X-rays for Archaeology

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Cover shows an image of the tomb of Amenhotep III in Egypt.
Photo courtesy of Masayuki Uda.

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Foreword

The First International Symposium on X-ray Archaeometry took place in the conference hall of Waseda University, Tokyo, Japan, on 18–20 July 2002. The participants of the symposium were from Belgium, China, France, Greece, Hungary, Israel, Italy, Japan, Korea, Mexico, Romania, Slovenia, Sri Lanka, Taipei, UK, and USA.

One of the most important aims of the symposium was to combine two scientific fields, i.e. archaeology or art and X-ray science. Finding archaeological sites, dating, analyzing of archaeological objects, and so on needs the help of natural scientists and technicians. Natural scientists have a taste for solving mysteries hidden in archaeology. However, previously, using x-ray techniques was only a small part of the archaeological fieldwork and the x-ray field was largely disinterested in the analysis of archaeological objects. Until this symposium, no attempt has been made on having an international meeting on a worldwide scale to discuss archaeological subjects under equal partnership between the two fields mentioned above.

The symposium provided a broad forum for discussing experimental results of X-ray-based analysis. Of particular interest for the participants of the symposium was the non-destructive analysis of archaeological monuments using several kinds of X-ray techniques, especially under *in situ* and contact-free conditions, as well as the introduction of experimental results using advanced technologies such as ion beam and synchrotron radiation techniques.

This book, named "X-rays for Archaeology", consists of papers selected from presentations in the First International Symposium on X-ray Archaeometry.

Finally, it is an especially great pleasure for me to warmly recommend this book to every reader interested in knowing more about X-ray archaeometry and understanding the importance of joining both scientists in the fields of archaeology or art and X-ray analysis.

Tokyo, Japan

Professor M. Uda
Chairman
Organizing Committee of the First International Symposium on X-ray Archaeometry

Chapter IV-3

Analytical Study of Paintings by X-ray Radiography and Spectroscopy

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1. Introduction

The various methods of scientific examination of paintings are divided into two classes, namely, surface examinations and point examinations. Surface examinations can in principle be carried out without even touching the paintings. Point examinations may or may not require the removal of a minute paint-sample. Selection of points likely to yield most information should be performed based on surface examinations.

Surface examinations are conducted by such methods as X-ray radiography, secondary electron emission radiography (emissiography), infrared reflectography (black & white, color), ultraviolet fluorescence photography, X-ray excitation, non-destructive X-ray fluorescence analysis etc. Point examinations usually require the removal of a small sample from the paintings, and this should only be accomplished after taking full advantage of surface examinations. The problem of point examinations is that the outcome does not tell anything about the surrounding area.

Therefore, best results are invariably obtained when various methods can be combined, complementing each other and allowing a better interpretation of data.

2. Surface examinations

2.1 X-RAY RADIOGRAPHY

X-ray radiography may be very useful in understanding the technique of the painting, especially in combination with paint cross-sections and infrared reflectograms. In comparing X-ray radiographs with infrared reflectograms and the painting itself, various modifications during the painting process may be elucidated.

M. Uda et al. (eds.), X-rays for Archaeology, 253–258.

2.2 SECONDARY ELECTRON EMISSION RADIOGRAPHY (EMISSIOGRAPHY)

Radiography by secondary electron emission is used for the study of pigments. In the secondary electron emission image, pigments are shown in relative lightness or darkness depending on their atomic number. The larger an pigment's atomic number, the brighter the image will appear, the smaller the pigment's atomic number, the darker.

2.3 APPLICATION OF SURFACE EXAMINATION TO THE PAINTINGS OF CHRISTIAN RELICS

When Christianity was first introduced into Japan in the middle of the Sixteenth century by St. Francisco Xavier, it was rapidly propagated and converted an immense number of the people. This new religion soon became one of very important powers in our country, spiritually as well as socially, reflecting its influence in every direction of the national life. But after only half a century's flourishing, Christianity was almost wholly rooted out, in consequence of severe persecutions and the strict prohibition of the authorities, leaving scarcely any remarkable monuments and relics, those of the prosperous days of the past being securely hidden or destroyed.

These of severely damaged paintings were investigated by scientific examinations to recognize how their original figures are, and how their painting techniques and materials are related to or influenced by European paintings. It would be revealed that Seminary's painting instruction and production, which was a school to learn Catholicism through Latin language, music, and manufacturing musical instruments and paintings organized by Jesus missionary. Standing point of view, we have examined severely damaged and discolored copper plate paintings and relatively well preserved paintings on paper such as the Painting of the Madonna with the Infant Jesus and Her Fifteen Mysteries and the Portrait of St. Francisco Xavier (Fig. 1).

X-ray radiography (Fig. 2), emissiography (Fig. 3) and color infrared reflectography of the paintings have played a great role to estimate original figures and a pigment of each color. Infrared reflectography has shown existence of under drawing of the paintings on paper support, which are extremely sophisticated lines drawn by a brush. The evidence will suggest a skillful Japanese painter was engaged in manufacture of the painting. X-ray radiography shows the brushwork for the paint. The evidence implies that the painter was not necessary good at practicing of painting by a European method.

We have not enough evidence to recognize the influence of European painting techniques and materials at present. It will need effort to conduct scientific investigations to the Christian relics toward understanding more details of interaction between European and Japanese culture.

3. Point examinations

3.1 POINT EXAMINATION IN TERMS OF ANALYSIS OF PAINT CROSS SECTION

The extremely small amount of samples taken form the paintings were first examined through an optical microscope to note the shape of the sample, its size, condition of front and back surfaces and its color. These characteristics were recorded in photographical form. Then the sample was in a sandwich of polyester resin, and after hardening the encased sample at 40 °C under double atmospheric pressure, the sample was split into two samples, using a microtome to cut the sample crosswise. One of these cut samples was then used for the chemical analysis, while the other was kept for reference or for use in the analysis of medium. The cut face of the sample for use in analysis was then successively polished using a polishing powder made up of aluminum oxide with particle diameter from 12 to 0.05 micrometer. This face could then be called a cross section of the paint and the ground, which could allow the painting process to be read through each successive layer.

First, the polished cross section was examined in reflected light through an optical microscope set at around 100x, to determine the color of each layer and the layer construction seen in the cross section. The information was recorded in photographical form. The sample fragment was placed in a low vacuum scanning electron microscope and enlarged until the pigment composition could be examined as a back-scattered electron image. The low vacuum scanning electron microscope precludes the necessity of a conductivity coating such as carbon or platinum. Therefore, repeated observation through electron microscope and optical microscope can be conducted. Further, as it is not necessary to remove the coating, scraping of the sample is minimized. Observation was limited to a back-scattered electron image. However, it was not possible to have a secondary electron image, or magnification to a hundred thousand times original size. In a back-scattered electron image, the elements found in a pigment are shown in relative lightness or darkness depending on their atomic number. The larger an element's atomic number, the brighter the image will appear, the smaller the element's atomic number, the darker it will appear. After preparing the optical microscope image that shows the observed color corresponding to the pigment, and the back-scattered electron image that reveals the relative size of the atomic number of the elements in the pigment, the elements of the pigments were analyzed through energy dispersive X-ray fluorescence analysis equipment (Fig. 7).

3.2 CHARACTERISTICS OF GROUND AND PAINT LAYER OF RUBENS' THE FLIGHT OF LOT AND HIS FAMILY FROM SODOM IN TERMS OF OBSERVATION OF THE OPTICAL AND ELECTRON MICROSCOPE

Rubens' "The Flight of Lot and his Family from Sodom" was investigated to analyze its attribution by comparing two other similar works (Fig. 4).

The ground of the work is a calcium carbonate layer, 150 micrometer thick (Fig. 5 and 6). As a grate number of calcareous nannofossils of around 10 micrometer were observed in the calcium carbonate layer, we can conclude that the calcium carbonate is chalk and that the ground is hence a chalk ground. In observation both through the optical microscope and the electron microscope, we could not confirm a many-layered structure in this chalk ground, and hence it can be considered as single layer.

The ground consists solely of chalk, and as the whole layer has maintained its white color, there is a high probability that an aqueous medium such as animal glue was used as medium. The application of Fuchsine S through the staining method revealed a red reaction, which indicates the presence of protein. An approximately 30 micrometer thick semi-transparent layer of ash brown can be observed in the upper part of the chalk ground. As nothing other than chalk could be detected from this part, we can assume that the semi-transparency is a result of the infiltration of an oil or resinous medium, which reflective index is close to that of chalk, such as drying oil. According to the back-scattered electron image, the reason for the upper layer of the ground to be of a relatively higher density than the lower layer could be because the upper section permeated with oil is harder, and the surface was polished to a smooth finish.

The red color layer from the sample of red robe of the angel is a single layer constructed of relatively finely ground vermilion particles of less than 5 micrometer in diameter, and a transparent red lake made up of indistinctly shaped particles. This layer is about 20 micrometer thick. The red lake is distributed throughout the red layer, although it is relatively denser in the lower part of the layer. There is no glaze layer made up exclusively of lake pigment.

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Figure IV-3-1.

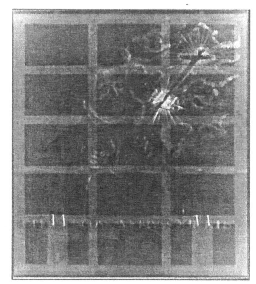

Figure IV-3-2. X-ray radiography of 'Portrait of St. Francisco Xavier'.

Figure IV-3-3. Emissiography of 'Portrait of St. Francisco Xavier'.

Figure IV-3-4. P.P.Rubens, 'The flight of Lot and his family from Sodom', (The John and Mable Ringling Museum of Art).