NEUTRON AUTORADIOGRAPHY OF PAINTINGS

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1. Introduction

Neutron activation autoradiography (NAAR) is a method used in the examination and analysis of the materials and techniques of paintings. The information provided by methods of examination using photon radiation at both extreme positions of the electromagnetic spectrum is limited. X- radiography principally indicates the distribution of the pigment lead white, whilst infrared reflectography is used to reveal black, carbon- based media which have been employed on a light ground (i.e. underdrawing). In contrast, NAAR is capable of revealing different coloured paint layers piled- up during the actual creation of a painting. In many cases, the individual brushstrokes applied by the artist are made distinctly visible as well as changes and corrections that were made during the painting process. By using paintings that have been reliably authenticated it is thus possible to identify the particular style or ´handwriting´ of a specific artist.

2. Image processing of autoradiographs

The first step in the examination is to expose the painting to a flux of cold neutrons. For the activation of the painting, one of the six neutron guide tubes at the Cold Neutron Source of the 10 MW research reactor BER II is used. The activation chamber in front of the 3 cm x 12.5 cm window (neutron flux 1.1 x 10^9 n/cm^2 s), was specially constructed for the activation of paintings. The entire surface area of pictures with dimensions up to 120 cm x 120 cm can be activated in one session. Larger paintings have to be activated in sections.

The neutron-induced radioactivity decays with time. Around a dozen different isotopes are created which emit beta and gamma radiation. The most important isotopes and their half-lifes for the investigation of paintings are: ^{24}Na, 15 h; ^{32}P, 14.2 d; ^{42}K, 12.5 h; ^{56}Mn, 2.6 h; ^{59}Fe, 50.7 d; ^{60}Co, 5.3d; ^{64}Cu, 12.8 h; ^{76}As, 1.1 d; ^{122}Sb, 2.8 d; ^{124}Sb, 60 d; ^{198}Au, 2.7 d; ^{203}Hg, 46.6 d.

In the second stage the area distribution of the inducted radioactivity of the isotopes is recorded as an image. Previously, this was only possible by means of highly sensitive X- ray film (Kodak X- AR5, 35cm x 43 cm). However, in the last few years imaging plates (Fuji BAS 2000, 20 cm x 40 cm) have been employed. Today, it is part of the normal procedure to use both methods alternately.

The exposure time required for the films is dependant on the specific half-life of the isotope involved and ranges from 1 hour to 6 weeks. Following exposure, the X-ray films are developed in the normal way and then assembled on a large light box. The imaging plates are ten times more sensitive than the X-ray films and therefore require proportionally less exposure time. This means that they can be placed on the painting and successfully exposed between two exposures of the X-ray films. The information recorded on the imaging plates is read by a laser scanner and stored as an 8- bit greyscale image, 2 MB per plate. Digital processing and assembling of the images is performed on an Apple PowerMac using Adobe Photoshop 5.0.

In between exposing the X-ray film and imaging plates a germanium detector with multi channel analyzer is used to analyse the entire radiation as well as that from specific locations on the painting. In this way it is possible to draw conclusions about the complete range of pigments that have been employed in the painting.

The poster displayed at EVA ´99 shows an example of digital image processing. The painting "Girl with a platter of fruit" by Titian was examined in the ´Hahn- Meitner- Institut` in 1997. It is a good example to show the differences between X- radiography and neutron autoradiography.

Through the X-ray film, which shows the distribution of the pigment white lead, we know that Titian used a canvas that was already painted with another portrait. This underlying portrait was interpreted as an official portrait of a doge in a standing position. There also are incisions indicating the lace of a dress and incisions for a skirt. Lines that are to be seen under the girls head were interpretated as a pentiment of an ornament in her hair. Before repainting the canvas with the girls portrait, Titian turned it upside down.

In contrast to the X-ray film neutron autoradiography revealed a woman sitting on a chair, her arm on an armrest. The dress is tied in front of her breast. The deep folds in the drapery around the armrest were formerly interpretated as the pentiment in the girls hair. The gamma-spectroscopy of the dress indicates a high rate of arsenic. In between some crackles a red paintlayer can be observed with the microscope. Thus we can say that the overpainted dress was done with the red pigment orpiment.

Trying to overlap the contours of the portrait shown on the X-ray film with that on the neutron autoradiography, it was found that they do not match in size. The portrait from the x-ray film is larger and seems to be in a standing position. Thus the result is that there are at least two different paintings lying below the visible painting. If they ever were completed cannot be said.

By neutron autoradiography the precise design of a pattern in the girls dress becomes visible. It is executed in an astonishing carefulness and it seems incomprehensible that Titian coated the pattern with a thin brown layer. But it was not Titian's purpose to turn one's eyes on a precious dress but to heighten the value of the represented girl by means of a precious gown.

Gamma spectroscopy indicates the presence of antimony in the pattern. The analysis of a taken sample proofed that Titian already used the antimony containing pigment Naples Yellow. This is the earliest evidence of Naples Yellow in a painting so far which as to literature only got into use two hundred years later.