Practice Points NUMBER 06

Architectural Finishes: Research and Analysis

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Introduction

The research and analysis of architectural paints — intended to understand their color, appearance, and composition — has been underway in the fields of architectural and fine-arts conservation for nearly a century. A. P. Laurie and R. J. Gettens were experimenting with techniques for cross-section analysis in the fine arts as early as the first quarter of the twentieth century.[1] In the 1960s renowned preservation figures such as Penelope Hartshorne Batcheler of the National Park Service and Morgan Phillips of the Society for the Preservation of New England Antiquities (now Historic New England) extended the scope of these earlier methods to historic buildings, and modern architectural-finishes research was born.[2]

The discipline of architectural-finishes research has come a long way since the early twentieth century. It is now widely regarded as an essential part of the documentation process for historic buildings. However, the ways in which finishes research is performed can be quite varied. There is no single approach or methodology for how such a study should be conducted or for what one should expect when commissioning one. The following article is intended to provide preservation practitioners, as well as their clients, with an understanding of what comprehensive finishes research should entail and what sort of product one should expect when hiring a paint conservator. It is by no means meant to be an exhaustive discussion of all paint-analysis techniques but instead is a brief overview of common procedures followed by conservators specializing in this area.

A quick word about terminology: The term *architectural finish* can include a wide range of materials, including opaque paints, varnishes or lacquers, wallpaper, and even decorative plaster treatments. For the sake of this article, however, the term will be used mainly in reference to opaque paint films. *Pigment* refers to the finely ground material dispersed throughout a paint film that contributes primarily color and opacity to a paint (e.g., yellow ochre or white lead).[3] *Binding medium* refers to the portion of paint that forms the film and binds pigment particles to each other and to the surface to which the paint is applied (e.g., linseed oil or animal glue).[4]

Fig. 1.
Historic photographs can yield a wealth of information to guide finishes research. For instance, this circa 1900 photograph taken of the occupants of The Oaks House in Jackson, Mississippi, shows that at the turn of the twentieth century the interior doors were grained, the door surrounds were painted a pale color, and the walls were covered with wallpaper. Photograph courtesy of The Oaks House Museum.

Objectives of Finishes Research

Before commissioning architectural-finishes research, one must first identify the reasons for doing so. Finishes research can reveal a wealth of information, so it is best to have a clear idea of the goals for the study from the onset of such a project. This objective is most effectively achieved through collaboration amongst the project stakeholders — the owner, architect, conservator, and painting contractor. Working together, the project team can establish a guide for the scope of work, the quantity of samples taken and their locations, the type of analysis that will be necessary in order to achieve the goals, and, lastly, the overall cost.

Typically, finishes research is performed in order to document the color scheme associated with a particular period of significance for a historic building (most often its original paint scheme). This documentation is achieved through a combination of historical research, in-situ investigation, and laboratory analysis. However, finishes research can serve many other purposes. Analysis of a paint sample's layering sequence can reveal valuable information about a building's construction chronology by comparing the sequences of samples removed from different portions of the building relative to each other. Documentation of paint-layer se-

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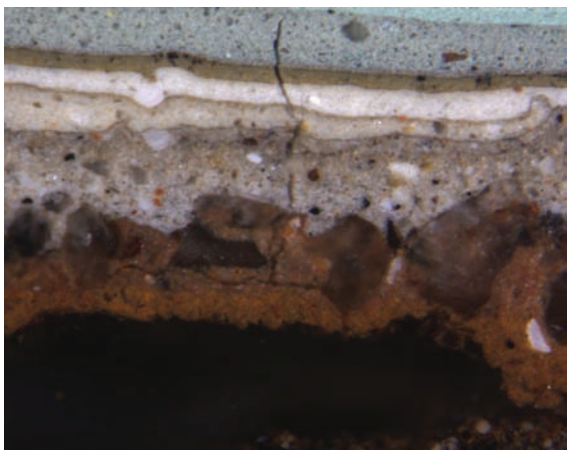
Fig. 2.
Removal of overpaint can often reveal very different previous finishes for a space. At the New Haven County Court House in New Haven, Connecticut, an immense Beaux-Arts–style building dating to 1909, a rectangular "window" exposed the original six-color, stencil-painted border and banded center field beneath approximately three layers of overpaint. Exposure work performed by and photograph courtesy of Melissa McGrew, Building Conservation Associates, Inc.

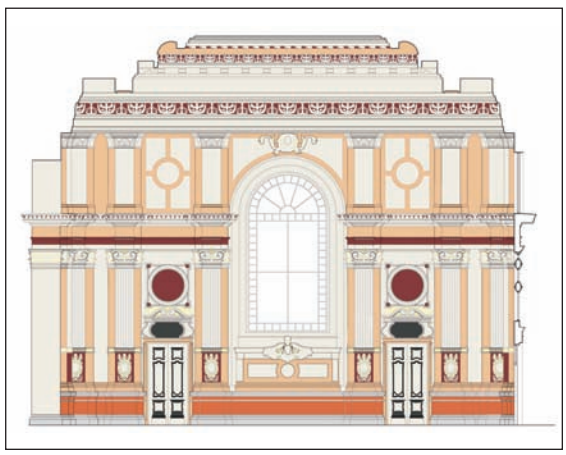
quences can also provide an essential guide for paint-removal projects in which an earlier finish is being exposed. Lastly, understanding the composition of a paint finish, primarily its binding medium and pigments, is vital to the process of designing an appropriate cleaning or conservation program and can also have implications for replication of the finish.

Whatever the reason may be for performing finishes research and analysis, some degree of interpretation of the findings should be expected. Oftentimes the research will provide the client simply with the facts collected during the study, which will require some amount of subjective interpretation in order to relate the findings to the building's current context. For instance, a finishes analysis may reveal that the exterior woodwork on a building was originally painted to match the color of its stone trim, which has weathered to a darker color than when originally installed. A subjective decision may have to be made by the project team as to which color is the more appropriate choice to repaint the woodwork — the original color, which would no longer match the existing stone, or a darker color to match the weathered appearance of the stone. The conservator should provide the greatest amount of objective information possible to the client so that the inevitable subjective interpretation of results can be well founded.

Fig. 3.
This photomicrograph of a sample removed from Towell Library at the College of Charleston in South Carolina shows that a sand paint intended to imitate brownstone was the first finish on the exterior woodwork. The grains of sand can be seen embedded in the top layer of brown paint at the bottom of the photograph. Subsequent paint layers include grays, creams, and a pale brown (110x, visible light). Photograph by author.

Fig. 4.
Sometimes it is necessary to prepare a visual representation of documented paint colors when the finishes scheme is particularly complex. In this case, computer software was used to indicate historic paint colors identified through paint analysis on an interior elevation of Memorial Hall in Philadelphia to illustrate the building's appearance during the 1902 period of interpretation. Image courtesy of Please Touch Museum/Kise Straw & Kolodner.



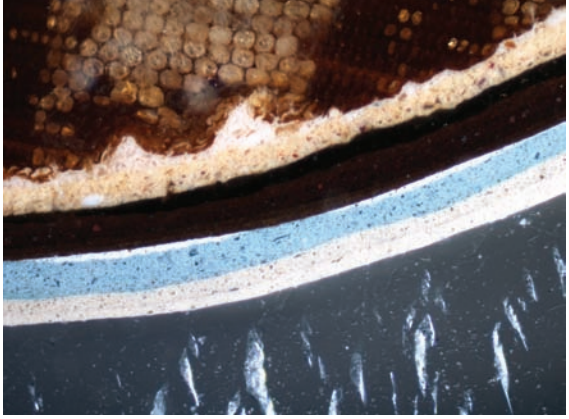


What can be gained from performing an architectural-finishes analysis?

- documentation of a color scheme associated with a particular significant historic period for a building
- construction chronology of a building
- the original aesthetic intent of the building's designer or occupant
- new information on traditional painting materials and techniques
- information to guide paint-removal projects and on-site exposures of earlier finishes
- information for cleaning or conserving a specific finish

Historical Research

One of the most essential components of architectural-finishes research, which is undertaken prior to any physical investigations, is the gathering of historic documentation, including written accounts, historic images, and building specifications. These primary documents can yield clues about earlier finishes that have long since been covered, and they can guide the conservator in site investigation and sampling. Historic images often contain information about color schemes and the location of decorative painting. Original building specifications can contain information on the type and even the color of the original paint. They also offer a glimpse into the original design intent of the architect, information that can be useful when interpreting the results of a finishes analysis and making recommendations for a restoration paint scheme (Fig. 1).



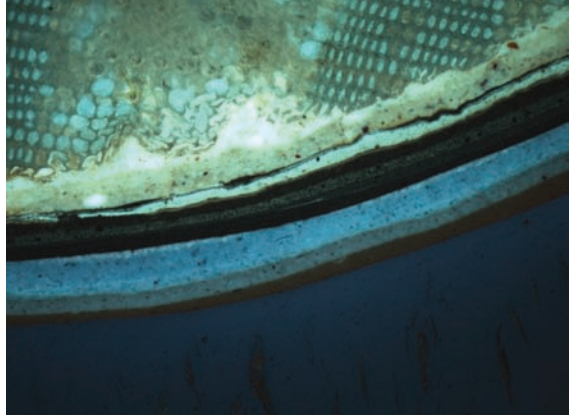


Fig. 5.
This photomicrograph (left) shows a paint cross section removed from the interior woodwork of the Coweta County Courthouse in Newnan, Georgia, in visible light. Courtesy of the author.

Fig. 6.
This photomicrograph (right) shows the same sample viewed through a "violet" filter cube EF4 V-2A Ex400/40 Dm430 Bar 450. The woodwork's original grained finish (composed of a ground layer, a figuring layer, and a layer of varnish) is more legible when viewed in ultraviolet light. The varnish layer in particular becomes easier to identify, with its characteristic blue-green glow. Courtesy of the author.

In-Situ Investigation

Once the historical research has been performed and a general understanding of the project's context has been established, the field investigation can begin. In-situ investigation of architectural finishes involves using a combination of techniques to reveal early paint histories and remove representative samples for further analysis. Revealing layers of paint on site typically includes removal of overpaint through mechanical scraping or solvent application, followed by visual assessment of the paint history using a field microscope. This technique provides an idea of the approximate number of layers present in a given area and can help to identify protected areas of preserved paint for sampling purposes. It is also useful in the identification of any decorative painting, which can sometimes be overlooked if performing only microscopic examination in the laboratory. However, using this type of "scratch and match" field investigation alone is typically inadequate for gaining a full understanding of all finish layers present. Removing samples and taking them back to the conservation laboratory so that they can be examined with a high-magnification microscope is the best way to confirm and supplement in-situ findings.

Field investigation, including removal of overpaint to expose earlier decorative painting schemes, is an important part of many finishes-research projects. While some decorative painting can be identified when using cross-section analysis, a full understanding of its original appearance cannot be gained unless it is exposed in situ. For instance, the decorative treatment of wood graining can usually be identified in cross-section by its characteristic three-layer structure: the ground, the grain or "figuring" layer, and the varnish layer. However, to gain insight into the artist's application technique and the actual appearance, the layers of paint covering this finish would need to be carefully removed using a combination of mechanical scraping and solvent application. This process requires testing and an understanding of the composition of the more recent paint layers to ensure the use of a solvent that will dissolve later paint layers without affecting the original finish (Fig. 2).

The other primary objective of site investigation is the removal of paint samples for laboratory analysis. Removing appropriate samples can be the most challenging part of a paint study. Care must be taken that the samples are complete and that they are representative of the finishes being studied. There is a huge range in sample size, from a few millimeters to a couple of inches, depending on the site and the person taking the samples. When selecting a sample location, it is especially important to look for protected areas of paint build-up or hard-to-reach places, in order to avoid taking samples from locations that may have been previously stripped or were heavily weathered. It is always preferable to have the conservator who will be performing the analysis also remove the samples. Although sampling techniques vary widely among paint conservators, the goal remains consistent: to remove enough intact, representative samples of adequate size to be able to perform physical manipulation, microscopic examination, instrumental analysis, and color matching. Removal of the finish layers, as well as a portion of the substrate, is also essential to ensure that all layers are present in any given sample and that the nature of the substrate is understood, as well.

Oftentimes substrates, such as some forms of decorative plaster or hardwoods such as mahogany, were meant to be exposed or clear-coated instead of painted. To exclude the substrate in these instances would be to miss the original finish application altogether.

What should an architectural-finishes analysis include?

- a clear objective
- historical research
- an understanding of the context of both the building and the restoration project
- in-situ investigation
- laboratory analysis, including cross-section analysis supplemented by analytical and instrumental techniques
- a written report thoroughly documenting the analysis methodology and findings

Microscopic Examination of Paint Samples

Laboratory analysis begins once the research and field investigation have been completed, although additional trips to the site may be required. Paint samples are initially examined under a stereomicroscope (10x to 80x magnification) to gain a general understanding of the number and character of layers present in each sample. These raw samples can be manipulated and viewed at various angles to identify the sequence and color of layers, including dirt layers, points of fracture, and decorative finishes, such as gold leaf, which can be missed when viewed in cross section. This process

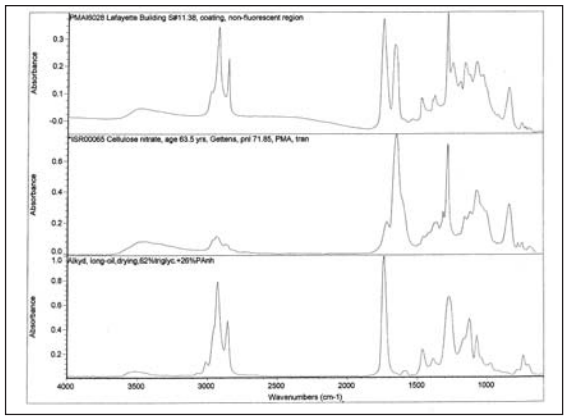


Fig. 7.
Fourier transform infrared spectroscopy (FTIR) can be used to characterize binding media in architectural finishes. This image illustrates typical spectra generated through this analytical technique. The top spectrum represents the sample coating, in this case a clear finish from wood paneling of a conference room in the circa 1940 Lafayette Building in Washington, D.C. The middle and lower spectra are reference spectra that were generated as possible matches to the sample, indicating that the coating was a nitrocellulose lacquer modified with an alkyd resin. Image courtesy of the Philadelphia Museum of Art Analytical Laboratory.

also allows the most-representative samples to be selected and processed for additional investigation, including cross-section analysis. Samples selected for cross-section analysis are cast in a permanent mounting medium, cut or ground to expose the edge of the paint sample, then polished to produce highly reflective cross sections of paint and substrate; the layer structure can then be easily deciphered. The polished cross sections are viewed using a high-magnification microscope, typically a stereomicroscope or compound microscope, with a coaxial stage and a wide range of magnification (25x to 250x) (Fig. 3).[5]

Cross-section analysis provides additional confirmation of the layering sequence preliminarily observed on site, as well as a more detailed examination of individual paint layers. Layering sequences can be recorded through photography or written notes, allowing for comparison of samples to establish general layering sequences and differences in individual stratigraphies. Special note can also be made during this examination of any distinguishing characteristics, such as degree of paint-film translucency/opacity, pigment-particle size and color, and paint-film thicknesses. Digital photomicrography has made the task of recording the layering sequences of samples much easier and more effective, because it permits direct visual comparison, sample to sample and layer to layer.

Once the layering structure of each sample has been recorded through these microscopy techniques, the analysis shifts focus to a more thorough understanding of the specific finishes identified as significant for that particular project. The extent of this additional research is dependent on the goals of the specific project or client. One project may require thorough documentation of all constituents in a given paint layer, while another could be interested simply in the color of a particular paint layer. When this additional research is requested, it typically involves color matching or analysis of paint composition.

Color Matching

The issue of color matching of historic paints is one of the most debated topics in the field of architectural paint conservation today. The dispute stems mainly from the fact that linseed oil–based paints (especially pale-colored paints) darken and yellow over time if not exposed to sunlight, including even oil-based finishes that have been covered with subsequent paint layers.[6] In addition, some pigments, such as Prussian blue and chrome yellow, change over time, greatly impacting the present and original appearance of a paint layer. However, the only way to determine if a paint layer contains a binder or pigment that may have changed over time is through identification of these components (discussed below).

Currently there is no standardized system for matching historic paint colors. However, conservators have worked out a methodology over the past few decades that attempts to make the color-matching process as objective as possible. First, the paint layer of interest is identified in cross section and exposed on a raw sample removed from the same area (the larger the area of exposure, the easier it will be to get an accurate color match). Following the creation of an exposure window, the color of the exposed paint layer is matched with a color system both visually and using a spectrophotometer or a colorimeter, a similar but simpler instrument. The visual match is typically made to both a standardized system, such as the Munsell color system, and a commercial-paint palette. Although the latter is subject to change, projects often require that a match be made to a readily available commercial paint. The spectrophotometer or colorimeter will provide a match to another standardized system, the CIE L*a*b* system. Taking a reading of the Munsell color chip or commercial color match is also recommended, in order to assess the difference between the color swatch and the actual paint color (Fig. 4).

Once the existing color has been documented, a subjective assessment is made as to whether or not the historic paint color may have changed over time through yellowing or some other type of discoloration. Such a conclusion cannot be arrived at without first identifying the binder medium or pigment composition of a paint. If the paint is identified as a linseed oil–based paint and it is believed to have yellowed over time, then some fairly simple measures can be taken to try to reverse the yellowing. By exposing the yellowed paint to a broad-spectrum fluorescent light or natural sunlight for approximately two weeks, the yellowing can be greatly diminished. However, it can be difficult to recognize the point at which the yellowing of the paint layer has been reversed but bleaching out of the color has not begun. In other words, there is really no effective way to know when to stop the lightening process to avoid bleaching. Nonetheless, some attempt to rectify the color change has to be made, and, as long as it is properly documented with before-and-after color readings, it is generally viewed as a necessary part of paint analysis. Any process used to reverse the yellowing of an oil-paint film should be fully documented by the conservator and included in the final paint-analysis report.

Analysis of Paint Composition

Some projects require additional investigation of the composition of a paint layer, including characterization of binding media and identification of pigments. This supplemental research is typically performed to pro-

vide information for paint replication, identify a layer's potential for discoloration or fading, or provide information about the best way to clean or conserve a finish.

Several techniques are currently used for binding-medium identification, although it is generally recognized that performing such characterization with any degree of certainty can be difficult because of the complexity and degradation of many architectural paints. One of the simplest techniques that can be used for binder characterization is microchemical testing, which is used to determine the solubility or reactivity of certain paint layers to specific chemicals or solvents. Many of these tests can be readily performed in the lab or on site using a field microscope to observe reactions. For instance, if a paint layer is soluble in warm water, this suggests a distemper, or a glue-size-based, paint. Although the results of this method are somewhat preliminary, they can be confirmed by using a range of other, more precise techniques, such as fluorescence microscopy, Fourier transform infrared spectroscopy (FTIR), or gas chromatography-mass spectrometry (GCMS).

Fluorescence microscopy is another readily available analytical technique. Many paint conservators have microscopes outfitted with fluorescence capabilities and use this type of analysis as part of their routine cross-section examination. Fluorescence microscopy makes it possible to observe the autofluorescence of an individual paint layer, the light emitted by a material when it is exposed to ultraviolet light. Because different materials autofluoresce uniquely, a material can often be identified by its autofluorescent characteristics. This tool is very useful for identifying the general layering sequence of a paint cross section, and many paint conservators rely heavily on its ability to make complex stratigraphies more legible (Figs. 5 and 6). Fluorescence microscopy can also be used in combination with biological stains that "tag" certain organic materials, causing a chemical reaction or change in color that is observable when viewed through appropriately filtered light.[7] This process can provide further information about a paint layer's binder.

Although microchemical tests and fluorescence microscopy can potentially help in characterizing a paint's binding media, the results can be difficult to interpret. Using these techniques in concert with other analytical tools, such as FTIR or GCMS, will generally yield more precise information, although concrete results are often difficult to achieve even with these more sophisticated types of analyses. These techniques, long thought to be beyond the reach of most conservators, are becoming available through conservation departments of many universities and art museums, as well as at a handful of firms specializing in materials analysis and characterization. This type of more detailed analysis is particularly useful for projects in which knowing the composition of a paint film is essential, such as those that involve the cleaning and conservation of an existing finish or the matching of the original ingredients for paint replication. However, not every paint-analysis project requires the use of such additional testing. It is the responsibility of the paint conservator to determine when this additional testing is necessary and discuss its importance to the project with the client (Fig. 7).

Identification of pigments is also sometimes necessary for a finishes-research project. However, like identification of a paint's binder, it is not typically a required part of finishes studies. Characterization of pigments within a paint layer can help in understanding the composition, color, and overall appearance of a historic finish, including its potential for discoloration. Of equal importance is its use to date a finish campaign, which is possible because certain pigments have known dates of commercial introduction and their presence can help establish approximate dates for particular paint layers. As with binding-media investigation, there are several ways in which to characterize pigments in a paint layer.

The principal way of identifying pigments is polarized light microscopy (PLM), mainly because polarized-light microscopes are readily available and a standard component of the architectural-conservation laboratory. Using plane-polarized and cross-polarized light, the microscopist observes the characteristics of pigment particles, including their color, crystal shape, size, polarization colors, and refractive index, and then compares them with those of known pigment particles that are identified in reference collections.[8]

Microchemical tests can also be performed on paint layers of both raw samples and in cross section, in order to identify the presence of certain pigments. In these tests a chemical solution is applied to a paint sample, and the resulting chemical reaction is observed. The most commonly used microchemical test for pigment identification is sodium sulfide, which, when dropped onto a paint sample, will turn any lead-containing layer black.

Scanning electron microscopy/energy-dispersive spectroscopy (SEM/EDS) as a technique for pigment identification is also available to conservators. SEM/EDS is used for topographical examination and analysis of a material's elemental composition, which is gained through the X-ray portion of the instrument and can identify which elements are present in a given pigment particle.[9] Once the elements in a pigment particle are identified, the search for pigments known to contain those elements can be undertaken. This search usually involves referencing texts that define the composition of pigments. Like most specialized analytical tools, SEM/EDS is most effective when a very specific question is being asked and the analysis is targeted (Fig. 6).

Analytical techniques

Binding-Media Identification

- microchemical tests
- fluorescence microscopy, including use of fluorchrome dyes
- Fourier transform infrared spectroscopy (FTIR)
- gas chromatography-mass spectrometry (GCMS)

Pigment Identification

- microchemical tests
- polarized light microscopy (PLM)
- scanning electron microscopy/energy dispersion spectroscopy (SEM/EDS)

Conclusion

Architectural-finishes research can contribute to our understanding of a building's aesthetic history and its construction chronology, as well as the intent of the original design. It is a powerful tool that adds substance to the documentation of any historic site. As such, there are certain basic requirements that paint research should meet to be successful. These include undertaking proper historical research, understanding the context of the building and the restoration project, performing in-situ investigation, conducting laboratory analysis, and creating a written report that thoroughly documents the methodology and findings. As discussed, laboratory analysis typically includes microscopic examination of paint samples and analysis of paint composition. It is the hope of the author that by providing a general overview of this process, we can begin to standardize our expectations for architectural-paint research.

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Notes

1. Joyce Plesters, "Cross-Sections and Chemical Analysis of Paint Samples," *Studies in Conservation* 3 (April 1956): 110.

2. Penelope Hartshorne Batcheler, "Paint Color Research and Restoration," Technical Leaflet No. 15, *History News* 23, no. 10 (1968). Morgan W. Phillips, "Discoloration of Old House Paints: Restoration of Paint Colors at the Harrison Gray Otis House, Boston," *Bulletin of the Association for Preservation Technology* 3, no. 4 (1971): 40.

3. Rutherford J. Gettens and George L. Stout, *Painting Materials: A Short Encyclopedia*, 2nd ed. (New York: Dover Publications, 1966), 137–138.

4. Gettens and Stout, 35.

5. Andrea Gilmore, "Analyzing Paint Samples," in *Paint in America: The Colors of Historic Buildings*, ed. Roger W. Moss (Washington, D.C.: The Preservation Press, 1994), 179.

6. Frank S. Welsh, "Paint, Caen Stone, and Acoustical Plaster at the Public Library in Mobile, Alabama" *APT Bulletin* 38, no. 1 (2007): 18.

7. Richard Wolbers and Gregory Landrey, "The Use of Direct Reactive Fluorescent Dyes for the Characterization of Binding Media in Cross-Sectional Examination," in *Preprints of Papers Presented at the Fifteenth Annual Meeting, American Institute for Conservation of Historic and Artistic Works, Vancouver, British Columbia, May 20-24, 1987* (Vancouver: American Institute for Conservation, 1987), 168–202.

8. Gilmore, 182.

9. James S. Martin, "Microscopic Examination and Analysis of the Structure and Composition of Paint and Varnish Layers," *Painted Wood: History and Conservation. Proceedings of a Symposium Organized by the Wooden Artifacts Group of the American Institute for Conservation of Historic and Artistic Works, Williamsburg, Va., Nov. 11-14 1994*, eds. V. Dorge and F. C. Howlett (Los Angeles: The Getty Conservation Institute, 1998), 67–68.

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