

An Overview of Scientific Techniques in the Technical Analysis of Paintings

By Luisa Hammond

Paintings Intern

Paintings conservators confronted with questions regarding the material makeup of a work of art often require scientific analysis of the object to help them understand its history and how best to proceed with its treatment. Whether conservators work with paintings of historical importance or private meaning, it is important that any analysis not harm the object. Many of the techniques used in examining works of art are not destructively invasive, though some require samples be taken. Scientific advancements have made the instruments we use so sensitive they provide accurate readings with minuscule samples. (Figure 1)



Figure 1: Anthony van Dyck (attr.), *Portrait of Antoine Triest, Bishop of Ghent*, c. 1627, detail. The blue dots indicate areas sampled for analysis.

The chief question a conservator must answer before proceeding with a treatment concerns the physical composition of the object. When materials are known, information regarding dating, authenticity, degradation, and treatment can be better understood. One of the most common tests for a paintings conservator is pigment analysis, which determines the chemical composition of an artist's colors. Many pigments have known dates of first discovery and use. This can be useful for dating a painting and extrapolating other information about the artist, his practice, and his context that can determine a course of action. At times, this process also detects nefarious or invasive activity. The presence of modern synthetic pigments on a supposed "Old Master" portrait can help uncover forgeries. Titanium white (titanium dioxide), for instance, was first commercially available around 1920 and it is not found in paintings earlier than this date. Its presence in a painting dated before this period may indicate a fake, or an instance of subsequent conservation. Pigments also degrade (fade or shift color) in unique ways over time, so analysis of a sample can help a conservator

understand what a painting originally looked like and how to prevent further degradation.

Light

Often the first analytical step for conservators involves simply inspecting an object under different light conditions. Raking light is created by a strong light source placed almost parallel to the face of the object, revealing the texture of surfaces and the condition of the work. Ultraviolet light is useful to test for varnishes, paint, retouching, and even mold that have a characteristic fluorescence in UV's short wavelengths. The older something is, the more oxidized it becomes and the stronger it fluoresces. Original varnish will fluoresce significantly, while recent retouches will not fluoresce at all.

When such relatively simple techniques are not definitive enough to inform a conservator of how to proceed, additional analysis is necessary. This may require one or more samples to be physically removed from the work. Samples are typically small and taken from a non-intrusive part of the artwork. The field of analytical chemistry provides a range of instruments conservators use to answer their treatment questions and satisfy their intellectual curiosity.

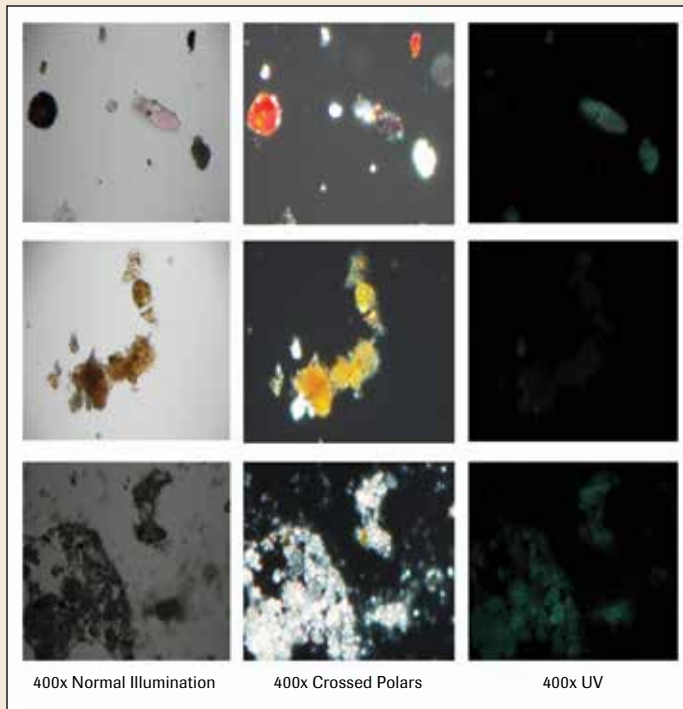


Figure 2: Comparisons of pigment samples from the van Dyck portrait, as examined under a microscope. Top row is from the red sash; middle row is from the brown background; and bottom row is from the gray sleeve. Each sample shows different sized particles and properties under differing light sources.

the nucleus move in to assume the more-stable central positions. This movement releases energy in the form of fluorescence. Each individual element has a unique fluorescence that the XRF detector reads, identifies, and quantifies. The XRF instrument provides a readout that displays all the elements found in the sample and their relative amounts. Using this information, a conservator can determine the extant pigments based on a knowledge of what elements make up what pigments. XRF instruments range in size from small portable machines that resemble futuristic ray guns and are easily taken on location, to larger versions with greater sensitivity that stay in the lab. Generally, XRF is used as a first resource to determine a broad range of elements present. However, when a conservator requires more specific knowledge about the different pigments in each layer of a painting, additional, more specific, analysis is required.

Microscopy

A more sophisticated level of analysis involves inspecting samples under a microscope, in normal illumination, UV light, or with polarized light, i.e., light filtered to control the axis

of its electromagnetic waves. In all instances, light is transmitted through the sample rather than reflected on it. When looking at a sample under a microscope, a conservator observes its unique physical properties, for example the crystalline structure, color, and size of the particles examined, as well as the way the particles look under polarized light and UV light compared to visible light. All pigments display unique structural properties that can be compared and cross-referenced for identification. (Figure 2)

Cross-sections are required to understand the layers of a painting, from the ground layer to any retouched layers or surface varnishes. A cross-section sample is larger than other samples and the conservator must carefully consider where it can be taken without causing noticeable disruption to the paint surface. Often a sample is taken from the edge of a painting or from an area that already has major losses or cracks revealing the underlayers of the painting. Surgical scalpels and micro-spatulas are often used to ensure precision. Once a sample is obtained and prepared, it may be looked at under reflected visible light, which produces a photographic-like image of the sample where all the layers can be seen and identified. This can sometimes reveal multiple paint layers, including overpaintings or restorations that are separate from the original paint layer. The use of ultraviolet light, alternately, will show the fluorescence associated with certain pigments or varnish layers that can be helpful in identification. (Figure 3)

A scanning electron microscope (SEM) uses an electron beam directed at the cross-section to produce different images of the sample. Two types of images are obtained through the scanning electron microscope. Backscattered electron (BSE) analysis occurs when the electrons in the beam are reflected off the sample through different types of interactions and back to the detector. Heavier elements will backscatter the electrons more than lighter elements, resulting in areas of increased brightness. The overall image of the sample shows the elemental distribution of lighter and heavier elements where the heavier elements are shown as areas of lighter color and the lighter elements appear as areas of darker color.

The SEM can also be used in a similar way to the XRF to obtain exact elemental analysis of much smaller samples. In this case, the electron beam serves as the high energy source instead of x-rays, but reacts with the atom in the same way, causing an electron to be ejected and another to fill its place, emitting characteristic radiation that is detected by the instrument. This process is called energy-dispersive x-ray spectroscopy (EDS or EDX). This technique results in an elemental map that shows the exact distribution of elements throughout the sample allowing for identification of pigments in each layer from the ground all the way up to any surface treatments.

FTIR and Raman Spectroscopy

The previous analytical techniques are useful for pigment analysis and other types of analysis involving inorganic materials. But materials such as oils and resins made from organic compounds must also be analyzed and understood. So-called Fourier transform infrared spectroscopy, or FTIR, examines the vibrational, stretching, and bending energies that are

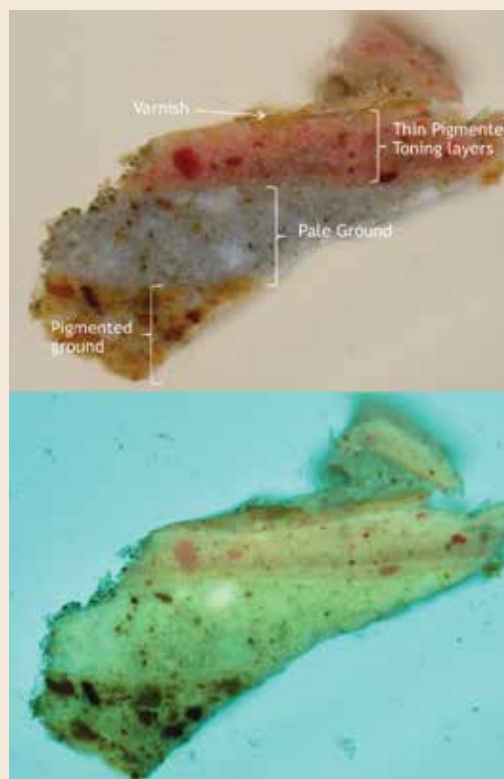


Figure 3: Cross-section taken from the earlobe area showing distinct layers of ground, pigment, and varnish, as seen under visible light (top) and UV light.

observed in compounds when they absorb light in the infrared region of the spectrum. Different functional groups in a molecule create distinct bands that absorb at different wavelengths. These bands can be broad or narrow. Each molecule has a unique spectrum “fingerprint” that conservators can cross-reference to vast libraries and databases to match an unknown sample. FTIR is useful in determining if an organic material such as cellulose is present, though the technology cannot distinguish the source of the cellulose—if, for instance, it is from cotton or wood pulp.

Raman spectroscopy is complementary to FTIR and also measures vibrational, stretching, and bending frequencies of molecules. Raman is used more for inorganic substances; a molecule that is FTIR silent it can be observed with Raman and vice-versa. Where FTIR measures the absorption of light, Raman spectroscopy calculates the scattering of light. Scattering patterns are unique to each molecule and allow for discrete identifications. This unique scattering is determined by the structure of a molecule, therefore, small differences in crystal lattice structure can distinguish different forms of the same molecule with various properties or uses. FTIR and Raman are often used together in order to achieve a greater overall understanding of an object and its components.

The analytical techniques described here, and many more, are typically employed by conservators or by specialized analytical technicians. Technical analysis at the Williamstown Art Conservation Center is performed in its own analytical laboratory and in cooperation with labs at neighboring Williams College. While the instruments can give us results in the form of pictures, graphs and readouts, it is a conservator’s knowledge and experience of artist’s materials that allows for the data to be interpreted into useful information regarding a painting’s composition and history.



Luisa Hammond is an intern in the Williamstown Art Conservation Center paintings department. A Williams College senior majoring in art history and chemistry, she is a candidate for graduation in June 2016, after which she hopes to pursue a career in art conservation and conservation science.