HISTORICAL BACKGROUND

Ancient Sogdiana, which was located within the borders of modern day Uzbekistan and Tajikistan, flourished between the 5th and 8th centuries AD as the main settlement of Sogdian traders who achieved great economic success through trade along the Silk Road. The earthen palaces and houses found in these settlements were often decorated with high-quality wall paintings. Some of these structures were burnt down during ancient wars and others were simply concealed below the ground for centuries until the 1940s when large scale excavations were first undertaken by archaeological expeditions of the Union of Soviet Socialist Republics (USSR).

The wall paintings were created using pigments bound in an organic medium applied to an earthen render made from local loess and are technologically similar to other wall paintings found in Central Asia. These wall painting fragments were excavated and were often subsequently consolidated using polybutylmethacrylate (PBMA) which was developed around 1950 (Kostrov 1954, 1959). This consolidation helped to preserve the friable pieces during decades of storage; however, some of the excess consolidant has yellowed over time and as a result has visually impaired the paintings so that many of the details can no longer be seen. This issue, plus the potential for adverse affects such as loss of solubility, have all contributed to the development of a new conservation approach.

Concerning the wall painting fragments excavated in Tajikistan, most of them were treated with PBMA at the archaeological sites and were then transported, partly to the State Hermitage Museum (St. Petersburg) and partly to the National Museum of Antiquities of Tajikistan (NMAT) where a selection of them are on display. Many of the fragments however have been neglected at the museum due to a lack of financial and human resources, largely through the collapse of the USSR.

In view of this situation, since 2008 the National Research Institute for Cultural Properties, Tokyo (NRICPT) and the Institute of History, Archaeology and Ethnography, Academy of Science, Tajikistan have been collaborating to develop a conservation approach for the extensive collection of wall painting fragments at NMAT. The collection contains large numbers of wall painting fragments excavated from one of the...
most important archaeological sites in Tajikistan: the Kala-i Kahkaha I site, which was a fortified city in Ancient Sogdiana.

**SOLUBILITY TESTS AND CLEANING TRIALS FOR THE REDUCTION OF PBMA**

Problems arising as a result of the historic application of acrylic polymers, such as PBMA, were studied. This included investigation of discoloration and decreased solubility due to cross-linking processes (Horie 1987). In order to safely remove excess PBMA from the surface of the paintings, in-situ and laboratory tests were carried out.

PBMA is known to be soluble in xylene and acetone (Sheinina and Vinokurova 2002). Solubility tests were carried out with a sample of aged PBMA stored for an unknown period in the laboratory at NMAT. Material datasheets for other materials such as Elvacite 2044 and Paraloid B67 (isobutyl methacrylates) (Horie 1987) were referred to in helping select solvents for testing PBMA solubility since new PBMA was not available. The tests based on solvent polarity (Cremonesi 1997) revealed that the aged PBMA was soluble in acetone, xylene and MEK, but not in octane or isopropylalcohol. Considering evaporation rate and workability, a mixture of acetone and xylene (27:73) was chosen for the reduction of the PBMA.

**CASE STUDY: FRAGMENTS EXCAVATED FROM THE KALA-I KAKHKAKHA I SITE (SHAKHR-I-STAN, NORTHERN TAJIKISTAN)**

Fragments from Kala-i Kahkaha I site

The wall painting fragments from the Kala-i Kahkaha I site were the main target for research and conservation treatments. The wall painting scheme, presumably painted between the 7th and 8th centuries, was found in the palace. The painting depicts epics, allegories, and historical events. It is believed that the palace and its wall paintings were burnt as a result of war and others simply collapsed and were concealed below the ground for centuries, until the 1960s when large-scale excavations began to be undertaken.

<table>
<thead>
<tr>
<th>Organic solvents</th>
<th>% (vol.)</th>
<th>Solubility Parameters</th>
<th>PBMA</th>
<th>Paraloid B67</th>
<th>Elvacite 2044</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone/Xylene</td>
<td>27-73%</td>
<td>73.28 12.29 14.43</td>
<td>○</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Acetone</td>
<td>100%</td>
<td>47 32 21</td>
<td>Slightly ○</td>
<td>○</td>
<td>Slightly ○</td>
</tr>
<tr>
<td>Octane</td>
<td>100%</td>
<td>100 0 0</td>
<td>Slightly ○</td>
<td>○</td>
<td>—</td>
</tr>
<tr>
<td>Xylene</td>
<td>100%</td>
<td>83 5 12</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>100%</td>
<td>36 17 45</td>
<td>x</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Methyl Ethyl Ketone</td>
<td>100%</td>
<td>53 30 17</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

*Fd: dispersion force, Fp: polarity force, Fh: Hydrogen bonds concentrate

The walls of the palace were constructed with dried bricks and blocks made of loess called *Pakhsa*. The surface of the wall was then prepared with several layers: from the lower layer upwards, first there is a thick and
rough layer made of loess mixed with chopped straw, then a finer layer made with loess and sand and finally a thin white ground. On the white ground, the images were created using pigments bound in an unidentified organic binding medium. Although the materials employed vary slightly, this structure is similar to other wall paintings found in Central Asia and for which media such as vegetal gum or oil were identified (Taniguchi et al. 2008).

Conservation state and reversibility of conservation materials used in previous treatments

More than 6000 fragments from the Kala-i Kahkaha site are confirmed to be in the storage of the museum. Most of the fragments were left in wooden boxes over several decades after excavation and many were heavily consolidated with PBMA.

The fragment size differs from less than a few cm\(^2\) to about 30 cm\(^2\). Some of the fragments, which have already been joined together during past conservation treatments, reach around 1m\(^2\). The general thickness of the loess render is about 1 to 2cm but some fragments only retain the fine upper render layer while others have a thick render of more than 5 cm.

The most influential factor in the current condition of these fragments is PBMA. While the treatments with PBMA preserved the friable fragments, the excess amount of PBMA applied to the fragments is problematic. In addition to visual disruption due to discoloration, the coating also makes it difficult to clean the paintings properly, as it has trapped dust and debris left on the surface after excavation. Many of the PBMA based joints and fills are now rather hard, especially in comparison to the original earthen render, and as a result have caused cracks or further fragmentation. Excess PBMA on the surface and inadequate joints and fills were reduced and cleaned with the solvent mixture developed.

Stabilization of the fragments

Some fragments were not damaged by high temperatures as a result of fire and had not previously been consolidated; in these cases the loess render was found to be very friable. In order to ensure the fragments were stable, to avoid additional loss of material, and to prepare the fragments to be safely joined it was necessary to consolidate them. Focusing on preventing an undesired darkening and glossy coating of the original material, consolidation tests with a diluted aqueous acrylic resin Primal\(^{®}\) E330S\(^{4}\) were carried out (Otake et al. 2007, Momii et al. 2008). The first trial of diluting the E330S to 5% vol in ethanol in order to let the consolidant penetrate deeper by reducing the surface tension failed. Volatilization of the ethanol was quicker than the absorption of the consolidant and as a result too much of the agent remained on the surface. As a consequence, dilution of the E330S in a mixture of deionized water and ethanol (Ethanol: DI water = 1:1, 5% vol) worked better to consolidate the fragments due to deeper penetration. Injection of the agent through holes resulting from
the loss of straw mixed into the loess helped to create access points for consolidation. The fragments gained the minimum necessary stability to continue their treatment. However, it is essential to continue research about consolidation materials suitable for earthen-based painting fragments.

Regarding the white ground and paint layer, powdering and lifting were observed in many areas. Powdering was caused by the lack of adhesion, due to the aging and damage of the original binder or insufficient consolidation if the fragment was treated previously. First, fixing tests with an ultrasonic mist of water-based solutions of 3 adhesives were carried out: isinglass glue (0.5% wt), Funori (0.5% wt) and Primal® E330S (0.5% wt). After several applications, the powdered pigments were fixed successfully with only the isinglass solution, but it required repeated application to consolidate one section. For the second test, the diluted Primal® E330S (5% vol in ethanol and DI water), also used for consolidation of the loess rendering, was simply applied by putting a few drops in a powdery area. Consequently the powdering was fixed sufficiently without color change or surface texture. However, as diverse paint surface conditions were observed in many fragments, this application needs to be carried out carefully and it is necessary to reduce the amount of acrylic emulsion depending on the condition of the surface.

Lifting of the white ground and paint layer seems to occur due to the contraction of the consolidating agent used in previous conservation treatments. These contain large quantities of the consolidant and are structurally stable but climatic fluctuations and the removal of excess consolidant from the surface increase the fragility of adhesion. Therefore trials to fix the lifting flakes were carried out. The lifting paint surface was first softened with the cleaning solvent and set back into place with a heated spatula and it was then fixed with acrylic resin Paraloid B72 (2 to 5% wt in acetone). There were some areas of flaking that were so stiff that they could not be softened with either solvent or heat, however many areas were successfully fixed using this method.

**Assembling of fragments**

Despite the large quantity of fragments, the excavation archive and grouping of fragments during excavation, it is possible to determine how the fragments join together, even though it is often a slow process. As more and more fragments are pieced together, it becomes easier to find other fragments that fit to these larger pieces. After a sufficient number of fragments were assembled, re-joining of the fragments was then carried out. Although the wall painting from Kala-i Kahkaha I site was originally painted on a flat surface, due to the effects of fire and collapse, many fragments are now deformed. The current form of the fragments is respected, as attempts to flatten them would lead to damage, therefore the surface may have large undulations after all the pieces are joined. Since there are many losses in the joined fragments and many painted figures do not survive clearly, making the surface appear flatter makes it easier to observe the whole painting.
The joining of the fragments was therefore carried out with the aim of making the surface as flat as possible. When bumps or deformations are present on the edges of fragments that inhibit proper joining, these areas are adjusted by scraping back projections and applying small amounts of grout to level the surface. To join the fragments safely, especially for large groups of fragments, they were first separated into several groups. Owing to the irregular shape of some fragments, the order in which they are joined is very important, if later joints may be difficult. It is necessary to keep some fragments independent and to join them later.

In order to join the pieces together, an adhesive grout material was developed. During its preparation, the following points were considered:

- sufficient strength to withstand subsequent treatments and handling
- balancing the cohesive strength of the original material with the requisite adhesive strength of the grout
- keeping the material lightweight
- appropriate consistency for application.

The PBMA used in previous conservation treatments was selected based on its reversibility; however, it has been demonstrated that it is not suitable due to its resistance to fracture, optical changes and the necessity to use toxic solvents to dissolve it. In addition, it is not a conservation grade material. Therefore, based on more suitable properties, a conservation grade water-based adhesive was selected as an additive for the grout: aqueous acrylate Primal®AC2235. In many cases, the fractures were uneven with large gaps, bumps or distortions and it was therefore necessary to develop an adhesive grout that would fill these distortions. However, in the cases where the join was level, a more dilute preparation was applied. The mixture of the grout was developed based on extensive trials to assess all of the desired properties. The materials used in the mixture include diatomaceous earth, pumice powder, brick powder, glass micro-balloons and diluted Primal®AC2235 as an adhesive agent. In order to raise the viscosity and to disperse the powder components in the mixture, a small quantity of methylcellulose was added. After application and joining of the fragments, the excess grout was cleaned immediately to avoid residues on the paint surface. Depending on the thickness of application, it takes from 10 minutes to one hour to dry. Removal of the grout and separation of joint pieces after drying was successfully tested to ensure the reversibility of the treatment.

**DESIGN OF A MOUNTING SYSTEM**

**Concept of the mounting system**

Despite the fact that wall painting fragments with thick renders are heavy for transportation and exhibition purposes, all of the surviving render layers were conserved during this project as they form an integral part of the original material of the wall painting. Removal of render layers is
therefore an unacceptable and unnecessary intervention and does not adhere to current international guidelines for conservation (Article 3.1, Burra Charter, 1999). This approach does however present greater challenges for the mounting and exhibition of the fragments.

**Preparation for making mounting support**

Before the mounting support was made, in order to support the joined fragments from the back, triaxial woven fabric (TWF) made of rayon fibre was employed. The woven structure of this fabric has manifold hexagonal shapes that have high tensile strength from any direction and therefore the desired characteristic of being very stable (Watanabe et al. 1998). The fabric also conforms extremely well to uneven surfaces due to the unique properties of the triaxial weave. This fabric was adhered to the rear surface of the fragment as a backing using an acrylic dispersion Plextol® B500.

**Making of the mount**

As it is planned that fragments from the Kala-i Kahkaha I site will be displayed on the wall of the gallery in the Museum, the strength and lightness of the auxiliary support was a priority. In addition, considering the possibility of a combined display with other fragments, and in the case that adjacent pieces might be found at a later date, it was decided to create a mount that follows the shape of the fragment. In order to create a mounting system that satisfied these conditions, the use of a mount with a sandwich structure was chosen. This structure is composed of two thin and rigid FRP (fiber reinforced plastics) with layers of light core materials in-between. Making the mount is a three step process.

**Making the carbon fiber FRP as the first layer of support**

One of the two FRP sheets, which will support the back of the fragment, is composed of a carbon fiber (CF) triaxial woven fabric (TWF) hardened with epoxy resin that conforms to the back of the fragment in order to
efficiently support it. CF-TWF was employed because of its strength and conformability. At first, the fragment is protected with plastic sheets and a nylon peel ply so that the materials used in creating the mount do not come into contact with the fragment, then the CF-TWF sheet is placed on the back of these protective sheets. Epoxy resin is then applied to the back of the CF-TWF sheet. After application of the epoxy resin, the CF-TWF is covered with another sheet of peel ply to absorb any excess epoxy resin. Using a vacuum system, the CF-TWF sheet conforms to the shape of the fragment as the epoxy hardens, without ever being in direct contact with the fragment. It therefore follows the form of the back of the fragment, creating a rigid and lightweight support, which is then removed easily due to the protective plastic sheet.

**Making the lower panel of the mount**

Two layers of plain woven carbon fibre fabric are adhered to one side of a polypropylene (PP) foam panel with epoxy resin and cut off in the shape of the fragment. The plain woven CF-FRP acts as another rigid layer and the PP foam is a part of the core in the sandwich structure. The PP panel is light but not strong enough to support the fragment with hooks and the additional CF layers are therefore needed. Holes are made in the PP panel in the areas where the hooks are placed and later filled with epoxy-phenolic micro-balloon paste. This results in greater stability when the fragment is displayed on the wall.

**Making of the core material and adhesion of the two mount layers**

To bridge the two layers, phenolic micro-balloons and epoxy resin are mixed at an approximately 1:2 ratio by weight making a paste for the core. The paste is applied on the CF-TWF-FRP and the holes in the PP panel. After flattening the paste on the CF-TWF-FRP shell, the PP panel is placed onto it combining all the layers. The level and edges are appropriately modified while the paste is still soft. Any excess CF-TWF-FRP which is larger than the borders of the fragment is then trimmed.

**Adhesion of fragment to the mount support**

Considering the method for adhering the fragment to the mount support, the appropriate adhesion force and the removability of the mount from the fragment were also addressed. Therefore two elements allowing the removability were realized. First, the application of an isolation layer between the backed fragment and the mount was created. To allow for this reversibility at a later date, a solution of acrylic resin Paraloid B67 in acetone (20% vol) was chosen due to the difference in solubility with Plextol B500, which was used as a backing adhesive. This layer can later be solubilized to assist in the removal of the mount from the fragment without disrupting the backing. Second, a thick and soft adhesive silicone paste was chosen to adhere the fragments to the mount support. According to tests of adhesion force, a 1.6 cm diameter and 0.15 cm thickness patch
of silicon paste\(^8\) can support about 66N of shear stress (6.6 kgf) (Fujisawa et al. 2011). Additionally, the thickness and suppleness of this material makes it possible to cut and mechanically remove the adhesive if required. This adhesive was applied only on the mount support surface and in spots at intervals of 3 cm. The fragment was then placed on the mount and adhered under gentle pressure. Displayed on the wall, the fragment does not move. This was proven by the effect that the filling made on the edge has not cracked after several months.

**CONCLUSION**

A case study using a group of wall painting fragments from the Kala-i Kahkaha I site and a comprehensive conservation treatment for eight groups of the fragments was successfully developed and executed. The conservation of earthen-based wall paintings painted with highly susceptible organic binding materials always presents technical challenges. Unfortunately, a vast number of wall paintings have been excavated and some detached from their supports during archaeological excavations in the past decades. For the most part these fragments were left neglected in museum collections in Central Asian countries without any conservation measures being taken.

While this project is a case study for some groups of fragments, it is hoped that some of the new materials and methods employed will be helpful in addressing conservation issues found throughout Central Asia. Further improvements for efficient assessment and treatment are also considered within the framework of this project.

**ACKNOWLEDGEMENTS**

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**NOTES**

1. E.I. duPont, co.
2. Rohm and Haas, co.
3. For identification of the binder, organic analyses were carried out at the Getty Conservation Institute. However, organic components which indicate the original binder could not be detected possibly due to the complete loss or degradation of the materials since the wall paintings were burnt down in the past and were also placed underground for a long period.
4. According to the product data sheet of Primal\(^{®}\) E-330S by Rohm&Haas, the product contains 47.0% acrylic resin.
5. According to the product data sheet of Primal\(^{®}\) AC2235 by Rohm&Haas, the product contains 46.5% solid, which is to say adhesive.
REFERENCES


