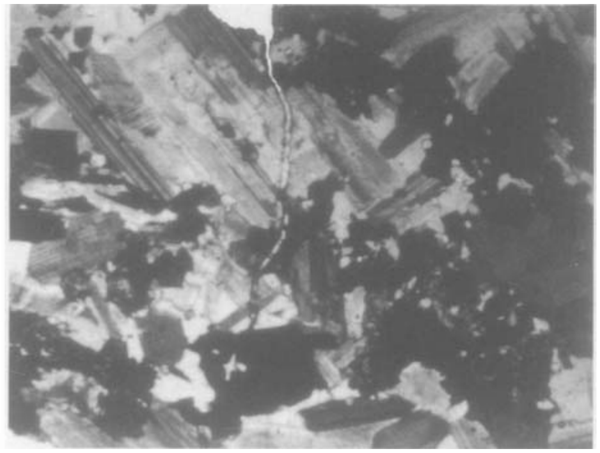

Figure 3, 10x, transmitted, polarized light

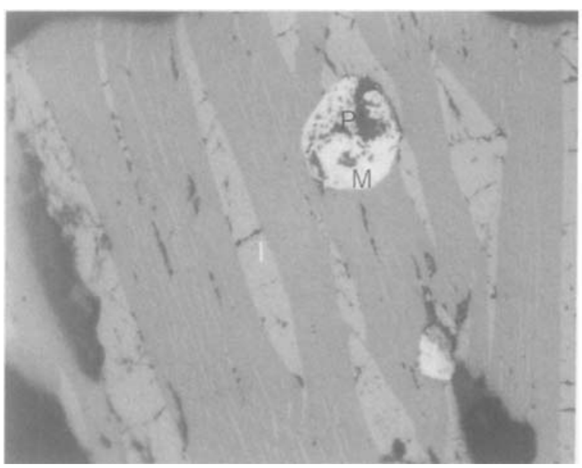

Figure 4, 400x, reflected light, ore minerals M=magnetite, P=pyrrhotite, I=Fe-TiO matrix

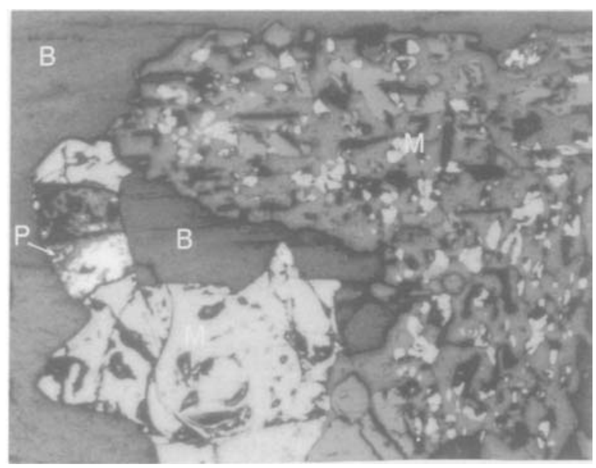

Figure 5, 100x, reflected light, B=biotite, M=magnetite, P=pyrrhotite

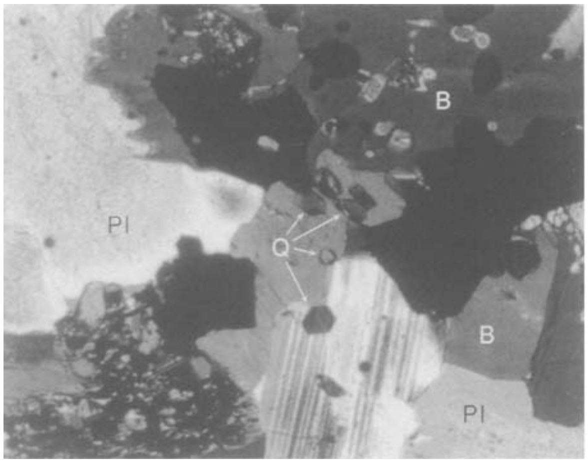

Figure 6, 50x, transmitted light w/crossed polars B=biotite, Q-quartz, Pl=zoned plagioclase with fine inclusions

Figure 7, 50x, transmitted light w/crossed polars, silicates filled with magnetite and ilmenite euhedra

FINITE ELEMENT

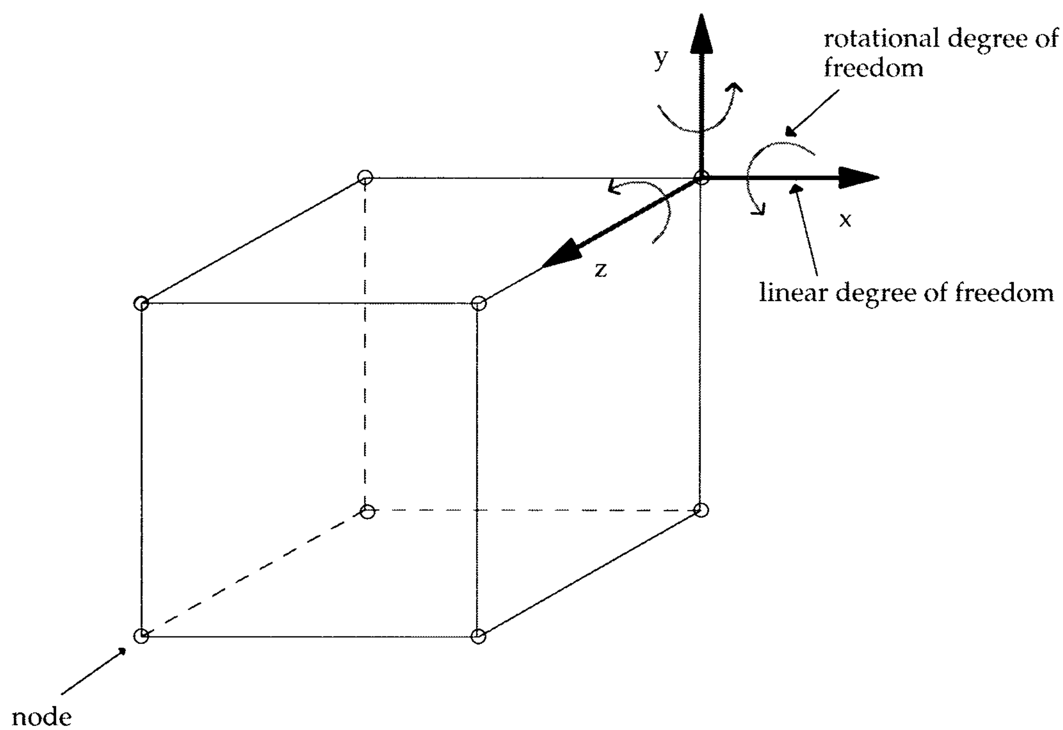

Figure 8. Unit of the finite element modeling program.

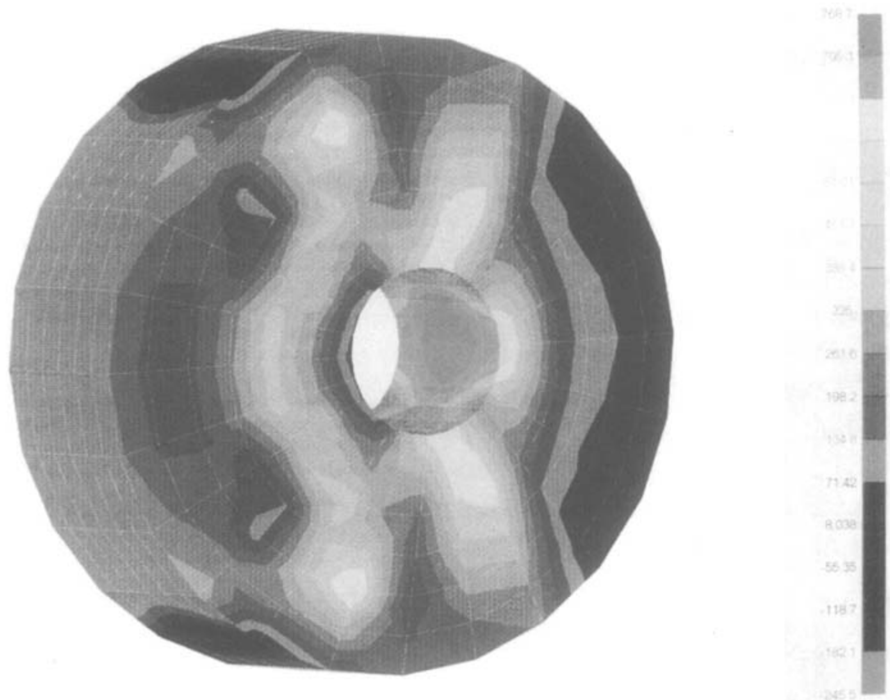

Figure 9. Computer model of temperature gradient, south to north.

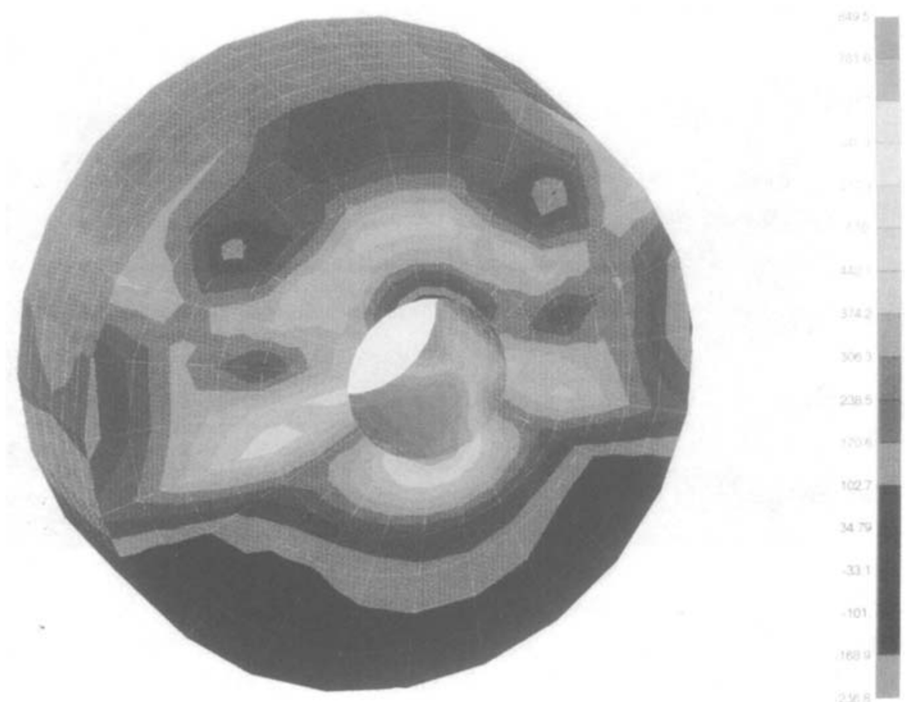

Figure 10. Computer model of temperature gradient, top to bottom.

WALTER COLE BRIGHAM AND MARINE MOSAICS

Mary Clerkin Higgins

Abstract

The artist Walter Cole Brigham (1870-1941) developed a unique method for fabricating stained glass windows and *objects de art* using a technique quite unlike the traditional lead-came or copper-foil techniques, where some type of metal provides the structural support for the glass. Brigham's method relied on the ability of his proprietary lead-putty mixture to hold shells, rocks, glass chunks, fragments of glass bottles, flat glass, and other materials imbedded in it to a transparent plate glass support. The putty network of a large window in the collection of The Brooklyn Museum of Art had weakened considerably over the years necessitating the development of a consolidation treatment using Acryloid B72. As part of the treatment EDS analysis of certain materials was undertaken.

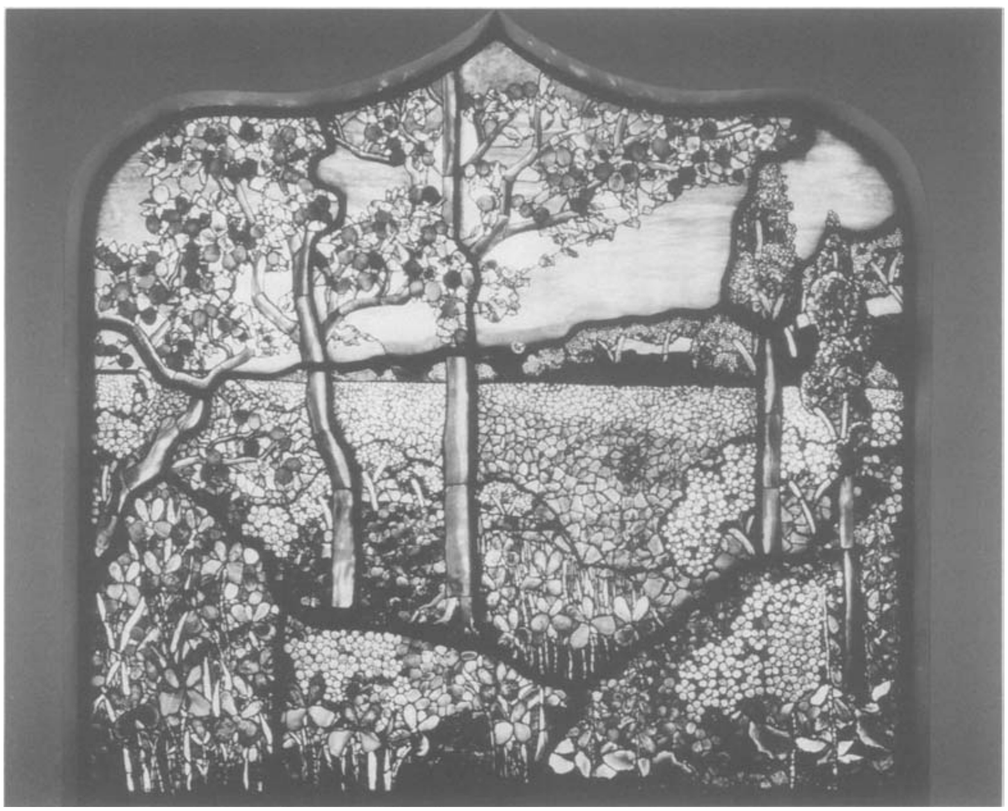

Figure 1. Walter Cole Brigham. The Charles Merrill Memorial Window, 1910. Brooklyn Museum of Art, Gift of the Roebling Society, Mrs. Frank K. Sanders, Mrs. Hollis K. Thayer, H. Randolph Lever Fund, and the Frank L. Babbott Fund 70.3, After treatment. Photograph - The Brooklyn Museum of Art.

Introduction

Between the years 1900-1915 the artist Walter Cole Brigham (1870-1941) fabricated jewelry, lampshades, fire-screens, and windows using a unique method which he developed and dubbed "marine mosaic". Unlike traditional lead-came or copper-foil techniques, where some type of metal provides the structural support of the glass, Brigham's method relied on the ability of his lead-putty mixture to hold materials imbedded in it to a transparent plate glass support. To quote Brigham, " It is impossible to use ordinary leading such as most mosaic artists use. I use cement. My uncle has used it for one thing and another for twenty years or more, which proves its durability, but it is a secret of our family."[1].

Unfortunately, twenty years isn't fifty years or eighty years, and Brigham may have been blissfully unaware of the serious flaws in his technique. Once the putty dried out and lost its adhesion to the base glass, the materials were only held in place by whatever mechanical hold the shaped putty had. As it dried out further and developed cracks, the work became structurally unsound. Though at least five of his windows are known to survive (and it did take a hurricane in 1938 to knock out three others), all remaining windows show numerous restoration campaigns, some quite intrusive and inappropriate. Three are in churches on Shelter Island, a summer resort off the eastern end of New York's Long Island where Brigham lived and maintained his studio - 'Harbor Villa'.

The other two are large landscape windows, approximately 6½ feet square with flattened gothic arches at the top, which were removed from the Charles Merrill Memorial Chapel of the Brooklyn Home for Aged Men. One, from 1915, is in a private collection in Las Vegas, Nevada and the sections in it which haven't collapsed yet are dangerously close to doing so. The other, the subject of this paper, dates from 1912 and is now in the collection of The Brooklyn Museum of Art (70.3). These were the last two windows Brigham constructed using the "marine mosaic" method.

Considering the materials he chose to use and his artistic goals, Brigham's decision to embed materials in a pliable putty rather than employing other methods in use in the stained glass field at the time makes some sense. Though he did make limited use of the traditional lead-came which comes in strips of even widths which are cut to size and then soldered together, these strips wouldn't accommodate his placement of thick chunks of glass and stone next to paper thin shells or have given him the organic lines he was able to create using the putty. With a cold setting material he could avoid the heat and messy flux needed for the copper-foil technique. However, unlike Brigham's work, copper-foiled windows from the same period are usually still in excellent condition structurally. Leaded windows may or may not be structurally sound, but the method allows for the replacement of the lead if necessary.

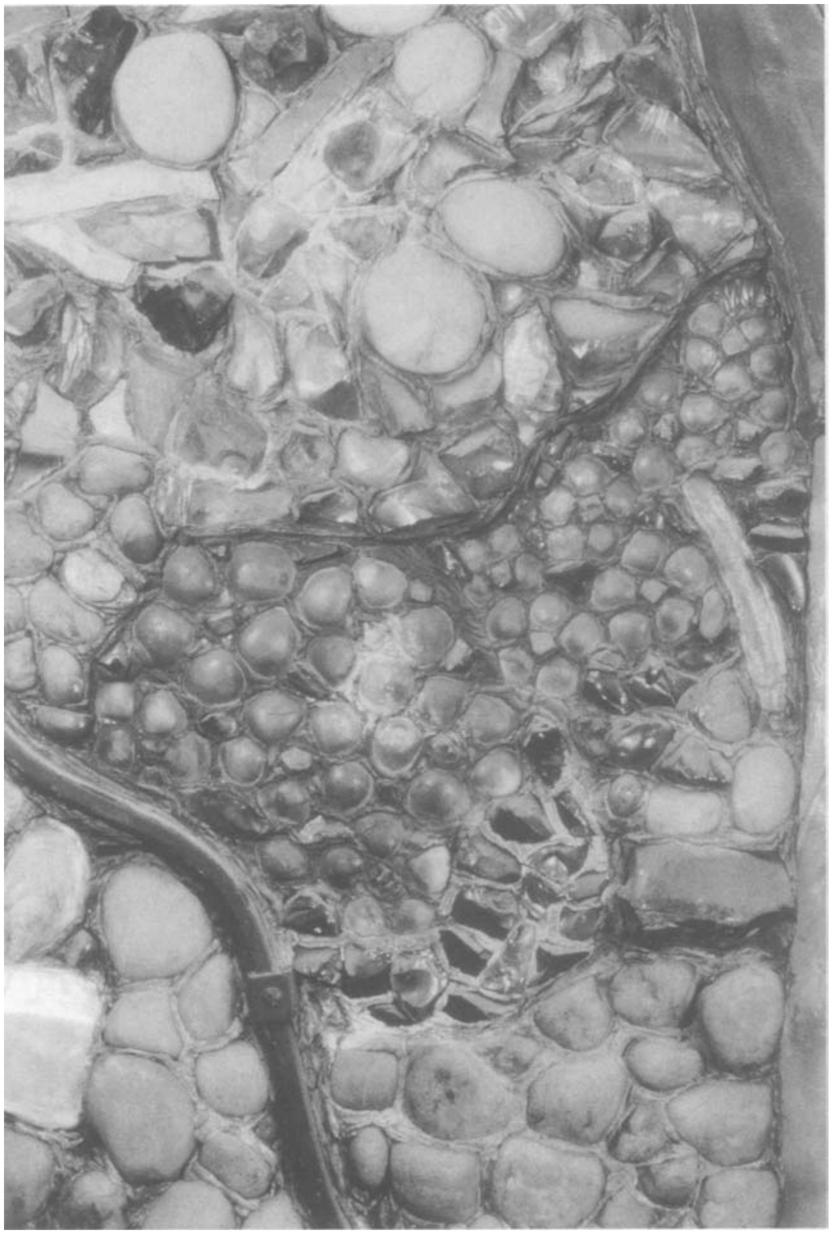

Figure 2. Detail showing rocks, various shells, chunks of glass, pieces of sheet glass, and putty. Photograph - M.C.Higgins

Brigham's creations consist of shells, rocks, glass chunks, fragments of glass bottles, flat glass, and other materials. The putty was warmed to a semi-soft state and tinted. It was placed around the edges of the various materials which were then pressed onto a piece of 3/8 inch plate glass while it lay flat. The front surface of the putty was shaped by Brigham with tools used for modeling wax and clay. The glass sandwich was put in a bronze frame and held in place by small metal clips and putty. The Brooklyn Museum of Art's window was made in twelve sections of varying sizes and shapes. Once the putty had set, which took about one week, the piece could be lifted. Final setting took several months.

Friends knew of Brigham's interest and brought him rocks and shells from all over the world. In his studio were bins labeled "white jingles, small; red jingles, large; red scallops, odds; white cockles; sand mussels; ribbed clams, telegraph glass...."[2]. In the Brooklyn windows (see Figure 2) we see many different types of shells, rocks and pebbles, glass from smashed telegraph insulators and from a variety of bottles. It has been reported that some of the colored opalescent sheet glass came from Tiffany Studios, which is quite possible and helps explain why, along with the fact that the chapel also contained three windows by Tiffany Studios, these two windows were initially identified as products of that studio when they were salvaged and put up for auction. The later of the two Brigham's also incorporates glass etched with hydrofluoric acid and areas of silver stain, techniques used with great skill by Tiffany Studios.

Consolidation of Putty

It is very unusual to have putty actually holding an art glass window together - it usually plays a secondary, though still important role of waterproofing and strengthening the ensemble, and when it dries out and ceases to function it is replaced. In this case, the putty had dried out, but being an integral part of the artwork, it could not be replaced.

The first priority was to develop a treatment to stabilize the entire putty network. Two areas had collapsed and needed to be re-established and other areas were extremely weak. Past repairs needed to be assessed, both aesthetically and structurally. Cleaning was also an issue: the front and back of the sandwich would be cleaned, but gaining access to the interspace between the art glass and the plate glass to remove disfiguring dirt and drips depended on the success of the consolidation process.

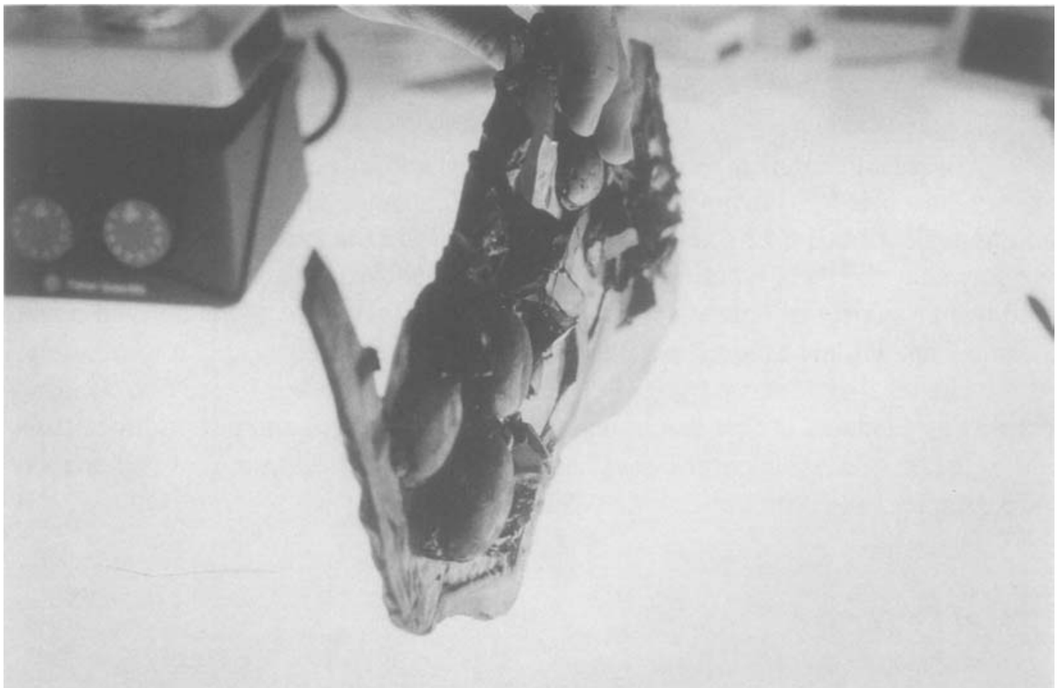

Figure 3. Small section after consolidation with Acryloid B72. The various materials and putty network are now strong enough to stand on their own. Photograph - M.C.Higgins.

Various materials were considered for the consolidation of the putty, ranging from several of the acryloids to conservation epoxies. Acryloid B72 (ethyl methacrylate copolymer) was determined to be the most appropriate. Although used extensively in the conservation field it has not had many uses in stained glass conservation beyond consolidating paint.

Once dissolved as a 20% solution (w/v) in ethyl alcohol it was applied around the edges of each of the different materials where they met the putty and onto the surface of the putty using eye droppers. One could see through the plate glass that the consolidant traveled through the cracks to the back of the putty. It proved to be very effective in holding all the materials together. Any excess was cleaned off the front surface of the glass, stones, and shells. For strength, very minor amounts were allowed to remain in places on the front of the putty, which was then brought to a matte surface using fiberglass brushes. Over the years some areas had bowed out of a flat plane. While it was possible to consolidate some small, partially collapsed areas and then, with the Acryloid B72 somewhat set, move the material back into plane, it was considered too risky to flatten the larger bowed areas and they were consolidated as they were.

It should be noted that this treatment is <u>not</u> proposed for putty which has dried out in stained glass windows. Since the putty in those situations is not providing the actual structural support, but rather waterproofing and supplementing the strength of the lead (or other metal), its consolidation could significantly impede the proper treatment of the lead and glass when that proves to be necessary. In such cases, if it has been determined that the lead is still strong and need not be replaced at that time, the dried-out putty should be carefully removed and fresh putty applied.

Separation of Layers

Once it was determined that the Acryloid B72 was effective in the consolidation of the putty it was possible to consider separating the plate glass support from the art glass layer in order to remove the unsightly drips and dirt trapped between them. The most disturbing areas were those above the horizon line (see Figure 4). Four of the 12 irregularly shaped sections were removed from the bronze frame. These sections had first been consolidated with the Acryloid B72 and selected areas were then further supported using a coating of silicone rubber (Dow Corning, 3110 RTV), which locked the materials in place but which readily separated from them afterward.

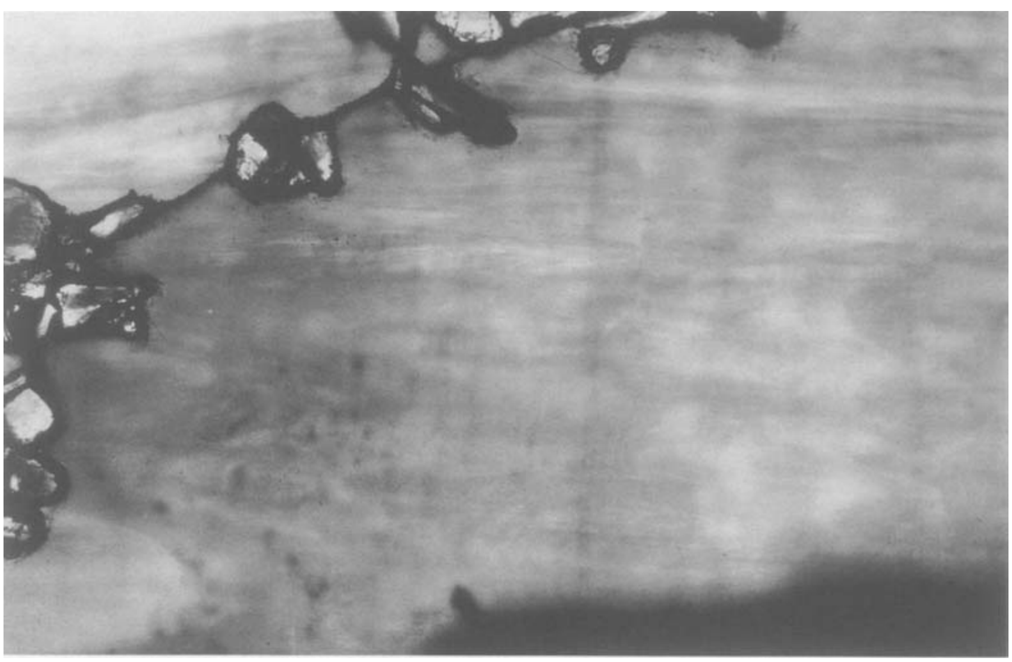

Figure 4. Disturbing vertical drips trapped between art glass and supporting plate glass. Photograph - M.C.Higgins

Once apart, the back of the art glass was also consolidated with the Acryloid B72 and the interspace surfaces were cleaned. While the consolidation significantly strengthened the putty matrix (see Figure 3), it was still considered too risky to separate any panels where it was not essential to clean the interspace for aesthetic reasons, and so none of the panels below the horizon line were separated. On the separated sections the decorative layer was secured to the plate glass around the edges with clear silicone (GE RTV 118). The largest of the removed sections was also attached to the plate in several places toward its center by drilling holes through the putty and forcing in small amounts of clear Acryloid B72. The Acryloid B72 was also used to consolidate an unstable glass which had developed numerous cracks.

Missing Putty

All of the fragments of old putty from the collapsed section were kept and laboriously sorted through to be matched up with the glass chunks, stones, etc., that had also been recovered (see Fig. 5). This was very important in re-establishing the layout, since many pieces of glass had been inserted on their sides or overlapping slightly, which couldn't be seen in the documentary photograph, and many of the rocks appeared interchangeable. Nestling the materials in the three dimensional putty fragments helped establish their locations and the pieces they abutted and greatly aided the reconstruction.

Figure 5. Collected fragments of putty, glass, stones, etc. Photograph - M.C.Higgins

Some of the putty had completely crumbled and was unusable, and in other areas of the window some original putty had been replaced with inappropriate materials (i.e. lead). Various materials were evaluated to determine what would best replace putty lost in the collapsed and previously repaired areas and Dap 33®, consisting of linseed oil, calcium carbonate, vegetable oil, talc, and petroleum oil, was chosen. It was developed from linseed oil putty, but is meant to dry more slowly and thus avoid the same degree of cracking, which was felt to be desirable here. A test section was fabricated and proved to be very satisfactory. The Dap 33® could be readily colored with powdered pigments to match the front surface color of adjoining areas - the color of the original putty is not uniform throughout - and tooled as necessary to match the look of the existing putty. For strength in the areas of collapse many of the rocks and heavy glass jewels were attached directly to the base plate glass using Acryloid B72 in acetone (50% solution w/v). The new putty was then worked around the materials to look like the original.

This new putty will, of course, also dry out in time, though the panel is now exhibited under museum conditions. No sections were completely re-puttied and the weight of some of the materials is now supported by the Acryloid B72. The conservation staff will periodically examine the re-established areas and may, in time, consolidate the Dap 33®.

Analysis of Putty

Table I. Energy dispersive X-ray spectrometry compositional analysis (EDS) of two putties.

Weight %	Na	Al	Si	S	Cl	Ca	Fe	Zn	Ba	Pb
Brigham	-	<1	1	9	-	4	<1	7	5	73
La Farge	4	<1	2	2	2	82	<1	3	-	4

Energy dispersive X-ray spectrometry compositional analysis (EDS) [3] shows that Brigham's putty contains a high proportion of lead and sulfur, with significantly less calcium (Table I). Barium sulfate or lithopone (barium sulfate and zinc sulfate) may have been added as filler. This can be contrasted with the analysis of a putty taken from a John La Farge window (The Metropolitan Museum of Art, 30.50) wherein calcium comprises 82% and lead only 4% of the whole, by weight. The La Farge uses the more traditional linseed oil putty, which is primarily whiting (calcium carbonate) mixed with boiled linseed oil. A small amount of powdered lead was frequently added as a drying agent, though in New York State that is now prohibited. Other ingredients, such as plaster of Paris as an extender and lampblack as a colorant, are also listed in contemporary recipes [4]. Brigham's recipe appears closer to ones for aquarium cement which contain litharge, plaster of Paris, sand, rosin and boiled linseed oil [5]. The uncle Brigham attributes his recipe to was a naval engineer and Brigham's two brothers ran a shipyard in

Greenport, L.I.. It may well be that Brigham's recipe derives from a maritime one, and the name "marine mosaic" may refer to more than the profusion of shells.

Various Repairs

A variety of repair methods had been used to either replace missing putty or to fill light leaks and consolidate original putty. Each of these needed to be assessed to determine whether: it was adequately holding the materials in place and could continue to do so; it had a positive, negative, or neutral effect on the aesthetic reading of the window; it could be safely undone if the effect was negative.

One restorer abandoned Brigham's putty method altogether and used lead-came for a small collapsed area to the upper right of the window. Most of the original glass must have been lost since new, replacement glass had been used in the fill, which had been toned down with a "cold" (unfired) green paint. When this was taken apart and cleaned it became obvious that the replacement glass was not a good match for the original and that there was not nearly enough of it to fill the hole. New glass chunks were found to replace those missing, using remaining original glass as a guide for color, size, and design. A few pieces of the old replacement glass were used where appropriate. This was puttied in place as it had been originally.

Cleaning

Cleaning involved not only removing the dirt that had settled on the front and back surfaces of the piece, but removing or minimizing the various materials which had been used in previous consolidation attempts - from shellac to hot melt glue sticks (ethylene vinyl acetate and hydrocarbon resin). The artist himself maintained that the shells and pebbles "are used in their natural state, no artificial coloring being added, nor any chemical brought to play to diminish or soften these quiet tones and delicate shades"[6]. While the artist's own statements cannot be completely relied upon, since at times they may state the ideal rather then the real, and they came two years before this piece was made, they nonetheless did reflect what was found on the panel. Where shells were now coated with what looked to be darkened shellac and others had a light white wash, these materials were found on the surface of the putty and in dried out cracks, indicating they were not original. They were removed.

At some point glass chunks near the horizon of the water had been re-adhered using a hot melt glue from a glue gun. While it is not an original material, it is holding the glass chunks securely in place and there was a danger that its removal could cause damage to surrounding areas or cause material to fall between the 2 layers. Its color was not a problem since it should actually be opaque, rather than a translucent milky-white. Putty was placed over it to outline the individual glass chunks. A dark, opaque plumber's epoxy-putty had also been used in this area, though not applied with anything like the care of the original. Again, because it was so well bonded with the glass beneath it, it was left in place, but excess material was removed using a Dremel Moto-tool® to bring it more in line with the look of the original. Some plumber's epoxy was inaccessible and had to be retained.

Table II. EDS of blue consolidant.

Weight %	Na	Al	Si	S	Cl	K	Ca	Ti	Cr	Fe	Zn
Blue Consolidant	11	12	69	1	>1	>1	>1	>1	>1	3	1

An opaque blue consolidant was found in a number of places on the window, on both the putty and the glass, to which it had bonded well, sometimes etching it. From its analysis (Table II) it appears to be a sodium silicate which is an ingredient in various sealant recipes and is known to have been used to restore other Brigham windows, though not with the blue colorant, and not very successfully - it had etched the glass in those windows, permanently damaging it. Why it was blue on the Brooklyn window is not clear. Since it was also found in the interspace at the perimeter of the lead repair, it was clearly done at that time and it may have been used as a binder to help hold the lead repair to the plate glass. Adjacent areas have the heaviest application and it certainly helped the inferior lead repair fit in better by masking original glass. After toning that area down it may be that the restorer continued to use it to fill in "light leaks" all over the panel. If the windows were seen primarily with light coming through them and not reflected off of them, it may not have been disturbing. It is possible that the material wasn't originally blue, but discolored dramatically over time. At the time of treatment it was still well bonded to the glass, though it easily flaked off the putty and shells. It was removed.

Conclusion

Walter Cole Brigham was innovative and ambitious, but his chosen material, while generating attention at the time for its uniqueness, ensured his relative obscurity as his works crumbled and disappeared. In his landscape window in the collection of The Brooklyn Museum of Art the consolidation of the putty matrix using Acryloid B72 proved to be very effective and allowed the retention of his original material with no significant alteration of its appearance. Cleaning of the outer surface and selected areas of the interspace was extremely important to return the "quiet tones and delicate shades"[7] of the shells and stones and to allow the glass to sparkle once again.

Acknowledgments

My thanks to everyone who helped with this project. Ken Moser (Chief Conservator), Ellen Pearlstein (Conservator of Objects), and Kevin Stayton (Curator of Decorative Arts) of The Brooklyn Museum of Art guided the project from start to finish. Mark Wypyski, Associate Research Scientist in the Sherman Fairchild Center for Objects Conservation of The Metropolitan Museum of Art, performed the EDS. Jack Cushen discussed his experience with other Brigham windows and provided some helpful references. The treatment itself was carried out by the author with the assistance of fellow conservators Marie P. Foucault Phipps and Elizabeth Ryan.

Endnotes

1. Dr. Stewart W. Herman, "Marine Mosaic...The Lost Art of Walter Cole Brigham," *Stained Glass Quarterly* 72, Spring (1977): 34.

2. Ibid., 33.

3. The EDS analyses were performed by Mark Wypyski in the Sherman Fairchild Center for Objects Conservation of The Metropolitan Museum of Art. A Kevex model Delta IV energy dispersive X-ray spectrometer attached to an Amray modified model 1100 (1600T) scanning electron microscope (SEM) was used for the analysis.

4. C.W. Whall, *Stained Glass Work* (London: Sir Isaac Pitman & Sons, Ltd., 1920 - reprint of 1905, London, John Hogg), 147.

5. Kenneth M. Swezey, *Formulas, Methods, Tips and Data for Home and Workshop*, (New York & London, Popular Science Publishing Company, Harper and Row, 1969), 200.

6. W. Cole Brigham,. "Marine Mosaic," *American Homes and Gardens*, January (1910): 23.

7. Ibid., 23.

Materials

Acryloid B72 is manufactured by Rohm and Haas Company, Independence Mall West, Philadelphia, PA 19105 and is available through Talas, 568 Broadway, NY 10012.

Dap 33®, manufactured by Dap, Inc. of Dayton Ohio, is generally available at hardware stores.

3110 RTV Silicone rubber is manufactured by Dow Corning. It is available at art supply stores.

RTV 118 Translucent, a general purpose self-leveling silicone, is manufactured by the General Electric Company, 260 Hudson River Road, Waterford, NY 12188.

Dremel® Moto- Tool is available in hardware stores.

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CONSERVATION OF CHINESE SHADOW PUPPETS FROM THE ANTHROPOLOGY COLLECTION OF THE AMERICAN MUSEUM OF NATURAL HISTORY

Lisa Kronthal

Abstract

Chinese shadow puppets of the East City type are traditionally cut from donkey skin that is treated to be translucent, painted with dyes and coated with tung oil. The history of the American Museum's collection of Chinese shadow puppets, and details concerning the materials and techniques used in their manufacture, are described in this paper. The tung oil coating in most collections has remained soft and tacky, resulting in extensive damages due to adhesion of elements to themselves and storage materials, and particulate dirt and fibers embedded in the coating. Preliminary research into the physical characteristics of this problematic coating is discussed. Other common damages in these collections include tears and warping of the skin and detached elements. A survey of the collection is described as well as research into appropriate materials and techniques for new storage and treatment. Silicone coated Mylar™ as a long term storage material was explored focusing on its methods of manufacture and transfer potential. For tear repairs of the translucent skin a range of intestinal lining materials including goldbeater's skin, reconstituted collagen, and natural skin condoms in combination with adhesives including BEVA™ 371, Acryloid F-10 and polyvinyl acetate resins were investigated.

Introduction

Shadow puppetry in Asia is a theatrical art form which has survived centuries to tell historical tales and myths which remain relevant to contemporary Asian societies. A comprehensive collection of 19th century Beijing, East City type shadow puppets were acquired for the American Museum of Natural History by the renowned Sinologist and ethnographer Berthold Laufer. The puppets were cut from thin, translucent skin which was painted with dyes and coated with oil. Accompanying the collection were typical items that would be carried with the figures by the itinerant performer, including musical instruments, stage props, carrying cases or trunks and screens. All artifacts were thoroughly documented and individual puppets and plays identified and described in detail by Laufer.

There are many similar collections of these East City type shadow puppets both in this country and around the world. The puppets within these collections have comparable condition issues due to the traditionally applied coating which remains sticky over time and to the inherent fragility of the finely carved skin that is prone to tears and losses. The American Museum archives contain extensive correspondence between the keepers of these collections, most of which concerns the problematic coating. There was clearly an attempt to solve these condition issues using a variety of materials and techniques. These previous treatments are no longer acceptable as they often left individual puppets as well as whole collections irreversibly damaged.

The rehousing and treatment of ethnographic collections requires approaches and techniques which are often very different from those involved with other collections. Although the coating is problematic, its historic importance makes its removal unacceptable. Therefore, in order to preserve it suitable rehousing environments and repair techniques and materials must be developed. Additionally, collections such as these which exist to perform a function require treatment procedures which will maintain this purpose. Returning the puppets to a usable condition and preserving this state assumed priority with this collection.

Background

In 1901, Franz Boas, then a curator in the Department of Anthropology at the American Museum, commissioned the German ethnologist Berthold Laufer to travel to China for field investigation and the collection of artifacts documenting the traditional daily life of the Chinese people. These investigations continued the work of the Jesup North Pacific Expedition, launched in 1897 to research the cultures living along the rim of the North Pacific Ocean, from British Columbia to China and Japan (Stalberg, 1983).

Laufer was particularly thorough in gathering objects connected with popular performing arts, such as the puppet theater, shadow theater, and local music. He purchased the complete repertoire of a 19th century puppet master of the late Qing dynasty including musical instruments, stage curtains, dramatic texts, wax cylinder recordings of dialogue and music, and more than 1000 shadow figures. This extraordinarily complete and well documented collection has been the focus of this project.

Laufer saw increasing value in studying Chinese shadow theater since he felt it could be the origin of shadow theater around the world. He explains to Boas that many studies had come out in Germany regarding the shadow theater of Turkey, Syria, India, and Java, yet were lacking information concerning Chinese Shadow theater. He also considered the material necessary to understand the migration of Indian tales since the plots of many of the dramas and myths are Buddhist ones. It was for all of these reasons and more that Laufer studied these collections and art forms with passion and dedication.

Unfortunately he was unable to secure funds to completely catalogue the material he collected and left for Chicago's Field Museum where another large collection of East City figures exists. In spite of the fact that the notes he left were written in three different languages as well as an obsolete version of German shorthand, dedicated researchers and specialists have continued to study his writing and have learned a great deal about the collection. They have identified figures and settings, described the plays in detail, and have published their findings extensively. A summary of this research follows allowing the reader to more fully appreciate this art form which is unfamiliar to many Westerners.

History of Chinese Shadow Theater

There are several hypotheses concerning the origin of shadow theater. A common attribution relies on a Han dynasty tale involving the Emperor Wu Ti (reigned from 140 - 86 BC). Devastated by the death of his wife the Emperor had his magician summon her spirit so that he could be comforted by her ghost. A curtain was erected with a light behind it so that the Emperor, sitting on the opposite side could see the shadow of his dead love.

There is recorded proof of shadow puppetry's existence in China during the Sung dynasty (960 - 1278) and some scholars will push this date back to the Tang dynasty (618-907). During the Tang dynasty, papercuts were pasted on lanterns, screens and windows with the light illuminating them from behind. This created images similar to those made by shadow figures, leading many to see them as a source of inspiration. Additionally, the style and technique used in cutting the puppets is very similar to those used in the papercuts. In fact, the earliest Chinese shadow puppets known from the Sung dynasty were made of paper.

From the 11th century on, tales of battles and myths were told by itinerant entertainers. By the 14th century, shadow puppet troupes were being sent to entertain armies in distant parts of China. Later officials brought their own troupes with them to their provincial posts. During the 16th century Ming dynasty (1368 - 1644) the art had assumed an important and respected role in theater and several distinct schools of shadow puppetry emerged. The Luan-chou school in Beijing (Peking) gained fame and royal sponsorship during the late Ming. Under the Qing dynasty (1644 - 1911) two branches within this school developed known as East City (Peking) and West City types.

The Eastern school, which is the focus of the American Museum's collection, is considered the most refined of the Chinese shadow puppet schools (Figure 1). It employs very skilled, detailed carving techniques and the thinnest and most translucent skins. The puppets are carved into shapes of human figures, animals or scenery and are designed to be manipulated in front of a lamp projecting shadow images onto a translucent screen. The audience gathers on the opposite side of the screen to view the shadow performance (Figure 2). Unlike their more common Indonesian counterparts, the East City shadow puppets are cut from skin that is thin enough to allow for colored light transmittance, and the images can be seen in color. Since the puppets are held very close to the screen the colors and details in carving are all sharply in focus.

The theater incorporates elaborate props, furniture and scenery creating spectacular and complex compositions on the screen. It can depict dragons, monsters and flying immortals as well as fires, battles and bloody deaths. Since the puppets are hidden behind a screen, more complex myths and legends can be performed in shadow theater than in the other performing arts such as opera or wooden puppetry. This allows fantastic transformations such as flight, decapitation, and other supernatural phenomena that often take place in Chinese legends to be illustrated.

Influence by Chinese Opera

Chinese opera and shadow theater are closely related and strongly impact one another. They share similar stories which cover both historic and mythological themes. Both performances are spoken and sung with the background music an integral aspect of the performance. Drums, flutes, gongs, horns and string instruments will often accompany the plays.

The puppet masters adopted painted faces, masks and costume design from the opera and also incorporated its stylized movements into the shadow theater. The articulated limbs of the East city type figures allow the puppeteers to achieve these complex movements. The masks, face painting and costumes allowed the viewer, familiar with the meanings of each color and form, to decipher the personalities of the characters in a drama.

As in Chinese opera, the characters in shadow theater are divided into four major groups. These groups include the Chou (comic actors), the Ching (male, military characters), the Sheng (scholars or officials) and the Tan (women characters who can be military, educated or servants). Immortals and supernaturals can take any of these roles (Broman, 1981). Painted faces and headdresses symbolize the personality traits or rank of the different characters. For example, a fierce and powerful general may wear a red and black mask, the red designating strength, and the black loyalty.

The style and methods used for cutting and carving the skin also help to distinguish personalities or identities (Figures 3, 4). The faces of noble gentlemen and women are usually completely cut away leaving graceful outlines of eyes, nose, lips and forehead while those of the comic actors, warriors, mythological or hell figures will most often be left solid or painted. Different styles of facial hair provide clues for male characters. A finely combed beard is appropriate for a highly respected gentleman while a more fierce character would wear a fuller beard. Costumes are also used to indicate social standing. Generally, the more detailed the carving, the more important the character. Lower class characters are depicted wearing very plain unembroidered and therefore uncarved garments (Figure 5). The costumes of officials and generals are elaborately carved and painted to represent the lavish embroidery that covered their clothing (Figure 6). These distinctions would have allowed the audience to remain completely aware of the hierarchy of the actors on stage.

Like opera, the shadow theater performances combine the spiritual nature of the stories with activities of daily life forming an important link between these worlds. Aspects of the Chinese Buddhist spiritual universe, including the layering within heaven's kingdoms and hell's law courts, are commonly depicted in the shadow theater. The Laufer collection includes many depictions of punishments in hell, such as criminals being sawed in half or victims writhing in kettles of boiling water (Figure 7). The agonized and tortured expressions of the characters are profoundly depicted in these simply carved figures (Figure 8).

Technology and Manufacture

The construction of a shadow puppet begins with soaking a hide, traditionally donkey, in water and then stretching it on a frame. The wet skin is rubbed and scraped, first with a stone then with bamboo until it is thinned to translucency. Often, the hide of a young animal or a hide which has been split or skived is used for parts of the figures which require greater translucency. When thicker skins were needed sheep or cow was used.

The outline of the figure is traced or drawn freehand onto the skin, usually by incising, and is cut out using chisels or knives. Most of the puppets depict human figures and are composed of eleven parts. For less important figures, the legs, torso, and even head may be cut from one solid piece of hide. These characters are not required to express individual personalities and therefore do not need to make the range of movements obtained with the more complex articulated puppets.

As mentioned, different parts of the puppet body are made from different sections of the hide. Traditionally, the skin from the belly of the donkey is employed for faces and upper body parts while thicker sections are more appropriate for the feet, legs and torso. The thinner skins of the faces allow greater light transmittance creating a sense of illumination while the weight and rigidity of the thicker skins in the lower body keep the puppet balanced and stable. Often tiny lead plates are attached to the bottom of the pant legs to obtain greater balance. All skin parts are cut parallel to the grain of the hide to reduce warping.

The puppet maker cuts the base of the puppet legs and arms, where they meet the torso, into shapes like spoked wheels. These radial cuts prevent a large, dark spot from appearing on the screen when the parts are overlapped and light is transmitted. Silk or cotton string holds the parts together and occasionally metal wire is used to reinforce separate parts. The heads are not attached permanently. Instead, they fit into a collar of parchment allowing the character to change costumes in the middle of a performance. Often many heads are needed to show the changing status and emotions of a single character in the course of a play. This construction also allows decapitation, a frequent mode of execution, to be convincingly portrayed. Iron alloy wires with bamboo handles were attached to the figures for manipulation by the puppeteer.

Traditionally, the skin was painted on both sides with vegetable dyes. Later, synthetic dyes and paints were used. An application of oil, usually tung oil, was applied in order to saturate the colors resulting in a more vivid projection as well as greater transparency. The coating was periodically reapplied by the puppeteer as part of the regular maintenance procedures for his collection.

Condition - Inherent Instabilities

Structural instabilities throughout the collection are mostly related to the manufacture of the puppets, specifically their thinness and intricately cut designs. Common damages resulting from this inherent vice include tears of the skin, warping, and detached elements. It was common for the puppet master to manufacture his own figures and to regularly restore damaged figures. Therefore, before treatment a clear distinction must be made between ethnographic and modern interventions. Ethnographic repairs in the Laufer collection include sewing, pinning and patching with skin. These repairs have historic importance and should be preserved if possible. Modern attempts at restoration include applying transparent, pressure sensitive tape to tears and using paper clips to connect detached elements. Repairs which were carried out after the puppets have left their original context should be removed and redone using more appropriate materials or techniques.

The tung oil coating has been the main culprit when considering condition and preservation issues within many shadow puppet collections. In the American Museum collection, old storage conditions in hot, humid environments aggravated these problems. Puppets were piled into shallow trays and were found stuck to adjacent puppets, to storage materials like brown Kraft paper or to plastic bag enclosures (Figure 9). Correspondence with other institutions indicates that this sticking problem was of widespread concern. One letter written to American Museum restorers in 1974 reads:

> We own a large collection of shadow puppets made of traditional "parchment", dyed with bright colors, and then coated with a shellac-like substance. The problem lies with the latter material which in time, has become tacky and sticky and adheres to whatever guard sheet we lay between the images. We've not been able to find a solvent which can remove the sticky material without removing the color (AMNH archives, 1974).

The response to this inquiry suggested either complete removal of the coating using MEK or 'if one wanted to preserve the coating then application of Butcher's wax would act to prevent sticking'. The collection was treated by soaking the artifacts in baths of MEK removing the coating entirely along with much of the originally applied colors.

Correspondence with a European institution describes a different approach. In their case, it was realized that removal of the coating would cause irreparable changes. So instead, paraffin was applied directly to the surfaces in an attempt to reduce the sticking. Unsatisfied with the results they then rubbed all surfaces with Vaseline (petroleum jelly). In their letter they state with pride, "now the certainty exists that the valuable collection is no longer in danger".

These previous approaches to the problematic coating either attempted to cover it with another material or to remove it all together. Both of these options are unacceptable. Instead, a less intrusive treatment involving upgrading storage conditions and developing treatment procedures compatible with these inherently fragile and sticky artifacts needed to be developed.

Tung oil

An investigation into tung oil and its drying properties offered some help in understanding the troublesome surface treatment. Most sources that have been referred to concerning Beijing shadow puppets describe tung oil as the primary coating material. Several oil samples were removed from puppets in the collection representing the range of oil types found on the puppets distinguished by their surface characteristics. All samples were positively identified as tung oil using FTIR and GCMS.

Tung oil, also known as Chinese wood oil, is obtained from the seeds of the fruit of Aleurites fordii, a tree which has grown in China for centuries. The native method for separating the oil involves roasting the seeds over a flame and grinding them with stones or wooden presses. A cold-pressed version of the oil called ‘white tung oil' is light in color and is mainly exported. The hot pressed oil has a very dark color and is called ‘black tung oil'.

Tung oil contains a large proportion (75 - 85%) of eleostearic acid, a stereo-isomeride of linoleic acid, the acid found in linseed oil. These acids contain two unsaturated double bonds, a property which gives an oil its drying property. However, under normal temperature and humidity conditions it takes tung oil approximately thirty days for a full gain in weight or for drying to be complete, distinguishing it as a slow drying oil. In fact, tung oil is not recommended as an artists material since it requires extensive processing to dry to a satisfactory level.

Under humid conditions the oil will dry more rapidly with a resulting film which is wrinkled, cracked or reticulated. This drying rate increase in moist air is not ‘drying' in the usual sense through oxidation and polymerization as the full weight gain is still not complete, but is a colloidal change in which moisture acts as the coagulant (Gettens and Stout, 1942). The reticulated surface texture of the coatings on the puppets is common and could have resulted from application and ‘drying' in a humid environment.

Preliminary examination by FTIR and SEM/EDS on the puppet coating has not found any additional ingredients which may have facilitated a drying process, i.e. metallic driers. At this point it remains unclear whether these additives would have been detected using the analytical equipment that was available. An interesting differential drying phenomenon was observed throughout the collection. The oil appears to dry to a harder, less tacky state in blue and green dyed areas and generally remains soft and tacky in red, orange and unpainted areas. Apparently, the blue and green dyes may contain elements or mordants different from those used within the other painted areas and could to be acting as driers when in contact with the oil. Further research focused on the composition of Chinese dyes and oils used in the 19th century and appropriate techniques to separate and identify these materials needs to be carried out to understand this phenomenon more completely. However, the preliminary investigation seems to indicate that the inadvertent inclusion of driers in some areas helped the oil to form a more stable coating, which could have been achieved overall if the original oil was modified before application.

Rehousing - Silicone Mylar™ Investigation

Since the oil is ethnographically important and cannot be altered or removed, choosing appropriate and compatible storage materials for rehousing is a priority. Several attempts at creating safe housing for the collection were undertaken in the past. In spite of good intentions, these campaigns have complicated storage and condition issues. A variety of materials were used as interleaves including silicone release paper, acid free tissue, brown Kraft paper, Mylar™ and plastic. The puppets stuck to all of these surfaces. Requirements for the new storage environment included controlled temperature and humidity conditions as well as storage upon a surface which is non-stick, non-reactive and non-textured. We considered vertical storage, Teflon™ surfaces and silicone Mylar™ surfaces. Vertical storage was found to be impractical due to space considerations and Teflon™ was too costly. This left silicone Mylar™ as the only safe and practical choice. The slick, smooth surface would inhibit future sticking. The only shortcoming of this material is that there may be some transfer of glossiness (burnishing) with time to the side of the puppet in contact with the slick surface due to the softness of the coating.

It was inadvertently found that the silicone coating on the Mylar™ that was on hand in the lab was not permanently adhered to its substrate and was readily removed by a range of solvents. For long term storage, such qualities were unacceptable. The eventual loss of the non-stick properties of this material when in contact with the soft oil seemed too risky.

While researching the variety of technologies involved in the manufacture of the product several interesting facts were found. Many companies purchase the raw Mylar™, using either Dupont Mylar™ A or D, and apply the silicone coatings. Due to issues of propriety, the coating companies were hesitant to describe in detail their application and/or polymerization techniques. A representative from Custom Coating and Lamination, a Massachusetts based company described several polymerization techniques that could be used. The major ones involve UV or heat curing technologies. Conflicting opinions from the suppliers concerning the effect these processes have on the final physical qualities of the coating was common. Several representatives claimed that if the film is polymerized it should not be possible to remove it, while others claimed there are varying levels of transfer of the coating to whatever material is laid upon it, the UV cured coatings transferring the least and the heat cured coatings having a higher possibility of transfer. Additionally, the heat cured techniques allow for a wide range of release levels while the UV cure is less flexible in that respect. Requirements for the storage surface for the shadow puppets included a film with a low transfer potential and medium or high release levels. A coating company named Douglas Hanson uses a UV activation polymerization technique which results in a product which meets these requirements. Both Conservators Products and Talas distribute this product.

Rehousing the collection involved preparation of each shelf by lining first with acid free corrugated board and then with the Douglas Hanson silicone Mylar™. Puppets were laid onto the silicone Mylar™ surfaces and pinned in position through pre-existing holes in the carvings with map pins that had been coated with an isolating layer of B-72. The B-72 should protect the steel pins from organometallic corrosion which could develop through contact with the acidic tung oil coating.

Treatment

During the rehousing, a survey of the entire collection was conducted in order to prioritize each puppet by its relative need for treatment. The survey results were entered into a database created specifically for the collection. It was found that over three hundred of the approximately 1500 puppets were considered priority one and most in need of treatment. These puppets often required a combination of the following; removal of old storage materials stuck in the coating, mending of tears within the skin and/or reattaching separated elements.

Solubility tests on the coating revealed that it was soluble, in varying degrees, in a wide range of solvents. Acetone and ethanol solubilized the coating readily, toluene, petroleum benzine and xylene moderately and Stoddards minimally. In most cases, the storage papers were saturated by the coating so that their removal would involve some loss of coating. The goal in removal of the storage materials from the puppet surfaces was to retain as much of the original coating as possible along with its original, reticulated texture. By wetting the papers with Stoddards, a scalpel could be inserted at the interface of the coating and the paper and, in most cases, the paper could be removed with minimal loss of oil. The Stoddards appeared to function mostly as a lubricant enabling separation of the layers while retaining the original surface texture of the coating.

The goals in mending were to find a combination of materials that were compatible with the skin and oiled substrate and would maintain the transparency of the skin when viewed through transmitted light or as a shadow. A variety of materials were considered for repair of tears including gampi papers, oiled papers, goldbeaters skin, natural skin condoms, and sausage casings (reconstituted collagen). The papers were eliminated as an option for many reasons including differential aging of the paper in contact with the acidic skin and oil, dimensional incompatibility and visual inconsistencies.

The collagenous materials were given primary consideration due to their visual and chemical compatibility with the skin substrate. A discussion on the Conservation Distribution List concerning reconstituted collagen as a mending material outlined relevant issues concerning the use of sausage casings in conservation. In summary, the preparation of the collagen in manufacturing a casing involves reducing bits of animal skin in hydrochloric acid, spin extruding the gelled product, bathing in aluminum sulphate, buffering, and adding plasticizers, consolidants and tanning agents. These steps, especially the acid preparation, reduce the length of the collagen fibers resulting in a product that has a very short shelf life and becomes quickly embrittled upon removal from the package (Conservation Distribution List, 4/16/97). Requirements for a stable, flexible mend led to the elimination of this product as an option.

The natural skin condoms were more promising. The intestinal material used in their manufacture comes from the caecum of the large intestine of sheep or lamb. The processes involved in its preparation include trimming and defatting of the skin, soaking in salt solutions, addition of surfactants, light tanning and coating with a lubricant which can be removed with acetone or ethanol. There is no acid preparation involved as maintenance of strength and endurance are crucial requirements for such products. Unfortunately, for use on the puppets, the final product is too thick and does not lead to visually acceptable results but may be useful for other types of mending which require more thickness or strength.

It was concluded that goldbeater's skin resulted in successful mends that were strong, unobtrusive and transparent. Talas supplies sheep appendix gold beater's skin but other suppliers will carry skin made from the caecum of intestinal material. Before use, it must be degreased using acetone and its surfaces lightly abraded with pumice to reduce unevenness. The final product is much thinner and more transparent then any of the other considered products. It can be toned with dyes in order to achieve desired colors while maintaining translucency. Orasol™ dyes in ethanol were used for this purpose.

Several adhesives in both film and solvent form were tested in conjunction with the goldbeater's skin lining. Requirements of the adhesive include compatibility with the skin, the coating and the lining material, as well as long term stability, transparency, and flexibility. Included in these categories were BEVA 371™, polyvinyl acetate resins and Acryloid F-10. After a number of trials it was found that the F-10 and PVA resins both had difficulty attaching to either the oily skin or the goldbeaters lining material. Additionally, they seemed to lack the strength required by some of the mends. BEVA 371 in solvent form or as a reactivated film adheres best to the coated skin and the lining material while also maintaining the strength and integrity required of the mend. Future monitoring and research into the aging properties of BEVA when used in this acidic environment will be undertaken.

Before applying mending materials, the oil in the mend locations was reduced. Since the oil penetrates into the porous skin it is impossible to remove it completely. If necessary, the area to be mended can be relaxed into position using controlled humidification techniques and dried under pressure. Often, both sides of a tear will need the reinforcement offered by the mending materials. A tinted varnish can be applied to the surface of the mend if necessary. The final mended tear is strong, clear and flexible (Figures 10, 11).

Conclusion

The rehousing, survey and treatment of the Chinese shadow puppet collection demanded resolution of conservation issues which, while focusing on ethnographic artifacts, can be applied to a wider variety of collections. Preservation of the original function and composition of the puppets was considered paramount and treatments were developed to accommodate the challenging materials which compose them. These treatments were customized for a large scale collection which is often the focus of research and exhibition.

In pursuing an acceptable approach to the needs of this collection, the author was granted the opportunity to research the history and technology of shadow puppetry in China. Simply understanding the importance of color and form within the figures was a determining factor in their subsequent treatment. Investigations into past treatments created focused awareness on the detrimental results these efforts can have. This accumulated knowledge concerning a wide range of issues allowed for the development of a sensitive and appropriate approach to storage and treatment.

Epilogue

In the 20th century, especially between 1920 and 1970, shadow puppetry went through dramatic transformations. Plastic sheets replaced the fine leather puppets and synthetic colors supplanted the natural dyes. Combined with cruder cutting techniques, the effect was cheap and represented a sad departure from the tradition of the elegant, older shadow puppets. Communist ideology became a dominant theme in shadow troupes so that content within the dramas changes as well.

After the Cultural Revolution (1966-76) ended village troupes again began performing old dramas, using puppets that were one hundred to two hundred years old (Berliner, 1994). Even with this rebirth, the popularity of this theater has suffered in the shadow of modern film and performance. An interview with an old shadow puppeteer in Beijing in the 1930's concerning the state of the theater reveals his beliefs concerning the future of shadow theater in China:

> We produce no plays in terms of present day life. Those who love the shadows, it seems, love also the glorious past . Young people and women are now going to theaters and motion pictures. Only four companies are now operating in Peking, all in the hands of white headed old fellows like myself. I have no son to succeed me and I have no pupils to continue the old traditions, to make my shadows dance when I am gone (Wimsatt, 1936).

Acknowledgments

I would like to thank Samantha Alderson and Judith Levinson of the Conservation Lab at the American Museum of Natural History for their continued support and suggestions concerning this project. Thanks to George Wheeler at the Metropolitan Museum of Art for his analysis of the oil samples and to Tracy Power at the San Francisco Asian for her input on the history of the treatment of similar collections.

Materials list

Silicone Mylar™:	Douglas Hanson, P.O. Box 528, Hammond, Wisconsin, 54015, (800)525-2400 Conservators' Products, Co., P.O. Box 411, Chatham, New Jersey, 07928, (973)927-4855
Goldbeater's skin	Talas, 568 Broadway, #107, New York, New York (212)219-0770
Orasol dyes	Conservation Support Systems, P.O. Box 91746, Santa Barbara, California, 93190, (800)482-6299

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Figure 1. Shadow figure, Beijing, East City type.

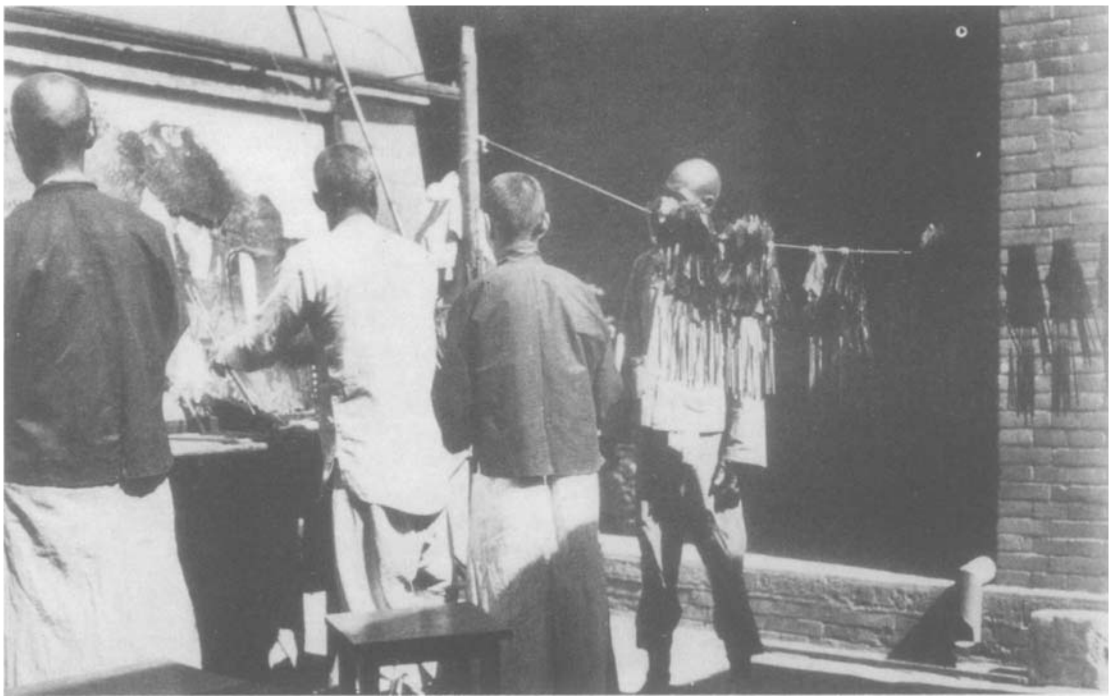

Figure 2. Shadow puppet performers.

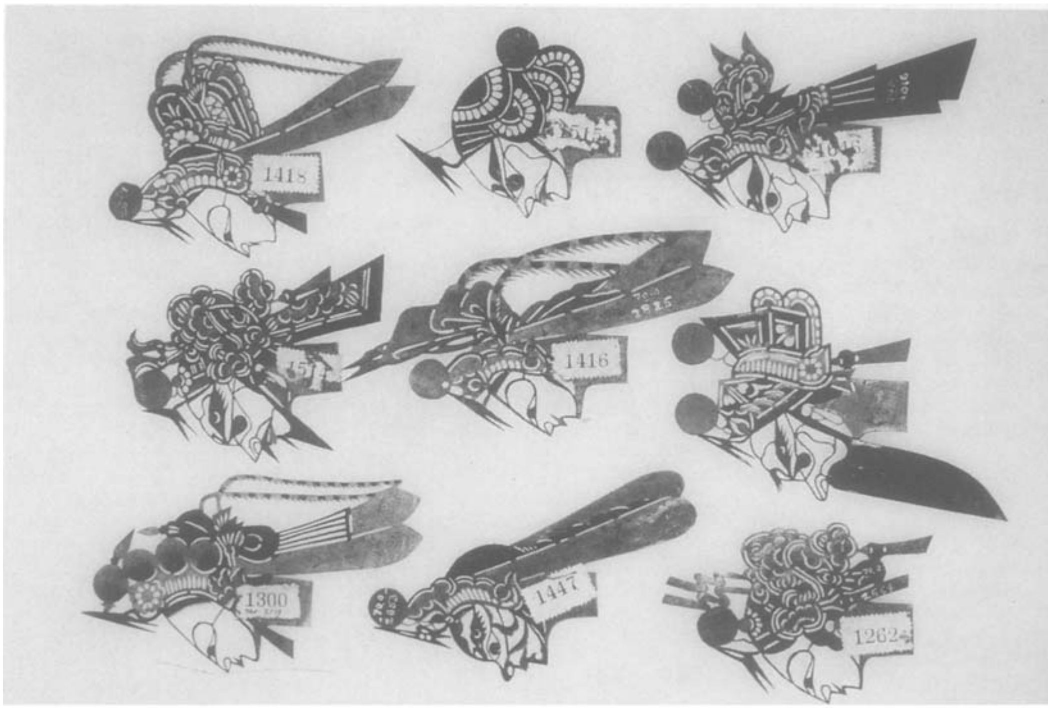

Figure 4. Heads, Beijing, East City type.

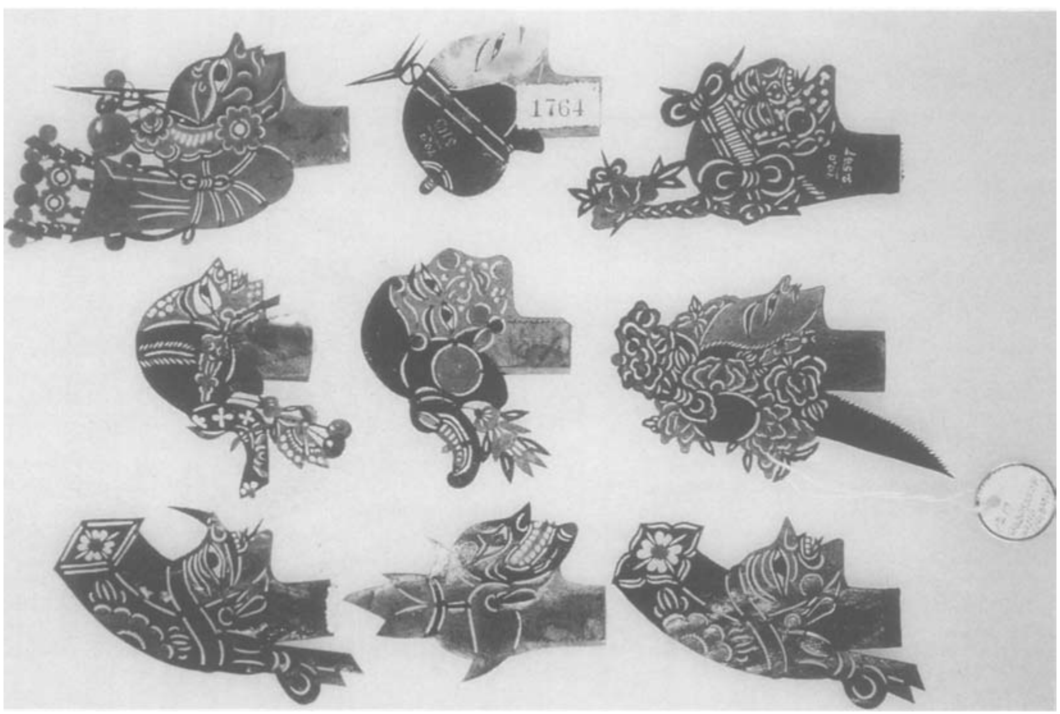

Figure 3. Heads, Beijing, East City type.

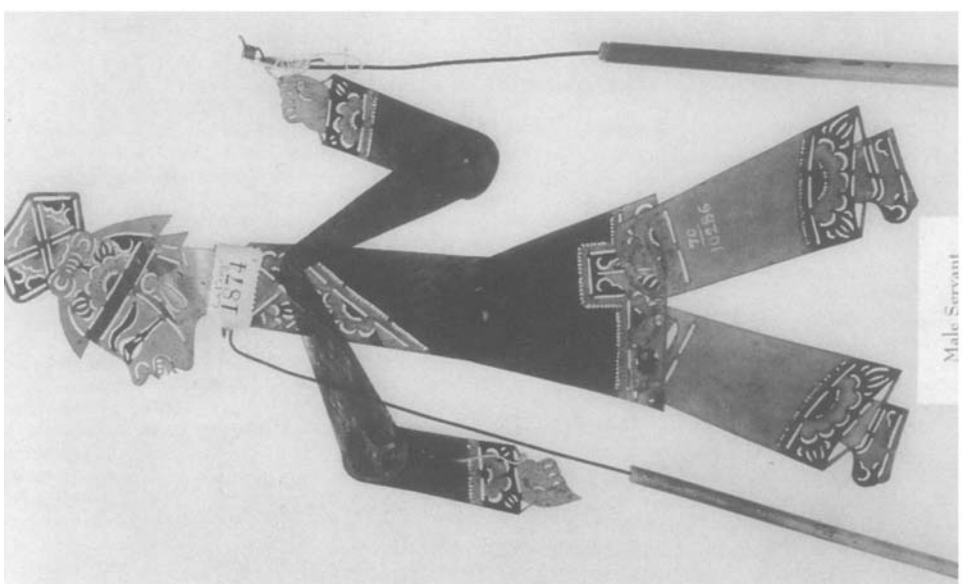

Figure 5. Shadow figure, Beijing, East City type.

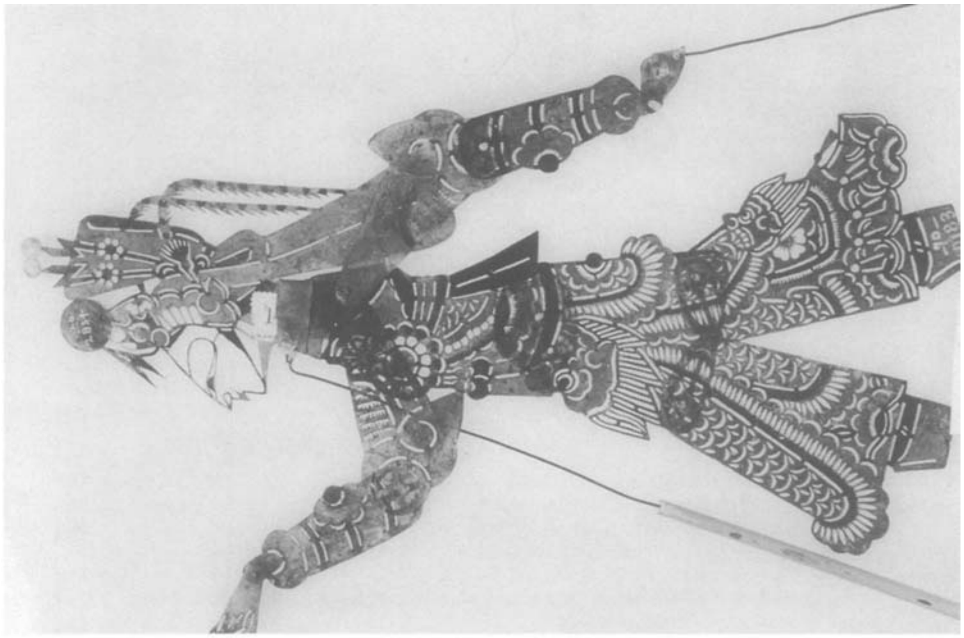

Figure 6. Shadow figure, Beijing, East City type.

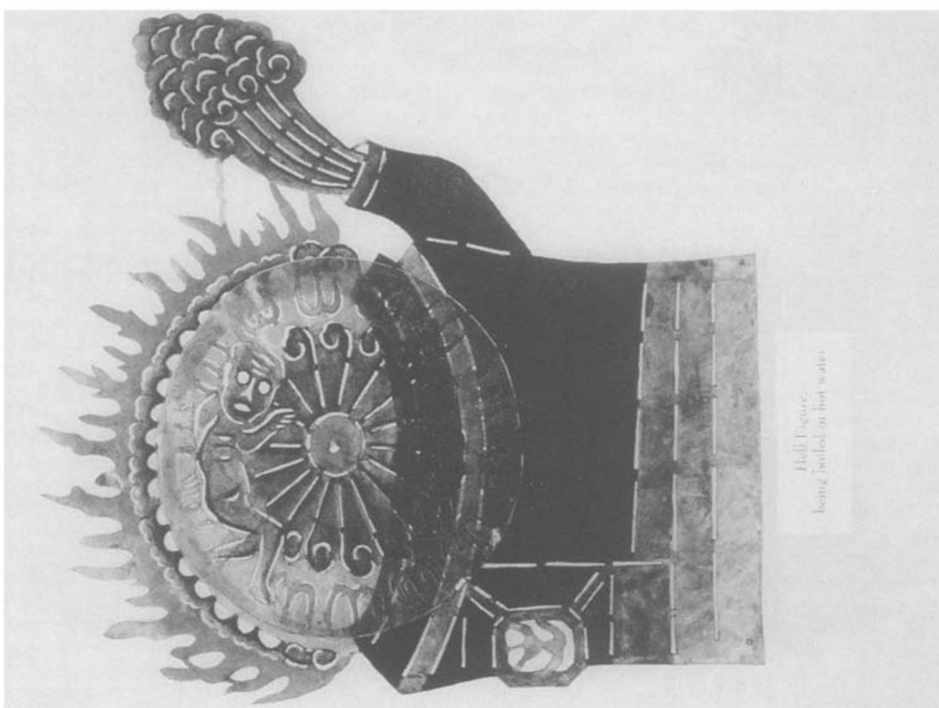

Figure 7. Shadow figure, hell character in kettle of boiling water; Beijing, East City type.

Figure 8. Shadow figures, hell characters; Beijing, East City type.

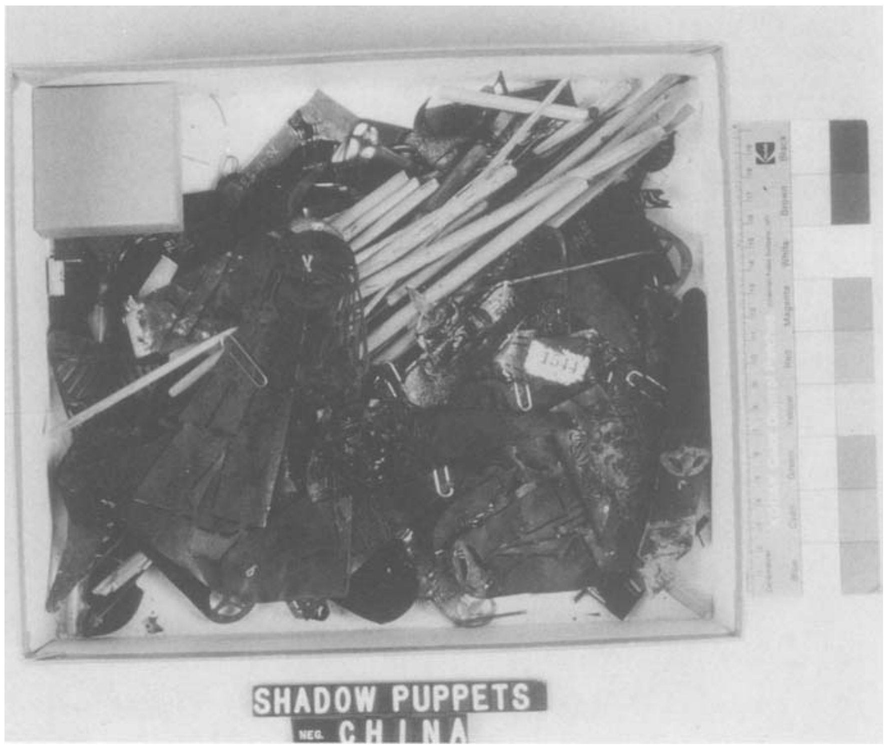

Figure 9. Old storage of Chinese shadow puppets at AMNH.

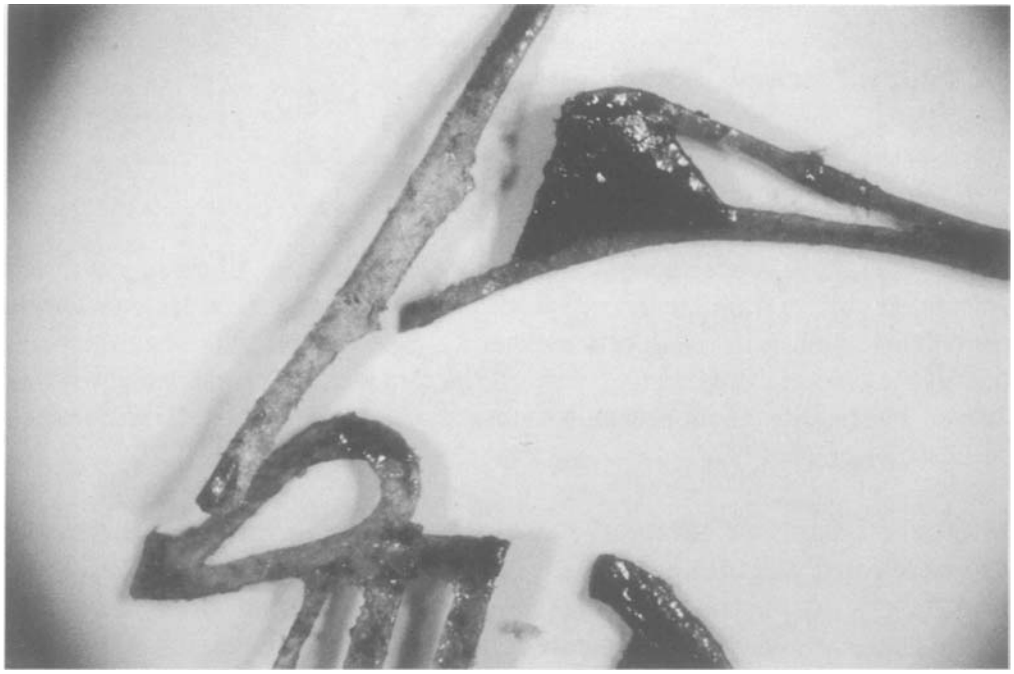

Figure 10. Head, detail, before treatment.

Figure 11. Head, detail, after treatment.

ANALYSIS OF RESTORATION MATERIALS: THE CAMPBELL COLLECTION AT WINTERTHUR MUSEUM

Margaret A. Little and Janice H. Carlson

Abstract

In 1996, the H. F. DuPont Winterthur Museum acquired a collection of ceramic and metal soup tureens and related objects from the Campbell Museum in Camden, New Jersey. The majority of the collection dates to the 18th - 19th centuries, and is of American and European manufacture. Examination of the objects indicated that many of the ceramic tureens had been restored in the past. However, information about previous restorations in the Campbell Museum's files was incomplete or nonexistent.

For the exhibit *The Campbell Collection of Soup Tureens at Winterthur*, 137 pieces from the collection were selected, and the objects were examined and conserved in Winterthur's Objects Conservation Laboratory. In treating the previously restored ceramic objects, one of the first decisions to be made was whether previous restorations should be reversed. With the curator, conservators established a list of criteria to guide the decision-making process. If a restoration was reversed, the methods used were recorded; the appearance of the materials used in normal and long-wave ultraviolet light was noted; and samples of adhesives, fill material and inpainting/coating materials were collected and analyzed using a variety of instrumental techniques. The goal of the analyses was to provide a better understanding of the types and variety of materials used in the restoration of ceramic objects in the Campbell Collection. The results of the analyses were also compared with lists of materials suggested for use in ceramic conservation and/or restoration, collected during a literature search. Because the restoration records for the Campbell Collection were limited, comparison of the analytical data with the literature gave an opportunity to compare the actual types of material used to restore the tureens with the material being used commonly by restorers and conservators reported in the literature.

1. Introduction

In 1966, John T. Dorrance, Jr., then chairman of the board of the Campbell Soup Company, suggested that the company begin acquiring soup tureens. From that beginning the collection grew to include over 300 metal and ceramic objects, all in some way related to the service or consumption of soup. The strength of the collection lies in 18th and 19th century objects made in England, continental Europe and North America. Silver tureens made by English firms of Garrard and Company, and Rundell, Bridge and Rundell, are included in the collection, as well as a silver ladle made by Paul Revere of Boston. Ceramic tureens are representative of the work of many famous ceramic manufactories in continental Europe and England, including Meissen, Sèvres, Chelsea, Staffordshire and Worcester. There are also a number of tureens made by contemporary artists in the collection. Many of the tureens were on permanent display at the Campbell Museum in Camden, New Jersey, at the Campbell Soup Company corporate headquarters. A smaller component of the collection was shown extensively throughout the United States in a traveling exhibition.

In March 1996 the Campbell Museum's collections were donated to the H. F. DuPont Winterthur Museum for exhibit in a new gallery named in honor of the Dorrance family. The Objects Conservation Laboratory at Winterthur was called upon to examine the 137 objects chosen for the new installation, and to establish a treatment plan to prepare the objects for exhibit. It was immediately apparent that all of the objects would need some level of conservation. As with many small museums, the Campbell Museum did not have a staff conservator and, for the most part, objects in the collection had not been treated after acquisition. The 40 metal objects chosen for exhibit would subsequently prove to be the most straightforward in terms of treatment needs. All but one of these objects was made of silver; treatment for most consisted of tarnish removal with mild abrasives followed by the application of a lacquer coating.

The 97 ceramic objects presented a far greater challenge, however. Preliminary condition surveys indicated that almost half of these objects were in good structural and aesthetic condition, and would require only surface cleaning to remove dirt and grime. The balance of the ceramic group had undergone some level of restoration in the past. Examination of the restorations revealed that aesthetic considerations had been given a high priority in earlier restoration work. In addition to reassembly of fragments and replacement of missing elements, manufacturing defects such as firing cracks had been filled and inpainted to minimize their visual presence.

It appeared that the conservation of the Campbell collection objects would provide an opportunity to study the materials used in previous restorations. A program was established whereby samples of restoration materials removed in the course of a treatment were saved for analysis by Winterthur's Analytical Laboratory. The goals of the analyses were to learn more about the range of restoration materials used in the past, to use the analytical information to assist in the choice of appropriate solvents or methods to reverse previous treatments, and hopefully to help in establishing a time framework for the previous restorations.

Each ceramic object was evaluated individually and treatment decisions were made based on the needs of the object. For the previously restored ceramic objects, the decision to remove old restoration materials was made jointly with the curator. The following criteria were used:

1) aesthetic appearance of the restoration;
2) physical stability of the object or the restoration
3) accuracy of the restoration; and
4) the constraints of the project timetable.

The aesthetic appearance of the restoration was usually the easiest factor to judge. Over time, the in- and overpaint used on many of the restored objects had darkened or yellowed, and now only served to draw attention to the restoration rather than to disguise it. There was unanimous agreement that restoration material in this condition should be removed. With regard to physical stability of restorations, the most common problem was embrittled restoration paint which was flaking from the surface of the object. In contrast, adhesive joins and fills were generally stable and therefore of less concern than the paint.

Many of the previous restorations had greatly changed the appearance of the object. The most common examples involved extensive overpainting, done to disguise major repairs. In many cases, paint had been applied to all surfaces of a tureen, cover or stand in an effort to cover a break line or a relatively small loss. In the process, many decorative elements had been reinterpreted. For example, flowers found in the overpaint of a cover did not exist on the original object. Once again, the decision to remove this kind of restoration was unanimous.

Less frequently, inaccurate restoration had resulted in reinterpretation of the physical shape of the object. For example, the restored handle from a two-handled soup bowl did not match the extant handle in size or shape. In another case, when both handles of a tureen had been readhered to the object, the length of the handles had been shortened. The restoration with the truncated handles created a profile which differed significantly from that of other tureens made in the same factory. In order to present the object accurately, it was decided that the handles should be removed and the length increased to accurately reflect the appropriate size.

Finally, the tight scheduling for exhibit preparation and installation, which required the treatment of 137 objects in 13 months, mandated that certain previously restored objects could not be treated. For those objects with physically stable restorations, deemed by the curator to be historically accurate and aesthetically acceptable, the decision was made to leave the restoration intact.

After examining all of the restored ceramic tureens with the above factors in mind, 37 restored tureens in need of re-conservation were identified. In all, 115 samples for analysis were collected from these objects in the following categories: adhesives, fill material, and inpaint/coating material.

2. Examination of Restorations

2.1 Ultraviolet Light Examination

All ceramic objects in the collection were examined using long-wave ultraviolet light (365 nm); a short-wave ultraviolet light source was not available for the project. In general, the overpaint of the restorations fluoresced bright white or a dull yellow in comparison to the original ceramic surface. Occasionally, glue joins or overpaint fluoresced orange, suggesting the presence of shellac.

2.2 Restoration Methods Used

In the initial examination of the objects and as treatment proceeded, a number of observations about the restoration methods used for this collection were made.

The surfaces of many of the objects were severely abraded, most often at break edges. This may indicate that inconsistencies at break edges caused by the misalignment of fragments during reassembly were evened out by abrasion. In many cases, abrasion had removed decorative elements which were then repainted. On all abraded surfaces, the glaze was duller, and a coating or paint had been applied, apparently to give the surface a more lustrous appearance. In some cases, firing cracks had been made deeper or wider, possibly to provide more surface area and better adhesion of the fill material to the ceramic surface.

In the course of the project it became evident that many objects had undergone at least two or even three restoration campaigns. For example, breaks had been repaired with rivets or staples, as evidenced by drill holes on either side of the break or channels cut in the surface across the break to receive the rivet/staple. However, the rivet/staple had subsequently been removed and the fragments were now held together with an adhesive, and drill holes and channels had been filled and inpainted. None of the Campbell collection objects chosen for the exhibit currently contain rivets/stables; any fragments once held together mechanically are now held together with adhesive.

Two restoration techniques were each found only once within the collection. The first was the use of a ceramic element (in this situation a handle) to replace a missing element on an object. In the second, a flat piece of metal had been inserted into a channel cut at the top of a crack for stabilization.

By far the most common restoration technique observed in the Campbell collection objects was the use of extensive overpainting, well beyond the area of repair, done to blend restoration work with the original and ensure that it was invisible.

3. Analysis of Restoration Materials

The analysis of the restoration materials was achieved primarily through the use of energy dispersive x-ray fluorescence spectroscopy (XRF) and Fourier transform infrared microanalysis (FTIR). XRF is a non-destructive technique for elemental analysis. Elements above atomic number 18, argon, on up through the rest of the periodic table can be detected. For most of the Campbell samples, which were quite small, the sample was lightly affixed to a strip of Scotch tape and then suspended in front of the x-ray beam. A molybdenum secondary target at 30 kV and 0.5 ma was used with a 200 second irradiation time. Because of limited sample size, response for most elements was weak but sufficient for identification. No attempt was made to physically separate fill from accompanying overpaint materials for XRF analysis because of limited sample size.

For micro-FTIR analysis, the sample was first examined under a binocular microscope. Where necessary or appropriate, discrete layers or components were physically separated. A tiny portion of each sample component was then transferred under a microscope to the surface of a diamond compression cell where it was rolled flat to an appropriate thickness for analysis. In some cases, samples were additionally extracted with chloroform or acetone for further FTIR analysis. FTIR spectral interpretations were confirmed by computer spectral search and by comparison with hard copy reference spectra.

The complexity of some of the samples is illustrated in Figure 1, an FTIR spectrum which shows three distinct layers in the an overpaint sample taken from an ecuelle. The top layer was found to be an acrylic material, while the middle and lower layers were nitrocellulose.

An advantage to both XRF and micro-FTIR analysis is that the sample is not consumed, and can be reused for other analytical purposes. However, as with all analytical techniques, certain limitations exist. For instance, XRF analysis is limited by the fact that it does not detect lower atomic number elements such as silicon, magnesium and aluminum; therefore such fill materials as talc, kaolin and other silicates are not detected and calcium containing compounds such as calcite and gypsum cannot be completely characterized. However, as most of these minerals absorb in the mid-infrared range, they are detected by FTIR as is seen in Figure 2 which shows the presence of plaster and kaolin together with cellulose nitrate.

FTIR analysis was complicated by the fact that all samples were mixtures of two or more components with frequently overlapping spectral bands. FTIR is not usually useful for mixture components in concentrations of less than 5-10%; nevertheless, through careful comparison with reference spectra and selective extractions with appropriate solvents, the major components of all samples were readily identified. Figure 3 shows the spectrum of a fill material before and after chloroform and acetone extraction. With extraction the very strong carbonate bands from the lead white pigment are diminished sufficiently to permit identification of the organic component as a natural plant resin.

To date, 29 of the 115 samples have been analyzed. Table 1 summarizes the results of these analyses.

The number of inorganic materials, used either as fill materials or as pigments or both, were fairly limited. Titanium, presumably as the pigment titanium dioxide, was detected in the majority of paint and fill materials. Lead white was identified as the sole pigment in one overpaint, and together with titanium white in two others. Zinc white was the sole inorganic component in an adhesive and was found together with titanium and calcium in two others. Calcium compounds, either calcium carbonate or plaster of Paris (calcium sulfate hemihydrate), were found in several instances. Silicate compounds such as talc (magnesium silicate) and kaolin were found in numerous samples as well. A metallic fill material found in old rivet/staple holes of a Derby tureen handle (96.4.221 a-c) was identified as a pewter-like tin-lead alloy, perhaps derived from a solder. Metal particles, possibly iron, were detected together with the more common calcite and talc in a gray-colored epoxy-butylated urea-formaldehyde fill used to repair a Meissen spoon (96.4.257). Copper and zinc were found in an epoxy-based metallic paint, indicating the use of a bronze powder pigment used to restore lost gilding on a Chinese export porcelain (96.4.196 a-c).

With only two exceptions, media for overpaint and/or fill materials were synthetic materials. Natural resins, probably of plant origin, were found in a fill sample from a Chinese export porcelain object (96.4.196a-c), and in an overpaint sample of a tureen made at Vincennes (96.4.245 a,b). Since these resins were found only in conjunction with historic pigments such as lead white and calcium carbonate, it is possible that they represent the oldest repairs. Cellulose nitrate, plasticized with an aromatic ester component, or as a modifier in an alkyd resin, appeared in eight samples. The inorganic components associated with cellulose nitrates were usually plaster of Paris, calcite, talc or clay. A second large group of resins, found on 11 objects, were typical epichlorohydrin-bisphenol A type epoxies, either alone or together with one of two different urea formaldehyde resins. Figure 4 shows an epoxy together with a urea-formaldehyde; in the same object epoxy is also used with a butylated urea formaldehyde. Acrylic resins were found in two samples, while a urethane-modified alkyd was found in one sample. The inorganic material most commonly found in association with the epoxy resins was talc, either alone or together with an additional silicate component.

4. Review of Ceramic Restoration/Conservation Literature

At the outset of this project one of the goals was to use analytical data to compare the kinds of materials used to restore the Campbell Collection objects with the kinds of materials in use during the early to middle 20th century, the period in which it seemed likely that the restoration were carried out. The collection files maintained at the Campbell Museum contained little information relating to the condition of most objects at purchase, or during their tenure at the Museum. When objects were purchased their condition, particularly the presence of restoration, was usually not documented. For example, no comments were made regarding the condition of a Chelsea tureen and cover (96.4.222 a,b) when acquired by the Campbell Museum. But when examined for the Winterthur exhibit, the tureen was found to have been broken into four large fragments, and had undergone two campaigns of restoration. In the first campaign the fragments had been reassembled using rivets. The rivets were removed in the second campaign and replaced with adhesive, and the interior and exterior surfaces completely overpainted.

If a flaw was noted in pre-acquisition documentation, correspondence indicated that the dealers negotiating the sale would have the problem taken care of before the object was delivered to the Museum. This was the case for the bowl of a tureen and cover made at Vincennes (96.4.245 a,b). The dealer from whom it was purchased assured the Campbell Museum that the flaw would be restored before the object was delivered to the Museum. It was, but there is no notation indicating who carried out the restoration or what materials were used.

Of those objects restored after acquisition by the Campbell Museum, a full conservation treatment report existed for only one object. Other restorations were inferred by invoices for the work done, or by memoranda detailing shipping information for the transfer of the object to the restorer's studio and then back to the Museum. The files also indicated that most of the restoration work had been done primarily by professional restorers working for the dealers or owners selling the pieces to the Campbell Museum.

The literature search for material on ceramic conservation/restoration techniques and materials was focussed on sources which discussed ceramic restoration/conservation in a general way, rather than sources which detailed restoration/conservation techniques and materials for a single object. It was thought that this approach to the literature would have a broader application at this point in the project. It is anticipated that as the analysis of the restoration materials found in the Campbell Collection continues the literature search will broaden to include those sources.

Even in this limited literature search a number of sources were found and reviewed. Many of the sources seem to fall into the category of training manuals for the interested amateur (for example Cross 1973; Everett 1976; Malone 1972; Pond 1970). Others, (for example Andre 1976, Larney 1973; White 1981) were written as a guide for the general public by restorer/conservators with long experience in the field, in private and museum settings. Three of the sources (Buys and Oakley 1993; Larney 1971; Tennent 1982) were written specifically for the professional restorer/conservator.

The materials recommended in these sources is summarized in Tables 2, 3 and 4. There is a significant correlation to be found between the materials suggested for use in ceramic restoration/conservation and the materials used in the Campbell Collection. This would seem to indicate that the restoration work performed on the tureens fell within the norm of treatment as indicated in the literature.

5. Continuing Research

5.1 Analysis of Commercial Restoration Products

The literature survey indicated that many proprietary materials were used or recommended for use in the restoration of ceramics. For example, specific brands of epoxy (e.g. HXTYL NYL-1 and

Devcon 2-Ton) are recommended for use, or a specific brand of loss compensation (Milliput or Sculpy) is recommended. An area of continuing research will include analysis of samples of proprietary materials using XRF and FTIR, to build a set of reference materials against which restoration materials from other ceramic objects can be compared.

An example of this type of work is found in Table 5 which summarizes the analysis of materials in the Master Mending Kit, a group of proprietary materials which were produced to accompany the book *How to Mend Your Treasures* by L. A. Malone. Presumably this kit would have been available since the publication of the book in 1972, and it is available today from Conservator's Emporium in Reno, Nevada.

5.2 Monitoring Restoration Materails in the Dorrance Gallery

Examination of previously the restored tureens had given evidence of the instability of the materials used. In many instances adhesives, inpainting and coating materials had physically failed or had darkened or yellowed, becoming aesthetically inappropriate. With this in mind, the color stability of restoration materials not removed prior to installation in the Dorrance Gallery was of concern to conservation and curatorial staff. To add to the problem, the Gallery has floor to ceiling glass windows on two sides, and although the window glass and the exhibit case glass have U.V. filters, there is an enormous amount of light in the Gallery. Though the design gives the exhibit space a light an airy feeling, the exhibit environment will probably accelerate the further degradation of the old restoration materials as well as the materials used in new conservation campaign.

To monitor this, a program to study color changes in a specific sample of both old and new restoration materials has been established. Using a Minolta Chroma Meter CR-100, readings of specific locations of a group of objects (with both old and new restoration materials) will be taken at six month intervals and any changes will be noted. This information will be correlated with the analytical data.

6. Conclusions

Examination of restored ceramic objects and restoration materials from the Campbell Collection prepared for the exhibit *The Campbell Collection of SoupTureens at Winterthur* has provided a window to restoration materials used in the mid-20th century. However, with only a quarter of the restoration material samples analyzed, it would be inappropriate to draw final conclusions about the restoration materials used for for the Collection. Preliminary results confirm that a variety of synthetic materials, with and without fillers was used. These tata correlate with conserfation literature. It is expected that further research will broaden our understanding of these materials and methods.

Acknowledgements

The authors would like to a thank the conservators and technicians who assisted in the preparation of the Campbell Collection for exhibit (Donna Farrell, Joanna Green, Carol Chapman and Laramie Hickey-Friedman), who carefully collected the samples for testing.

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Figure 1

FTIR Spectrum of Paint Sample from Ecuelle (96.4.88) Showing Three Discrete Layers

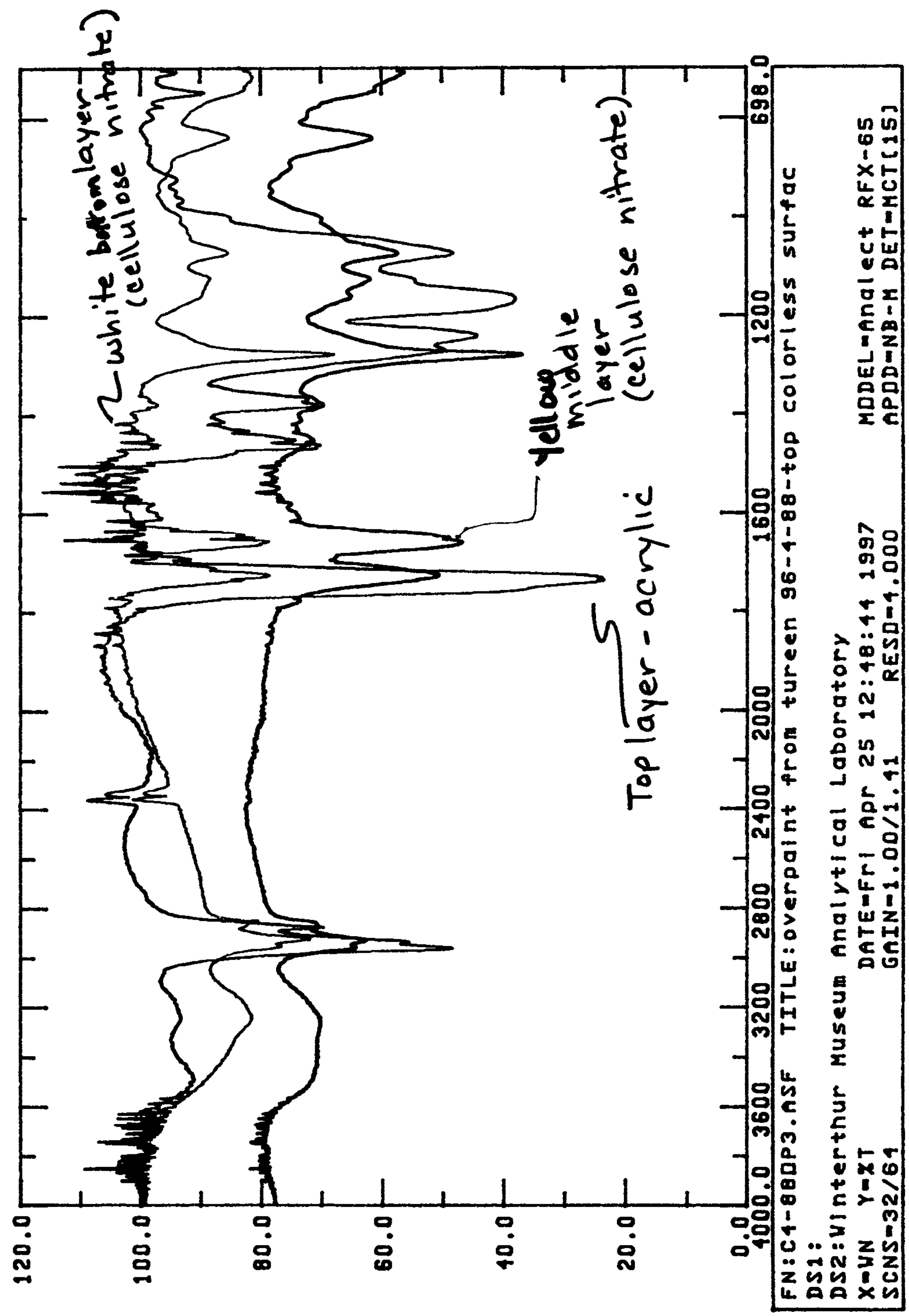


Figure 2

FTIR Spectrum of Fill Sample from Tureen (96.4.2)
Showing the Presence of Plaster, Kaolin and Nitrocellulose

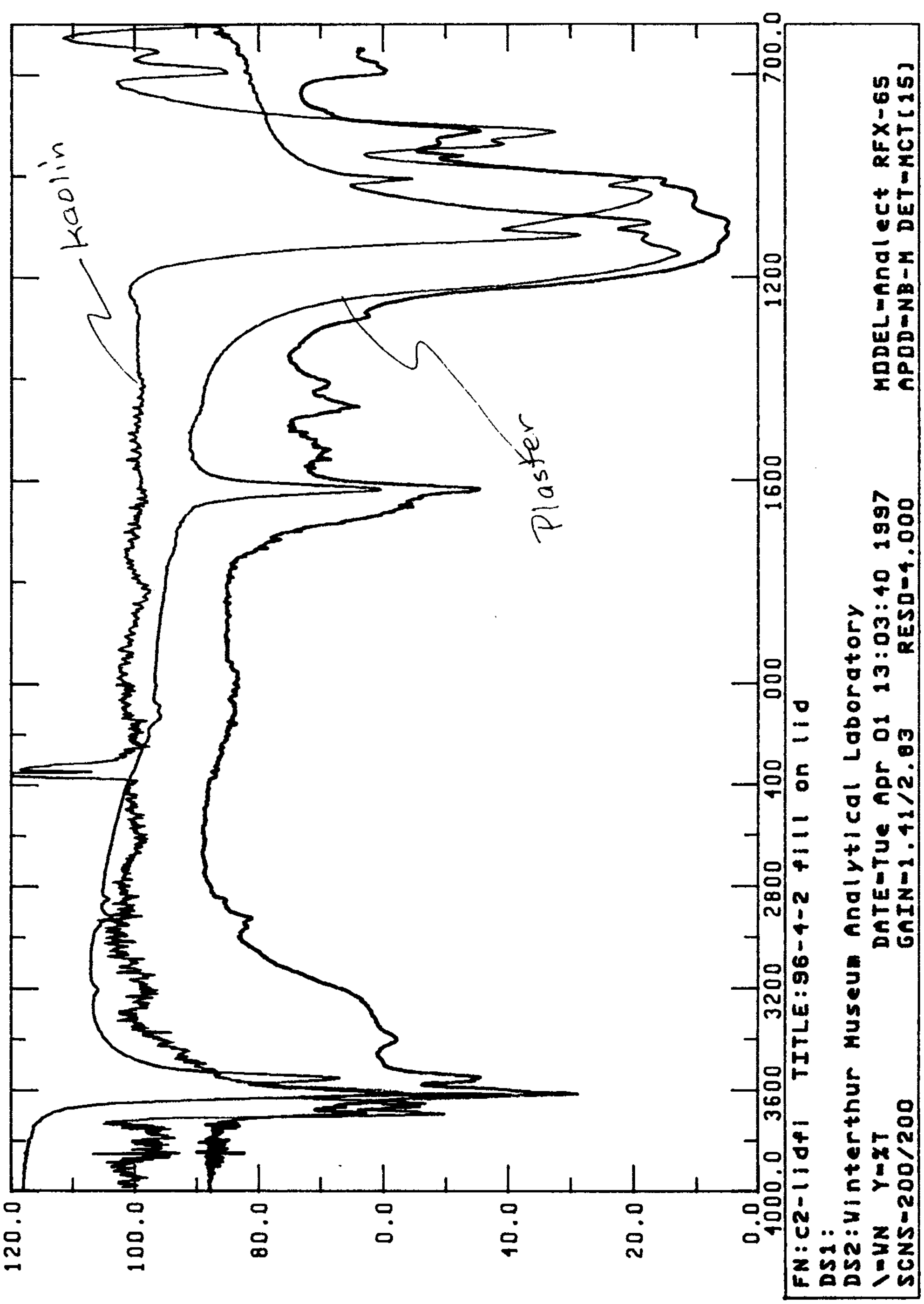


Figure 3

FTIR Spectrum of Fill Material from Tureen (96.4.245)
Before and After Chloroform and Acetone Extraction

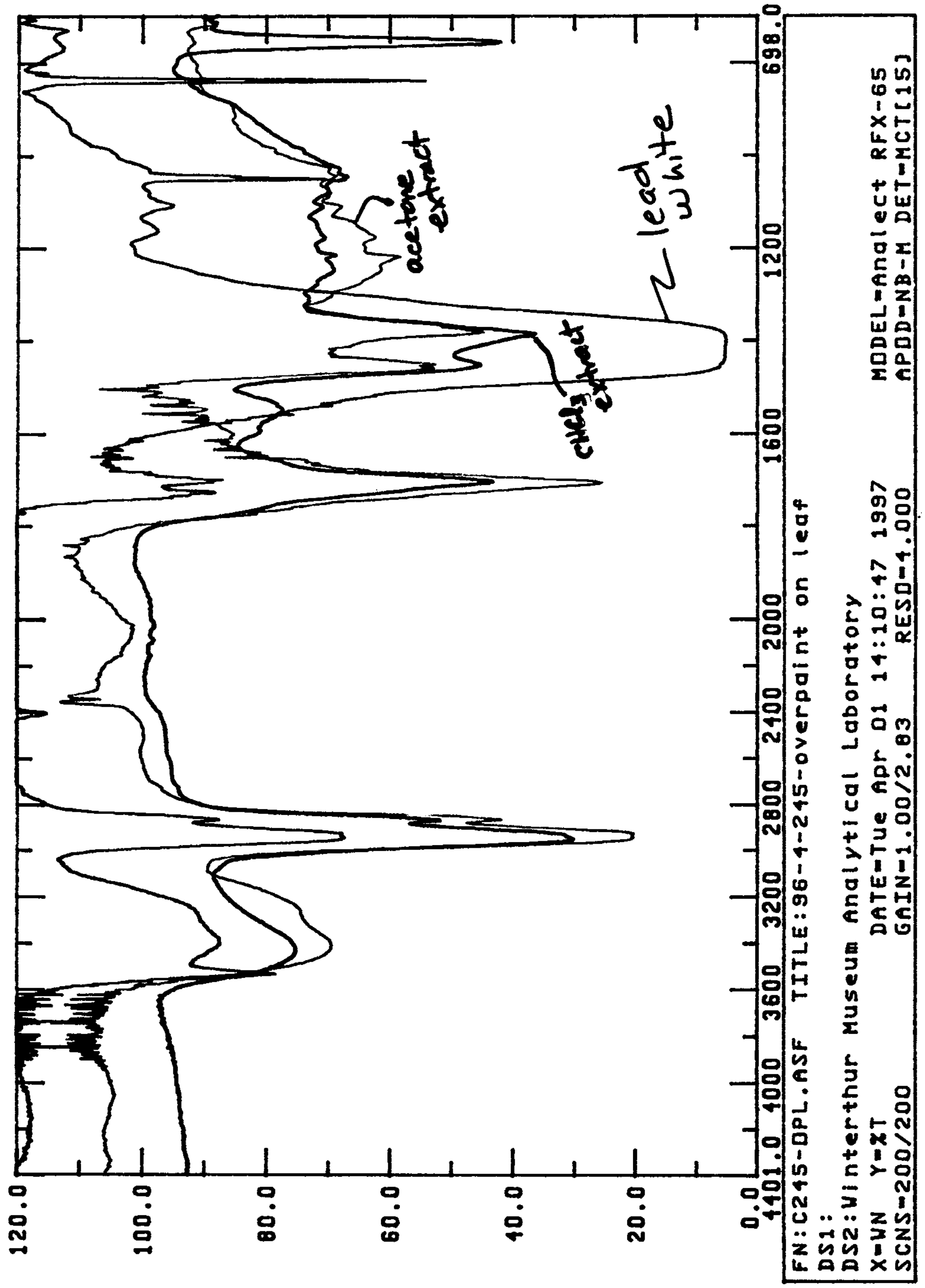
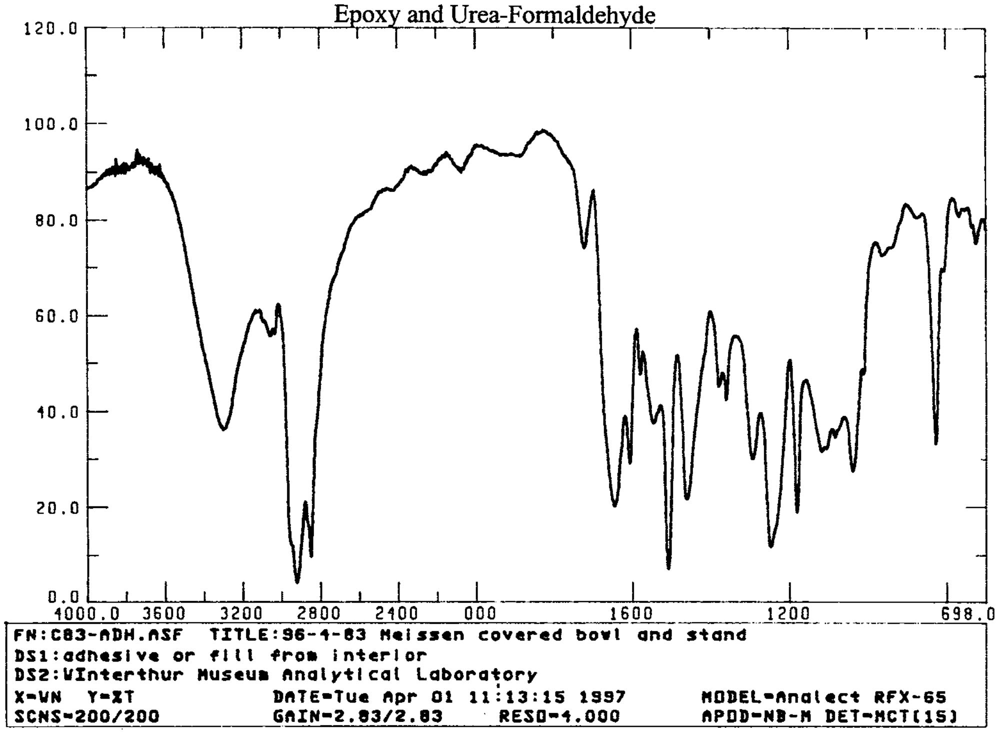


Figure 4

FTIR Spectra of Fill and Adhesive Material from Bowl (96.4.83)

Epoxy and Urea-Formaldehyde



Epoxy and Butylated Urea-Formaldehyde

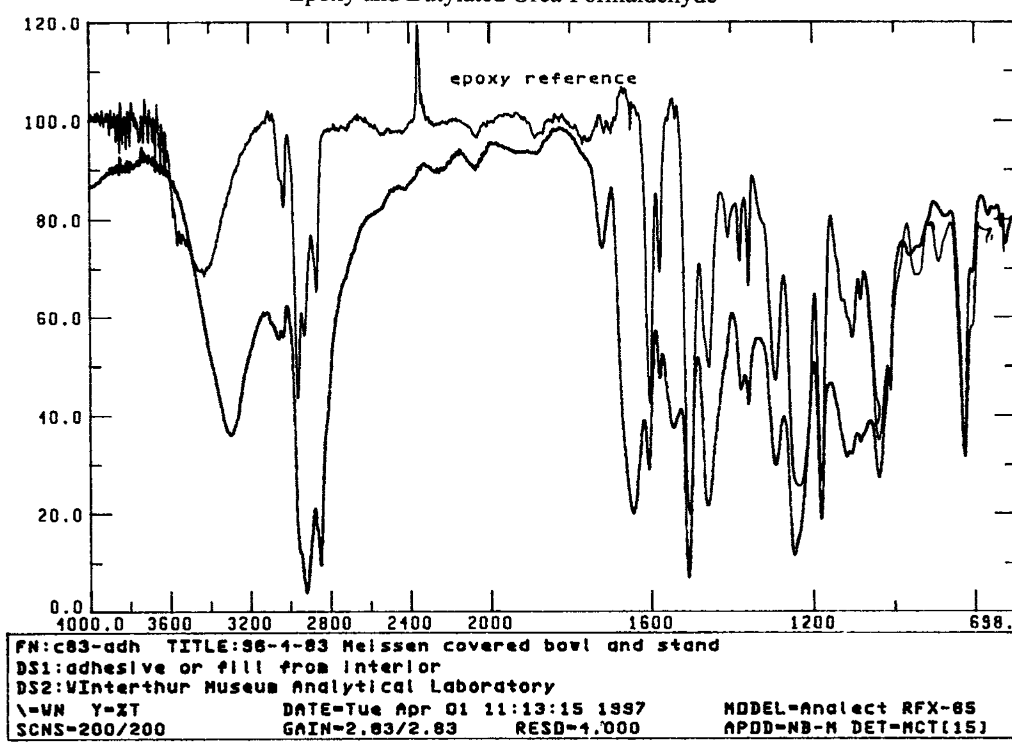


Table 1

Analysis of Restoration Materials from Campbell Collection: Results of Instrumental Analysis

ACCESSION NO.	OBJECT	SAMPLE TYPE	SAMPLE AREA	XRF: ELEMENTS	FTIR: ORGANIC	FTIR: INORGANIC
96.4.2 a,b	Tureen and Cover	Fill	Cover	Ca, Ti, Sr, Fe	Cellulose Nitrate	$2CaSO_4.H_2O$, Clay
96.4.2 a,b	Tureen and Cover	Overpaint	Exterior Lid, Pink	Ti, Pb	Cellulose Nitrate	Lead White
96.4.2 a,b	Tureen and Cover	Overpaint	Exterior Lid, White	Ti, Pb	Cellulose Nitrate	
96.4.2 a,b	Tureen and Cover	Overpaint	Interior Lid	Ti	Nitrocellulose Modified o-phthalic Alkyd	
96.4.3 a,b	Tureen and Cover	Overpaint	Exterior Tureen	Ti, Ca	Cellulose Nitrate/Ester Plasticizer	
96.4.83 a-c	Bowl, Cover and Stand	Adhesive	Handle of Bowl	Zn	Epoxy+butylated Urea-Formaldehyde	
96.4.88 a-c	Ecuelle, Cover and Stand	Overpaint	Bottom Layer, Cover	Ti	Cellulose Nitrate	
96.4.88 a-c	Ecuelle, Cover and Stand	Overpaint	Middle Layer, Cover	Ti	Cellulose Nitrate	
96.4.88 a-c	Ecuelle, Cover and Stand	Overpaint/Coating	Top Layer, Cover	Colorless	Butyl/Isobutyl Methacrylate	
96.4.88 a-c	Ecuelle, Cover and Stand	Fill	Cover	Ti	Cellulose Nitrate/Ester Plasticizer	$2CaSO_4.H_2O$
96.4.98 a-c	Tureen, Cover and Stand	Overpaint	Stand, p. Left Side	Ti	Acrylic (probable)	
96.4.98 a-c	Tureen, Cover and Stand	Overpaint	Stand, p. Right Side	Ti	Cellulose Nitrate/Ester Plasticzer	
96.4.107.1 a-c	Tureen, Cover and Stand	Overpaint/Coating	Cover	-	Urea/Formaldehyde+ Epoxy + Ester	
96.4.107.1 a-c	Tureen, Cover and Stand	Overpaint	Cover	Ti, Zn	Urea/Formaldehyde + Epoxy + Ester	

Table 1 (cont.) -- Analysis of Restoration Materials from Campbell Collection: Results of Instrumental Analysis

ACCESSION NO.	OBJECT	SAMPLE TYPE	SAMPLE AREA	XRF: ELEMENTS	FTIR: ORGANIC	FTIR: INORGANIC
96.4.160 a,b	Tureen and Cover	Coating	Cover	-	Bisphenol A - Epichlorohydrin Epoxy	
96.4.196 a-c	Tureen, Cover and Stand	Fill	Finial, Cover	Ca	Prob. Natural (Plant) Resin	$CaCO_3$
96.4.196 a-c	Tureen, Cover and Stand	Fill	Stand	Ca	Cellulose Nitrate/Ester Plastizer	Talc, $CaCO_3$
96.4.196 a-c	Tureen, Cover and Stand	Overpaint	Gold Colored Paint	Cu, Zn	Bisphenol A-epichlorohydrin Epoxy	
96.4.197 a-c	Bowl, Cover and Stand	Fill	Cover, Fill A	-	Bisphenol A-epichlorohyrin Epoxy	Talc
96.4.197 a-c	Bowl, Cover and Stand	Fill	Cover, Fill B	Ca(tr)	Epoxy + butylated Urea-Formaldehyde	Talc + Clays
96.4.197 a-c	Bowl, Cover and Stand	Overpaint	Cover, Overpaint A	Ti	Butylated Urea-Formaldehyde	
96.4.197 a-c	Bowl, Cover and Stand	Overpaint	Cover, Overpaint B	Ti	Epoxy + Butylated Urea-Formaldehyde	Talc + Clays
96.4.221 a-c	Tureen, Cover and Stand	Fill	Tureen Handle, Dowl Hole	Sn, Pb, Sb, Cu	XRF: Pewter or tin/lead solder	
96.4.221 a-c	Tureen, Cover and Stand	Overpaint		Cu, Fe, Ti, Ca	Buylated Urea-Formaldehyde	Talc
96.4.228 a,b	Tureen and Cover	Overpaint/Fill	Cover	Zn, Ti, Ca	Bisphenol A-Epichlorohydrin Epoxy	
96.4.245 a,b	Tureen and Cover	Overpaint	Cover, Leaf	Pb	Natural Plant Resin	Lead White
96.4.245 a,b	Tureen and Cover	Overpaint	Tureen, Exterior Surface	Ti, Pb	Urethane Modified o-Phthalic Alkyd	
96.4.257	Spoon	Fill	Grey Fill Material	Ca, Ti, Fe	Butylated Urea-Formaldehyde	$CaCO_3$, Metal Filings, Talc(?), CaSO
96.4.257	Spoon	Fill	Yellow Fill Material	Ca, Mn, Fe	Butylated Urea-Formaldehyde	Talc, Silicates

Table 2

Literature Review: Adhesives Suggested for Use in Ceramic Restoration/Conservation

Adhesive*	**Cited By:**
fish bladder glue	Andre, Yates
shellac	Andre, Parsons and Curl
cellulose nitrate	Buys and Oakley, Savage, Yates
gum mastic	Leland
gum mastic	Parsons and Curl
rosin/beeswax	Yates
whiting/silicate of potash	Leland
egg white/quicklime	Leland
casein	Leland
silicate of soda	Leland, Savage
cellulose acetate	Parsons and Curl
acrylic resin	Buys and Oakley
epoxy resin	Andre, Buys and Oakley, Cross, Everett, Evetts, Larney (1971), Larney (1973), Malone, Parsons and Curl, Pond, White
polyester resin	Andre, Buys and Oakley, Evetts, Larney (1971), Larney (1973)
polyvinyl acetate emulsion	Andre, Buys and Oakley, Everett, Evetts, Larney (1971), Larney (1973), Parsons and Curl
polyvinyl acetate resin	Buys and Oakley
cyanoacrylate	Andre, Evetts, Larney (1971), Larney (1973)
Acryloid B-72 (acrylic resin)	Buys and Oakley
UHU (cellulose nitrate)	Cross, Pond
HMG (cellulose nitrate)	Buys and Oakley
Duco Cement (cellulose nitrate)	Buys and Oakley, Everett
Vinamul 6815 (polyvinyl acetate emulsion)	Evetts
CM Bond M-3 (polyvinyl acetate emulsion)	Evetts
Evostick Resin 'W' (polyvinyl acetate emulsion)	Larney (1971), Parsons and Curl

Table 2 -- Literature Review: Adhesives Suggested for Use in Ceramics Restoration/Conservation

Adhesive*	**Cited By:**
Mowilith (polyvinyl acetate emulsion)	Larney (1973)
General and Sebralit (polyester resin)	Buys and Oakley
Akemi (polyester resin)	Buys and Oakley
Sintolit Transparent (polyester resin)	Evetts, Larney (1971), Larney (1973)
Alpha Aron (cyanoacrylate)	Evetts
Eastman 910 (cyanoacrylate)	Larney (1971), Larney (1973)
Cyanolit (cyanoacrylate)	Larney (1973)
Araldite (epoxy resin)	Cross, Everett, Evetts, Larney (1971), Larney (1973), Pond, White
HXTAL NYL-1 (epoxy resin)	Buys and Oakley
Ablebond 342-1 (epoxy resin)	Buys and Oakley, Evetts
Uhu Plus (epoxy resin)	Pond
Bostic 7 (epoxy resin)	Pond
Devcon 2-Ton (epoxy resin)	Pond
Cascamite (unknown composition)	Parsons and Curl
Seccotine (unknown composition)	Parsons and Curl
Durofix (unknown composition)	Parsons and Curl
unspecified proprietary materials	Klein, Malone

* Aauthors sometimes cited both a general category of adhesive (e.g. cellulose nitrate based adhesives) and proprietary brands of the general category (e.g. Duco Cememt and HMG). Both the general category and the proprietary brands are listed in the table.

Table 3

Literature Review: Loss Compensation Materials Suggested for Use in Ceramic Conservation/Restoration

Loss Compensation Material*	**Cited By:**
plaster of Paris	Andre, Buys and Oakley, Cross, Evetts, Leland, Parsons and Curl, Pond, Savage
plaster of Paris with polyvinyl acetate emulsion	Evetts
plaster of Paris with gelatin	Cross
pipeclay (unknown composition)	Leland
blanc d'Espagne (whiting/silicate of soda)	Leland
epoxy resin	Andre, Buys and Oakley
epoxy resin with fillers (e.g. kaolin, powdered pigments, marble flower, titanium dioxide, barium sulphate, kaolin, collodial fumed silica, glass microballoons)	Andre, Buys and Oakley, Cross, Everett, Evetts, Larney (1973), Malone, Parsons and Curl, Pond, White
epoxy putty	Buys and Oakly, Cross
polyester resin	Andre, Buys and Oakley, Parsons and Curl, Pond
acrylic resin	Parsons and Curl
polyvinyl adhesive with powder pigments	Andre
polyvinyl acetate resin	Larney (1971), Larney (1973)
polyester resin with fillers (e.g. colloidal fumed silica, ground pigments, glass microballoons)	Buys and Oakley
gesso (various formulas)	Cross, Pond
acrylic dental filling compounds	Cross
Polyfilla (cellulose reinforced plaster of Paris)	Buys and Oakley, Evetts, Larney (1971), Larney (1973), Parsons and Curl
Fine Surface Polyfilla (vinyl acetate copolymer with mineral fillers, thickeners and a biocide)	Buys and Oakley
Barbola (unknown composition)	Cross, Pond
Certofix (unknown composition)	Savage
Fortafix (unknown composition)	Savage
commercial porcelain filling compounds	Cross

Table 3 (cont.) -- Literature Review: Loss Compensation Materials Suggested for Use in Ceramic Restoration/Conservation

Loss Compensation Materials*	**Cited By:**
HXTYL NYL-1 (epoxy resin)	Buys and Oakley
Ablebond 342-1 (epoxy resin)	Buys and Oakley
Devcon 5-Minute Epoxy (epoxy resin)	Everett
Araldite (epoxy resin)	Evetts, Larney (1973), White
Devcon 2-Ton Epoxy (epoxy resin)	Evetts
Epo-Tek 302 (epoxy resin)	Evetts
Milliput (epoxy putty)	Buys and Oakley
Seel-Masta (commercial epoxy with filler)	Pond
Sylmasta White Ceramic Plastic (unknown composition)	Everett
Sculpy (polymer clay)	Everett
Cascamite (resin glue) with plaster of Paris or TiO_2	Parsons and Curl
Seccotine (unknown composition) with plaster of Paris	Parsons and Curl
Isopon (polyester resin/fiberglass)	Pond
Vinagel V. G. 118 and Hardening Putty (unknown compositions)	Parsons and Curl
Technovit 4004A (acrylic resin)	Parsons and Curl
unspecified proprietary compounds	Klein, Yates

* Authors would sometimes cited both a general category of loss compensation material (e.g. epoxy putty) and proprietary brands of the general category (e.g. Milliput). Both the general category and the proprietary brands are listed in the table.

Table 4

Literature Review: Inpainting/Coating Materials Suggested for Use
in Ceramic Restoration/Conservation

Inpainting/Coating Materials*	**Cited By:**
ground pigments	Evetts, Parsons and Curl
commercial paints (watercolor, casein tempera, oil paint, acrylic emulsion)	Buys and Oakley, Cross, Evetts, Leland, Malone, Parsons and Curl, Pond, Savage, White
cellulose paint	Savage
commercial enamel paints	Cross, Everett
oil paints in Chintex (stoving enamel)	Larney (1973), White
oil paint in enamel medium	Parsons and Curl
oil paint in glaze medium	Parsons and Curl
ground pigments in Chintex (stoving enamel)	Larney (1973)
ground pigments in Paralac (stoving enamel)	Larney (1973)
ground pigments in varnish (acrylic polyvinyl)	Andre
ground pigments in epoxy resin	Andre
ground pigments in acrylic emulsion	Buys and Oakley
ground pigments in polyurethane	Buys and Oakley
ground pigments in urea-formaldehyde	Buys and Oakley
ground pigments in acrylic solvent systems	Buys and Oakley
ground pigments in Rustins Clear Gloss (polyurethane)	Buys and Oakley, Larney (1973)
ground pigments in PU11 (polyurethane)	Larney (1973)
polyurethane	Cross, Larney (1973)
fingernail polish (cellulose nitrate)	Cross
wax	Andre
U.V. curing epoxy resins	Tennent
Chinaglaze (urea formaldehyde)	Evetts, Tennent
PU11 (polyurethane)	Tennent
PU11 (polyurethane) with matting agent	Larney (1973)
Chintex (stoving enamel)	Evetts, Larney (1973)
Ablebond 342-1 (epoxy resin)	Tennent

Table 4 (cont.) -- Literature Review: Inpainting/Coating Materials Suggested for Use in Ceramic Restoration/Conservation

Inpainting/Coating Materials*	**Cited By:**
Araldite HY951 (epoxy resin)	Tennent
Medset Resin SW (polyester resin)	Tennent
Rustins (polyurethane)	Larney (1973)
Plastogen G (acrylic resin)	Tennent
Sylegard 184 (silicone resin)	Tennent
Acryloid B-72 (acrylic resin)	Tennent
Acryloid B-48N (acrylic resin)	Evetts
Rowney's #800 Clear (picture varnish)	Pond
Cryla Colour (acrylic emulsion paints)	Buys and Oakley
Maimeri Colors (ground pigment in resinous gum)	Evetts
unspecified proprietary materials	Klein, Yates

* Authors sometimes cited both a general category of material (e.g. polyurethane) and proprietary brands of the general category (e.g. PU11). Both the general category and the proprietary brands are listed in the table.

Table 5

Analysis of Materials from *Master Mending Kit**

MATERIAL	MATERIAL TYPE	XRF: ELEMENTS	FTIR: ORGANIC	FTIR: INORGANIC
New Gloss Glaze	Coating Material	Colorless	Acrylic	
Porcelainate Powder	Filler	Zn	Polyvinylacetate	
Pactra Yellow	Enamel Paint	Ti, Fe	not analyzed	Talc
Epoxy	White Finishing Resin	Ca, Ti, Zn	Bisphenol A-Epichlorohydrin Epoxy	$CaCO_3$
Epoxy Putty	Resin and Hardner	Ca(tr)	Bisphenol A-Epichlorohydrin Epoxy	Talc, $CaCO_3$
Epoxygloss	Resin and Hardner	Colorless	Bisphenol A-Epichlorohydrin Epoxy	-----

* The *Master Mending Kit* is a commercial glass and ceramic restoration kit produced by Atlas Minerals & Chemicals, Inc. of Mertztown, Pennsylvania. The instruction booklet which accompanys kit refers the user to *How to Mend Your Treasured Porcelain, China, Glass and Pottery* by L. A. Malone. The kit can still be purchased from Conservator's Emporium, 100 Standing Rock Circle, Reno NV 89511.

AN OVERVIEW OF LOSS COMPENSATION IN THE ATHENIAN AGORA

Alice Boccia Paterakis

Abstract

A series of case studies are presented which exemplify decisions regarding the compensation of artifacts from the Agora Excavations in antiquity and in modern times. The artifacts represent utilitarian, votive, military, honorary and architectural functions and include 5th and 4th c. B.C. bronze statuary and a bronze shield, a 4th c. B.C. ceramic water clock (klepsydra), a marble ionic capital from the 2nd c. B.C. Stoa of Attalos, the marble stage facade from the 1st c. B.C. Odeion of Agrippa, a Roman ivory statuette of Apollo, 5th c. B.C. red figure kraters, Hellenistic and Byzantine ceramics, and human skulls from various periods. The decisions regarding the type and extent of compensation are shown to be influenced by numerous factors which include 1) the uniqueness and degree of preservation of the artifact, 2) the availability of physical and literary evidence to support the compensation, and 3) the destination and function of the object after treatment

I. Introduction

A number of artifacts in the collection of the Athenian Agora have been chosen which exemplify various approaches to loss compensation. In the discussion of materials for compensation are included adhesives, consolidants, lacquers and inpainting media. Unfortunately individual treatment records were not kept from 1931, the beginning of the excavation by the American School of Classical Studies, until 1979, when the conservation laboratory was established by Koob. Fortunately, however, the published archaeological record of a few of these objects included conservation information . Also, a few old notes discovered in the files regarding conservation materials have contributed significantly to this article. The following factors which have influenced the decision for and extent of compensation are 1) the uniqueness and degree of preservation of the artifact, 2) physical and literary evidence to support the compensation, and 3) the destination and function of the object after treatment.

II. Case Studies

II.A. Copper Alloy Objects

II.A.1. Nike Head (acc. no. B30)

A bronze head of Nike represents a unique ancient example of compensation for loss. A 5th c.

B.C. copper alloy head of Nike, the winged goddess of victory, was recovered from a well in 1932 and was cleaned by prolonged soaking in water followed by electrochemical cleaning in zinc and sodium hydroxide (Shear 1933). This head was originally gilded by the foil gilding method in which sheets of gold were attached using grooves cut into the surface of the statue (Thompson 1940, Paterakis 1995, Paterakis 1998) (Figure 1). The gold reserves of the Athenian state were stored and displayed on Nike sculptures in this manner in the 5th and 4th centuries B.C. on the Acropolis. The sculptural detail and refinement of the bronze surface suggest that the statue was intended to be presentable to the public with or without its gold (Shear 1973). Two sets of grooves in the surface suggest that the head was covered with gold at two different times. The first set was carved after casting in inconspicious places in order not to interfere with the aesthetic appearance of the head without gold. It is believed that the statue was stripped of its gold in the crisis of 406 B.C. to contribute gold to the needs of the state. After stripping most of the grooves were disguised by filling them with bronze (Figure 2). A bronze was chosen similar in color to the head which was hammered, carved and polished to render it indistinguishable. In 336 B.C. gifts made to Athens by Alexander the Great may have enabled the second gilding, traces of which remain today. Instead of reusing the grooves for the second gilding, new grooves were carved in more conspicuous places.

II.A.2. Copper alloy sword (acc. no. B1382)

A copper alloy sword was found in two pieces in a well in 1971 (Shear 1973). Although there are no conservation records from the first intervention, a recent treatment revealed that the sword had been doweled and filled around the dowel with a polyester resin paste and fiberglass strands. This paste was probably made from an unidentified polyester resin, which was marketed as a 'stone cement', to which a filler, metal powder and pigment had been added. In the recent intervention to combat bronze disease the sword was immersed for several months in a 3% solution of BTA in ethanol. This softened the fill which was then removed mechanically exposing more bronze disease (Figure 3).

The earliest reference found by the author to the use of polyester resin putty for gap-filling bronze is a 1961 article by Organ (Organ 1961). This was followed by articles dealing with polyester resin and fiberglass sheets for the repair of bronze by France-Lanord in 1969 (France-Lanord 1969) and Lane in 1974 (Lane 1974). Polyester resin puttys manufactured by the Plastic Padding company of the U.K. have been used by conservators in the U.K. since the early 1970's for gap-filling copper alloy objects. The Plastic Padding puttys are styrenated polyester resins with a benzoyl peroxide catalyst. The only written reference found by the author for this material is a British Museum report from 1992 (Shashoua 1992).

Once the sword was stabilized it was necessary to fill the join for strength and for display in the museum. The successful use of polyester resins on copper alloys over the last 20 odd years and the strength demonstrated by the first fill were deciding factors in the choice of the two-part polyester resin putty, "Chemical Metal", manufactured by Plastic Padding Ltd. in the U.K. The surface of the metal was lacquered with Incralac prior to filling with 'Chemical Metal'. One side of the gap was moulded with dental wax which reduced the extent of mechanical finishing using a scalpel, metal files, a Dremel Moto Tool, and fine grade sandpaper moistened with ethanol. The fill was painted with Rowney Cryla colors (Figure 4).

II.A.3. Bronze Shield (acc. no. B262)

A bronze shield was recovered in 1936 which has been identified as one of those captured by the Athenians from the Spartans in 425 B.C. at the battle of Pylos (Shear 1937) (Figure 5). The bronze was reported to be extensively corroded preserving little metal. After removing most of the overlying earth it was coated with paraffin wax to provide support for lifting, a technique mentioned by Lucas in his 1932 volume entitled *Antiques: Their Restoration and Preservation*. (Lucas 1932). After removing the paraffin wax the pieces were chemically cleaned. The fragmentary condition of the shield was supported by a backing of bleached beeswax into which each fragment of the shield was set. The gaps in the shield were integrated by painting the beeswax (Figure 6).

Waxes and copper alloys

Beeswax and paraffin wax have been used extensively in the past for consolidation, compensation, mending and lacquering of copper alloy objects and other materials in the Agora. Lucas recommends these waxes for the consolidation of copper alloys after cleaning (Lucas 1932). Severe corrosion of copper caused by the acids in beeswax is evident in several objects (Paterakis 1996). The acids produce metal soaps containing copper ions which can increase the rate and degree of corrosion (Burmester and Koller 1987). The mineralized state of the Agora shield may account for its relatively stable condition embedded in beeswax. Paraffin wax may be distinguished from beeswax in the Agora by its lower melting temperature of 50 to 54 degrees Celsius. Molten paraffin wax was used for coating metal objects as described by Plenderleith in his 1934 volume entitled *The Preservation of Antiquities* (Plenderleith 1934).

Resins and copper alloys

Unidentified lacquers which have remained soluble in acetone or ethanol have been applied to many copper alloy objects. The following commercial synthetic resins documented in our files may have been used: Unichrome A-140, Maranyl, vinyl acetate, Celluloid, Vinylite or Alvar. Unichrome A-140 was probably a polyvinyl acetate manufactured by the Metal & Thermit Corporation in New York city in the 1950's. It is still soluble today in acetone. Maranyl soluble nylon, manufactured by Imperial Chemical Industries Ltd. of London, was reportedly used as a

5% solution in ethanol to lacquer objects in the 1970's; it is still soluble in ethanol. A few references to an unspecified vinyl acetate, used as a 5% solution, are mentioned in the files. Vinyl acetates were popular as consolidants for fossils in the 1920's and 1930's in the U.S.A. and the U.K. (Howie 1984). It is not clear in all cases whether vinyl acetate refers to the monomer or polymer. According to Howie, polymerization of the vinyl acetate monomer occurred in the object, presumably producing a low molecular weight polyvinyl acetate. Notes from the 1940's in the Agora mention the use of Vinylite, a polyvinyl acetate resin manufactured by the Bakelite Company, for the lacquering and consolidation of artifacts, in particular ivory.

II.B. Ivory and Bone

II.B.1. Ivory Statuette (acc. no. BI236)

More than 200 fragments of an ivory statuette were recovered from a well in 1936 (Shear 1937) (Figure 7). This 30 cm high Roman statue has been identified as a replica of the statue of Apollo Lykeios attributed to Praxiteles. Conservation treatment began in 1936 by drying the fragments slowly to prevent splitting. They were cleaned with alcohol and consolidated with a solution of 'Celluoid' in amyl acetate and acetone. Cellulose nitrate was produced by the Celluloid Manufacturing Company in the U.S.A. beginning in 1872, and their product name 'Celluloid' became the generic name for cellulose nitrate around the world. An Agora recipe calls for 2 grams of Celluloid in the form of Leica film strips to be dissolved in acetone and amyl acetate forming a 2% weight to volume solution. A British Museum report of 1926 (British Museum 1926) and Lucas (Lucas 1932) recommend a 1% Celluloid solution in equal volumes of acetone and amyl acetate for the consolidation of ivory using Celluloid from motorcar side screens! Lucas discourages the use of photographic film since the gelatin coating must first be removed and since the film may be contaminated with the reagents used for developing. The Agora recipe must predate the Second World War since Leica film was no longer made from cellulose nitrate after the war. A celluloid solution was also used for reconstruction of the statue. Lucas (Lucas 1932) recommends sealing the edges with Celluloid before joining them with Celluloid. Apparently Plenderleith's 1934 volume was not consulted for the treatment of the Apollo statue in which he states that cellulose nitrate adhesive should not be used on ivory, presumably on account of its acidity. Instead, Plenderleith recommends a 15% solution of vinyl acetate in toluene for mending ivory. The statue was gap-filled with bleached beeswax as recommended by Plenderleith (Plenderleith 1934) (Figure 8).

The use of cellulose nitrate as an adhesive has been the subject of debate over the past two decades. Koob in a 1982 publication states that acid impurities from the nitration process during manufacture accelerate the hydrolysis of the cellulose nitrate and contribute to its instability (Koob 1982). The literature states that this acidity may also damage ivory and lead. In spite of these negative characteristics, the Apollo statue displays sound joins and solid beeswax fills, and the ivory appears in good condition. Shashoua after testing artificially and naturally aged cellulose nitrate determined that the HMG brand adhesive may have a lifetime up to 100 years (Shashoua et. al. 1992). The museum case displaying the Apollo statue was severely jarred in the early 1980's knocking the statue loose from the base along the cellulose nitrate join under the feet. Fortunately the adhesive proved to be weaker than the ivory.

In stark contrast to cellulose nitrate is shellac, which was used extensively on many materials in the Agora between the years 1931 to 1978 (Figure 9). Shellac is difficult to reverse and is often stronger than the material it joins. Extensive damage has occurred to the joined edges of ceramic, stone and other materials as a result of the detachment of the fabric by the shellac! If Lucas's suggestion to seal the edges with Celluloid before mending had been followed, the shellac joins might have resulted in less destruction and easier reversibility (Lucas 1932). Cellulose nitrate has been used in the Agora from the early days. The first adhesive brand used was Duco Cement, followed later by UHU Hart and HMG. Today the two adhesives used most frequently in the Agora are HMG cellulose nitrate and HMG Paraloid B72. Paraloid B72 was used as an adhesive prior to its manufacture by the HMG Company (Koob 1986).The use of Paraloid B72 is avoided in the hottest months when the temperature in the laboratory reaches its Tg of 40 degrees Celsius! HMG cellulose nitrate, with a Tg of 100 degrees Celsius, is often substituted in these cases. Paraloid B48N is also used occasionally.

II.B.2. Human Skulls (acc. nos. AA25, AA82, AA143, AA147A)

Human skeletons were treated by the physical anthropologist, Angel, in the Agora from 1939 to 1970. We know from publications in the 1940's that he impregnated skulls with a 35% solution of Alvar 2½/70 in acetone and that he reconstructed skulls using Alvar 7/70 and celluloid (Angel 1943, Angel 1945). Angel also used metal wires, sheets of Alvar, plasticine and plaster for reconstruction of the skulls. Some of these joins had sagged due to the low Tg of the resins used. Attempts to reverse the adhesives used by Angel on four human skulls in the Agora proved for the most part successful using acetone, ethanol or toluene.

II.C. Stone

II.C.1. Marble Ionic capital (acc. no. A2073)

One of the original marble Ionic capitals from the Stoa of Attalos dating to the 2nd c. B.C. was partially restored in plaster from many fragments (Travlos 1971) (Figure 10). The reconstruction was used as a model to carve the new capitals during the reconstruction of the Stoa of Attalos in the 1950's (Figure 11).

II.C.2. Stage Front of Concert Hall (Odeion) of Agrippa (acc. nos. A586, A1174, S553, S554, S558, S1391)

A section of the stage front from the auditorium of the concert hall of Agrippa, dating to 15 B.C., was originally faced with a marble screen panelled with herm statues (Thompson 1950). The reconstruction of the panelled stage front was made in 1949 and is on display to the public in the lower colonnade of the Stoa of Attalos. Although no records have been found of the materials used, cement is apparent on the face where panels are missing. Rather than replacing these panels with new marble, the surface of the cement has been painted to imitate marble veining (Figure 12).

II.D. Ceramics

II.D.1. Clepsydra (acc. no. P2084)

In 1933 fragments of a ceramic clepsydra, or waterclock, were found in a well of 400 B.C. context (Young 1939). Water clocks were commonly used in the Athenian law courts in the 5th and 4th centuries B.C. to time the length of speaches. In the 1930's the clepsydra was mended with shellac and restored in painted plaster. The complete reconstruction of the waterclock was required to determine its capacity and the duration of the water flow (Figure 13).

In the following four ceramic objects (II.D.2-5) a fine grade dental plaster was used for reconstruction. The edges of the plaster fills were incised to facilitate sealing and inpainting. Paraloid B72 was used to seal the edges of the vessels before mending and filling and to seal the surface of the plaster fills before inpainting with Rowney Cryla colors.

II.D.2 Black Glazed Hellenistic Skyphos (acc. no. P31796)

This black glazed skyphos is an example of complete structural reconstruction carried out in 1990 (Rotroff 1997, no.161). Double-sided dental wax moulds were used to cast missing areas. A template and circumference chart proved to be very useful during the reconstruction of the body and rim. Silaplast, an elastomeric impression material with silicone base, was used to cast the handle which was adhered with Paraloid B72. The two floating sherds were inserted into the plaster fill (Figure 14). All surfaces of the ceramic were protected with a layer of Clear Plastico no. 10, a latex masking fluid, prior to inpainting by airbrushing.

II.D.3. Red glazed Hellenistic Amphora (acc. no. P31964)

The scholar who published this piece requested a reconstruction of the profile for photography and publication in 1991 (Rotroff 1997, no. 444). Since a large amount of the vessel was missing a total reconstruction was not considered necessary. The pot was mended with UHU Hart cellulose nitrate adhesive. Discs the size of the original circumference at the shoulder and rim, which were supported on a central stand in the amphora, were used as a guide during the reconstruction. Reconstruction was made by moulding with dental wax and Silaplast (Figure 15).

II.D.4. Red Figure Bell Krater (acc. no. P30019)

This 5th c. B.C. krater, excavated in 1972, is an example of partial reconstruction for the presentation of the figurative sherds (Rotroff and Oakley 1992, no. 48). Paraloid B72 adhesive was used in the reconstruction. A circumference chart was used as a guide during the assembly of the rim. Use of a template during the reconstruction showed the pot to have an assymetrical profile. Since the entire foot was lost its replacement was not considered feasible; the krater was instead given a flat resting surface in plaster. The fills were inpainted by brushing (Figure 16). The scholar who published this piece determined the placement of the figurative sherds. Too much was missing to consider a pictorial integration of the figurative sherds. A middle grey tone was chosen for the inpainting since it distinguishes the filled areas from the exisitng sherds and from the light backround in black and white photo reproduction. Since the krater was not destined for display in the museum but rather for storage in the study collection the filled areas were not repainted a more harmonious color.

II.D.5. Red Figure Column Krater (acc. no. P30197)

This red figure column krater had been mended with shellac, a polyester resin 'stone cement' with fiberglass and an epoxy adhesive and completely restored in painted plaster after its excavation in 1972. The rim had been drilled and doweled with nails and adhered with the polyester resin. No records were kept of this intervention. Since a correct alignment of the pieces had not been achieved, damage caused by an earthquake in 1981 afforded the opportunity for the krater's reconstruction by Koob. After taking down the first restoration and removing all forms of adhesive, plaster and paint using ethanol, acetone and methylene chloride, the 140 krater pieces were desalinated and reconstructed with Duco Cement. All areas to be filled were moulded with plasticine. Sections of the base, neck and rim and the handles were restored using detachable plaster fills, a technique published by Koob in 1987 (Koob 1987) (Figure 17). Once completed, 3 more sherds were found belonging to the krater which were keyed into cutouts in the plaster. The degree of painted integration which delineates the figures was determined by the Director of the Agora Excavations who wished to display the krater in the Museum (Figure 18). The scholar who published this piece considered this painted intervention excessive (Rotroff and Oakley 1992, no. 71).

II.D.6. Glazed Byzantine Bowl with Salt Efflorescence (acc. no. P9602)

A Byzantine bowl displayed extensive contamination by soluble salts which had crystallized lifting the glaze off the surface (Frantz 1938) (Figure 19). Since this bowl had been extensively restored in plaster in the 1930's its desalination was problematic (Figure 20). Conservation treatment of this bowl was undertaken by Stamm (Stamm 1997). The uplifted glaze was lowered into position onto the surface by dissolving the underlying salt crystals with the application of ethanol as a wetting agent followed by a 2.5% (vol/vol) concentration of Primal WS24. The glaze was subsequently consolidated with 3% and 5% (wt/vol) solutions of Paraloid B72 in ethanol:acetone (7:3). The paint coating the plaster fills was removed and the plaster consolidated with several coats of 3% and 5% Paraloid B72 to protect it from dissolution and to prevent its migration into the ceramic fabric during desalination. If the paint coating the plaster is intact and water resistant, it could serve to protect the plaster during immersion. The goal was to remove the salts without dissolving the plaster. The solubility of plaster in water is minimal, approximately 2 grams per liter. During desalination by immersion, the minimum quantity of water possible should be used to minimize dissolution of the plaster. Once the saturation point of the plaster has been reached with an ionic conductivity of approximately 450 µmhos (µsiemens) (20° to 25° Celsius), the vessel may remain immersed until maximum ionic concentration of the salts is reached. It was found that consolidation of the plaster with a 3% solution followed by a 5% solution of Paraloid B72 prior to immersion protected it against softening but not against dissolution .

III. Conclusion

Those conservation materials and methods recorded in the Agora prior to 1979 were based largely on the publications of Lucas (Lucas 1932) and Plenderleith (Plenderleith 1934). For many applications locally available materials were used whereas polymers such as Maranyl, Vinylite, Unichrome and Alvar were imported. These resins and waxes served multiple uses as adhesives, consolidants, lacquers and fill materials. Although the old notations are few and don't identify objects with treatments, they are invaluable for the diagnosis of the present condition of the artifacts and for their retreatment. The factors which have influenced compensation decisions in the Agora over the last 65 years are, for the most part, unchanged. Two basic trends distinguish the approach to compensation today from the earlier years and these are the rules of reversibility and minimal intervention. In the early years the concept of reversibility existed but was not a principal consideration. Notes dating from 1951, which refer to adhesives and consolidants as 'cements', state that "the nature of the cement and of the solvent used is of less importance, in our experience, than is the method of application." (Anonymous 1951). Since the establishment of the conservation laboratory in 1979 the rule of reversibility has been respected and the principle of minimal intervention guides all phases of conservation, including compensation.

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Manufacturers of Materials

Alvar (polyvinyl acetal; 1940's): Shawinigan Products Corporation, Shawinigan Falls, Canada.

Celluloid (cellulose nitrate; 1872): Celluloid Manufacturing Company, New York.

Chemical Metal (polyester resin putty): Plastic Padding Ltd., Wooburn Industrial Park, Wooburn, High Wycombe, Bucks HP10 OPE, U.K.

Clear Plastico no. 10 (latex masking fluid; 1980's): California [Author was unable to identify the manufacturer of this material]

Dental Wax: Anutex, Toughened Pink Dental Modelling Wax, Associated Dental Products Ltd., Purton, Swindon SN5 9HT, U.K.

Dremel Moto Tool: Dremel, Division of Emerson Electric Co., 4915 21st Street, Racine, Wisconsin 53406.

Duco Cement (cellulose nitrate adhesive): E.I. du pont de Nemours & Co., Inc., Wilmington, Delaware 19898.

Harbutt's plasticine: Peter Pan Playthings Ltd., Bretton Way, Bretton, Peterborough PE3 8YA, U.K.

HMG cellulose nitrate adhesive, HMG Paraloid B72 Adhesive: H. Marcel Guest Ltd. Collyhurst Road, Riverside Works, Manchester M10 7RU, U.K.

Maranyl (soluble nylon; 1970's): Imperial Chemical Industries Ltd., Millbank, London SW1, U.K.

Paraloid B72, B48N and Primal WS24: Rohm and Haas Ltd., Lennig House, Masons Avenue, Croydon, Surrey CR9 3NB, U.K.

Rowney Cryla (Artists' Acrylic Colour): Daler Rowney, Bracknell, Berkshire, U.K.

Silaplast (elastomeric impression material, silicone base): Detax, Karl Huber GmbH & Co., KG D-7500 Karlsruhe 1, Germany.

UHU Hart (cellulose nitrate adhesive): UHU GmbH, 77813 Buhl, Germany.

Unichrome Lacquer A-140 (polyvinyl acetate?; 1956): Metal & Thermit Corporation, 100 East 42nd St., New York 17, New York.

Vinylite VYHH-1, VMCH (polyvinyl acetate; 1947): Bakelite Corporation, 30 East 42nd St., New York 17, New York.

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Figure 1. Nike head (B30) after cleaning, showing grooves for foil gilding.

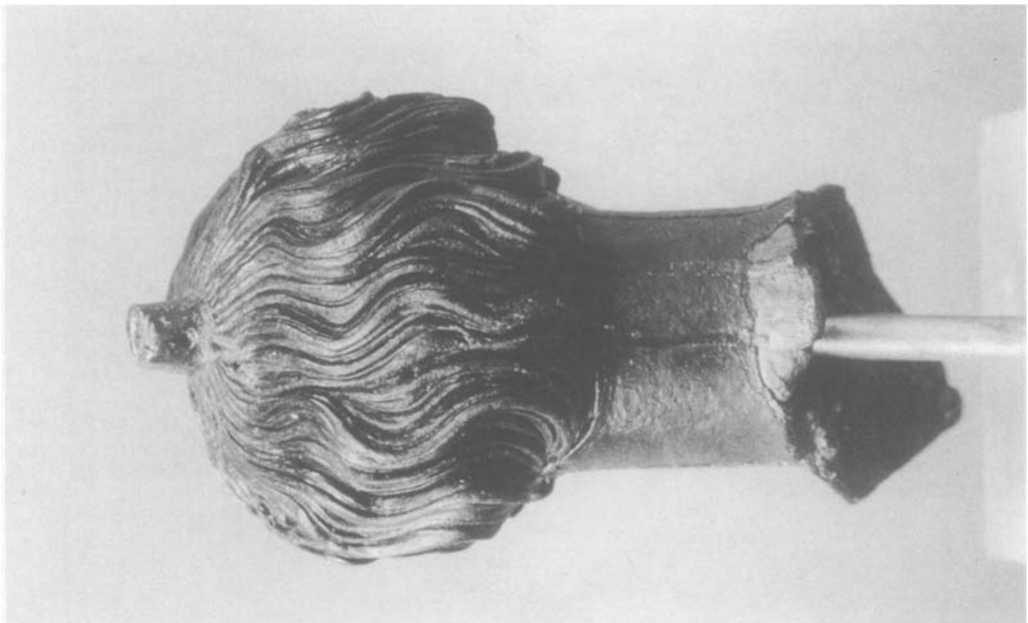

Figure 2. Rear of Nike head (B30) with grooves filled in antiquity with copper alloy.

Figure 3. Sword (B1382) joined before recent filling.

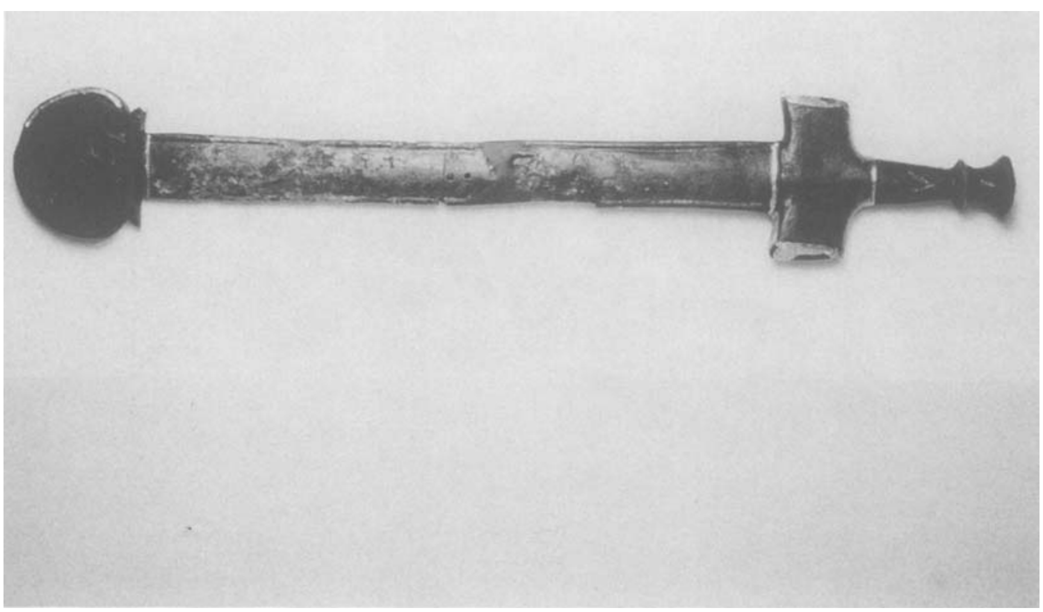

Figure 4. Sword (B1382) after recent filling and inpainting.

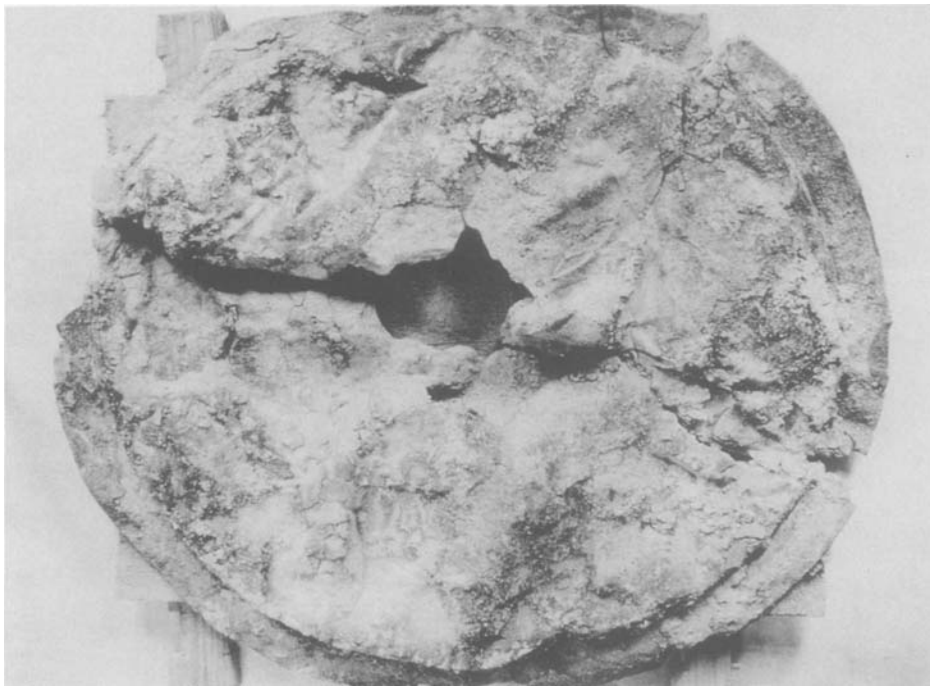

Figure 5. Shield (B262) as discovered in 1936.

Figure 6. Shield (B262) after filling with beeswax and inpainting.

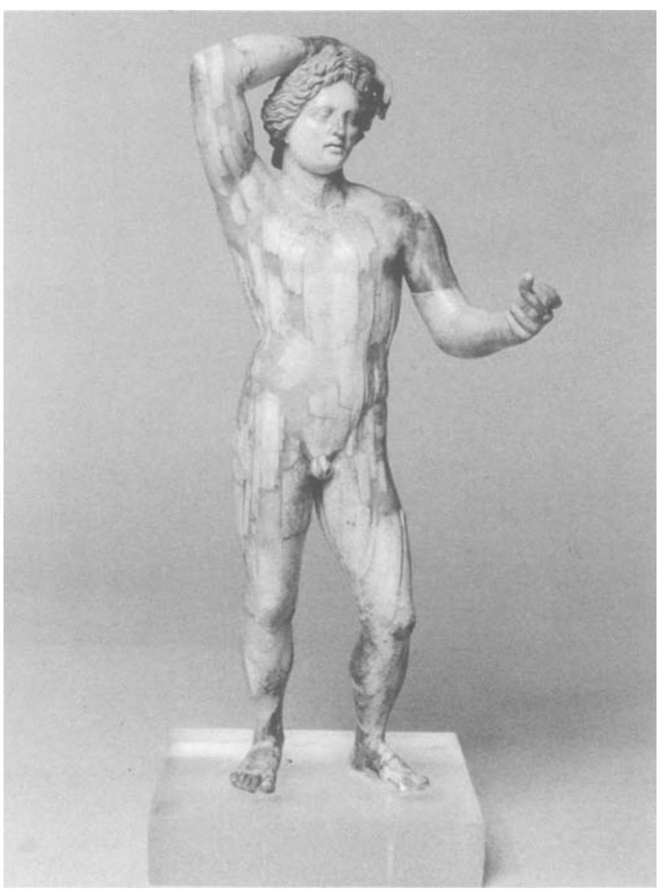

Figure 7. Ivory Apollo statuette (BI236) prior to reconstruction in 1936.

Figure 8. Ivory Apollo statuette (BI236) after reconstruction with cellulose nitrate and gap filling with beeswax.

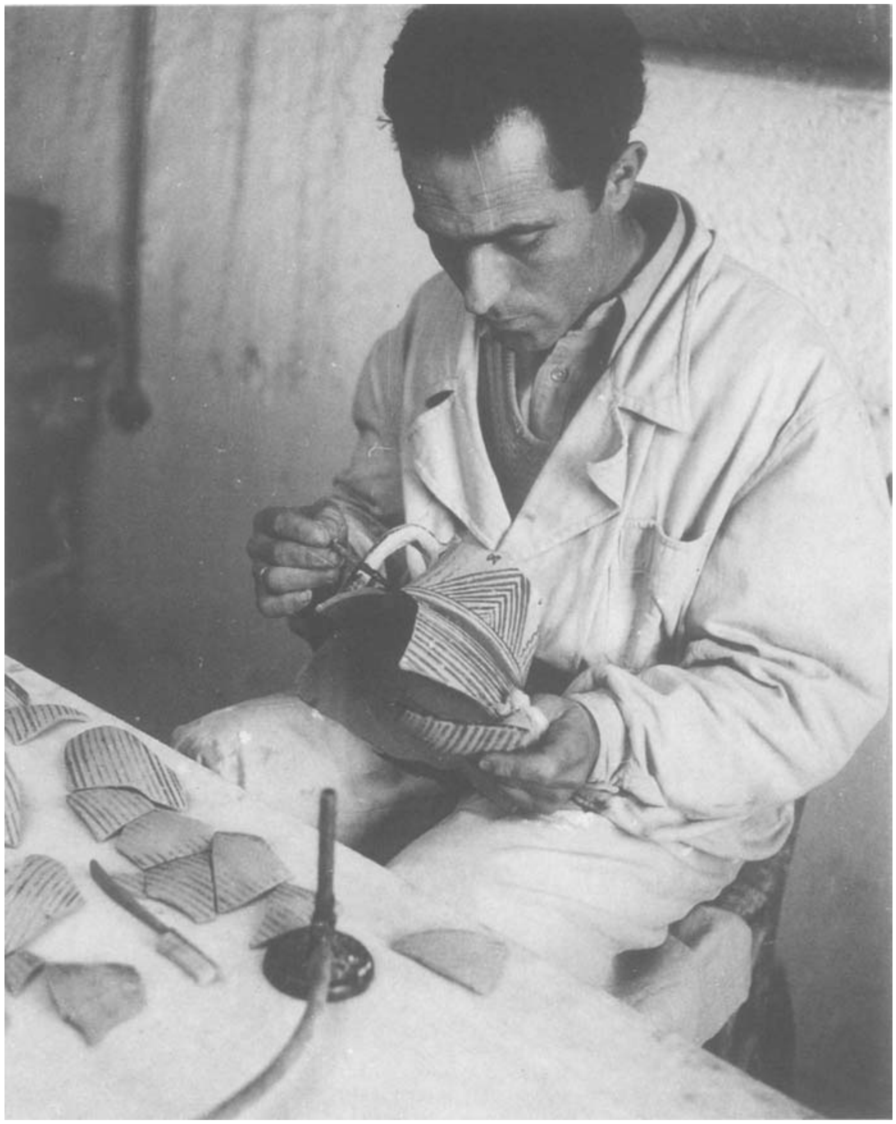

Figure 9. Pot mended in the early days of the Agora Excavations using shellac.

Figure 10. Marble capital (A2073) from the Stoa of Attalos after reconstruction with plaster.

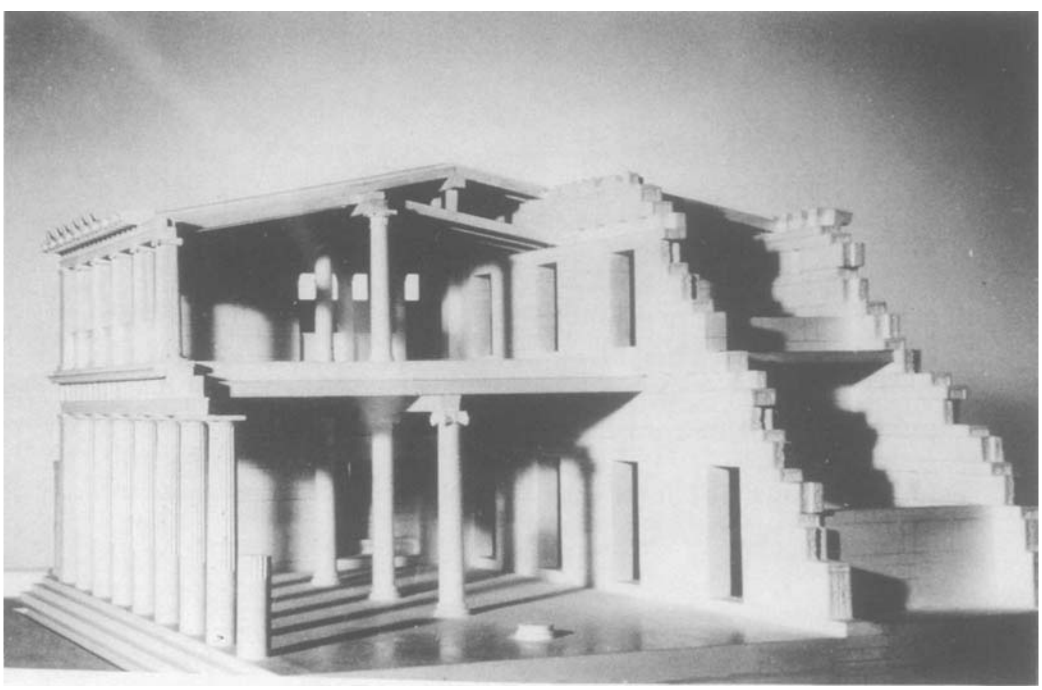

Figure 11. Replicas of marble capital (A2073) used in the 1950's reconstruction of the Stoa of Attalos.

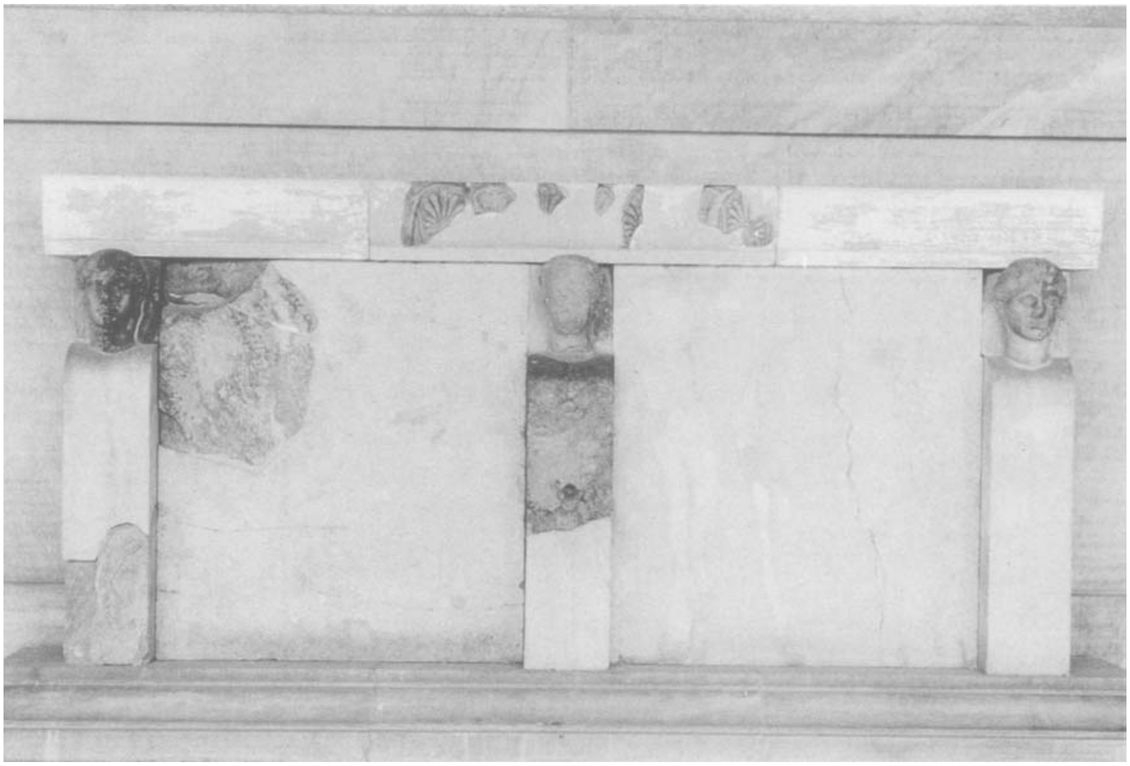

Figure 12. Marble stage front of Odeion concert hall (A586, A1174, S553, S554, S558, S1391) after reconstruction with cement.

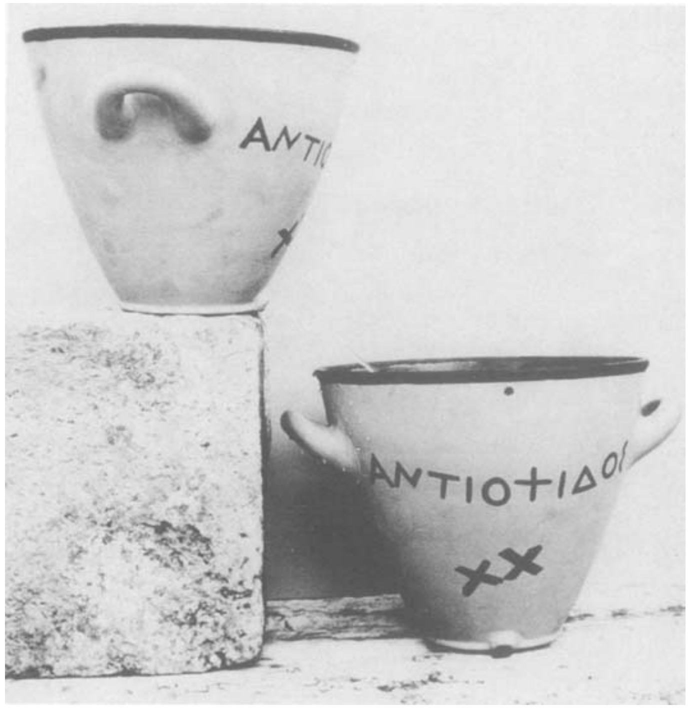

Figure 13. Reconstructed water clock (P2084) in action.

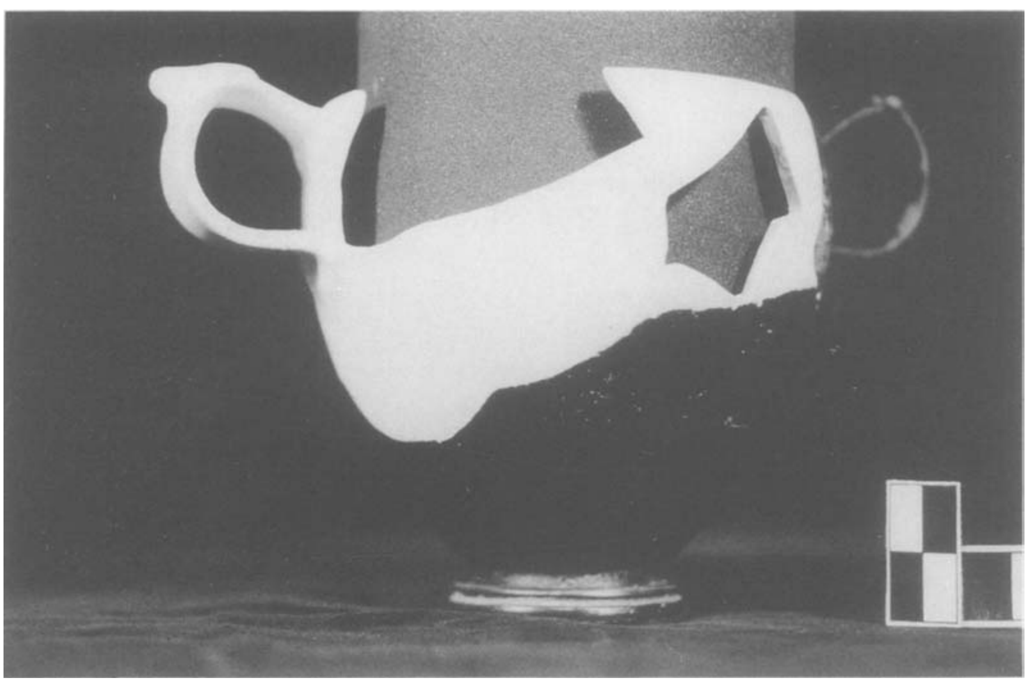

Figure 14. Black glazed Hellenistic skyphos (P31796) during reconstruction with plaster.

Figure 15. Red glazed Hellenistic amphora (P31964) reconstructed with plaster before inpainting.

Figure 16. 5th c. B.C. red figure bell krater (P30019) after reconstruction with plaster and inpainting.

Figure 17. 5th c. B.C. red figure column krater (P30197) after reconstruction with plaster.

Figure 18. 5th c. B.C. red figure column krater (P30197) after inpainting .

Figure 19. Byzantine bowl (P9602) with glaze dislodged by salt crystals.

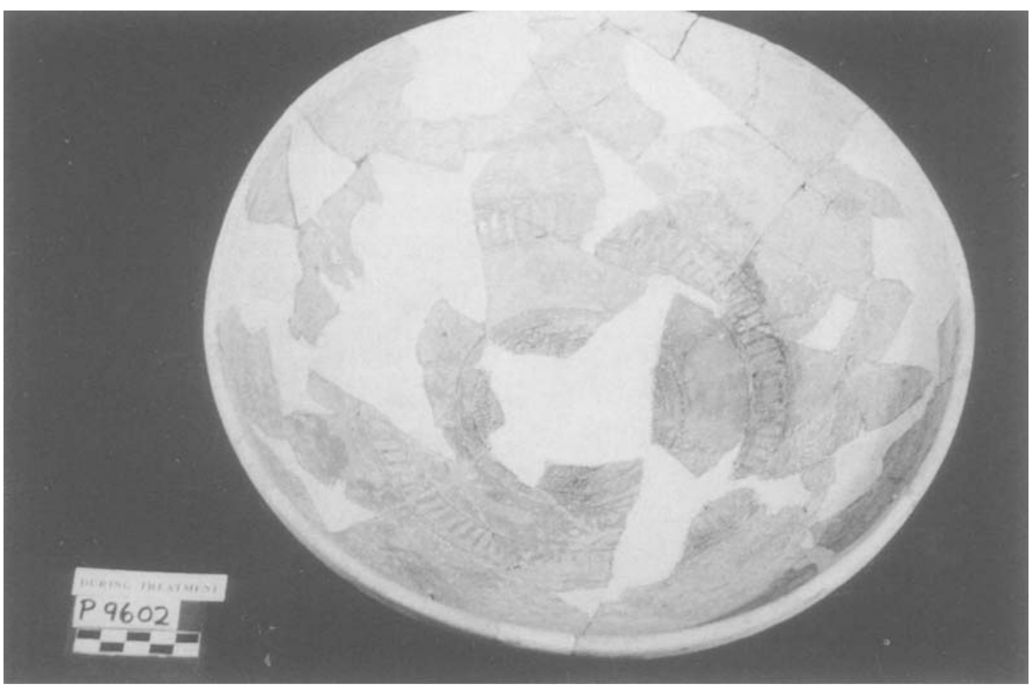

Figure 20. Glazed Byzantine bowl P9602 with extensive plaster fills during treatment.

CONSERVATION AND RESTORATION UNDER FIELD CONDITIONS: CERAMICS TREATMENT AT SARDIS, TURKEY

Tony Sigel and Stephen P. Koob

Abstract

During the course of two field seasons at the archaeological excavations at Sardis, Turkey, ceramics from the Lydian empire dating to 546 B.C. were treated, including a group destined for exhibition at the regional archaeological museum. Working out of doors, with extremes of temperature and limitations in resources, encouraged innovations in technique, use of materials, and methods of work. The principle of using only stable, easily reversible and well understood materials was followed. Combinations of materials which may interact poorly in the future were avoided, and previously treated ceramics requiring re-treatment were examined in this light. This paper describes in detail the techniques for conservation and restoration employed on site with an emphasis on simplicity and improvisation. The use, behavior and idiosyncrasies of materials are discussed as well as adjusting for, and taking advantage of, environmental conditions. Topics include cleaning, desalination, consolidation, reversing earlier treatment, adhesive preparation, assembly, loss compensation strategies, molding and fill materials and their use in structural and detachable fills. Emphasis is placed on the correct uses of plaster of paris, and plasticine as a molding material. Shaping and finishing techniques are discussed along with variations in restoration styles. Inpainting methods and materials are also described.

Introduction

This paper deals with the treatment and re-treatment of archaeological ceramics from the ancient Lydian kingdom of Sardis, in Western Turkey, and is derived in part from the authors' work during the 1995 and 1996 field seasons. Sardis is situated about 90 km east of the Mediterranean coast and is the capital of the ancient Lydian empire. The ceramic materials under discussion date precisely to 546 BC, when the armies of Cyrus of Persia laid waste to Lydian Sardis, ending the reign of the fabled king Croesus.

The conservation of excavated artifacts at the Archaeological Exploration at Sardis in Turkey has been ongoing since the establishment of the modern excavation in 1958. In its conservation laboratory constructed within the original expedition compound, Sardis has also provided conservation training opportunities to many object conservators, including a long-standing arrangement with the Conservation Center of the Institute of Fine Arts, New York University.

The excavation compound is situated just a sherd's throw from the temple of Artemis, where our worktables were set up under the trees. The palette of conservation supplies used for the treatment of ceramics has been intentionally limited to a few very stable, well understood, and easily reversible materials: Plaster of Paris, Acryloid B-72, and acrylic emulsion paints. This should reduce the possibility of future negative interactions between a larger variety of proprietary materials which may themselves be of questionable stability and permanence.

Through sorting and puzzling through thousands of sherds, groups making up individual vessels were assembled and recorded. After testing for stability, the sherds were washed in water. Friable and weak pottery often required particularized cleaning and consolidation. After cleaning, the sherds were tested for soluble salts. The conductivity of the ceramics tested over the last 2 years has averaged around 150 micro mhos, which fortunately indicated a relatively salt-free burial environment. For occasional insoluble deposits, 3-5% nitric acid has proven to be an excellent treatment, preceded and followed by soaking in deionized water.

Joining

Well-known for its stability and reversibility, Acryloid B-72 resin in adhesive form was made up in acetone/ethanol 4:1 with a small amount of fumed silica. The ethanol is added to slow down the solvent evaporation rate and setting time, to compensate for the often very hot and dry conditions. Prepared and transferred into tubes it is very easy to apply. Lighter and heavier solvent-to-resin concentrations can be made to suit the requirements of different wares.

Before assembly, all break edges are sealed with a solution of 7.5% B-72. This 'priming' of the substrate strengthens the adjacent ceramic fabric, creates a 'like to like' bond, and prevents premature absorption of the adhesive solvent from the join. After applying the adhesive, the join is registered and closed without pressure to evenly distribute the adhesive, then pulled apart for a few seconds. This is done to pre-set, or allow a little tack to develop through evaporation, and is perhaps the most important and least appreciated component of making successful B-72 joins. Pulling the join open quickly reduces adhesive 'stringing'. Open time will depend on the amount of 'tack' needed for each particular join depending on weight, size, porosity and on the prevailing temperature and humidity. Experience is the best teacher. The join is then re-closed and pressure is applied. After a minute or two the excess glue and consolidant along the join can be cleaned up quite rapidly with a brush and acetone, taking care not to over-wet the new join. A vessel can thus be built up rapidly and with great accuracy, completing one join and going on to the next, then returning to the first to clean, and so on.

Brush cleaning is non-abrasive, allows complete access into cracks and recesses, and avoids the 'nasty cotton fibers from swabs' problem. The brush is dipped into acetone, blotted on paper toweling to reduce the volume, and the join surface lightly rinsed clean of excess adhesive. The brush is blotted and the procedure is repeated until the area is clean. In this manner the excess resin is suspended in solution and transferred off the surface in a controllable, gentle way. This technique is extremely useful for a wide variety of cleaning activities on various substrates.

Windsor & Newton 'Scepter Gold 606' brushes, 1/4" width, are particularly well suited for general cleaning and removal of excess adhesive. Often a worn, and therefore shorter and somewhat stiffer, brush is more effective for these chores.

If you find mis-alignments, the thermoplasticity of B-72 can be taken advantage of using a hair dryer, the sun, or other heat source to warm and adjust a join. To 'set' a join warmed for this purpose, after realigning, switch the hairdryer to cool or hold the repositioned join under the cold water tap.

Before filling, break edges and also the surfaces surrounding the fill may be given a protective coating of 10-15% B-72. This prevents plaster ghosting and inadvertent abrasions to the surface. It can be left in place throughout the filling and inpainting process, and then removed as the final step. For detachable fills, the edge coating can be doubled in thickness to ease removal.

Filling

Plaster of Paris is the principal fill material used at Sardis. It has unique and variable handling properties that can be exploited throughout its setting process. When properly consolidated, or sealed, and attached to the vessel, it is extremely stable. When possible, fills or restorations are made 'detachable', removed, and glued back in place much like another fragment. As plaster is not a particularly adhesive material, the use of adhesive to attach the fill greatly strengthens and adds to the long term stability of the vessel. It is also advantageous in that fills can be cast, removed, and taken away from the vessel for shaping and finishing, avoiding both plaster dust mess and exposing the vessel to physical and psychological trauma.

Mold preparation

Plasticine is used almost exclusively as the backing or molding material, although dental sheet wax, masking tape and other materials all have their uses. Hard gray Harbutts brand plasticine is non-sulfur containing, has a low oil content and is therefore well suited for the purpose. Its thermoplastic properties can be exploited easily in the field: it can be warmed and softened in the sun to take an impression, and cooled to harden and set with cold water. It is capable of capturing fine detail, such as interior wheel marks (Figure 1). As the concave interior surface of a fill is considerably more difficult to work than the exterior, time and trouble can be saved by perfecting the fill backing. The plasticine is first rolled out on a plastic tray or glass sheet to form a smooth slab. Knead in some dry plaster if it feels too oily. A few drops of water on the glass will prevent sticking. It can then be shaped to an adjacent undamaged interior area with the same profile as the loss area, again with water to prevent sticking. If you have access to cold water, cool the mold at this time to minimize distortions when transferring. The backing is then gently removed, dried, and shifted to the loss area, where it is adhered with pressure applied carefully to the edges first, then inwards towards the loss, bringing the mold up to, but not past, the plane of the surface of the loss. When everything looks nice, check for leaks by pouring water into your mold. If any are found (check inside) they may be plugged with more plasticine and/or squeezed close.

Pouring fills

Mix the plaster gently with the fingers to avoid generating air bubbles. Use warmer water to accelerate, cooler to retard the setting process if needed. Avoid additives such as adhesives, etc. (they will invariably alter the setting process and may affect long term stability. The properties of the dry plaster fill will be modified with B-72 later). Position the loss in a horizontal orientation with props. It's also a good idea to leave a paper towel or two in and around the vessel to catch any spills or drips. Pour the fills, corners first, to ensure no air is trapped. The loss is overfilledso that the plaster is contained but 'bulging' slightly. Tap the vessel gently to release air bubbles. It will probably be necessary to redistribute plaster as it sets, as it will shrink slightly away from the edges. When the surface shine of water is gone, the surface is shaped and refined with spatulas, scraping, redistributing, and smoothing. At a certain point the plaster will start to tear, and should be left alone. If the weather is very hot, add drops of water to complete the reaction.

Finishing

When the plaster has achieved a 'hard but damp' state, initial shaping of the fill is begun with a scalpel, carving first from just past the fill edge towards the center. The scalpel is held flat, the inside edge of the blade bevel resting lightly on the surface outside the loss; this keeps the cutting edge fractionally but safely above the ceramic surface (Figure 2). With the rough shape completed (Figure 3), the fill is finished with small scrapers and sandpaper, under a running tap if possible.

Incising fills

Incising fill edges defines replacement areas clearly, provides a more consistent visual appearance with adjacent joins, and can save considerable time finishing and inpainting. Establishing the width of the incised line is a judgment based upon the degree of wear and consequent size of adjacent breaklines (Figure 4). It should also be done with the plaster damp, using very little cutting pressure. If the plaster has dried completely, re-wet. Simply guide the upside down blade tip along at the chosen angle, taking a light cut and letting the weight of the scalpel do the work.

After drying, fills are consolidated with 7 to 10% B-72 by immersion or pipette. A polyethylene bag can be loosely draped to slow drying. Consolidation strengthens the fill, seals the plaster from moisture exchange, and forms a compatible and non-absorbant substrate for inpainting.

Structural and detachable fills are often required to utilize poorly joining and non-joining sherds on fragmentary vessels. The first example is a beautiful and very fragmentary East Greek 'wild goat style' Oinochoe (Figure 5). The plasticine backing provided support for both the floating sherd group, and the structural fill that allows it to be incorporated into the pot. Bamboo sticks were used to support the weight of the backing, with the upward pressure distributed through cardboard and a rubber clay smoothing tool (Figure 6).

Bamboo can be exploited for its thermoplastic properties to create curved braces, temporarily glued in place with B-72 to hold sherds or groups, in this case the foot, in proper orientation (Figure 7). Wet the bamboo before bending over the flame from a candle or alcohol lamp, and keep it moving to avoid charring. These temporary bamboo attachments can be removed later by draping their adhesive joins with cotton soaked in acetone, under polyethylene wrap.

Large, heavier coarse wares with significant structural losses may require a supporting structure to hold sections safely in proper orientation during the casting of a detachable fill. Temporary structures using ephemeral materials such as bamboo, paper towel tubes and tongue depressors, as well as more substantial materials can be improvised for this purpose, and removed later with acetone (Figure 8). The combined weight of the plasticine and wet plaster can easily distort the shape of a large plasticine backing, so support it well, use cold water to firm it up, and work in the shade (Figure 9).

Very large files are invaluable for leveling and refining large fills. When used carefully and correctly, they excel at bridging and leveling planar inconsistencies rather than amplifying them. On the other end of the scale, dozens of small sanding sticks can be made up, in a variety of grits, from flat wood coffee stirrers and spray adhesive. Trim the tip to whatever shape is needed for odd corners and close-up work at the fill edge, and cut the stick back to expose fresh abrasive as the tip becomes worn or clogged (Figure 10).

Case Study: Treatment of a large Orientalizing Dinos

One major case study serves to illustrate many of the techniques discussed in this paper. A large Lydian orientalizing Dinos, or wine mixing bowl, was excavated at Sardis and assembled in 1963, spending the next 30 years at the regional archaeological museum. In the intervening years two additional sherds belonging to the Dinos had been unearthed and it was felt the time had come to retreat this important piece, incorporating the new sherds and making the restored vessel more exhibitable. Substantial areas of the body and rim were missing, and the fill was mis-shapen and tenuously attached, with badly discolored and flaking paint. The original joins were of a poor quality, some having failed, the brilliantly colored slip glaze decoration was obscured by a film of insoluble green/brown burial accretion, and the previous restorer had inadvertently filed down areas of the original surface with a plaster rasp (Figure 11a).

The Dinos, having been assembled with a PVA adhesive, was disassembled with an alternating warm water/acetone bath (Figure 11b). Following a thorough pre-soak, the disfiguring burial accretions were removed from the surface with 3% nitric acid applied locally with a soft brush. This was followed with several post-soakings in changes of de-ionized water, with regular conductivity monitoring to ensure the removal of any acid remnants. The sherds were allowed to dry and arranged for reassembly (Figure 11c).

The Dinos was re-assembled with B-72, and given a protective working coating of a 20% solution of B-72 in acetone (Figure 11d). It was decided that portions of the old plaster fills could be re-used, with what turned out to be a great deal of reworking (Figure 11e). In retrospect, this did not turn out to be the time-saving step imagined and I would not do it again, much preferring to start fresh. With the body fills attached and augmented, the correct exterior contours were formed with the aid of very large files, as discussed before, using a series of horizontal and diagonally overlapping strokes. Profile templates made with the aid of plastic contour gauges were used to monitor progress. A flexible plastic ruler, bent into the proper arc over the fill, will indicate high and low spots needing further attention.

A cardboard-backed plasticine ring was assembled (Figure 11f) and installed into the vessel as a scaffolding to support the interior wall of the rim mold with springy bamboo skewers (Figure 11g). The plasticine sealed the ring to the interior of the vessel, and to the rim molds, preventing leaks. Dovetail sawcuts were made in the edge of the roughened plaster shoulder to provide a mechanical key for the soon to be poured rim plaster.

Inner and outer rim molds were formed against the remaining original rim surfaces in a continuous linear fashion and applied. The cardboard disc cut-outs remaining from the scaffolding were used to ensure concentricity of the molds (Figure 11h). Masking tape was used as a 'strap' to hold the plasticine against the plaster shoulder, as it adheres poorly when wet and can leak under the weight of the plaster. After filling the finished mold with water to saturate the plaster shoulder and check for leaks, the rim was emptied of excess water and the plaster poured in one of those exciting conservation moments. When the mold was removed, the lengthy preparations were rewarded with a successful result (Figure 11i). The plasticine nicely reproduced the faint chatter mark texture on the rim edge, and the rim and shoulder were well integrated, requiring little further work.

Air bubbles and other minor repairs fills were completed, wetting the plaster again and using a thicker plaster mixture, small spatulas, and the finger tips. The fills were wet sanded with first 220, then 400 grit waterproof sandpaper. With the fills completed, the plaster was consolidated from the inside out through percolation. The keyed joins of the reused fill areas were visually distinct from the integration of the new plaster, slightly darker in tone. Final sanding of the consolidated plaster was carried out with 400-600 grit papers.

Generally, it is a good idea to start inpainting on the interior of an open vessel. In that way all of the application issues can be worked out before starting on the exterior, or 'money' surface (Figure 11j). Wheel-applied slip artifacts and register lines can be effectively reproduced by holding the paint-loaded brush stationary and spinning the vessel on some sort of a turntable. Used judiciously this can help to moderate the blank, artificial appearance of large inpainted fill areas. The paint can be carried over onto the B-72 barrier layer to maintain the continuity of the brush strokes, then both the excess paint and coating are cleaned back to the break edge with a brush and acetone (Figure 11k). Restoration of losses in surface decoration was limited to continuing the register lines, which added visual interest and continuity to the otherwise large, blank fill areas (Figure 11L).

Acknowledgments

We thank our respective institutions for their support, and our colleagues at the Freer Gallery of Art and Arthur M. Sackler Gallery, the Straus Center for Conservation and the Archaeological Exploration of Sardis; both of the Harvard University Art Museums, for their help in the preparation of this paper. Thanks also to Paula Artal-Isbrand for her ideas, techniques and encouragement.

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Koob, S.P. 1996. Using Acryloid B-72 for the repair of archaeological ceramics, Conservation Notes, 21, May, Materials Conservation Laboratory, Texas Memorial Museum.

Sigel, T. 1995. Notes from Sardis, 1995. Unpublished MS.

Suppliers

Fine tip glue tubes: Unipac Supply Co., Pittsburgh, PA 15227, 412-885-2266
Tin mastitis tip/black friction fit. A box contains a gross (144) and costs 58.75.

Acryloid B-72: Conservation Materials Ltd. Box 2884, Sparks, NV 89431

Hydrophobic Fumed Silica: Aerosil 202. DeGussa Corp., Pigments Division, PO Box 2004, Teterborough, NJ 07608

Cleaning Agents: Symperonic 'N'. Archival Aids, or Conservation Materials.

Plaster of Paris: French's Diamond 'P' fine dental plaster. Samuel H. French & Co., 4446-50 Cresson St. Philadelphia, PA 19127.

Plasticine: Harbutt's Ltd. High Street, Bathhampton, Bath BA2 6TA, UK, also Conservation Resources International, L.L.C. 800-634-6932.

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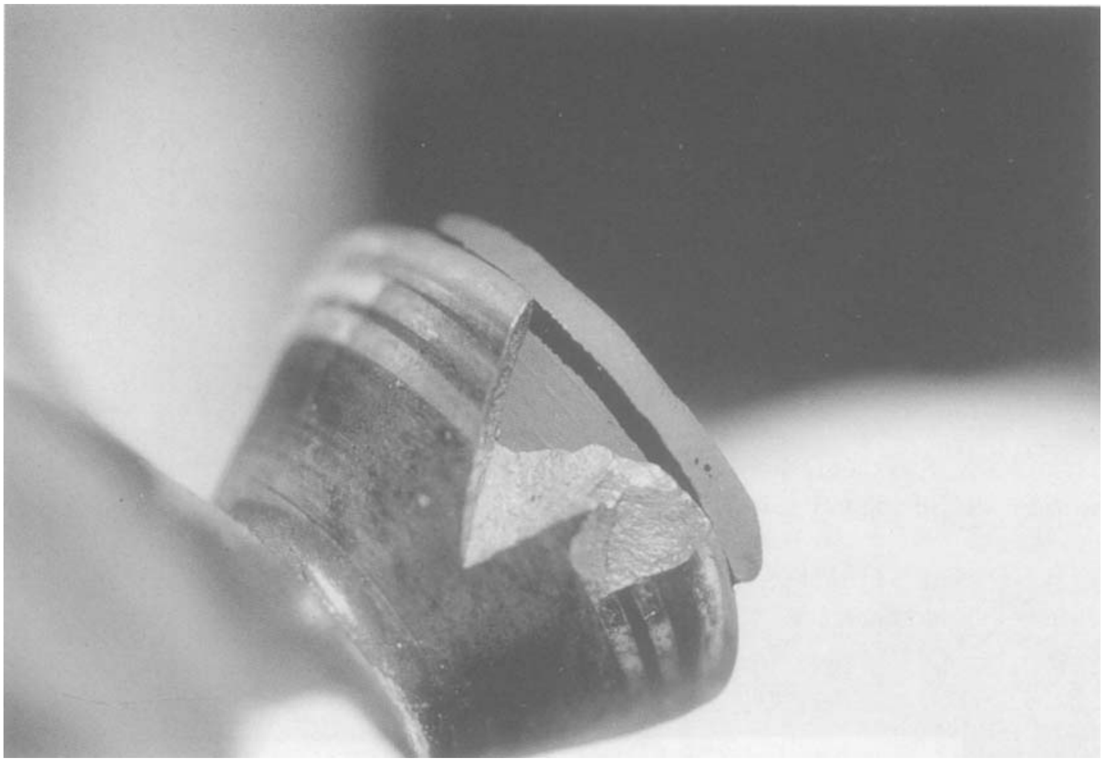


Figure. 1. Plasticine backing for foot rim loss in Lydian skyphos.

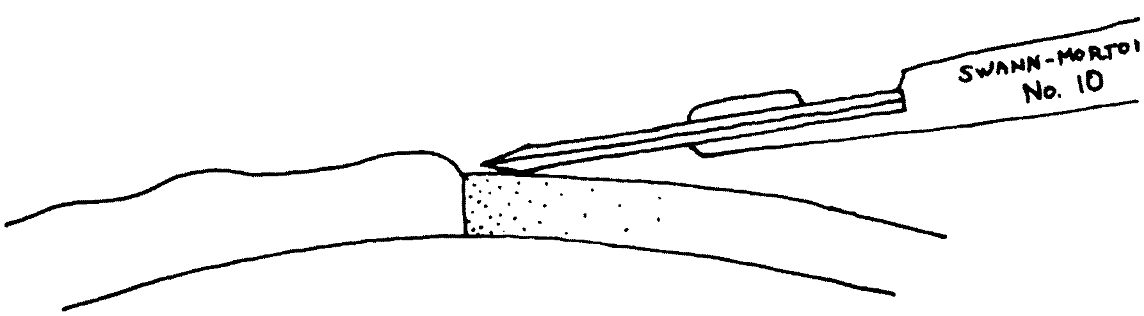


Figure. 2. Scalpel position for fill carving.

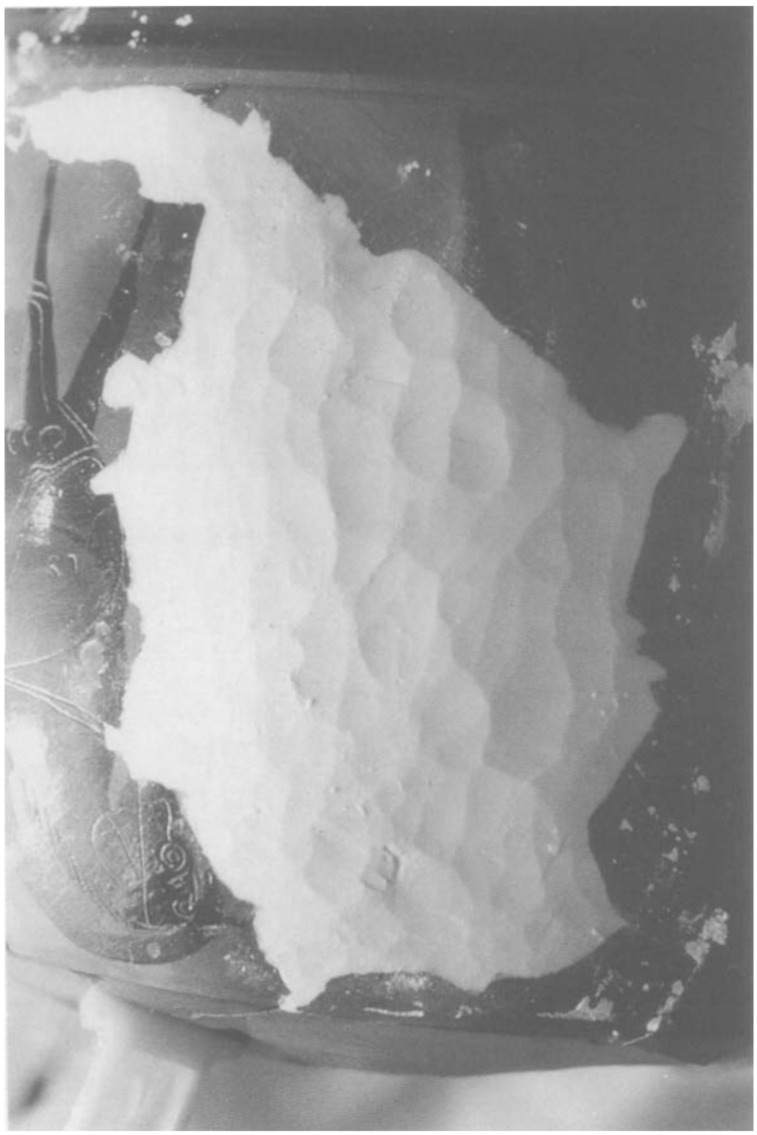


Figure. 3. Completion of rough carving on fill in Attic hydria.

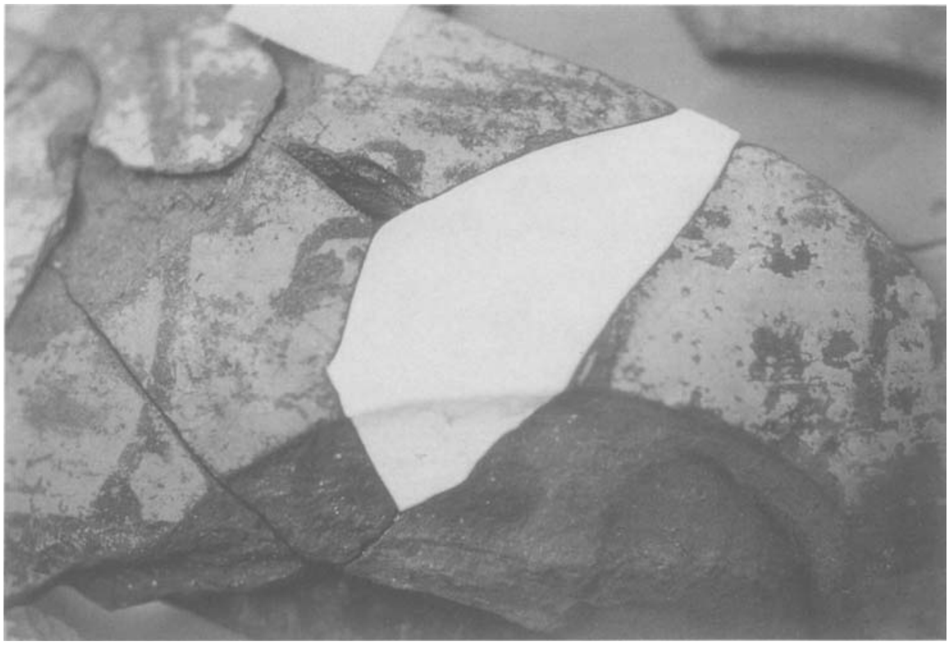


Figure. 4. Incised fill edges complementing adjacent break edges.

Figure. 5. Plasticine backing supporting floating sherd group; plaster poured (above).

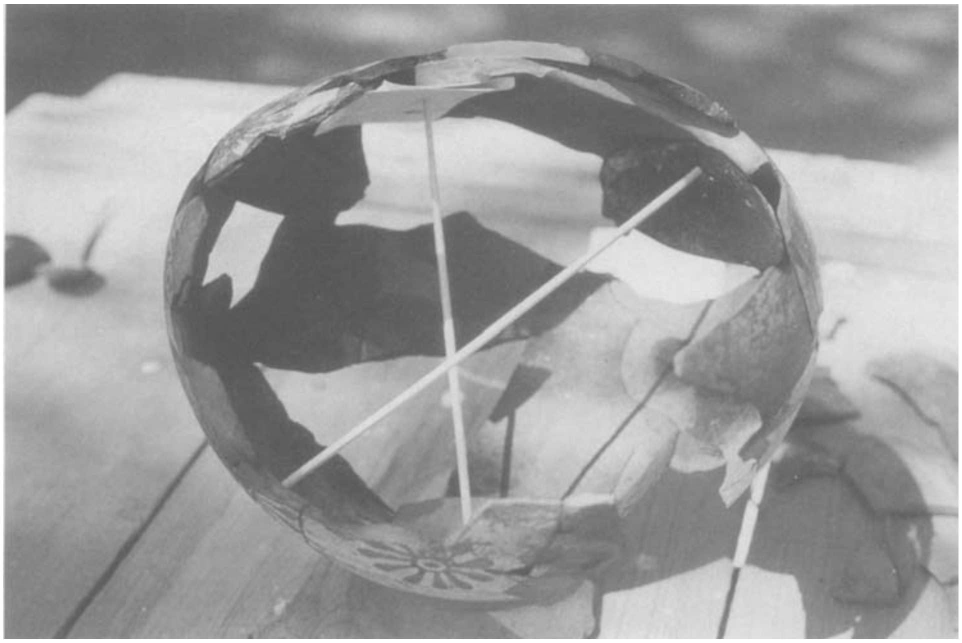


Figure. 6a. Bamboo struts under tension supporting backing.

Figure. 6b. The completed shape showing bridging, or structural fill.

Figure. 7a. Temporary bamboo struts in place. Note shiny isolating B-72 layer and plasticine backing.

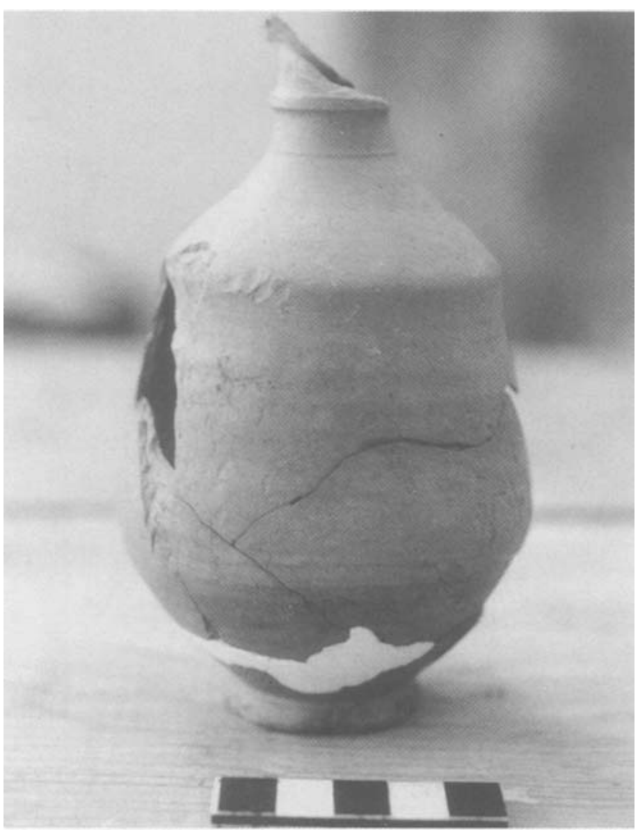


Figure. 7b. The completed fill.

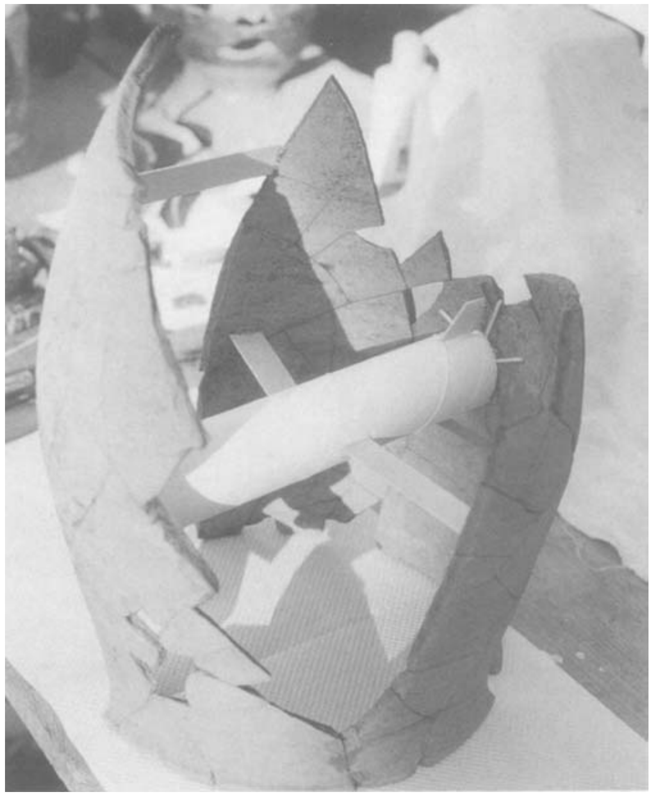


Figure. 8. Fragmentary vessel braced temporarily in preparation for structural fill.

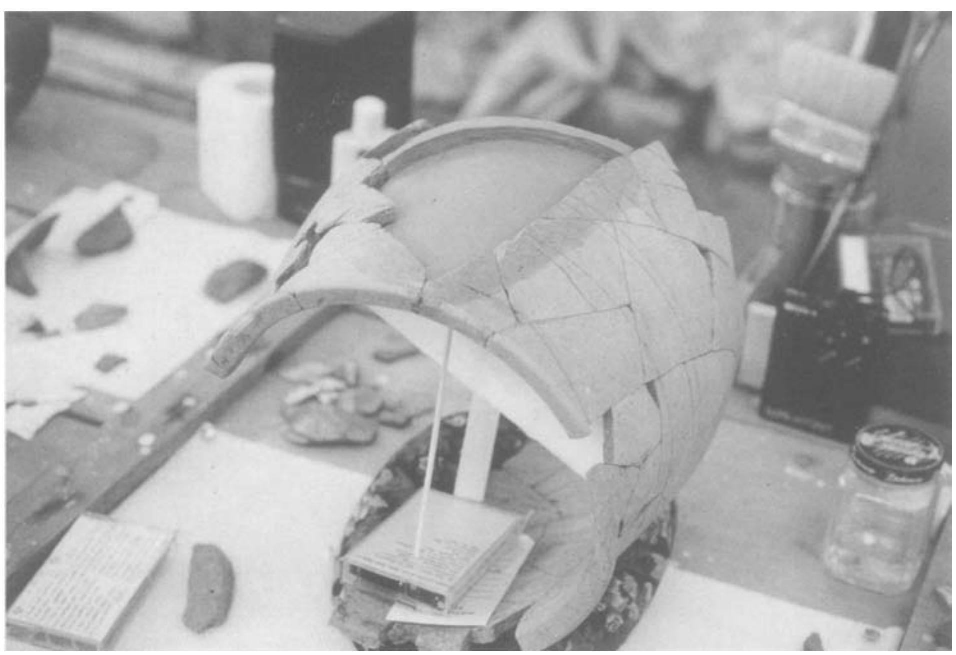


Figure. 9. Ready to pour. Note also tensioned bamboo support for mold.

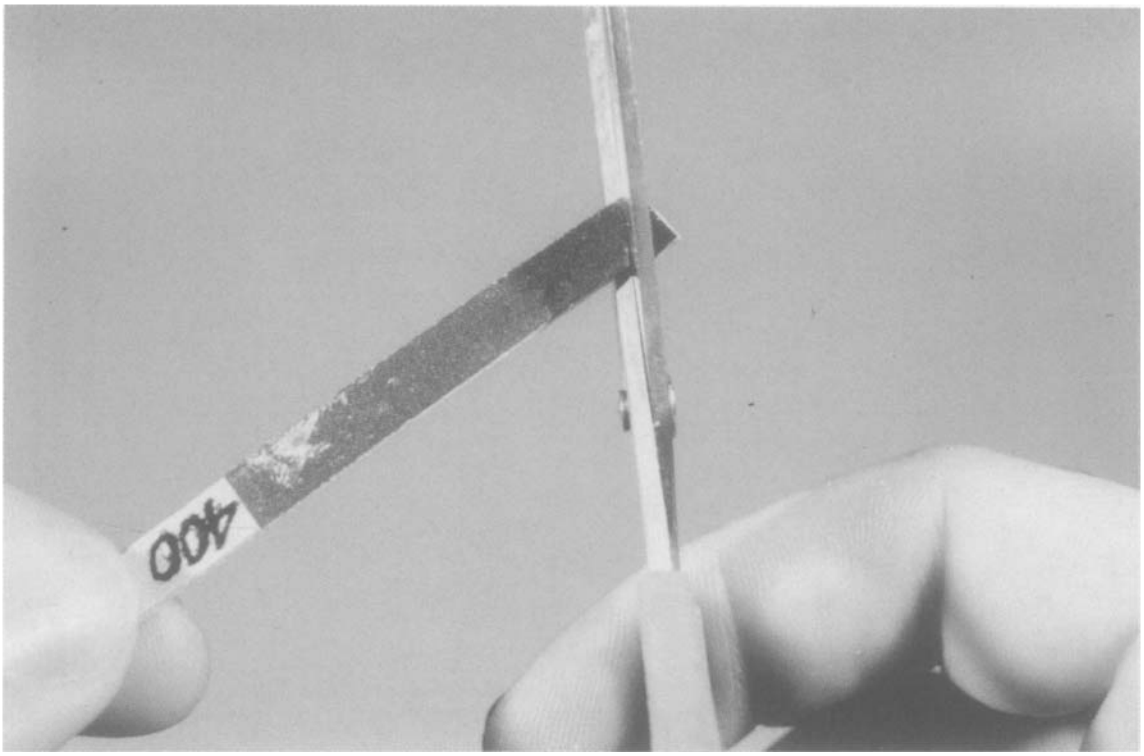
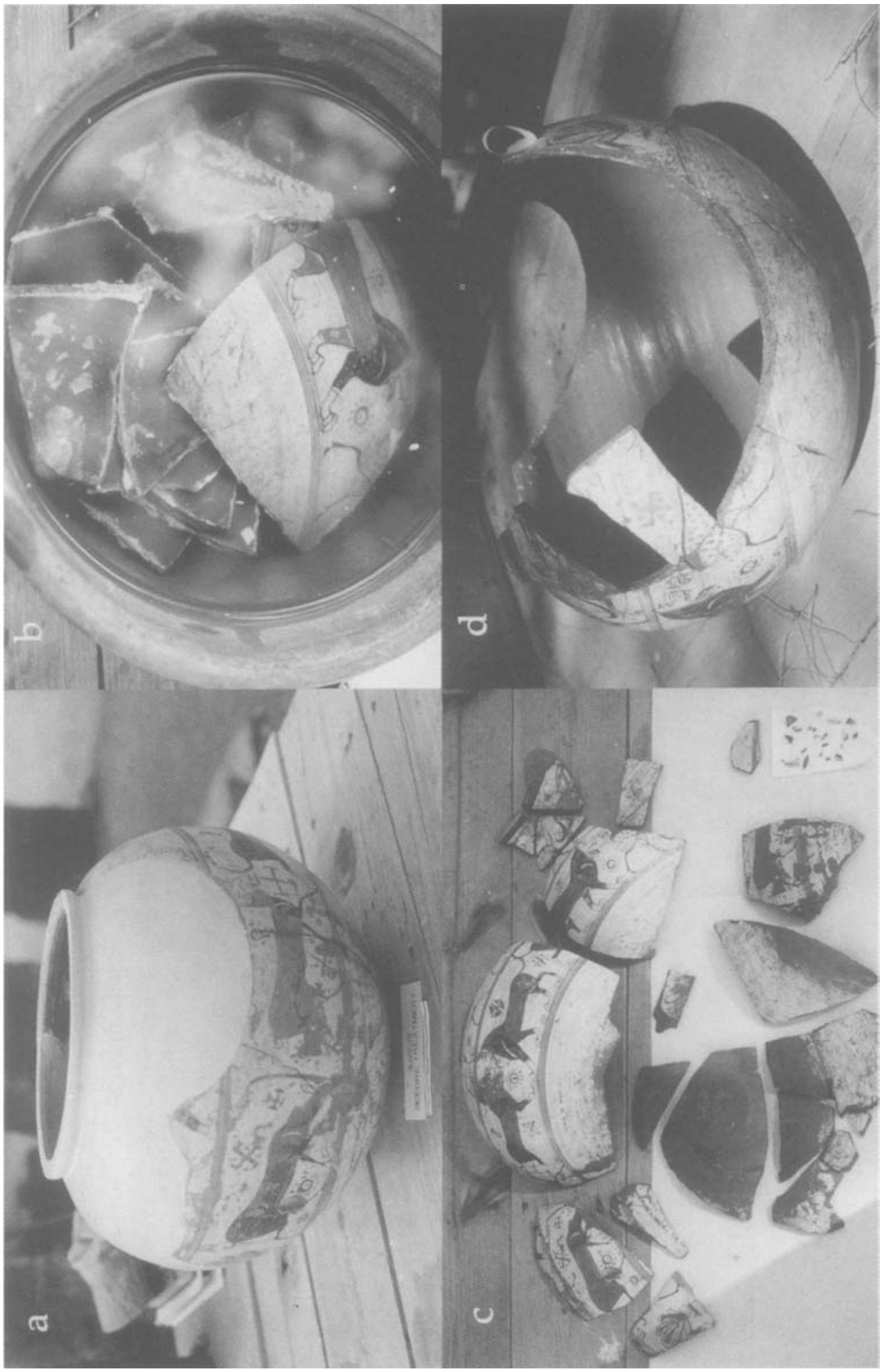
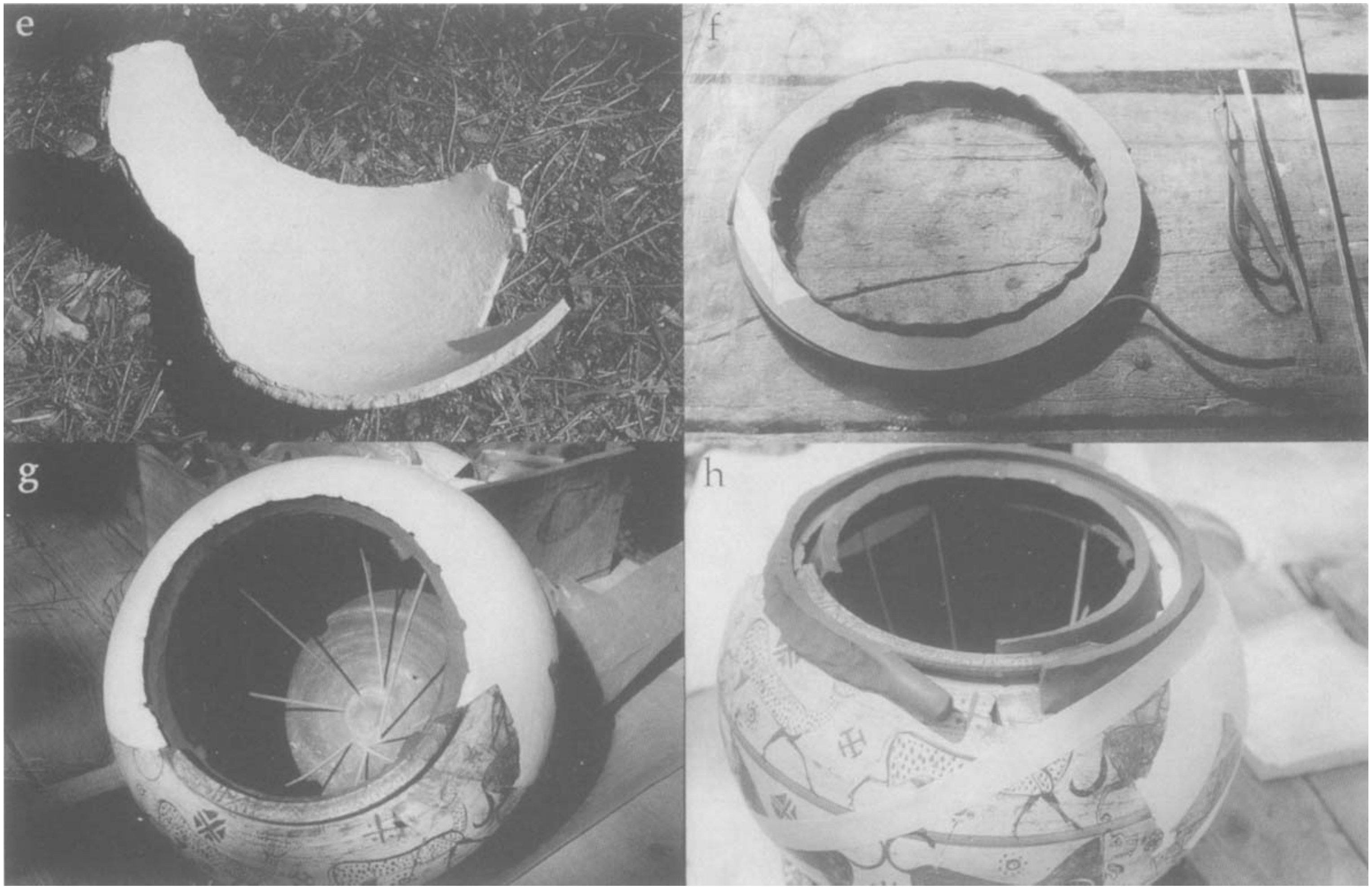


Figure. 10. Trimming sanding stick tip.



Figures. 11a-d. (a) before treatment, (b) disassembly, note opaque PVA accretions, (c) clean, dry and ordered for reassembly, (d) reassembled and coated.



Figures. 11e-h. (e) portion of old fill prepared for re-use, (f) cardboard backed plasticine ring, face down, (g) ring in place, supported with sprung bamboo. Note sawcuts to receive rim plaster, (h) Outer and inner rim molds in place.

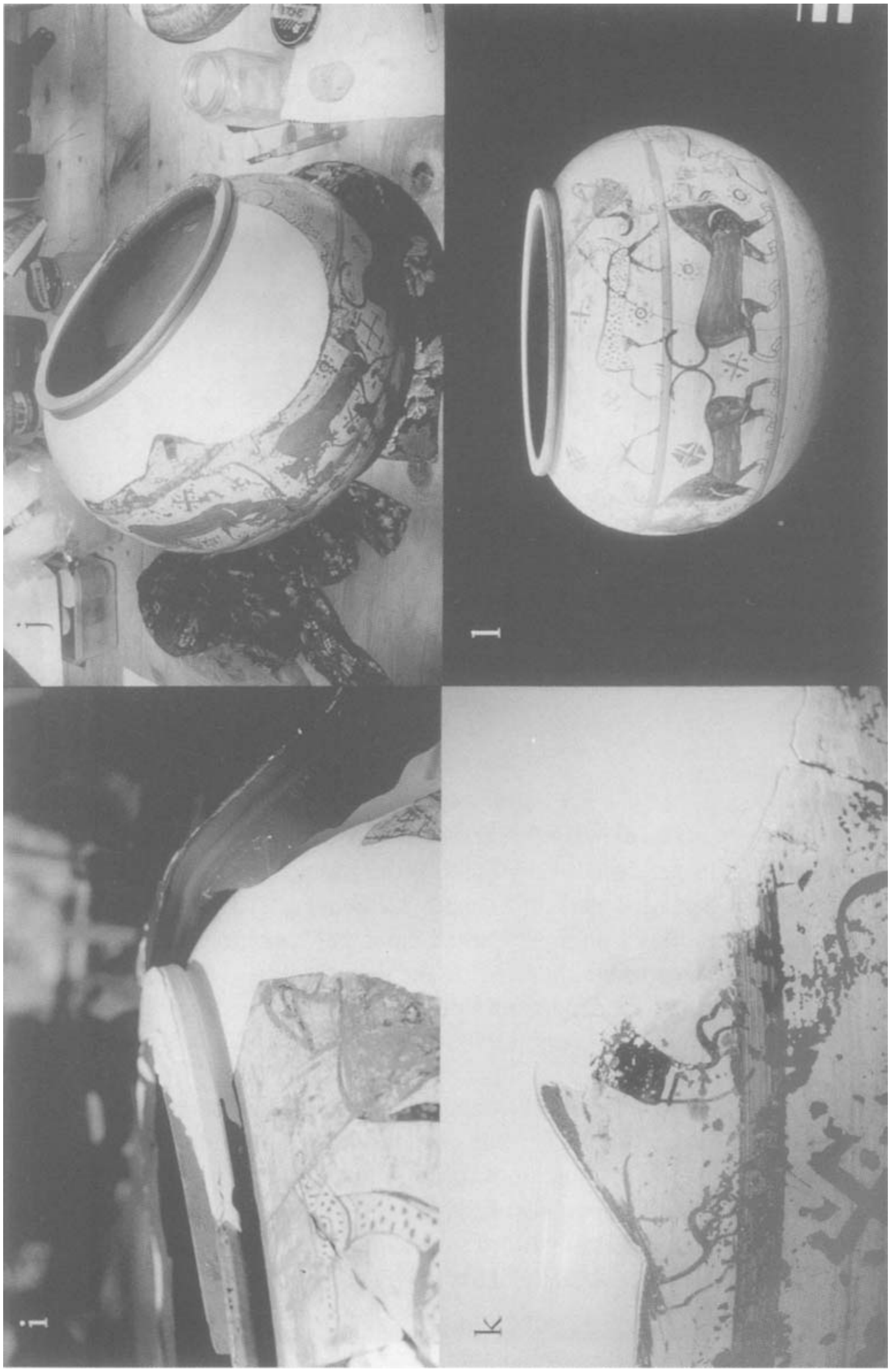


Fig. 11 i-l. (i) Removing outer rim mold. Ahh..., (j) Interior inpainted, exterior rim underway, (k) Paint overlap on B-72 barrier (right), cleaned back to incised edge (left), (l) Completed vessel..

THE RESTORATION OF OUTDOOR STONE SCULPTURE: TRADITIONAL METHODS REVISITED

Peter Champe

Conservation of outdoor stone sculpture is particularly challenging because of the uncontrollable forces of the outdoor environment and of human activity. Exposed to these conditions, treatment solutions must be chemically stable, durable, reversible and inconspicuous. The specific challenge of loss compensation in outdoor stone sculpture is that the same requirements met in a protected museum environment must be made viable in a harsh outdoor setting. Some of the destructive forces which challenge the conservator of outdoor sculpture include: weathering (acid rain, wind erosion), guano deposition and human vandalism.

The treatment criterion of inconspicuosness listed above is more than an esthetic consideration, but actually plays a broader role protecting the sculpture from future vandalism. We have observed that areas of obvious restoration can actually serve as beacons for further vandalism. Sociologists refer to the "broken window" theory to describe the fact that if an object or structure is not maintained and is allowed to decay, subsequent vandalism increases. If, however, a baseline good condition is maintained, with restoration blending relatively seamlessly into the original, the occurrence of vandalism can be greatly reduced. This observation has led to a treatment approach which has as one of its goals to render loss compensation as inconspicuous as possible.

Bethesda Terrace

The sandstone carving at Bethesda Terrace in Central Park offers an excellent example of the effects of conspicuous restoration. The exquisitely carved New Brunswick sandstone panels depicting birds amidst scrolling foliage, designed by Jacob Wrey Mould in the 1870's, are a frequent target for vandals. The damaged elements, usually the heads and wings of the birds, have been replaced over the generations with finely carved dutchmen[1] only to be frequently broken off again. It was clear that a contributing factor in the vulnerability of the panels was the fact that the newly carved New Brunswick sandstone stood out against the original soiled and weathered stone, with a distinct join line between the two.

A toning material for the newly carved stone must exhibit chemical stability, be insoluble in water and render a flat stone-like appearance. Of the various paints we tested, including, acrylics and oils, the most suitable material was Keim Granital potassium silicate paints [2]. The liquid potassium silicate binding medium of the paint, also known as "water glass," is a mineral which forms a durable chemical bond with mineral substrates such as sandstone. The paints employ mineral pigments which are chemically stable and unaffected by UV light.

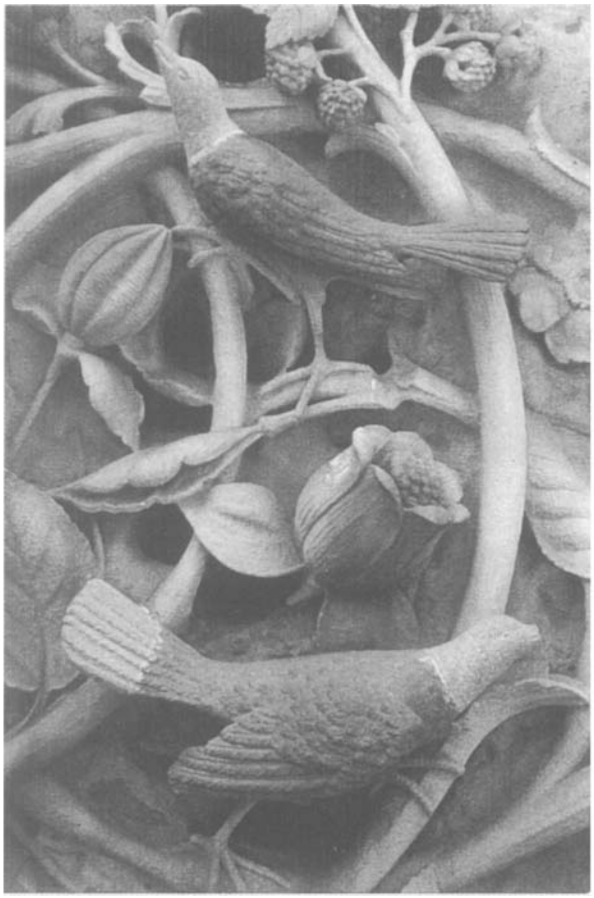


Figure 1. Bethesda Terrace.
Before Treatment.

Figure 2. Bethesda Terrace.
After Treatment.

In addition to toning the carved stone restoration, we concealed the epoxy join-line by carving a channel with a small diamond burr on a flexible-shaft drill. We filled the resulting channel with Jahn M1003 mortar to blend the join-line and applied Keim paint as with the stone.

One year after the application of the Keim paint, some fading of the color had occurred. The reason for this is not clear, but it could be due to lack of sufficient protection from rain during the critical cure-period (7-10 days) so that the paint actually washed away. Despite this, the stone restoration blends significantly better with the original stone than before the treatment. In a one year period, no subsequent vandalism has occurred to the stone carving where previously, birds' heads were being lost due to vandalism at a rate of approximately 2-3 per year. While this success cannot be attributed solely to the treatment, as conditions in Central Park in general have improved, there is no doubt that the treatment not only restored the appearance of the carved panels, but increased their chances of survival in a harsh urban environment.

The Giuseppe Verdi Monument

Figure 3. Giuseppe Verdi Monument.
Historic Photo circa 1908.

The restoration of the Giuseppe Verdi Monument at West 72nd Street in New York City, sculpted by Pasquale Civiletti in 1906, presented several challenges in the area of loss compensation and required a reexamination of previous treatment approaches. The Verdi Monument is composed of two types of stone, Carrara marble is used for the sculpture depicting Verdi, Aida, Falstaff, Leonora and Othello while the steps and pedestal are a Monte Chiaro brescia limestone. The Carrara marble had suffered significant loss due to acid rain erosion and breakage: the finely carved details of the figures (particularly the faces) were eroded and several of the hands were broken. In examining the archival photographs of the monument from circa 1908, we were surprised to find that at some point in the sculpture's treatment history, the form of the hands had been altered: Falstaff's right hand was transformed from its original open and expressive gesture to a closed fist and Leonora's individually articulated fingers had become joined to form solid block-like hands.

Figure 4. Figure of Leonora. Detail of circa 1908 photo showing articulated fingers before 1945 restoration.

Figure 5. Figure of Leonora. After restoration of hands employing polyurethane composite material.

Past treatment reports indicated that during the last major restoration in 1945, the hands had been recarved as solid masses, presumably to compensate for the inherently fragile nature of the marble. While this solution is understandable and indeed, was partially successful (while Leonora's hands were broken, Falstaff's fist was still intact 51 years after treatment), it was clear that this treatment solution had sacrificed the expressive function of the hands for the sake of durability. Our intention in this treatment was to restore the hands to their original expressive form using historical photographs, while achieving a sufficient durability. This would necessarily exclude any restoration method employing carved stone, and forced us to explore appropriate cast materials.

Materials suitable for casting the hands would be required to have significant tensile strength, chemical stability and a marble-like appearance. Polymer-modified mortars and gypsums were rejected as they did not significantly exceed the tensile strength of the marble they were to replace. Thermoset resins with internal armatures seemed to offer the best combination of strength with potential to simulate a marble-like appearance. However, thermoset resins have the major drawback of UV instability, which we hoped to control by use of chemical stabilizers and bulking with inert material in the form of marble dust. The resin which we chose for casting the hands was a two-part polyurethane, Ciba-Geigy RP64054 which combined the required characteristics of exceptional strength with an opaque white color.

To stabilize the polyurethane, the following chemical stabilizers were used as recommended by Ciba-Geigy: Tinuvin 765 (free radical scavenger), Tinuvin 328 (UV absorber) and Irganox 245 (thermal stabilizer)5. To determine the UV stability of the material, we exposed it in the Xenon Arc Fadeometer at the Metropolitan Museum of Art to 20 million lux (approximately 200 hours)6. Accelerated aging was calculated to correspond to nine months to a year of actual outdoor exposure. The stabilized polyurethane displayed slight yellowing after exposure in the fadeometer but yellowing was negligible in the samples which were mixed with 90% by weight marble powder which we intended to use as a face-coat

The method devised for fabricating the hands is outlined below:

1. Missing hands were sculpted in clay on the basis of historic photographs.

2. Two-part flexible molds of the clay models were made.

3. A putty composed of the liquid polyurethane and 90% by weight marble powder was pressed into each side of the two-part flexible mold, to a thickness of approximately 1/8" to establish a "face-coat". This proportion of resin to marble powder was found to offer the best balance between strength and the simulated appearance of marble.

4. Quarter-inch stainless-steel rods were laid into the fingers of each hand to serve as structural reinforcement.

5. The two halves of the mold were closed and polyurethane poured in to fill the remaining void and form a solid mass.

The resulting cast hands possessed exceptional strength and a convincing marble-like appearance. A cross-section of the fingers of a fabricated hand would appear as below:

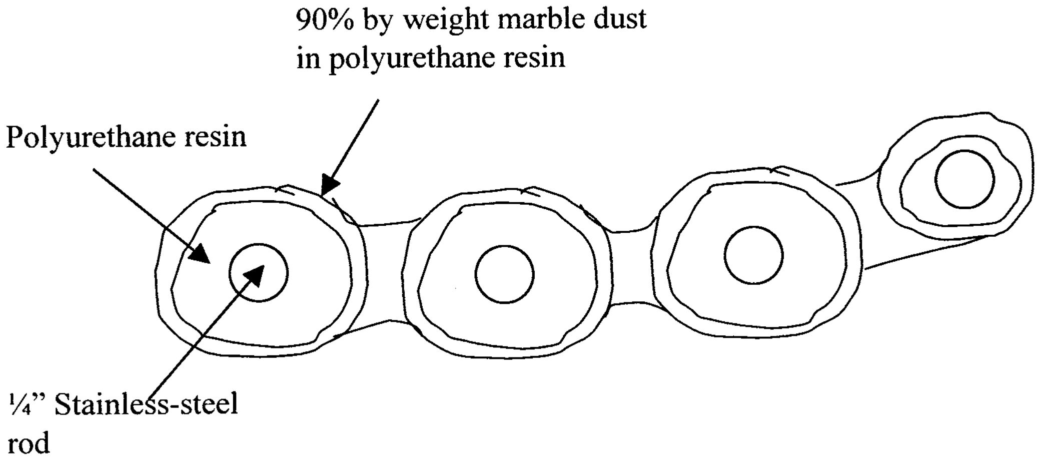


Figure 6. Cross-section of fingers of cast replacement hand.

Figure 7. Figure of Falstaff showing fist from 1945 restoration.

Figure 8. Figure of Falstaff. After restoration of hand employing polyurethane composite material.

The hands were attached to the statue using threaded stainless-steel rod and Sikadur 317 epoxy. This method has application in any situation where restoration of fragile sculpted stone elements requires greater strength than the original stone can provide. While accelerated aging tests in the laboratory suggest that the material will remain stable in high UV environments, this material is untested in outdoor conditions and only actual weathering will determine its stability.

Composite Repair

The problem of loss compensation due to erosion is more complex than that due to breakage. Whereas damage due to breakage is clear and the element can be recarved or cast and reattached, erosion results in a gradual overall diminution of surface detail. The question then arises at what point the loss is no longer acceptable so that restoration must be chosen as a course of action? The figures of the Giuseppe Verdi Monument had suffered significant loss of carved detail due to erosion, particularly in the faces, resulting in a highly disfigured appearance which compromised the function of the monument.

Composite repair in this case is defined as a cementicious material applied directly to the surface of the marble and modeled in situ. Composite restoration was chosen over the dutchman method as the overall erosion did not call for the unit replacement as much as a minimal, localized build-up of the surface. Furthermore, the composite restoration affords a much greater degree of reversibility than the dutchman method which requires preparation of the stone and insertion of pins.

The composite repair material developed here was based upon a traditional 1:1:5 type "N" mortar and modified in the following way for this application:

1. One part white Portland cement, one part lime and five parts marble powder were ground with a mortar and pestle and passed through a sieve stack to achieve a particle size no greater than 250 micrometers. The reduced particle size increases plasticity and adhesion.

2. Fumed silica to a proportion of 25% by volume was added which further reduced the average particle size and rendered the material lighter and increased thixotropy, thus reducing the tendency of the mortar to sag while being modeled on vertical surfaces.

3. A proprietary acrylic emulsion Edison Custom 458 (3% solids in water) was added to the composite mortar to increase plasticity and adhesion.

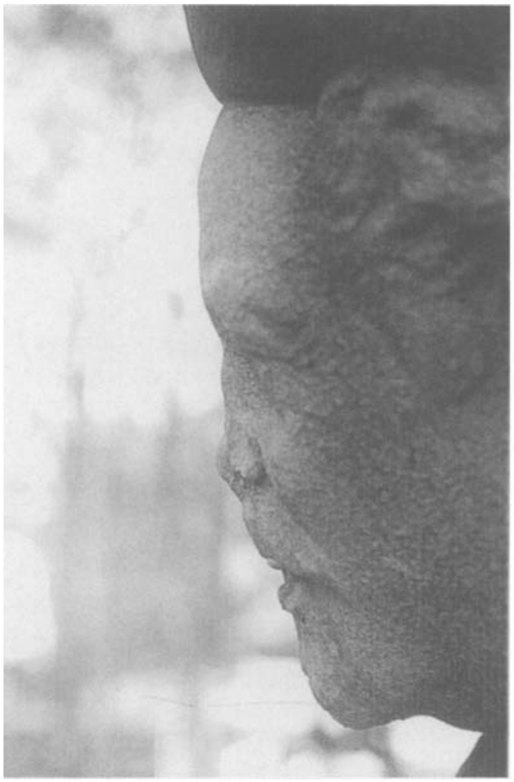


Figure 9. Figure of Falstaff displaying severe erosion.

Figure 10. Figure of Falstaff after Composite repair treatment.

The entirely reversible composite repair succeeded, with only minor intervention, to significantly revitalize the sculpture.

Conclusion

Treatment decisions in the conservation of public monumental sculpture should take into consideration not only the work of art itself, but the community in which the monument resides. The decision to pursue a composite repair of the faces of the Verdi Monument was based upon a thorough discussion of the relevant issues with the curator, the Director of Art and Antiquities for the City of New York. These discussions weighed the physical impact of the treatment on the sculpture against the function of the monument. The primary function of public monuments is to honor the person or group for whom it is erected. A secondary function is to serve as a source of civic pride and a focal point for the community and finally the monument provides esthetic enjoyment (optimally) of its sculptural form. Because of the extremely deteriorated state of the sculpture, there was a consensus that none of these basic functions were being achieved and so restoration in the form of composite repair was pursued.

The Conservation of the Verdi Monument was symbolic of the revival of a neighborhood. Until recently, Verdi Square was known as Needle Park due to the rampant drug trade in the area. Since then, the Upper West Side has experienced a rebirth and the conservation of the Verdi Monument is a strong reflection of that. The conservator is entrusted to find the balance between the ethical guidelines of the profession in the treatment that is best, not only for the sculpture, but for the community to which it belongs.

Acknowledgements

I would like to thank Mark Rabinowitz, for his leadership on this project as well as Vallessa Monk for the contribution of her fine technical abilities. Also, John Griswold for his encouragement to address the ethical issues involved.

Endnotes

1. Anecdotal evidence has it that the term "dutchman" to refer to a unit stone repair, was coined in the 18th century by British craftsmen to describe what they felt was a questionable method of repair rather than replacing the entire block. The term no longer carries a derogatory connotation.

2. Keim Farben GMBH &Co KG. Georg-Odemar-Str. 4-6 D-8902 Neusass b. Augsburg American Distributor: The Cohalan Company #62 Port Lewes, Lewes, DE 19958; 302-644-1007

3. Jahn Mortar Products. Cathedral Stone, 8332 Bristol Court #107, Jessup, Maryland 20774; 202-832-2633.

4. Ciba-Geigy Corporation. Three Skyline Drive Hawthorne, New York 10532 ; 800-431-1900

5. As #4

6. Thanks to Mr. Christopher McGlinchy, Conservation Scientist in the Department of Paintings Conservation at the Metropolitan Museum of Art for providing the use of the fademoter.

7. Sika Corporation, 201 Polito Avenue Lyndhurst, NJ 07071 Tel: 800-933-7452

8. Edison Chemical Systems, Inc. 25 Grant Street, Waterbury, Connecticut 06704; 203-597-9727

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DECIPHERING THE PUZZLE: THE EXAMINATION AND ANALYSIS OF AN EASTERN HAN DYNASTY MONEY TREE

John Steele, Leon Stodulski and Karen Trentelman

1. Introduction

The focus of this paper is a Chinese artifact of the Eastern Han Dynasty identified as a money tree or *yaoqianshu* (Erickson 1994). Money trees are so named by modern scholars because of their most prominent feature: cast bronze branches laden with images of coins. In addition to the coins the branches also contain mythological figures and objects important to Han beliefs.

Currently there are only four known money trees outside of China, one of which the Detroit Institute of Arts (DIA) acquired in 1996. The other trees belong to the Royal Ontario Museum in Toronto, Canada, the Asian Art Museum in San Francisco and a dealer in New York City. In China there are perhaps eighty fragments of trees from excavated tombs but because of the fragility of the bronze branches, only a few trees have survived to an extent that permits reconstruction (Erickson 1994).

The DIA's money tree stands 58 inches (147 cm) high and consists of thirty-four branches, a finial and a trunk which fits into a ceramic base (Figure 1). The branches are very thin and fragile, and upon initial investigation it was apparent that the base and many of the branches had undergone prior restoration. Based on a stylistic analysis of the branches, Laurie Barnes, DIA Associate Curator of Asian Art, suspected that branches from at least five different money trees had been brought together to make this one complete tree.

Acquiring the money tree afforded us the opportunity to thoroughly examine and analyze the component parts of one of these rare objects which, to our knowledge, has not been done before. The purpose of our study was to unravel the complex treatment history as well as the origins of the DIA's tree, and to provide a source of data for comparison to other trees when they are eventually analyzed.

In this paper the context and meaning of money trees will be briefly discussed. The examination and condition of the DIA's money tree will be described and a technical study of two of the bronze branches will be presented.

2. Money Trees: Context and Meaning

Money trees were produced during the Eastern Han Dynasty (about 25 to 220 A.D.) in and around an area that is now the modern province of Sichuan, in the People's Republic of China (Erickson 1994). Money trees were created to be placed in the tombs of wealthy individuals to provide them with an unending source of funds in the afterlife. However, the composition and iconography of money trees, with their ceramic bases and elaborately decorated hanging bronze branches, are thought to also represent the Han dynasty conception of the journey from earth to the heavenly realm and the quest for immortality (Erickson 1994). This journey is described in a Han text as follows:

> He who climbs the Chilly Wind Peak of Kunlun will achieve deathlessness; he who climbs twice as high onto the hanging garden will become a spirit and will be able to make wind and rain; he who climbs twice as high again will reach heaven and become a god. (Liu An, 2nd century A.D.)

The bases of many money trees are often mountain-shaped like the mythical Mount Kunlun. This mountain is important in Han mythology because it is the home of Xiwangmu, the Queen Mother of the West, a major Daoist deity who possessed the elixir of immortality and is said to have ruled the land of immortals from the top Mt. Kunlun. The bases frequently are topped by auspicious animals, such as rams, whose function it is to convey the deceased upward toward heaven (Erickson 1994).

The branches of a money tree can be considered to be a stylized representation of the hanging garden described above. In addition to coins, the most prominent image in the branches is Xiwangmu. She is typically depicted enthroned on her dais and flanked by the dragon of the east and the tiger of the west, symbols of her power over the world. Also found in the branches are images of the makers and partakers of the elixir of immortality, such as toads and Daoist immortals as well as other celebrants in the heavenly realm. The top of a money tree is usually crowned by an elaborate finial incorporating the image of Xiwangmu or an auspicious creature such as the sun bird or phoenix, an omen of world peace (Erickson 1994).

3. The DIA Money Tree: Examination and Condition

The initial examination of the ceramic base and the metal trunk, branches and finial of the DIA's money tree was carried out with the aid of x-radiography, x-ray fluorescence (XRF), and thermoluminescence (TL) dating.

3.1 The Base

The terra cotta base, in the shape of a ram surmounted by a rider, is hollow and covered with an iridescent light green and brown glaze. The base was probably made from two molds, evidenced by the fact that the two halves are out of register (one side of the ram is about 3/4" higher than the other). The base had been broken into approximately twelve pieces and was reassembled in a previous restoration with an unknown adhesive.

Two sites from the interior of the base were sampled for TL dating and the results were consistent with the dates of the Eastern Han Dynasty (25-220 A.D.). Following TL analysis, the glaze was analyzed using XRF and found to contain lead, typical of Eastern Han ceramics.

3.2 The Trunk

The trunk, which fits into a hole in the top of the base, has rings mounted to it at regular intervals along its length. A hook at one end of each branch affords a way to attach the branch to the trunk. An authentic money tree trunk, according to the curator's research, would have been a bronze, oval-shaped tube. The trunk of the DIA's money tree is a solid rod which was shown by XRF analysis to be composed of brass. Therefore, we conclude the trunk is a reproduction.

3.3 The Branches

Money tree branches traditionally would have been cast in a ceramic piece mold using a bronze alloy (Chase 1994). The form of the branches is thought, in part, to have been inspired from the molds for Chinese coins. Coin molds of the period show a branched or channeled construction, with smaller channels radiating from a central one, each channel terminating in a coin (Erickson 1994). The cast from such a mold would have had multiple coins attached to a branched structure, not unlike a simple, unadorned money tree branch.

The thirty-four branches of the DIA's money tree can be divided into two groups according to their size: there are twenty large and fourteen small branches. This study concentrated on the examination and analysis of the large branches. Analysis of the small branches is reserved for a later date.

Initial visual examination of the DIA's money tree indicated that some of the branches are particularly thin casts and that corrosion has made them even thinner and more fragile. In fact, seven of the branches were broken in shipping from the dealer to the DIA because of their fragility. Fortunately, most breaks occurred at the site of old repairs.

Following visual examination, each branch was x-radiographed[1]. The x-radiographs reveal repaired breaks in the branches as well as areas of replacement or repair using materials other than bronze. In many instances, the repairs were very skillfully disguised on the surface and would have been undetectable without x-radiography.

The x-radiographs also aided the stylistic analysis of the branches by revealing surface details that had been obscured by layers of corrosion. The branches were divided into five stylistic groups named according to a characteristic feature within each group. The groups thus named are: "Kneeling Immortals," "Moon Toad," "Blue Queen Mother," "Brown Queen Mother," and

"Cricket." Two branches from each of these five style groups are shown in Figure 2.

3.3.1 "Kneeling Immortals"

The "Kneeling Immortals" group contains four branches which are named for the kneeling figures present along the top of each of the branches. The Immortals, who became so by drinking the elixir of immortality, are characterized by big ears, double top knots and wings or feathered bodies (Erickson 1994). These branches are very thin casts with finely detailed surfaces and are perhaps the most stylistically refined of the five groups. The corrosion layer is relatively thin and compact and ranges from light green to blue in color.

Because of their inherent fragility, these branches had been heavily repaired. All have had sections replaced, which appear in the x-radiographs as brighter, less detailed regions (see Figure 3). Using XRF analysis, the replacement sections were determined to be composed of a lead-tin alloy (approximately 1:1 Pb:Sn). The replacement sections were most likely cast from a mold taken from an existing original section. They were soldered into place and then artificially patinated to match the corrosion on the bronze. Another skilled method of repair observed within this group was the use of metal pins and solder to repair breaks in the branches.

3.3.2 "Moon Toad"

The "Moon Toad" group consists of two branches and is named for the toad figures found on the branches. In Han mythology, the elixir of immortality was stolen by a beautiful woman, Chang'e, who fled to the moon where she was transformed into a toad as punishment for stealing. The branches of the "Moon Toad" group are thin, detailed casts, and along with those of the "Kneeling Immortals" group, are the most stylistically refined of the five groups. The corrosion layer is dark green, glassy, and compact in appearance. The branches are fragile and contain numerous repairs: metal pins to repair breaks in both branches and replacement sections of lead-tin alloy on one of the branches. In addition, the hooked ends of the branches, which originally would have been cast integrally as part of the branch, have been skillfully replaced with copper. The new hooks were installed with small tongues of copper extending from the tip into the center of the bronze stem, as shown in the x-radiograph in Figure 4.

3.3.3 "Blue Queen Mother"

The "Blue Queen Mother" group consists of six branches and is named for the heavy layer of blue/green corrosion present on the branches and the figure of the Queen Mother of the West at the top of each branch. These branches are thicker and less refined casts than those in the other style groups, and four of the branches have small sections replaced with lead-tin alloy. In general, there are fewer repairs here compared to the other groups. However, as seen in the "Moon Toad" group, the hooked ends of four of the branches have been replaced with copper or brass.

3.3.4 "Brown Queen Mother"

The "Brown Queen Mother" group consists of four branches and, again, is named for the color of the branches and the presence of the Queen Mother of the West at the top of each branch. All four branches are thin, fragile casts and have a very thin, brown corrosion layer on the surface. However, XRF analysis revealed that two of the branches are a brass alloy and therefore probably are copies. The two bronze branches show numerous repairs while the brass ones show very few. The repair materials found on the two bronze branches include lead-tin solder, grey putty, and clear resin. Also of note in this group is the absence of lead-tin alloy replacement sections on any of the four branches.

3.3.5 "Cricket"

The last style group, the "Cricket" group, consists of two branches and is named for the small insect found on the outer edge of the branches. In the *Shijing* (the *Classic of Poetry* compiled by Confucius in 551-479 B.C.), the migration of the cricket to areas of warmth are described. The cricket on the money tree represents the journey from the chilly peak below to the warmer celestial garden above. These branches are thin casts and are more stylistically refined than both the blue and brown "Queen Mother" groups, but not as refined and detailed as the "Kneeling Immortals" or "Moon Toad" group. Replacement sections of lead-tin alloy were found on one of the two branches, and both have numerous breaks repaired with lead-tin solder and pigmented resins.

3.3.6 The Finial

The tree is topped by a finial depicting Xiwangmu, Queen Mother of the West. The authenticity of the finial was initially in doubt. Finials from excavated trees have a metal pin or dowel at the bottom which slides inside the hollow oval tube which forms the trunk. The finial from the DIA's money tree has a cap on the bottom which fits over (not inside) the solid (not hollow) tip of the brass trunk, known to be a replacement (see Section 3.2). Additionally, the finial from the DIA's money tree very closely resembles a finial from the archaeological site Hejiashan, Mianyan, Sichuan (*Wenwu* 1991), even to the extent that the same losses are present in both finials. XRF analysis confirmed that the DIA finial is made of a lead-tin alloy and thus is most certainly a copy of the excavated finial.

3.4 The DIA Money Tree: Conclusions from Examination

The examination and study of the DIA money tree confirmed that its ceramic base is of an age consistent with the Han dynasty (25-220 A.D.). The variety of repair methods and materials on the branches show that numerous restoration efforts have taken place. Branches in four of the groups show replacement sections made of a lead-tin alloy while most of the hooked ends of the branches have been replaced with copper or brass. The two most stylistically refined groups, the "Kneeling Immortals" and the "Moon Toad", have more extensive repairs using techniques requiring greater skill, such as the use of metal pins to repair breaks. All of the groups have sometraces of pigmented resins or putty on them indicating recent restoration efforts using modern repair materials. Finally, the finial, the trunk, and the two brass leaves were reproduced in order to complete the tree. Establishing a chronology of the repairs would help in determining when the various branches were brought together; further study and analysis of the repair materials is ongoing.

4. Technical Study of Two Bronze Branches

The main questions addressed in the technical study of the branches of the DIA's money tree were:

a) what is the composition of the alloy in which the branches were cast?

b) what corrosion processes have the branches undergone?

c) is there any correlation between alloy composition, corrosion processes and style grouping?

Although branches from all five stylistic groups were studied, the analytical results from only two branches from the DIA's money tree will be discussed here: a branch with a matte, green patina from the "Kneeling Immortals" style group will be compared to a branch with a glassy, brown patina from the "Cricket" group. The composition of the original alloys, the thickness, composition and nature of the corrosion layers and the resulting colors and surface appearances of these two branches are discussed.

4.1 Experimental

To determine the composition of the bronze alloy and the nature and depth of the corrosion layers, small pieces of the branches were removed for the preparation of cross-sections. The tiny pieces (approximately 1-2 mm across and 3-4 mm long) were removed using a jewelers saw fitted with a 000 blade. The samples were embedded in a cold-setting polyester resin (Bio-Plastic, Ward's Scientific), and were sectioned using an ultramicrotome (LKB Ultramicrotome III Model

8801A) fitted with a glass knife. In order to avoid introducing any foreign substances which might influence the subsequent elemental analysis, no polishing or chemical etching of the sections was performed.

The sections were coated with a thin layer of elemental carbon for examination under a scanning electron microscope (SEM). All SEM images were obtained using a CamScan Series 4 SEM (LaB_6 emitter operated at 20 kV) equipped with a Noran Voyager 4 energy dispersive spectrometer (Pioneer detector with Norvar window) for elemental analysis. The SEM images presented in this paper are backscatter electron images (BEI), in which the intensity is proportional to the average atomic number of an area (e.g. heavy elements such as lead will appear white while low average atomic number compounds, such as the carbon-based polymers of the mounting resin, will appear black).

4.2 Results and Discussion

4.2.1 Section from "Kneeling Immortals" Branch

The visible reflected-light photomicrograph of the cross-section from the "Kneeling Immortals" branch (Figure 5, top) shows three distinct regions of interest: KI-1, a core of uncorroded alloy surrounded by KI-2, a pale green corrosion layer with a few red inclusions (unfortunately not visible in this black and white photograph), on top of which lies KI-3, a fragmentary layer of darker green material. The light and dark bands visible within region KI-2 are not additional layers but are artifacts produced by light scattered off the rough surface in this region. The backscatter electron image (BEI) in figure 5 (bottom) clearly shows that there are only three regions present in this section. The BEI is not affected by surface roughness, and therefore provides a better means of judging the uniformity and width of region KI-2 than the visible reflected-light photomicrograph.

Elemental analysis by energy dispersive spectroscopy (EDS) of the uncorroded metallic core (KI-1) yielded an average overall composition[2] of 72% Cu, 16% Sn and 10% Pb. SEM and EDS analysis of the microstructure evident in this region revealed the as-cast structure of the alloy: dendrites of α phase Cu-Sn alloy (the first phase to solidify upon cooling, which can contain up to 15.8% Sn) surrounded by $\alpha\delta$ eutectoid (an intimate mixture of α and the more Sn-rich δ phase ($Cu_{31}Sn_8$) which can contain between 15.8 and 32.6% Sn) (Hanson and Pell-Walpole 1951). That portion of the lead which does not form a solid solution with the Cu and Sn is the last component to solidify after casting, and segregates into globules which become trapped in the $\alpha\delta$ eutectoid regions; these globules are visible as white spots in region KI-1 in the BEI image.

In the pale green corrosion layer (KI-2), the as-cast phase structure of the Cu-Sn alloy is still evident, but the α and $\alpha\delta$ phases (and the Pb globules) have undergone corrosion. Close inspection of the boundary between the uncorroded metallic core and the first corrosion layer

(KI-2) indicates that the Cu- rich α phase undergoes corrosion before the Sn-rich $\alpha\delta$ eutectoid. Elemental analysis of this layer reveals it is depleted in Cu and enriched in Sn relative to the metallic core, with O and C also present, supporting the observation of preferential corrosion of the Cu-rich α phase. The visual appearance of the red inclusions within this layer suggest they might be cuprite, Cu_2O; this identification was confirmed by energy dispersive spectroscopy (EDS). The inclusions of cuprite appear to have formed within the spaces originally occupied by the globules of unalloyed lead. The lead, which undergoes oxidation, migrates to the surface where it may remain as a layer of oxide or carbonate or spall off.

Elemental analysis of the topmost darker green corrosion layer (KI-3) indicates that only Cu, O and C are present. A small sample of this layer was removed and isolated, and was identified by x-ray diffraction (XRD) as the basic copper (II) carbonate, malachite ($CuCO_3 \cdot Cu(OH)_2$). The characteristic habit of malachite, forming in tufts of long prismatic or needle-like crystals (Palache et al. 1951) can easily be seen in the magnified view of this region shown in Figure 5. The presence of a malachite layer suggests that the original surface of the branch lies directly under this layer, that is, at the boundary between regions KI-2 and KI-3. The pale green corrosion layer (KI-2) appears to have progressed from the original surface towards the interior of the bronze with the corrosion of the α and $\alpha\delta$ phase regions as described above, while malachite grew outwards from that surface.

A corrosion mechanism which is consistent with these observations is as follows: preferential corrosion of the Cu-rich α phase and migration of Cu ions to the surface (where they combine with CO_2 to form malachite) leaving behind the Sn-rich $\alpha\delta$ eutectoid which subsequently oxidizes to SnO_2. Although pure SnO_2 is white, it is easily stained by metal ions (Gettens 1969); Cu ions present in the first corrosion layer (KI-2) may thus account for the pale green coloration of this layer. The corrosion of the lead globules can be treated as a separate but parallel process: lead is oxidized and migrates towards the surface. Eventually, the spaces originally occupied by globules of lead are filled with cuprite (which may undergo further corrosion to form copper carbonates).

4.2.2 Section from "Cricket" Branch

The visible, reflected-light photomicrograph of the cross-section from the "Cricket" branch (Figure 6, top) reveals three general regions of interest: C-1, an uncorroded metallic core, surrounded by C-2, a blue-gray corrosion layer, on top of which lies C-3, a golden tan corrosion layer. Interestingly, the two colored corrosion layers C-2 and C-3 are not evident in the BEI shown in Figure 6 (bottom); only a single corrosion layer is evident. Since backscatter electron images indicate average atomic number, this suggests that the blue-grey and golden tan materials have similar average atomic numbers.

Elemental analysis of the uncorroded metallic core (C-1) by EDS yielded an overall average composition of 75% Cu, 17% Sn and 8% Pb, similar to that found in the section from the

"Kneeling Immortals" branch. Not surprisingly, a similar as-cast microstructure was also observed: dendrites of α phase Cu-Sn alloy surrounded by αδ eutectoid with globules of unalloyed lead in the αδ eutectoid regions. However, the dendritic structure is larger and more defined in this section than that from the "Kneeling Immortals" branch, suggesting that this branch cooled more slowly after casting. The inset in Figure 6 (bottom) shows a magnified portion of the cross section: a dendrite of uncorroded α phase is visible as a line of dark gray spots.

As with the section from the "Kneeling Immortals" branch, the as-cast phase structure of the Cu-Sn alloy is still evident in the corrosion layers. The magnified inset in Figure 6 (bottom) shows the leading edge of the corrosion. Dendrites of corroded α (black in the BEI) are surrounded by uncorroded αδ eutectoid. Therefore, as before, corrosion apparently occurs initially in the α phase and subsequently proceeds to the αδ phase. Elemental analysis reveals that the corrosion layer(s) are depleted in Cu and enriched in Sn relative to the uncorroded core, with O and C also present in significant amounts, exactly analogous to the results from the section from the "Kneeling Immortals" branch. However, elemental mapping shows Fe is present in the outermost 1/3 of the corrosion layers: this corresponds to the thickness of the golden tan layer at the surface. Since there is no iron present in the metallic core, we must assume that the iron has penetrated *into* the corrosion layer from the outside.

Therefore, we propose a slightly different corrosion process for this branch: as before, preferential corrosion of the Cu-rich α phase and migration of Cu ions to the surface created a Sn rich corrosion region which eventually was oxidized to SnO_2. However, in this branch the Cu ions did not form malachite at the surface, but rather were "washed" away by the surrounding matrix of water/earth. However, some Cu ions remained and stained the SnO_2 producing the blue-gray color observed for C-2. Either subsequently or simultaneously, Fe ions from the surrounding matrix migrated into the porous corrosion layer, staining the SnO_2 brown creating the golden tan layer, C-3. The corrosion of the lead globules appears to proceed by a similar mechanism as the previous section: lead oxides are subsequently displaced by copper oxides and carbonates.

4.3 Conclusions from Analytical Study

In this study, the examination of branches from two different stylistic groups have been shown to have a similar alloy composition with approximately 15-20% Sn and 10% Pb. This relatively high amount of Sn would produce an alloy which melted easily and the large amount of Pb would facilitate the flow of the molten metal into the narrow and intricate forms of the branches. The resulting cast would be relatively brittle (Reeve *et al.* 1953), but this would not be of particular concern in a non-utilitarian piece such as a money tree. The high Sn content would also increase the corrosion resistance of the bronze. Compositions and corrosion processes similar to what we have found here been documented for other ancient Chinese bronze ritual vessels (Barnard 1961; Chase 1994; Gettens 1969). The corrosion processes we have proposed are based on the theories of Robbiola (1990) regarding the migration of ions during corrosion. These mechanisms are consistent with our observations and can account for the differences in the surfaces on the two branches discussed here. Unfortunately, no published analyses of money tree branches are available for comparison.

Although the two branches investigated here belong to different stylistic groups, they have comparable alloy compositions. Thus, the environment under which they corroded must have been different, as evidenced by the formation of an outer layer of malachite on the branch from the "Kneeling Immortals" group and the lack of this layer on the branch from the "Cricket" group, which instead shows an influx of iron into the corrosion layer. This suggests that the branch from the "Kneeling Immortals" group was most likely in a relatively dry and aerated environment while the branch from the "Cricket" group was exposed to a wetter environment for at least some period of time (Schweizer 1994).

5. Summary

The examination and analysis of a complex object such as the DIA's money tree necessarily must draw upon many different fields in order to develop a complete picture of the history and composition of the object. In this study we have used numerous techniques ranging from stylistic and historical analysis of the object as a whole to scanning electron microscopic investigations of the most minute details.

Our results have confirmed that the ceramic base is of an age consistent with the Eastern Han Dynasty. The bronze composition as well as the nature and extent of the corrosion seen on the branches is also consistent with the currently available data on ancient Chinese bronzes. In the two branches discussed in detail here, we appear to have examples of the products of two different corrosion environments, wet versus dry, on bronzes with similar composition. Additionally, the variety of repair materials found throughout the object contains clues to the repair history of the individual pieces. Technical, iconographic and historical analyses of branches from all five style groups, the base, trunk and finial is continuing and we hope that the combined results will enable us to develop a better understanding of the manufacture, corrosion, prior repair and chronology of assembly of the component pieces of this money tree.

Acknowledgements

We would like to thank Ray Lints and Dr. Chongmin Kim, of General Motors Research and Development Center, Metallurgy Department, for the use of the CamScan 4 SEM and many helpful discussions regarding the metallurgy and corrosion of bronzes. We would also like to thank Laurie Barnes, Associate Curator of Asian Art, DIA, and Susan Erickson, Department of Art History, University of Michigan, Dearborn, for their stylistic and iconographic analysis of the money tree. Finally, we would like to thank, Paul Cooney, technical photographer, DIA, for x-radiography and photography and Carol Forsythe, senior objects conservator, DIA, for helpful discussions.

Endnotes

1. The x-radiographs were done at 70kV and 5 mA.

2. Compositions are calculated from the x-ray emission peak intensities using a standardless analysis. The percentages are constrained to total 100% for all elements used in the calculation (trace amounts of Si and O were often detected, thus the percentages of Cu, Sn and Pb may not sum to 100%). Using known bronze standards, we determined that the error associated with these calculations is 5% or less.

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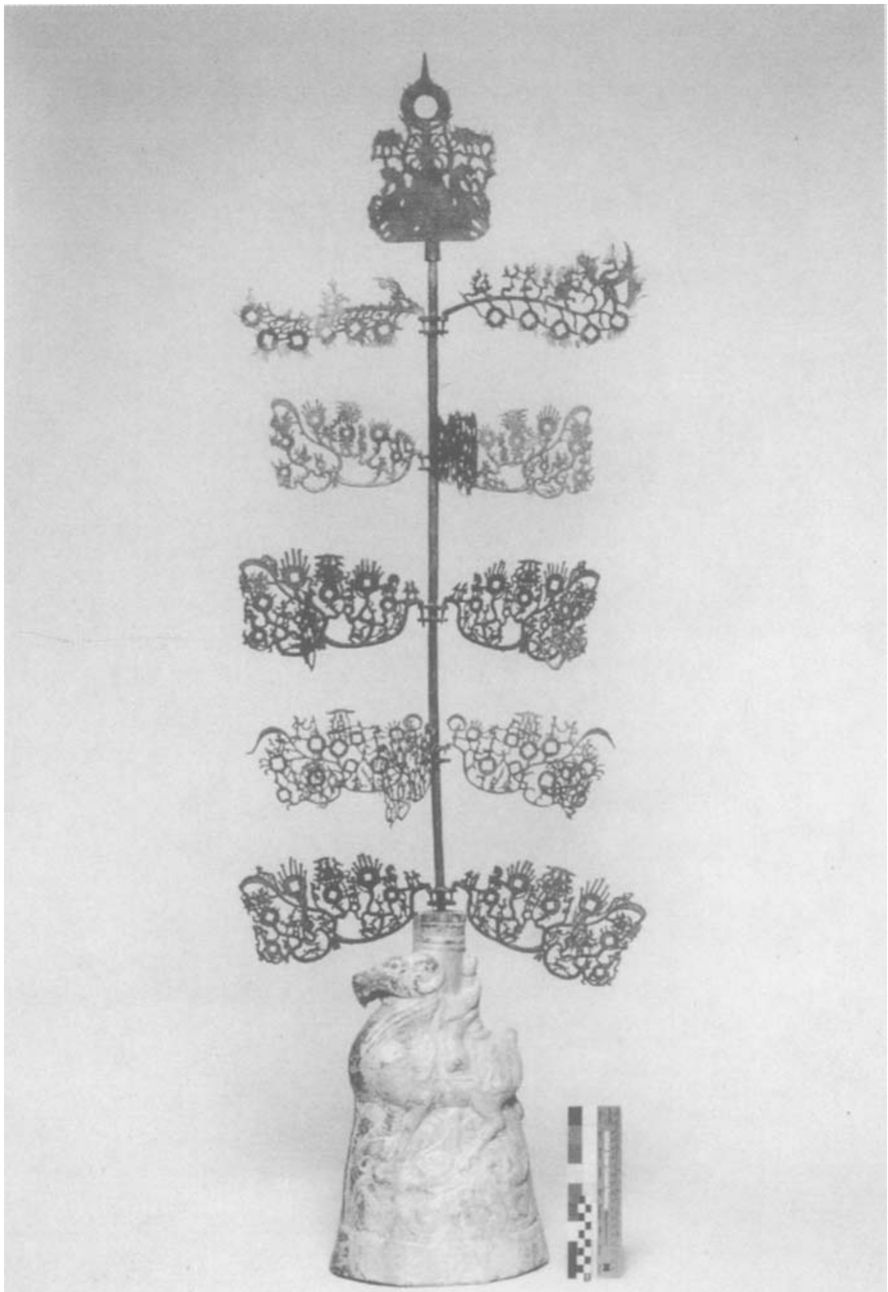

Figure 1. The Detroit Institute of Arts Money Tree, DIA 1996.29, partially assembled for photography.

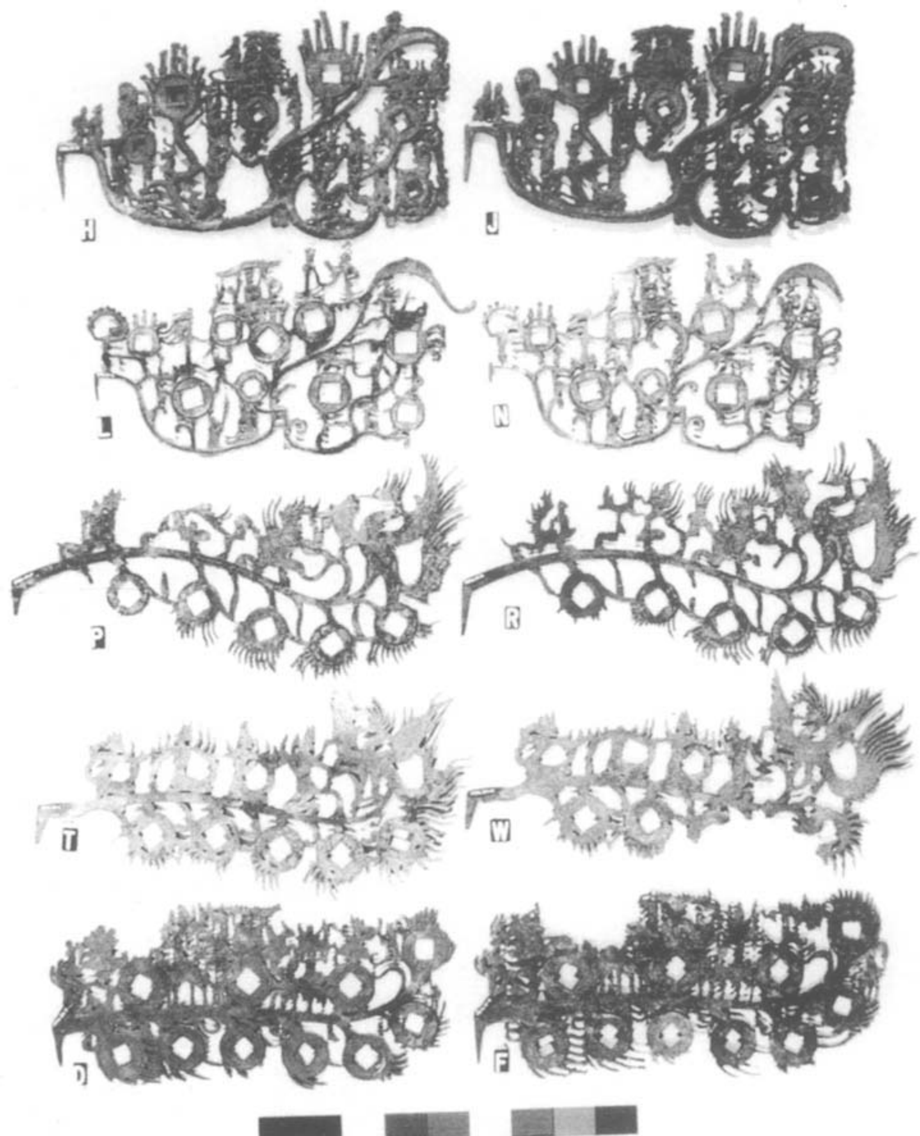

Figure 2. Two branches from each of the five style groups (from top to bottom): "Blue Queen Mother," "Brown Queen Mother," "Moon Toad," "Kneeling Immortals" and "Cricket."

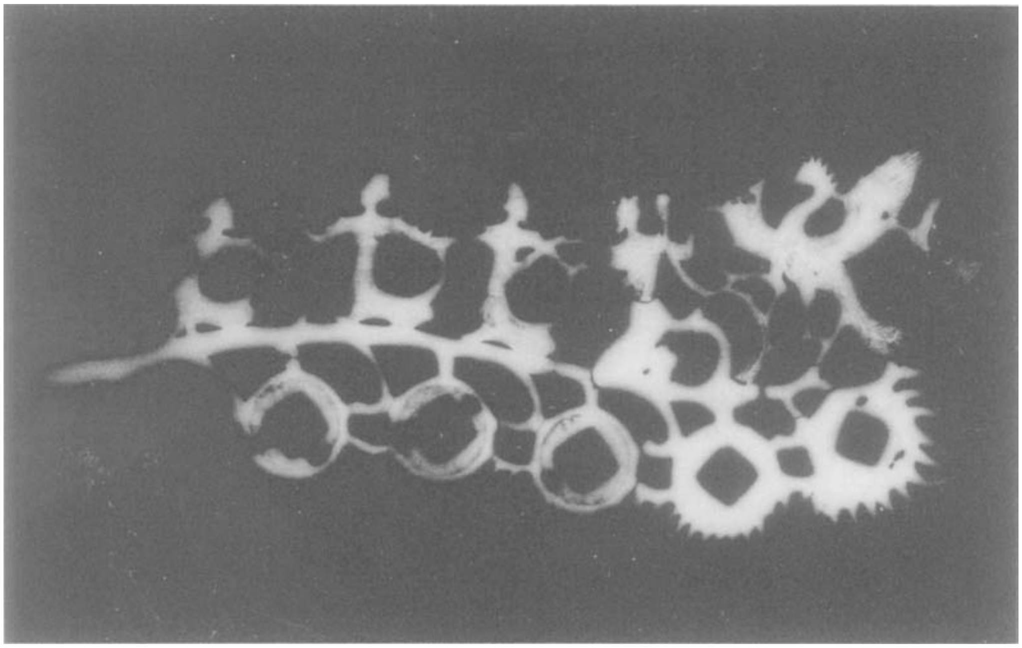

Figure 3. X-radiograph of a branch from the "Kneeling Immortals" group showing a replacement section (in bright white) of lead-tin alloy in the lower right end of the branch.

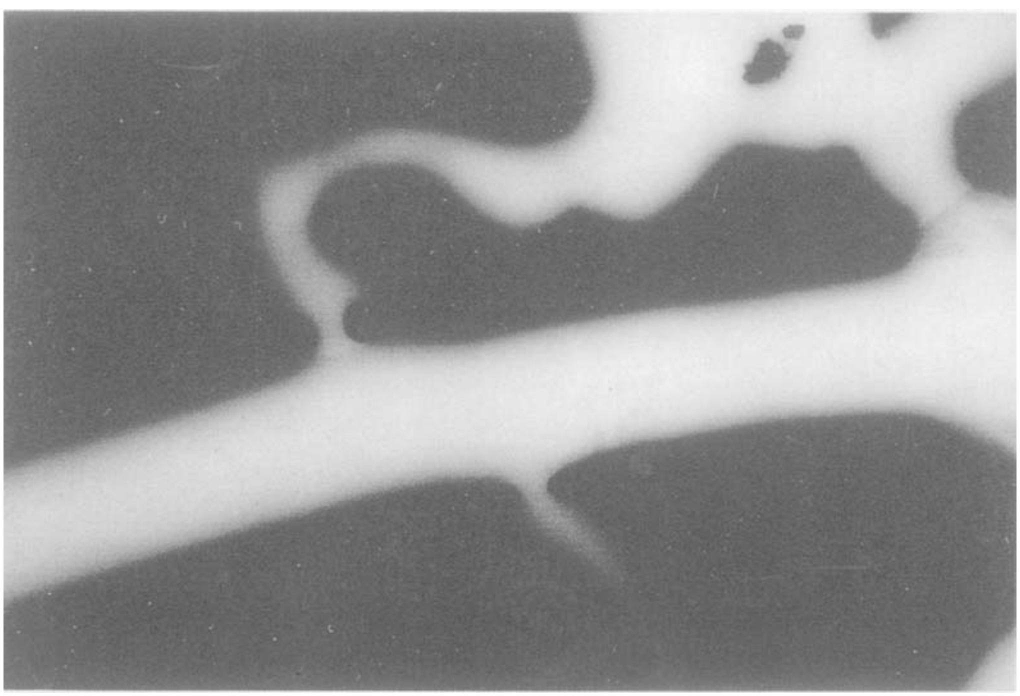

Figure 4. Close-up of an x-radiograph of a branch from the "Moon Toad" group showing the join between the copper hook on the left (a replacement) and the bronze branch on the right.

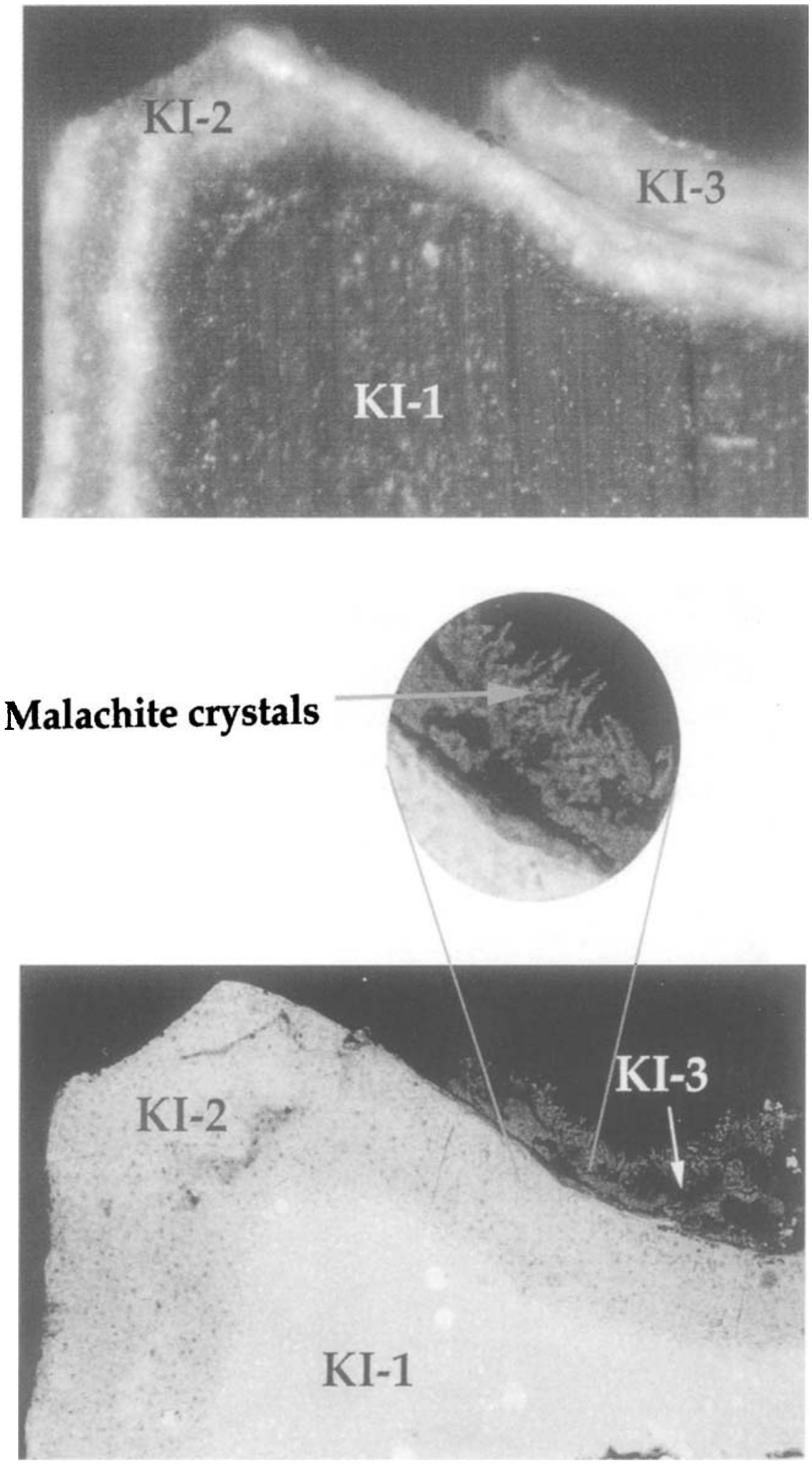

Figure 5. Section from the "Kneeling Immortals" branch. Top: visible reflected light photomicrograph. Bottom: backscatter electron image; a region of the outer layer of malachite is magnified to show the crystal habit.

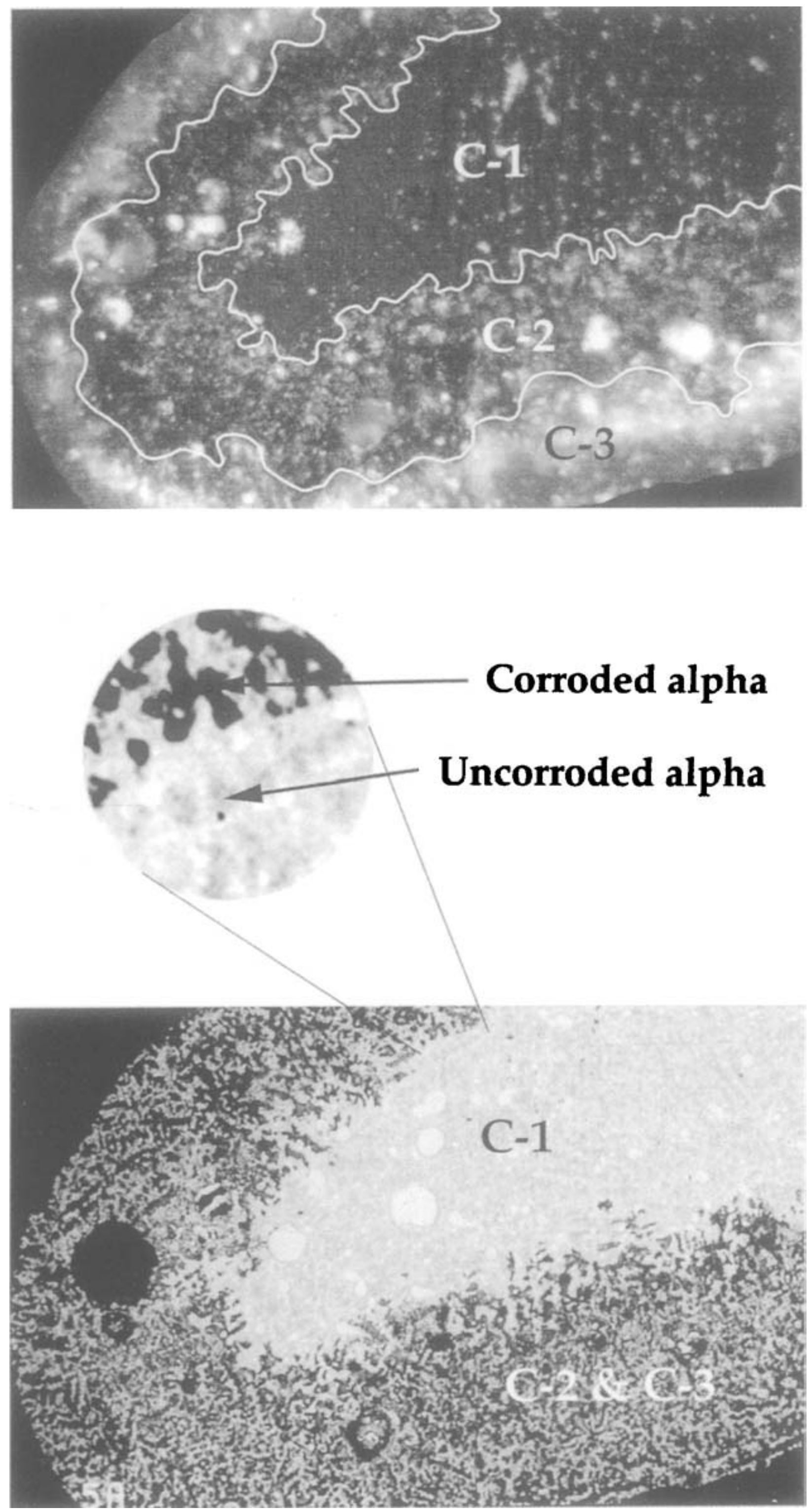

Figure 6. Section from the "Cricket" branch. Top: visible reflected light photomicrograph. Bottom: backscatter electron image; a portion of the figure has been magnified to show the edge of the corrosion layer.

NO OBJECT IS FROZEN IN TIME: REVISITING TRADITIONAL AND NONTRADITIONAL LEATHER TREATMENTS AS A COLLABORATIVE EFFORT

Alexandra Allardt O'Donnell

Abstract

Examination and treatment of leather artifacts is the subject of debate when the wide degree of variability in the nature of animal skins is overlaid with how the leather has been prepared and its subsequent defined function or method of appreciation as an object. As this durable material ages and is exposed to use and display, maintenance and repair become part of its history adding another level of intricacy. With time a web is spun that often adds numerous layers of materials and techniques (known and unknown) to the current interpretation of how and when to treat the material in its present state.

The past decade has brought greater understanding of how some of these factors work independently and react with one another. With the advance of analytical techniques, the effects of a number of traditional and non-traditional treatments can be more accurately understood. This presentation briefly presents a historical review of a range of treatments and concerns. It emphasizes the importance for detailed documentation and continuing assessment of prior treatments, as well as the need to foster collaborative forward looking efforts.

Introduction

Leather is a versatile material that has piqued man's interest through the ages. As methods of skin preparation were expanded from simple scraping and chewing techniques to include means of oiling and stuffing the fibers, to further include a variety of more sophisticated chemical tanning processes, the use of animal hides spread widely though human cultures.

Animal hides are a versatile and important material in the development of cultures. In Europe the processing of hides into leather and the subsequent manufacture of objects from leather became important crafts by the time of the Middle Ages. With the advent of political stability, the formation of merchant and craft guilds fostered social and economic changes. In an effort to limit competition and protect their market, the craft guilds established strict admission requirements and stringent rules on prices, wages, standards of quality, and operating procedures. Like other craft guilds, the processing of leather and manufacture of leather items were dictated by guild procedures. Instruction and experience were handed down through an apprenticeship format. In the United States, this European apprenticeship training format in modified form continued up through the period of the Industrial Revolution. Even today one can still see a type of apprenticeship in small rural industries and living historic museum sites where shoemakers and saddle makers continue their crafts in the hand sewn traditions.

Historically paralleling European guild traditions are the leathercraft traditions of Native Americans. Although the end product of hide into leather is similar, the means to this end by Native Americans differ greatly. These skin preparation methods were passed through oral traditions and not established through a controlled set of procedures. Rather than the European vegetable and alum tanning methods, the tanning procedures of native Americans generally embraced a broad category of oil and smoke tanning techniques. Not confined by rigid procedures, methodology varies by tribal association and geography. The leathercraft techniques and materials differ so widely from a European perspective that they can for convenience be called "non-traditional."

Whether the methodology focused on traditional or non-traditional techniques, an understanding of tanning in its many different forms could make this material strong or weak, flexible, rigid or moldable, water resistant, and wonderfully durable. Human resourcefulness readily incorporated these physical characteristics into improving mans existence. Regardless of where in the world they originated, the range of leathers and their functions are vast.

As with all items made for enjoyment or consumption, with time leather objects became worn, damaged or in need of restyling. When justified, damaged pieces were simply replaced. When total replacements were not required and methods of repair more appropriate, patching was achieved with skived leather, or in more recent times cloth. Means of attachment varied widely. Commonly observed are hand stitching or gluing with a hide-type adhesive or a resinous bitumen–like adhesive that hardened and smoothed the reverse flesh side. These methods allowed for making strong repairs and worked with an understanding of the physical compatibility of these materials. Pragmatic approaches to repair and treatment of leather objects continue to work well for objects that are outside the restrictions imposed on the treatment of museum collections.

However, once incorporated into the museum environment a new set of questions is imposed on the treatment of these pieces. As the object is often no longer required to have a durable or applied function, the approach to treatment is viewed in a different light. Increasing the life expectancy of the leather, not durability, becomes the dominant focus. Among a long list of dictates both formally through our Code of Ethics and informally between ourselves, conservators query reversibility, longevity and stability of the treatment methods and materials. Practitioners also debate the appropriate means to impose minimal intervention as a treatment course of action. We concern ourselves with the historical and cultural integrity of the repairs and how we as interlopers can skew interpretation of the artist's intent. These questions, among others, have caused in the past, and continue to cause, discussion, exchange and experimentation. I offer this selective review of leather treatments in an effort to prompt a retrospection and discussion among ourselves and to reinforce the need for detailed documentation, collaborative assessment and progressive thinking.

Treatment of the Ghent Treaty Box

In reflecting on the examination and treatment of leather objects, revisiting a leather project I undertook twenty five years ago seemed appropriate. The treatment of the Ghent Treaty Box was a novel treatment at the time. Belonging to the American Institute of Architects, the smalldomed box has a long history of display at the Octagon House in Washington, D. C. I choose this as an example because it represents an approach to treatment reflective of the procedures, knowledge and ways of thinking of that fledgling period of our profession. The treatment involved the most contemporary of materials and resulted from a compilation and study of our then existing knowledge of the deterioration of vegetable tanned leather. It also is reflective of our fascination with synthetic resins and how we hoped their potential suggested the ultimate answers. Different approaches to strengthening weakened and brittle leathers were being devised. Consolidation with methacrylate resins and vinyl acetates and epoxies were sources of studies. The use of these materials in this treatment fostered discussion, experimentation and collaboration then as, I hope, it does now.

In 1973 initial examination notes on this small leather covered box detailed the condition of the leather surface as being extensively cupped and brittle. Most exposed edges were powdery. The leather was very fragile and dry. Extensive damage had been caused by beetles which had tunneled along the sizing layer between the leather and wood, leaving little to support an exterior grain layer but pockets of air or at best frass residues. Numerous areas of loss to the leather were also noted throughout the four sides and domed top. A number of surface pH tests indicated ranges in the 4.1 to 4.7 range.

Treatment involved brushed and injected applications of a diluted Pliantex, an ethyl vinyl acetate. The surface was repeatedly coated. Subsequently additional injections of a more viscous solution of Pliantex were forced under the surface skin to bulk up and support the thinned areas. As the treatment report relays, "In this manner the broken leather fibers were saturated and flexibly encased, the wood strengthened and filled and the vermin frass consolidated forming a base for immediate support for the leather and insuring against further infestation from the existing eggs and larvae" (O'Donnell, 1973). After a prolonged period of drying, the impregnated cupped leather surface was relaxed and set down using local application of heat "to return it to an optimum plane" (O'Donnell, 1973). The treatment at completion was visually smooth and intact. The issue of fills for areas of losses was discussed. "Out of respect for the original materials because of its historic importance, and in hope not to falsify or create an incorrect aesthetic appearance, only two areas of major loss were filled in the leather with a putty mixture of the resin and pigment. They were given a unifying tone but left detectable upon close examination but diminishing the disturbing contrasts" (O'Donnell, 1973). Notes from several telephone conversations show that the preference of the owner was to leave them void except for the two largest losses which were to be toned but not made invisible. A gloss was desired for the finish.

When the treatment was completed, the leather covered box was returned to its owner and placed prominently on display on a table in the center of the room. During the next few years a number of my classmates and my professor, Sheldon Keck, offered when in Washington to make side trips to view the box and report back to me. With a sense of sadness they observed that in an unregulated environment which at times included direct sunlight from a series of bay windows, the leather surface returned to its pre treatment cupped condition within a few years.

In the past decade in conjunction with a long term project to renovate the museum house, the box was taken off display and placed in storage. It has not been available for examination. In speaking with the collection manager, Sherry Berg, the box has been placed on a high treatment priority list as they would like it returned to display as a focal interpretation element of the house. The issue of treatment need is centered on correcting the cupping of the leather surface. Other than the surface cupping no other markers of deterioration were noted by the collection manager. Interest was also expressed in compensating areas of loss that had been left uncompensated and reducing the high surface sheen.

Re reading the treatment file gave me an opportunity to rethink how I might approach this now and what might I learn from this exercise. While this particularly fragile and powdery leather surface at the time of initial examination seemed to call for a radical treatment approach, I will share that it never occurred to me not to treat this piece. Nor did I earnestly consider taking a minimally invasive treatment approach. The assumption after physical and microscopic examination was that the leather was too damaged from the ravages of "red rot" and was too dry, brittle, and insecure to merit a more traditional treatment of potassium lactate buffer and an oil based dressing. My focus, which I believe to be reflective of the profession at that time, leaned towards the aggressive treatment of symptoms of damage and insecurity, and the potential to formulate an acceptable solution that met the professional criteria of reversibility and object treatment sensitivity. Discussions with classmates, professors and more experienced colleagues, and exchanges with the Central Research Laboratory of Objects of Art and Science in Amsterdam led me to explore impregnations with a variety of resins, the samples of which I still retain along with my notes, correspondence, and treatment report. What I now appreciate more clearly is that no object can be frozen in time. With twenty five years behind us, the leather covered box will present an interesting discussion when it begins a second generation examination. This prior treatment has added a twist to the future treatment as now this object is not simply a leather covered box. It is leather that has been embedded in a synthetic resin.

A revisit to the treatment notes, display observations and the past twenty years history of the object also underscores the need for the environment into which it would be returned to have its own set of limitations. Although correspondence shows that I inquired about display conditions, it was focused on whether the box would be opened or closed. The inquiries were concerned with the aesthetics and physical security of the piece on display. The inclusion of recommendations for the storage and display environment would have further insured the stability of the treatment and the object. This holistic approach to treatment was not more thoroughly embraced until the 80's. The current condition of this particular project is partially the result of those missing elements.

Since my initial plunge into leather conservation, we have learned more about the properties of leather and the effects of ambient conditions on the different tanning solutions. Conservators have gained a better understanding of the material and the processes of deterioration. A generation ago, we were basing our judgements on touch, feel, and visual interpretations of condition. We used our tactile experience and the intuition gained from working with leather as a material. In reality we did not have a clear quantitative or qualitative evaluation of how far the red rot had progressed, what the dressing needs were, or how moisture deprived the leather was. We worked blindly from an analytical standpoint. Over the years, as conservators built upon insights and support from our conservation scientists, we also realized that the more we know, the less we knew in relation to the whole. As more questions were formulated, more questions needed to beanswered. Publication and advances in research at the Leather Conservation Centre in England and the Instituut Collectie Nederland in Amsterdam have spearheaded much needed research and fostered cooperative efforts around the world. As part of this evolution we continue to need to debate, analyze and explore additional plausible methods and examine our past treatments for their success and markers of deterioration.

Dressings Review

It is simple to reiterate how hindsight is always 20/20, but it is interesting to look back to see from where we have come and how it has helped us where we are now. Prior treatments on museum objects have led to a better understanding of the dressings and how they affect the leather themselves. A brief survey of leather dressings may yield another perspective to consider. My own treatment of the Treaty Box precluded a dressing on the unqualified assumption that the leather was beyond a level of deterioration that a dressing would help. Now I would more accurately characterize the condition of the leather.

The need to "feed" and clean leather is a maintenance task that has persisted without necessarily a clearly identified purpose until recently. It comes perhaps from the traditional maintenance procedures of heavily used equestrian leather such as bridles and saddles, where the need to remove sweat, dirt, and body oils is important in order to maintain the physical flexibility (slippage of leather fibers over each other) and durability (removal of embedded particulates) of these objects as well as adding a protective surface layer against physical abrasion over the exterior grain layer.

This traditional maintenance process has been translated into the need to maintain many leather objects with dressings. Numerous dressing recipes are published in literature. Commonly, combinations of lanolin, neatsfoot oil, fish oils, and waxes were utilized in the past century on vegetable tanned leathers. During the past generation we broadened our palette of materials. Synthetic waxes and oils, including different weight water soluble waxes and synthetic oils were the sources for experimentation especially on native tanned leathers. I surmise that applicators like myself were seduced by the short term humectant quality of the synthetic coatings. Information about potential cross-linking factors did not come to light for another decade after these treatments.

Once a dressing was selected, the question of how much dressing to apply remained a variable. How much a leather piece could or should absorb was a gray area. With time we could observe the effects of overdressing as surfaces remained tacky or sometimes the leather itself appeared to become weaker rather than stronger. In some cases, a disfiguring white surface bloom resulted from overdressing. Without analysis these fatty acid deposits were sometimes mistaken for mold rather than the markers of deterioration they are.

Besides the disfiguring visual affects of a hazy bloom accumulating on a surface, the long term contact with excess oil can affect the physical stability of the leather itself as well as any decorative paint layers that might have been added over the leather substrate. Exposure to oxidizing acidic oils slowly softens paint layers making them more easily affected by future mechanical and solvent action undertaken by caretakers. The excess applications also create a barrier layer on the surface as they oxidize. Oxidation causes a hardening of surface accumulations causing them to further inhibit future dressing applications from penetrating through to the backside. The failure of the dressing to penetrate in effect starves the leather from the secondary humectant benefit of some oils. As a consequence the leather appears physically dry and feels brittle.

To further complicate the potential diagnosis, these symptoms of dryness and embrittlement are conditions that can also describe a chemical deterioration of the fibers themselves, in what is more commonly known as red rot. We are now aware that visual and tactile examinations need further supporting information in order to more accurately determine the cause of this symptom. An accurately targeted diagnosis of the condition is especially important as each rationale suggests a different approach to treatment.

What we did not understand with clarity was the effect these oils might have on pH if left alone in a static setting. A clearer understanding of the pH and its chemical relationship to the hide is published information (Wouter, 1992; Calnan and Haines, 1991). The fatty acids that have saponified on the surface from residual oxidizing oils and soaps are markers of deterioration and poor environmental conditions. In addition to the acidic oxidation process there is the more potentially damaging effects of acid hydrolysis. The absorption of airborne acidic pollutants by vegetable tanned leather in a humid ambient environment can set into motion the chemical deterioration processes of acidic hydrolysis when no buffering agent is present to mitigate the pH changes. A prolonged exposure causes a slow irreversible breakdown to the leather fibers themselves. These processes are hastened with temperature increases and when the leather is moisture deprived (Whitmore and Farrel, 1987).

In my own experience in the past 15 years with European gilded and painted leather wall hangings, the recommended dressing proportions continue to be refined. Conservators havegained over the years an appreciation of analytical documentation to reveal more objective information on the state of deterioration. Analysis is undertaken to document the extractable fat content which allows for a calculated application of a specific amount of dressing at a specific percentage to bring the fat up to a desired content. Ten years ago I aimed for a 5% total content. Currently, 3% total content is my desirable goal so as not to soften the paint layers or to hasten acidic oxidation but to provide enough lubricant and humectant to the leather to allow it to become more flexible, pliable and resistant to physical stresses. As the information we gain from technical analysis becomes more refined, our reasoned course for proposed treatment will also continue to change.

Within this century, buffers in the dressings were suggested as a protection against the leather deterioration known generically as red rot by providing a buffer against an increasingly acidic environment. For decades the use of potassium lactate was advocated. More recent analytical evaluations demonstrated that the organic buffer imidizole has improved residual buffering results. We also now know that extensive chemical deterioration resulting in the quantitative presence of free mineral acids can lower the pH to such an extent the use of ammonia vapor may first be needed to neutralize the leather before a buffer can be applied.

Today, there are better means to evaluate the deterioration symptoms and identify the cause. If I had know this a generation ago, I may not have felt the need to consolidate the Ghent Treaty Box leather so agressively or to dismiss the benefits of a buffer and dressing application.

Current Collaborative Efforts

As has been illustrated, conservators have grappled for over a generation with how to approach treatment of leather in a museum environment. Approaches have changed as an understanding of the material and the associated deterioration factors evolved. As a final example, I would like to highlight an upcoming project at the Isabella Stewart Gardner Museum in Boston that I believe is a notable current example of the theme of the talk—the need for clear documentation of past observations and treatments, and re-assessment of those records with collaborative efforts and forward thinking.

The Gardner's project focuses on the leather wall coverings in the Veronese Room, a room appointed with European decorative arts which is on permanent display. This project has been funded in part by the Institute of Museum and Library Services and a private donor. The four walls of this 37'9"(L) x 22'3"(W) x 16'(H) room are covered with panels of embossed painted and gilded leather, a traditional European decorative wall technique. These 17th and 18th C wall panels and altar frontals are from the Netherlands, Italy, France and Spain, according to Dutch art historian Eloy Koldeweij. They offer an opportunity to revisit a well documented series of examinations and treatments starting in the late 1950's. The leather project under the auspices of Barbara Mangum and Valentine Talland at the Gardner Museum conservation laboratory will culminate in an extensive collaborative research and treatment project in the coming few years.

The panels were purchased for the Museum between 1897 and 1899. The Gardner Museum opened in 1903 and the Veronese room was part of the original installation. Photographs document that the gilded leather panels have remained in their current position since at least 1926, the year in which archival photographs were taken of each gallery in the Museum. Numerous photographs taken in subsequent years document the placement and begin to render a sense of collection history. Augmenting the photographic records, conservation notes from 1957 begin a carefully detailed written observation of condition and treatment history that continues through to the present day. These records provide invaluable information for the current focused assessment and treatment collaborative efforts. As an example, initial notes indicate the panels warping and the weak and brittle condition of the leather. Trial treatments were initiated to clean and stabilize the painted surfaces and the weakened leather supports. Over the following years a series of panels were treated in various well documented processes. A number were cleaned with a variety of combinations of saddlesoap, green soap, and castille soap and water. To reduce the stiffness and distortion some leather panels were dressed with neatsfoot oil, castor oil or Lexol, a commercially formulated leather dressing. As part of investigations into lining methods, procedures for a few panels utilized different formulations of wax-resin and PVA emulsions combining a variety of backing materials and heat. By 1966 it was noted in a "review of the leather situation...do not use any adhesive requiring heat. Changes in RH drastically change the leather's response. The waxes are not satisfactory" (ISGM Conservation Files). Detailed lab notes in the late 60's document continuing use of saddlesoap, water, neatsfoot oil, PVA emulsion, PEG 1500 and hard waxes for surface finishes. Notes today continue to indicate distortions in the leather panels and their stiff, and brittle conditions (ISGM Conservation Files).

With the advance of analytical techniques for the markers of deterioration of leather, this project provides a timely opportunity to revisit these panels to see how prior treatments may have affected the panels both chemically and physically and to devise an approach to retreatment that addresses the identified concerns. All the panels with known treatments plus all the remaining panels in the room are planned as a large examination, documentation and treatment project over the coming several years. The initial steps in examination and documentation of condition have begun. I have a role as Project Consultant.

In the Fall of 1996, eighteen samples representing the different kinds of decorative and historical panel groupings were taken and sent for pre-treatment documentation and analysis at the Instituut Collectie Nederland in Amsterdam. The analytical investigations undertaken by Pieter Hallebeek have at this point focused on the determination of the extractable fat content, the pH and differential numbers, the shrinkage temperatures, the total sulphate and metals content, and the soluble sulphate contents and soluble nitrogen content such as ammonia (Hallebeek, 1996). By piecing together the information gleaned from these analyses, this collaborative effort hopes to yield a better understanding of the degree of degradation and its causes and its effects. This in turn allows for a reasoned course of proposed treatment.

Pieter Hallebeek's analytical information indicates that, "The leather as a whole is reasonably sound but in vulnerable and unbalanced state and before the leather is treated, any kind of physical movement can cause much damage. The leather fibers are visually still in reasonable condition and not broken but very brittle and they break easily because of the lack of moisture and fat" (Hallebeek, 1996). The panels are fragile. Fortunately, however, the degree of chemical deterioration and presence of red rot is relatively moderate and probably does not indicate the need for total impregnation with an irreversible consolidant. The degree of dryness is extreme and appears to be a leading cause of the frailty of the panels. The analysis also indicates that there may be a connection between the state of deterioration and the presence of wax on the surface. The preliminary conclusion is that the absorption and release of moisture by the leather is altered by the non-porous wax coating.

The project collaborators will continue further in the investigation and examination of the condition of the panels in the coming year. This will also involve developing approaches to reduce the excess amounts of waxes, oils and lining products in the leather in order to prepare it for potential neutralization, buffering, and dressing in an appropriately controlled and quantitative method. Backing and remounting systems will also be investigated and chosen. Additional analysis is planned to document changes that occur through treatment.

In summary, with this review I have no definitive answers for treatment of leather. I do know it is a more complex material than was initially assumed. I have learned by my successes and mistakes and by sharing discussions and investigations with others. I have learned by asking questions and obtaining the support of conservation scientists. I have learned by sharing resources among colleagues and with other related industries. I have learned by looking back and realizing that collaborative efforts have brought us forward; that sometimes answers are not as simple as they appeared before; and that we sometimes have complicated the issues with our solutions of the past few decades.

Acknowledgments

I would like to thank my colleagues and classmates Chris Tahk, Dan Kushel, and Miriam Peck Dirda, and my colleague at the Octagon House, Sherry Berg, for their willingness to search files, duplicate slides and provide long distance legwork and dialogue in support of the revisit to the Ghent Treaty Box project. I would also like to acknowledge the extensive analytical support and shared experiences over the past two decades provided by my colleagues in the Instituut Collectie Nederland, Netherlands Institute of Cultural Heritage, especially Pieter Hallebeek, during our quests for analysis, methods of repair and treatment of gilded and painted leather. I wish also to thank the conservators at the Isabella Stewart Gardner Museum for their thoughtful support in involving me in their upcoming project by sharing their records, photo documentation and collaborative processes.

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ARTIFACTS REVISITED: THE EVALUATION OF OLD TREATMENTS

Tom Stone

In 1994 one hundred and twelve objects treated at the Canadian Conservation Institute and presently housed in eighteen different museums across Canada were examined. The objects inspected were mostly ethnographic and had been treated at the Institute between 1974 and 1985. The aim of the survey was to see if any problems had arisen due to certain treatment approaches or materials which had been used in the conservation of the objects and to develop an appreciation for the subsequent role the museums may have played in the current condition of the artifacts (Figure 1).

The conservation work done on sixty percent of the objects inspected in this survey had suffered no visible alterations in the ten to twenty years since it had been done. Almost without exception the remaining forty percent showed alterations of only a very minor nature such as a gap along the edge of a fill, the lifting of several quills on a porcupine quill decorated object or a few small spots of iron corrosion. It was apparent that in the vast majority of cases the conservation interventions were doing the job intended of them across a fairly wide range of materials and artifact types and that the materials used had not lead to any direct harm or deterioration.

During the survey, one of the categories of materials inspected was adhesives. Adhesives of one sort or another were used in almost every treatment examined in the survey. These included a large number of poly(vinylacetate) emulsions and resins, cellulose ethers, liquid hide glues and a few examples of epoxies, Acryloid B-72 (methylmethacrylate/ethacrylate co-polymer resin), nitro-cellulose adhesives, Lascaux 360 HV (butyl methacrylate/butyl polyacrylate emulsion), sturgeon glue, gelatin and Rhoplex AC 33 (ethyl acrylate/acrylate emulsion). Of these adhesives, only the poly(vinylacetate) emulsions and the cellulose ethers were encountered with enough frequency to begin to show interesting trends. Thirty-four PVA emulsion glue joins were inspected and of these, only four had failed. Fourteen glue joins made with cellulose ethers were inspected and of these ten had failed.

Cellulose ethers are seen as relatively weak adhesives but adhesives which are generally reversible; ideal qualities for many conservation applications. Due to their general weakness, ease of application and reversibility they have been used in many different applications in conservation. A variety of cellulose ethers have been available to conservators; the water-soluble varieties, methylcellulose, hydroxypropylcellulose, ethylhydroxyethylcellulose, methylhydroxypropyl-cellulose, ethylhydroxyethylcellulose and sodium carboxymethylcellulose and the organic solvent-soluble types ethylcellulose and ethylhydroxyethylcellulose.

Over the years, the Ethnology Laboratory (now the Objects Laboratory) at the Canadian Conservation Institute has used a number of these cellulose ethers in a variety of ways and on a number of different substrates. Of the objects examined which had been treated with cellulose ethers, methylcellulose was by far the most frequently used (12 times). Klucel G (hydroxypropylcellulose) and Ethulose (ethylhydroxyethylcellulose) were used once each. Methylcellulose had been used in several ways; usually at 3-5% to butt join edges of basketry or applied to Japanese tissue which was applied as a backing across broken elements on basket repairs or split birchbark. Methylcellulose and ethylhydroxyethylcellulose (Ethulose 400) had also been used in combination with macerated Japanese paper to make a combination fill and adhesive known as "basket goo" which could be applied to the edges of breaks, the paper fibres acting to provide additional strength. Occasionally, methylcellulose was used to adhere lifting quills to birchbark and lifting and split sections of both birchbark and cedarbark. Hydroxypropylcellulose (Klucel G) had been used to adhere delaminating and splitting cedarbark.

Often the failures of the cellulose ethers seemed to be related to situations where the glue joins may have been under stress. For example, methylcellulose had been used to adhere a black paper lining to the interior of a small leather dressing case. One edge of the leather dressing case had curled back slightly out of proper alignment and the glue join had failed. In this case it was appropriate for the glue join to fail as the paper lining may have otherwise torn. With porcupine quill decoration, the quills are usually held to the substrate (often birchbark) by pinching both ends of the quill into the substrate. Often one end will break and the quill, still held at the other end will spring up away from the surface like a drawbridge. To re-lay the quill, adhesive is applied to the underside and at the broken tip. The quill is then pushed down into proper alignment and allowed to dry under a slight weight. In some instances, quills had been glued with methylcellulose and in one case a number of lifting quills had been adhered with ethylcellulose. Examples of the failure of both of these adhesives were seen which had allowed the quills to spring up again, making them vulnerable to damage when being handled.

At one museum two similar, spruce root baskets were examined. These had been repaired in the same way and at the same time but by two different conservators. One of the baskets (Tlingit) showed an approximate failure rate of about 50% of the glue joins. According to the treatment record these repairs had been made using "methylcellulose and paper fibre basket goo"as well as "Ethulose 400 and paper fibre". Unfortunately it was not more specific so it is difficult to tell how the adhesives were used and whether it was the methylcellulose or the Ethulose (ethylhydroxyethylcellulose) or both, that had had a tendency to fail. The other basket (Haida) showed no failure of glue joins at all. The basket had been repaired using "basket goo" made solely with methylcellulose. This Haida basket had been treated somewhat more heavily with more adhesive being present and the paper fibres of the "basket goo" seeming to be somewhat longer. In effect, the treatment of the Haida basket seemed to have been somewhat "overbuilt" in comparison to its Tlingit companion. Since their return from the Canadian Conservation Institute in 1983 the baskets had been through two storage moves. While the choice of a weak adhesive makes sense if it helps prevent damage to adjacent material, this advantage must be weighed against the potential for failure and loss of some of the repaired elements.

At the ICOM CC meeting in Edinburgh in September of 1996 the Ethnographic Conservation

Working Group agreed to take a closer look at these adhesives during the next three years to see if the results seen in this survey are supported across a wider sample or are simply an anomaly. I would ask that where possible, members of the Working Group take a little time to go through some of their previous treatments that were done between ten and twenty years ago and which had used cellulose ether adhesives. Please be sure to note the following: the substrate, the type of cellulose ether used and its concentration, physical description or a diagram of how it was used and some background about the storage, display and handling it may have received since it was conserved. It is also very important to look at success and not just failures. Please forward this information to me so it can be compiled for presentation at the next triennial meeting and for publication in the Newsletter.

While the examination of cellulose ether adhesives should be an interesting venture in itself, a very useful spin-off is that it forces one, while trying to compare "condition now" with "condition then", to quickly come to grips with the adequacies or lack thereof of previous treatment documentation methods. Good luck and I look forward to hearing about your failures and successes.

Editor's Note

A longer and slightly different version of this paper, with the same title, was published in the ICOM Edinburgh Preprints. James & James (*Science Publishers*) Ltd. kindly gave the OSG permission to reprint the original, but it was decided to use the version presented by the author at the AIC meeting for this volume.

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Canadian Heritage — Patrimoine canadien

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Post-Treatment Examination

OBJECT

Institution			
Object	Sheepskin Coat "Kozhukh"	Catalogue No. HU.1.779	Date Treated February 17, 1983

OBSERVATIONS

Dossier Usefulness & Condition — Useful, easy to read although hand written. Test samples included and very good diagram. Photos well organized and useful. Dossier and photos in excellent condition.

Significant Features	Comments
Stiff areas softened with 30/70 ETOH/water.	Areas that had been softened seem to have remained soft. There is no noticable re-stiffening.
Tear repairs - nylon gossamer tissue and Jade 454.	All tear repairs seem to be holding very well. There is no evidence of lifting and the adhesive has not penetrated or discoloured. There seems to be some stiffening of the backing as a result of the adhesive and this is most evident in the area of the right proper shoulder that received extensive backing.
Dry pigments of complementary colour applied to red stain.	There appear to be some new splits that have appeared on the less flexable area of the outside edge of the right proper sleeve.There are six new splits present. The longest is about 7cm with the rest ranging from 4 to 1cm. The two largest are located in the vacinity of two repairs done in 1983 that had toned in surface patches applied. These are still in excellent condition. These new tears may have occured as a result of the coat being placed in a plastic bag for freezing or as a result of being picked up by the sleeve. The mount that was made for the coat is still in good condition and is functioning well. The pigment applied to the red stain has not transfered at all. There is no evidance of moth infestation anywhere in the hair on the inside.

Storage & Exhibition History — The coat has been kept on its mount flat and under acid free tissue in a more or less uncontrolled and cramped storage area. It has been on exhibition twice. Once flat and it is suspected that it was placed on a manniquin for the second exhibition. The coats suffered an insect infestation and were bagged and frozen. The coat went through a double freezing. The first was of a month's duration or longer and the second for less.