The Digital Restoration of the Afrasiab Palatial Mural

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Introduction

On Afrasiab Hill of Samarkand, Uzbekistan is located a wall painting that reveals the culture and the history of the Sogdians, who played an important role in the development of the ancient Silk Road. The mural on the wall of Room 1, Section 23, which was accidentally found during road construction in 1965, has a particular significance for understanding the geopolitical situations of 7th-century East Asia.[1]

The mural portrays a royal parade of King Varkhuman, envoys from various countries, hunting and boating, archers on the bank of a river, and a variety of fish. Judging from the international relations of that time, it is highly probable that the two figures on the right end of the front wall, who are wearing feather-decorated hats, *Jowooguan* (鳥羽冠), and swords with rings on the heads of their hilts, *Hwandudaedo*, were Koreans.

The painting is heavily damaged. The upper part of the wall and the ceiling had already collapsed at the time of the discovery, leaving only about 2 meters of the mural from the ground. The mural was moved and is currently being displayed in the Afrasiab Museum. Although a copy of the

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[1] Л. И. АЛЬБАУМ, ЖИВОПИСЬ АФРАСИАБА, ТАШКЕНТ, ФАН (1975).

painting was made in 1965, it has been pointed out that its depiction is not detailed enough, with some images even being omitted, to restore the original picture of the painting. Also, the maintenance and the conservation conditions are not optimal, such that, despite the efforts of the Uzbek government and relevant international agencies, it is inevitable that the mural will be further damaged.

In July 2013, South Korea's Northeast Asian History Foundation and the United Historical-Architectural and Art Museum in the Samarkand State of Uzbekistan signed an academic collaboration agreement and began a restoration and conservation project for the mural.[2] The project resulted in significant accomplishments, including the production of 2D digital restoration copies of the entire mural from 2013 to 2015, the production of a 3D video clip with multilingual subtitles, the establishment and operation of a video-viewing room in the Afrasiab Museum, the installation of conservation equipment for the mural in the exhibition room, the production of a restoration replica of the parts of the west wall that depict the envoys and the figures in letter-engraved clothes, and its exhibition at the National Museum of Korea.

This presentation briefly describes the processes engaged in and outcomes achieved by the project for the digital restoration of the Afrasiab palatial mural and the production of relevant video materials.

High-Definition Shooting

To prepare for the production of a copy of the palatial mural, the team used

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[2] The project team was supervised by Kwangeui KO, Ph.D., from the Northeast Asian History Foundation, and it consisted of historians, archeologists and art historians, including Yong Suh, a painter as well as a professor at Dongduk Women's University; Bit Shin, a cultural heritage photographer; Kwonwoong Lim, Ph.D., the Director of the Joongang Conservation Center for Cultural Heritage; Sungyun Jung, a researcher; Jikio Kim, the Director of the Technology Research Institute for Culture and Heritage (TRICH); and Jin-ho Park, a researcher from the Korea Culture Technology Institute. The research team consulted with local experts such as Samaridin Mustafkulov, the Director of the Afrasiab Museum; and Marina Reutova, the Head of the Department of Chemical-Technological Research and Restoration at the Academy of Sciences, Republic of Uzbekistan Institute of Archeology.

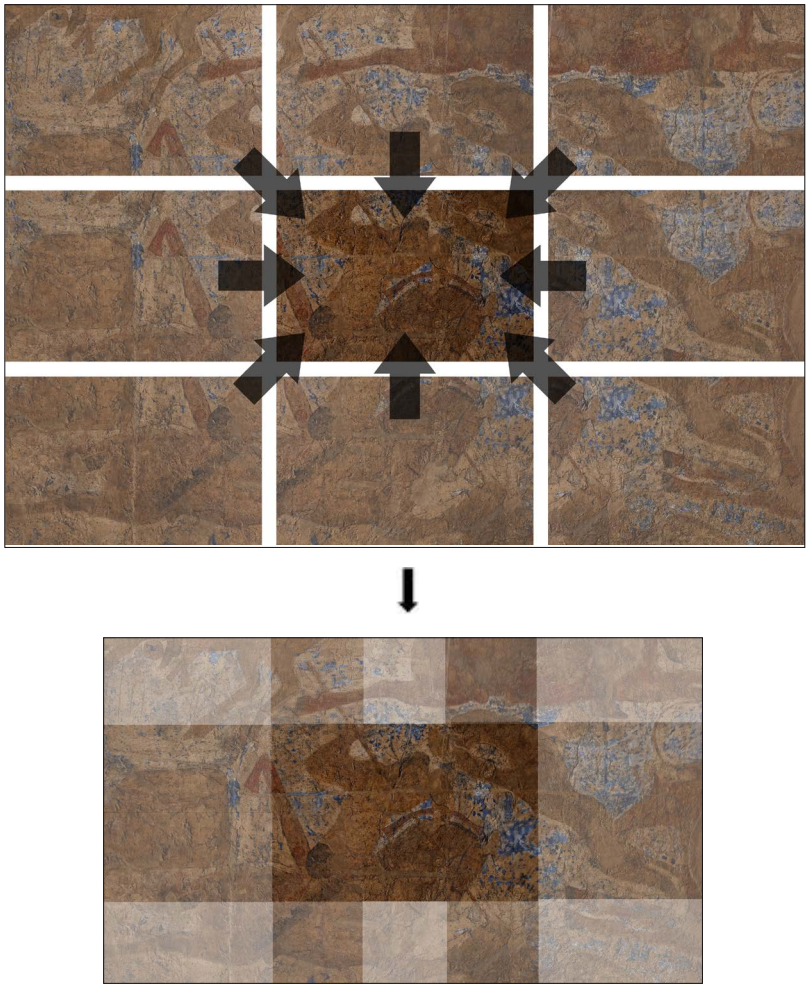

Figure 1. Merging the Segmental Images of the Mural

a CANON EOS 5D MARK 3 camera body with a CANON 85mm lens under two monotype 600-watt strobe lights with umbrellas. A color checker passport was also used to reproduce the colors of the original painting accurately.

The mural in the Afrasiab Museum could not be captured in a single

shot due to its size, with a width of 1,100 cm and a height of 250 cm. We thus split each wall horizontally into 8 bands and vertically into 18 bands (while the eastern wall was vertically split into 16 bands due to the door it includes), thereby creating 560 segments. Each segment measures 61cm x 32cm, and the sides of each of them had an overlap of 30% with neighboring segments. A laser inclinometer and a telemeter were used to ensure an equal and consistent vertical and horizontal segmentation, minimizing possible image distortions.

The shots of the four walls were then sorted into four categories, and they were subsequently transformed into various formats: small JPEG files for quick views, raw files for high-definition revisions, and images of major details and of the entire walls. After adjusting the colors of the photos, we merged the eight segments of each vertical section into a column, and then merged two adjacent columns into another wider column, then these wider columns into yet wider columns and so on until we obtained each of the four entire wall paintings in a single image file, resulting in a high-definition photo, or digital copy of the mural.

Forensic Analysis

Component Analysis of Pigments

The pigments used in the mural could be discerned by the naked eye into six color categories: green, red, yellow, blue, white, and black. We first shot previously designated points on each wall—27 on the east wall, 24 on the south wall, 31 on the west wall, and 14 on the north wall—and color patches for comparison. Then, we analyzed the components of the pigments of each pre-designated point with a portable X-ray fluorescence spectrometer (P-XRF), measured the chromaticity with the CM-700D, and examined the conditions and characteristics of the layers of the painting with a digital stereoscopic microscope.

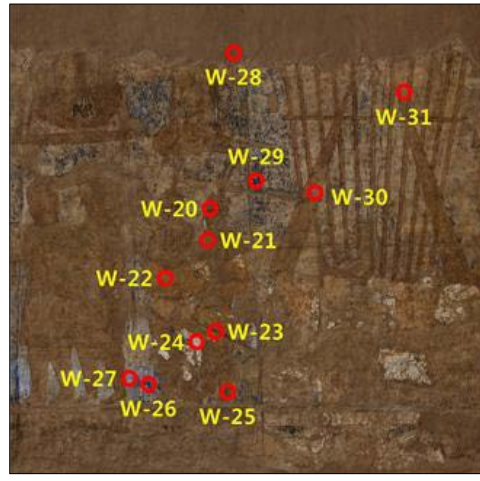

Figure 2. Pigment Analysis Locations (West Wall, W-20~W-31)

Table 1. Components of Red Color, Estimated Pigments, and Chromaticity

Analyzed Point	Chromaticity			Major Components	Estimated Pigments
	L*	a*	b*		
W-1	35.56	9.04	15.00	Ca, SiO_2, Hg, Pb, Al_2O_3, Fe_2O_3	cinnabar
W-8	57.46	16.13	30.05	Ca, SiO_2, S, MgO, Al_2O_3, Fe_2O_3	ocher
W-10	58.60	13.54	28.41	Ca, SiO_2, S, MgO, Al_2O_3, Fe_2O_3	ocher
S-9	53.56	16.71	21.86	Ca, SiO_2, S, MgO, Al_2O_3, Fe_2O_3	ocher
S-10	45.19	21.06	23.01	Ca, S, SiO_2, Fe_2O_3, Al_2O_3, P_2O_5	ocher
S-12	45.17	20.84	23.47	Ca, S, SiO_2, Fe_2O_3, Al_2O_3, P_2O_5	ocher
S-14	39.90	25.10	18.81	Hg, SiO_2, Ca, Al_2O_3, W, Pb, S	cinnabar
S-18	43.43	18.80	19.89	Ca, SiO_2, S, MgO, Fe_2O_3, Al_2O_3	ocher
S-22	34.26	22.02	25.87	SiO_2, Ca, S, Fe_2O_3, Al_2O_3	ocher
N-9	35.14	21.99	19.42	SiO_2, Ca, Hg, Al_2O_3, S, Fe_2O_3	cinnabar
N-11	32.90	14.37	17.87	SiO_2, Fe_2O_3, Ca, Al_2O_3	ocher
N-13	38.22	11.96	22.21	SiO_2, Ca, S, Al_2O_3, Fe_2O_3	ocher

In terms of the components of the pigments, the analysis determined the following: the red pigment was largely comprised of hematite (Fe2O3), or, at points such as W-1, S-14 and N-9, it was constituted by a mixture of cin-

nabar (HgS) and minium (Pb3O4). In the yellow pigment, a high proportion of Fe2O3, a major component of ocher, was detected, suggesting that it was produced with the use of ocher from Afrasiab Hill. The blue pigment was determined to contain high proportions of such elements as SiO2, Al2-O3 and MgO, components of lapis lazuli ((Mg, Fe^{+}2)Al2(PO4)2(OH)2), which is produced in abundance in Central Asia. The white pigment seems to be a chalk- or clam shell powder-based limestone mixture. At the points S-19, S-23 and E-R13, a high volume of zinc (Zn) was found. The examination of a set of photos and digital stereoscopic microscope images identified a white pigment layer on the plastered image of a swan on the southern wall, which is presumed to have been produced during a conservation process since its major component zinc oxide (zinc white; ZnO) is a modern compound. Conventional black pigments contain carbon. However, since the P-XRF we used did not detect light elements whose atomic numbers were lower than 15, we failed to determine the elements contained in the black pigment. But recent research on pigment component analysis suggests that it is probable that the black pigment was made from vegetable or animal carbon.

Video Zoom Microscope Analysis

A video zoom microscope (VZM) was employed for a precise component analysis, which is impervious to the obstructions of substances applied on the paintings during conservation treatments.

Due to the time constraints of the project, the team decided to concentrate on the images of Korean envoys on the seriously damaged western wall, instead of all four walls. As most of the pigment layers—with the exception of the swords and the belts of the envoys and parts of the background—had peeled off, it was essentially impossible to determine the figures precisely. We first divided this section of the mural into 140 segments for photographic purposes, and magnified each photographed segment 7-fold with the VZM in order to unearth obscured pigments.

Upon digitalizing the data acquired by these means via Adobe Photoshop CS5, we restored the outlines of images by connecting areas in which

the dots that indicated the remaining traces of pigments were most densely clustered.

Digital Tracing

We attempted a surface restoration of the Afrasiab palatial mural based on the information acquired through the high-definition digital tracing and forensic analyses.

By overlapping the high-definition digitally traced copy produced by the photographic crew and the hand-painted copy produced in 1965, we were able to compare them, thereby firstly, identifying errors in the current images, and secondly, identifying the further damaged parts, which used to be perceptible in the hand-painted copy.

The restoration was carried out based on the comparison between the old copies and the new copies and on the data such as the components and chromaticity of the pigments and the outlines of the envoys, garnered through the forensic analyses. But restoring lines, images, and colors that have been too seriously damaged to be detected by the unaided eye requires an unusual set of skills, thus highly trained painters should be employed, as they are best placed to interpret a mural painted by another group of painters who lived more than 1,300 years ago.

For printing purposes, PAPYRUS300, the French paper, was used as it accurately reflected the texture of the painting. Due to the large size of the image files, the photo of each wall was printed on roughly 10 sheets of paper, which were later amalgamated. Two hard copies of the final product were printed, one of which is now stored at the Northeast Asian History Foundation and the other at the Afrasiab Museum.

While the restored copy is based on digital technologies, human painters also played indispensable roles in restoration. In this respect, the accomplishment should be seen as the result of a novel method of replication based both on conventional techniques and the cutting-edge technologies of modern times.

Figure 3. West Wall (Before Restoration)

Figure 4. West Wall (After Restoration)

Figure 5. Ancient Korean Envoys (Before Restoration)

Ancient Korean Envoys (After Restoration)

Replica Production

The reproduction of the mural adopted art techniques that are employed in the actual painting of murals. We selected the Korean envoys wearing *Jowooguan* in the northern section of the west wall and the people with engraved Sogdian words in its southern section as the main objects for the replica.

Through the component analyses of the pigments and the wall itself, the latter being an integral element of every mural, we had already ascertained that the wall was made of ocher from Afrasiab Hill, mixed with grains of sand.

In fabricating a wall for a mural, the first priority is the choice of an appropriate substance that can adequately support the weight of the clay to be plastered on the wall. Hence, we selected a honeycomb board, as it is light but resistant to deformation. We affixed a sheet of jute to the surface of the board, on which two layers of ocher, similar in its makeup to that from Afrasiab Hill, were plastered and dried.

When the wall was completed, we commenced the application of the restored copy of the mural to it. The replication team made an initial conté sketch on the rear side of the printed mural, which was then pressed onto the wall. Based on the sketch—now on the wall—the team line-drew an outline with hair pencils with reference to the relevant data. Next, in order to replicate the mural, we used ash-gray pine-soot tusche, manipulating the strength and moisture level of the brushes as necessary.

The coloring was carried out with the aim of replicating the properties and chromaticity of the mural's pigments as accurately as possible—with the exception of our using artificial powder pigments instead of natural lithic pigments of the sort employed in the mural. This exception was motivated by the consideration that powder pigment is more effective in replicating the color-fadedness of the original, and its being more economical and compatible with our limited budget.

Finally, comparing each and every corresponding aspect of the replica and the digitally restored mural, we believe we have reproduced details as minute as peelings-off and hairline cracks, thereby bringing what is ef-

Figure 6. The Replica of the Mural in the Central Asia Section at the National Museum of Korea

fectively another Afrasiab palatial mural into existence over 1,300 years after the advent of the original. The replica of the restored copy is currently on display on the main board in the Central Asia section at the National Museum of Korea.

3D Digital Image Restoration

The 3D digital image of the Afrasiab palatial mural, produced by means of advanced digital media technologies, offers the mural site and its walls in the form of virtual reality so as to give viewers an indirect but vivid experience of the mural.

There are only scant records on the structure of Afrasiab Palace and the locations of its murals, except for a single planar ordnance map produced upon its discovery, which sparsely illustrates approximately thirty rooms and their dividing walls. Thus, we attempted to acquire further information on the palatial site based on 3D broadband scanning of the architectural remains of the entire site. Using the Trimble TX5, the image we scanned is significant as a source of precise numerical and visual data on the surface of the Afrasiab palatial site, which we were able to utilize in measuring various objects and in drawing a blueprint.

In addition, a collection of older blueprints generated at the time of the excavation and another set of scanned data derived from architectural remains found in the building with the mural and satellite photographs were amalgamated in overlapping layers, and matched at 47 points on the

Figure 7. Restored 3D Image of the Interior of the Afrasiab Palace

walls. Based upon this, we could locate Room A-1, where the mural is situated, as is indicated by the blueprints, and specify the planar form of the old palace. Moreover, the first aerial drone photograph of the Afrasiab historic site is of special significance in that it captured its sublimity and beauty, which had never been seen from the ground.

Finally, for the 3D digital image restoration project, we developed a variety of contents for a website, a promotional video clip and virtual reality (VR) applications, which are currently available on the website of the Northeast Asian History Foundation and on YouTube.

On April 1, 2015, the Northeast Asian History Foundation and the Afrasiab Museum exchanged the final outcomes of the project and established a video-viewing room in the museum. The video clip is subtitled in eight languages (i.e., Korean, Uzbek, English, Russian, French, Spanish, Chinese, and Japanese), imparting the beauty of the Afrasiab palatial wall painting and the histo-cultural significance of the Silk Road.

► **Website on the Afrasiab Wall Painting**
- http://contents.nahf.or.kr/goguryeo/afrosiab

► **Video Guide of the Afrasiab Wall Painting**
- English: https://youtu.be/HuuHrNQugt4
- Korean: https://youtu.be/6vYTtY6hQPc

Conclusion

Concluding this presentation, we will discuss the significance of this digital restoration project of the Afrasiab palatial mural.

Primarily, the digital restoration project gave impetus to devising new methods of restoring cultural properties of historic significance, which draw upon such technologies as high-precision photography and actual-size image merging, analysis and chromaticity measurement of pigments, stereoscopic microscope analysis, and infrared and ultraviolet examinations. This provided us with opportunities to learn about and experience the various techniques needed to study murals of historic importance. This project establishes a new paradigm for the conservation and utilization of cultural heritage artefacts by establishing "digital copying" as another genre of art that draws on computer graphics, as well as for the conduct of forensic analyses through the use of high-tech devices.

It is also significant in that it achieved the purpose of copying a cultural artefact to the fullest possible degree thanks to high-definition photography and detailed data acquired via forensic analyses. The old copy that was produced upon the mural's discovery in 1965 did not depict the entire mural and failed to capture the figures and colors accurately. By contrast, the new digital copy, as it represents the original "just as it appears," renders itself a highly useful reference material, which we believe any further work on or analysis of the mural must take stock of.

Furthermore, a great deal of information on the mural itself has been analyzed and recorded, even if belatedly, one-half century after it was unearthed. The database that was developed during the analyses of the mural can be utilized for future research on cultural artefacts throughout the world, and not simply in the Silk Road region.

The use of cutting-edge digital technologies have made the Afrasiab palatial mural more accessible to the public than ever. Its replica is current-

ly on display at the National Museum of Korea, and in the form of a digital restoration copy at the National Museum of India in New Delhi as well as on the Web, all of which raises the awareness of the value of the Afrasiab wall painting.

We expect that the Northeast Asian History Foundation and the Afrasiab Museum's project will continue to contribute to deepening our understanding of the Silk Road's history and culture, and of the history of civilization in general.