Cross-section Paint Microscopy Report
Exterior Paints

Historic Sandusky
Lynchburg, Virginia

For: Gregory H. Starbuck
Executive Director
Historic Sandusky Foundation
757 Sandusky Drive
Lynchburg, VA 24502

Conservator: Susan L. Buck, Ph.D.
303 Griffin Avenue
Williamsburg, VA 23185

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Historic Sandusky Side Porch Door

Purpose:

The goal of this project is to use cross-section microscopy analysis techniques to analyze paints from selected exterior elements of ca. 1808 Sandusky, a brick Federal-style house built by Charles Johnston. If analysis suggests that the paints related to the 1860s interpretation period survive, they will be color-matched for replication using a colorimeter/microscope.

Procedures:

One large bag containing sixteen labeled samples were mailed to Susan L. Buck for analysis. These samples had been taken by Travis MacDonald, Director of Restoration at Thomas Jefferson's Poplar Forest. At the lab these samples were first examined at 45X magnification with a binocular microscope and the best samples were selected for analysis. This group of samples was cast into polyester resin cubes for permanent mounting. The cubes were ground and polished for cross-section microscopy analysis and photography. The sample preparation methods and analytical procedures are described in the reference section of this report.

The cast samples were analyzed with a Nikon Eclipse 80i epi-fluorescence microscope equipped with an EXFO X-Cite 120 Fluorescence Illumination System fiberoptic halogen light source and a polarizing light base using SPOT Advanced software (v. 4.6) for digital image capture and Adobe Photoshop CS for digital image management. Digital images of the best representative cross-sections are included in this report. Please note that the colors in the digital images are affected by the variability of color printing and do not accurately represent the actual colors.

Paint Analysis Results:

The most complete cross-section samples were selected to illustrate the comparative paint stratigraphies as some of the elements sampled appear to contain only modern (twentieth century) paints. In general, the evidence from this group of sixteen samples suggests that there is a long history of painting all the trim elements, including the windows, cornices, and door trim, with off-white, white and cream colors. The comparative evidence also suggests the blinds and louvers were most often painted dark colors, primarily black and greens. There were a few surprises when the paint stratigraphies on the louvered blinds were compared because the two most complete paint samples (HS-2 from the tripartite window blind and HS-15 from a first-floor window on the north elevation) do not match up.

Sample HS-2 contains approximately 12 generations of paint, beginning with a dark gray (almost black) paint on top of the wood. This is followed by four generations of green paint which range in color from yellowish-green to bright green. Generations 4 and 5 clearly contain the copper-based pigment verdigris, which are the coarse blue-green pigments that can be seen in the cross-section image. Verdigris produces a brilliant green paint, but it was an unstable pigment which readily discolors to brownish or black. Generation 6 in HS-2 is a gray paint, which contains the pigment zinc white, based on the positive reaction for zinc (Zn^{2+}) with the fluorochrome stain TSQ. Zinc white is not commercially available until about 1845, which means this gray paint has to be later than 1845. The gray paint is followed by four generations of green paint, and then the most recent black paint. This sample shows that this louvered blind was always painted a dark color, but it is difficult to be certain which specific layer dates to the 1860s.

Sample HS-15 has approximately 13 generations of paint, beginning with two dark tan paints in generations 1 and 2. Generations 3 through 5 are dark green paints which are considerably darker than the comparable layers in sample HS-2. Generation 5 reacted positively for the presence of zinc, which dates this layer to after 1845. The evidence shows that window blind is off-white (perhaps to match the window trim) in generation 6, followed by tan in generation 7, and off-white again in generations 8 and 9. The most recent four generations of paint on this element are dark green. The two louvered shutters were only painted to match each other in generations 10 and 11 with the same green paints.

Examination of all the trim samples under a binocular microscope at 45X showed that there is a long history of painting all these elements cream-color, off-white or white. One sample was taken from the Greek Revival door trim to help with relative dating of the most intact paint chronologies. This later element should have considerably less paint than the original ca. 1797 elements. Unfortunately, only the two most recent paint layers remain in the area sampled, so its stratigraphy does not help to document the Greek Revival trim color.

The two most complete samples taken from original trim elements (HS-4 and HS-6) contain approximately 13 generations of primarily off-white and white paints. The first layer in both cross-section samples is a weathered gray paint which remains trapped in the wood. This gray layer is followed by off-white paints in generations 2 through 5, and cream-colored paints in generations 6 through 8. The most recent finely ground, nonfluorescent paints in generations 9 through 13 are all off-white paints that are considerably more intact and less weathered than the early paints. The second generation paint in sample HS-6 contains zinc, based on staining with TSQ, thus dating it to after 1845. So, there may be earlier paints that are missing from these samples.

For the purpose of interpreting the 1860s color, it is likely that one of the off-white paints (composed primarily of white lead) in generations 3, 4 or 5 represents the 1860s trim color. The paints in the sample taken from the window putty (sample HS-10) begins with the off-white paint layer identified as generation 5, confirming the windows were painted the same color as the window trim from generation 5 to the present. The early paints in all three samples are so degraded that it is not possible to obtain an accurate color measurement or to confidently establish a visual match, however, the comparative evidence suggests it would be appropriate to use a typical white lead-based paint color (a warm off-white) as a match for the 1860s trim color.

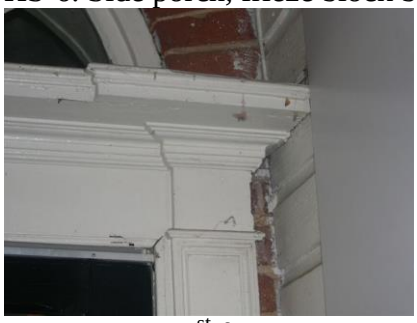
Binding media analysis suggests that all the layers in the cross-sections examined for this study are oil-based paints, with the exception of generations 7 and 8 in sample HS-15. These two intermediate layers may be late nineteenth-century emulsion paints as they contain weak oil components, and also have carbohydrate and protein components.

Sample Locations

HS-2. Side porch, tripartite window blind

HS-4. Side porch, tripartite window cornice

HS-6. Side porch, frieze block below cornice

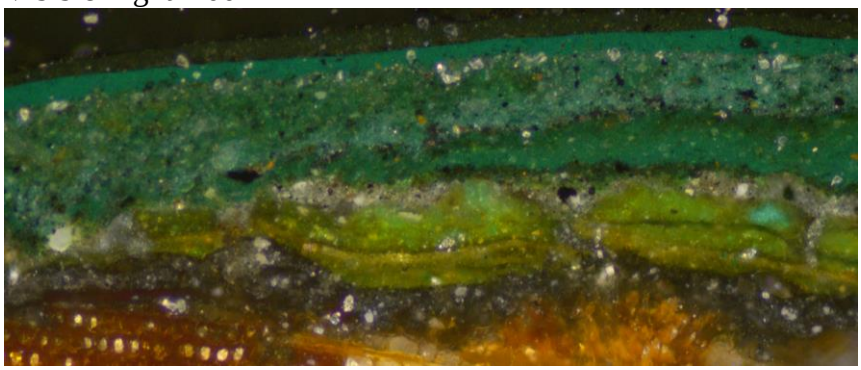


HS-10. Front 1st floor window, lower sash

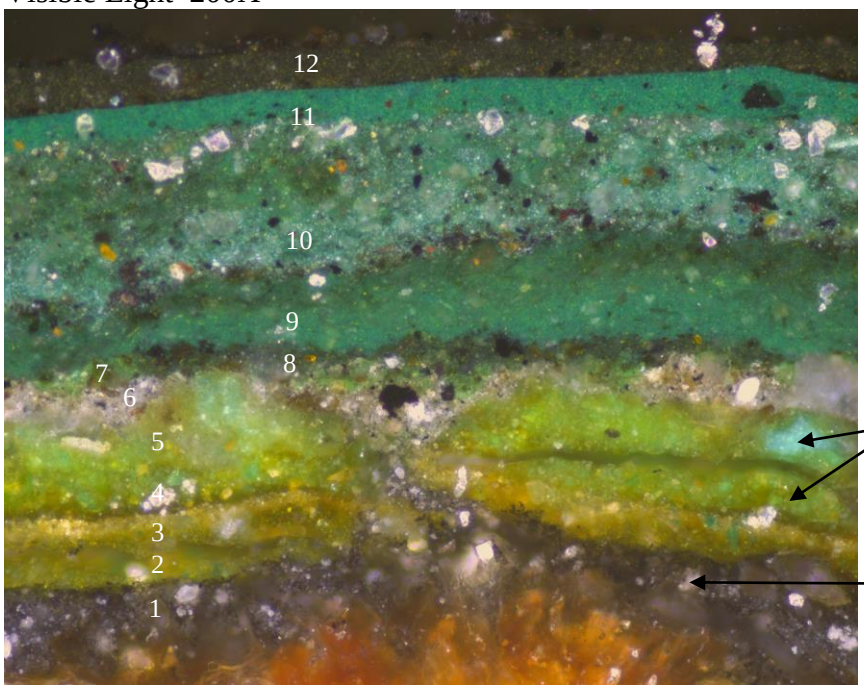
HS-14. Front porch, left side pilaster

HS-15. N. back 1st floor window, louvered blind, right of door

Sample HS-2. Side porch, tripartite window blind, right, top louver-(in).
Visible Light 100X



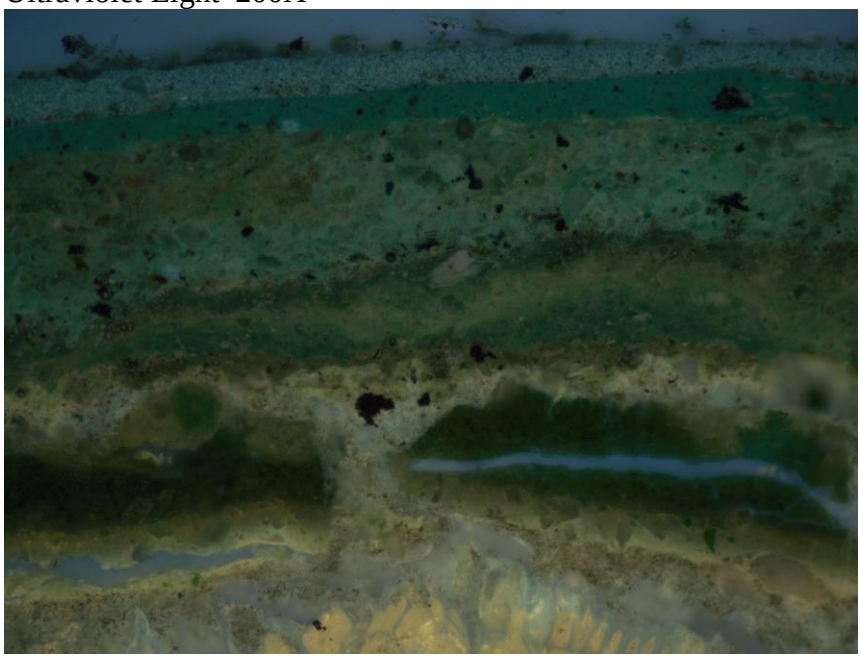
Visible Light 200X



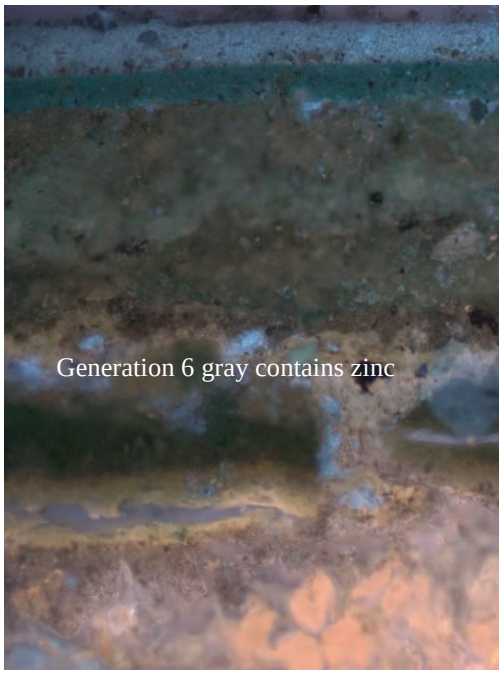
Generations 4 and 5 contain the copper-based green pigment verdigris

First generation is dark gray, almost black

Sample HS-2. Side porch, tripartite window blind, right, top louver-(in).
Ultraviolet Light 200X



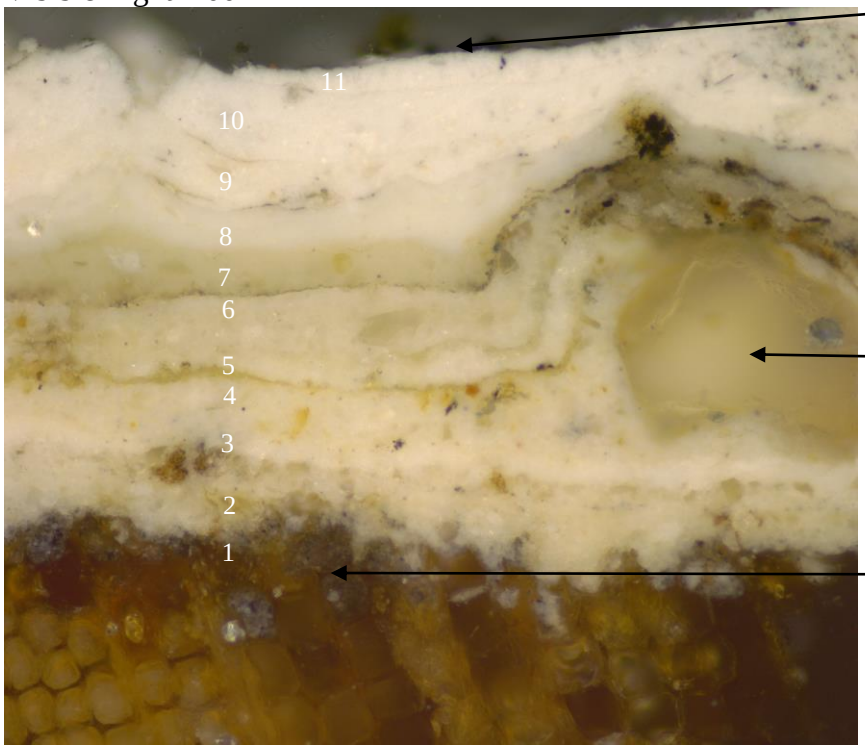
UV Light & TSQ for the presence of zinc 200X



UV Light & RHOB for oils 200X
All layers reacted positively for oils

Sample HS-4. Side porch, tripartite window "cornice," left side, back corner.

Visible Light 200X

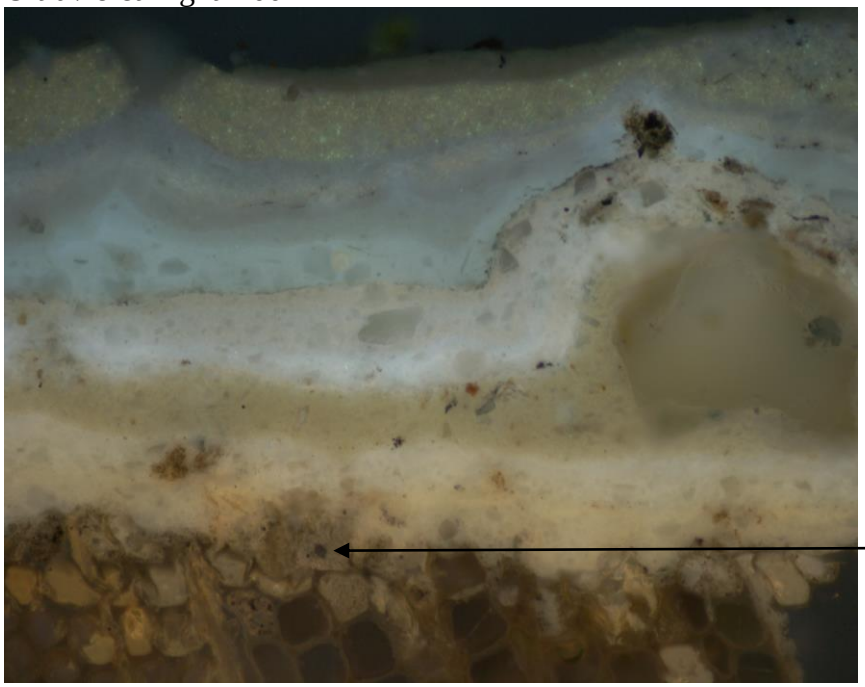


Most recent paint is missing from this cross-section

Sand particle in the off-white paint may be a contaminant as it was not found in any other cast or uncast samples

Early weathered gray paint trapped in the wood

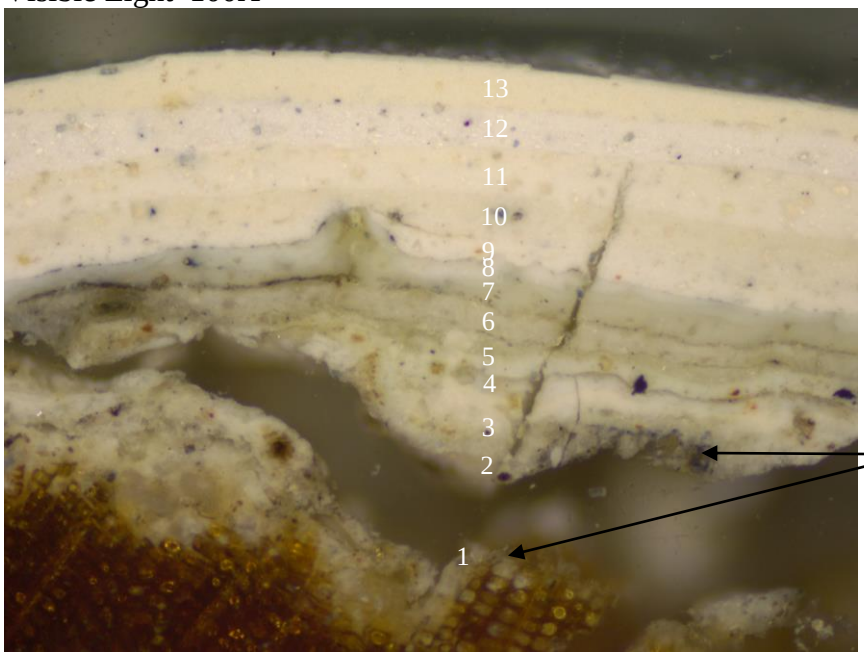
Ultraviolet Light 200X



Early weathered gray paint trapped in the wood

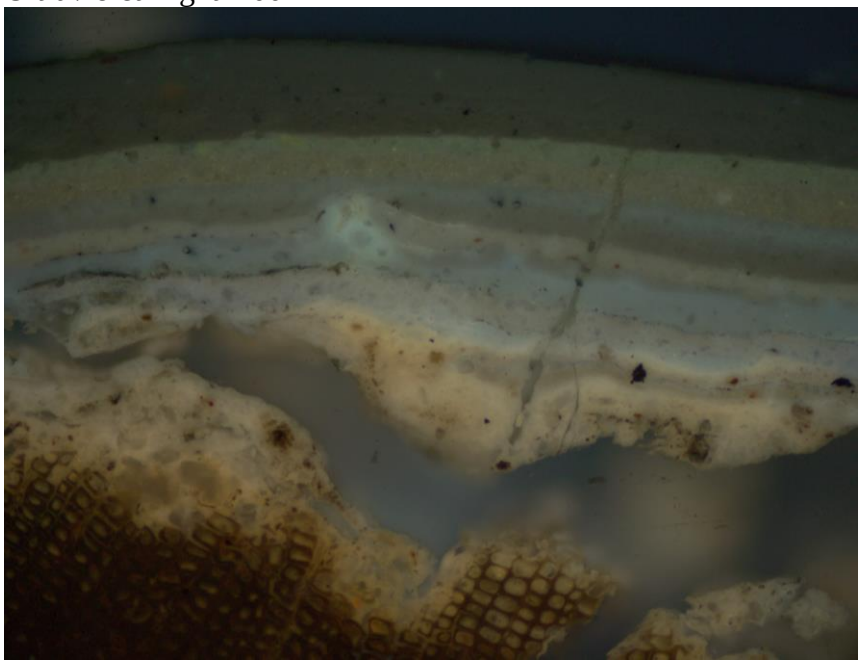
Sample HS-6. Side porch, 1st per. doorway, right side architrave, "frieze" block below cornice, front edge, (same location as HS-1).

Visible Light 100X

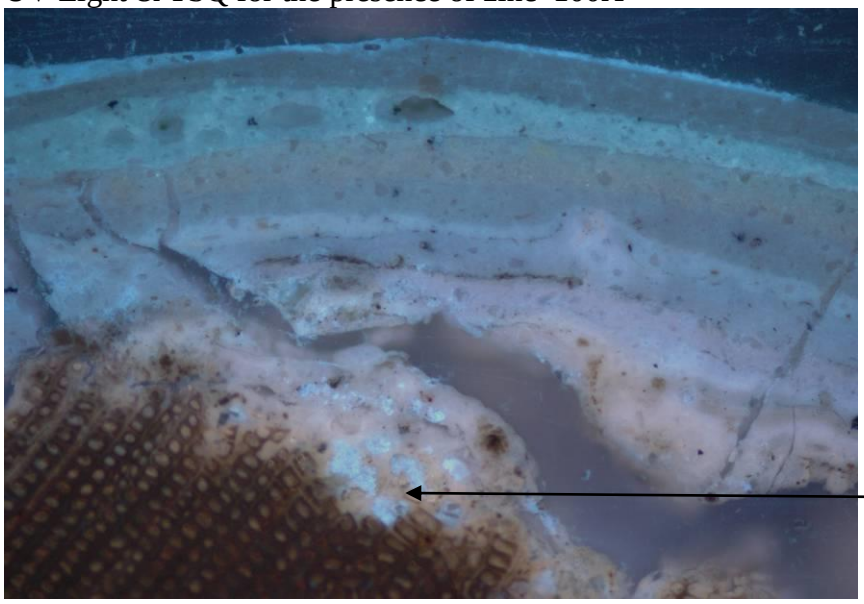


Remnants of the first gray paint below later off-whites. Early layers are quite weathered and disturbed.

Ultraviolet Light 100X

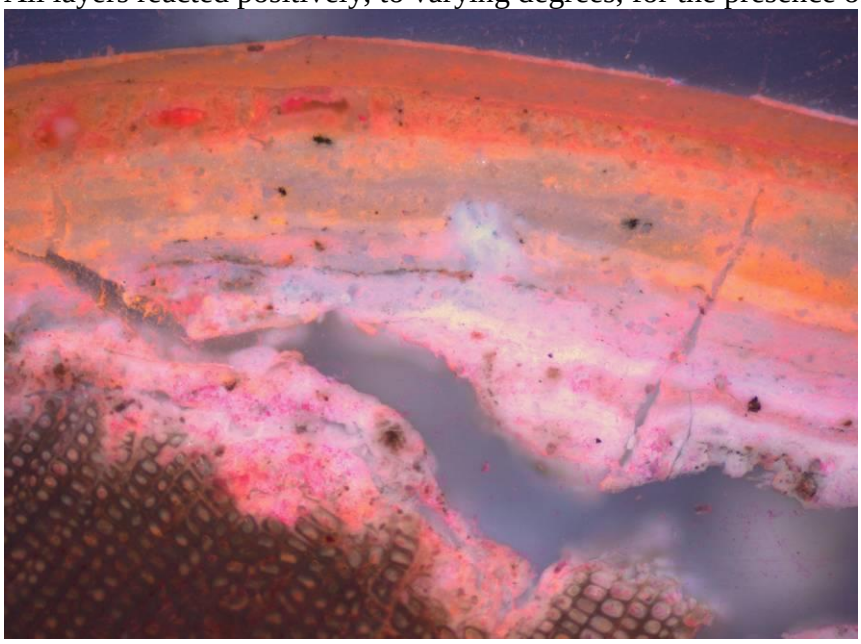


Sample HS-6. Side porch, 1st per. doorway, right side architrave, "frieze" block below cornice, front edge, (same location as HS-1).
UV Light & TSQ for the presence of zinc 100X



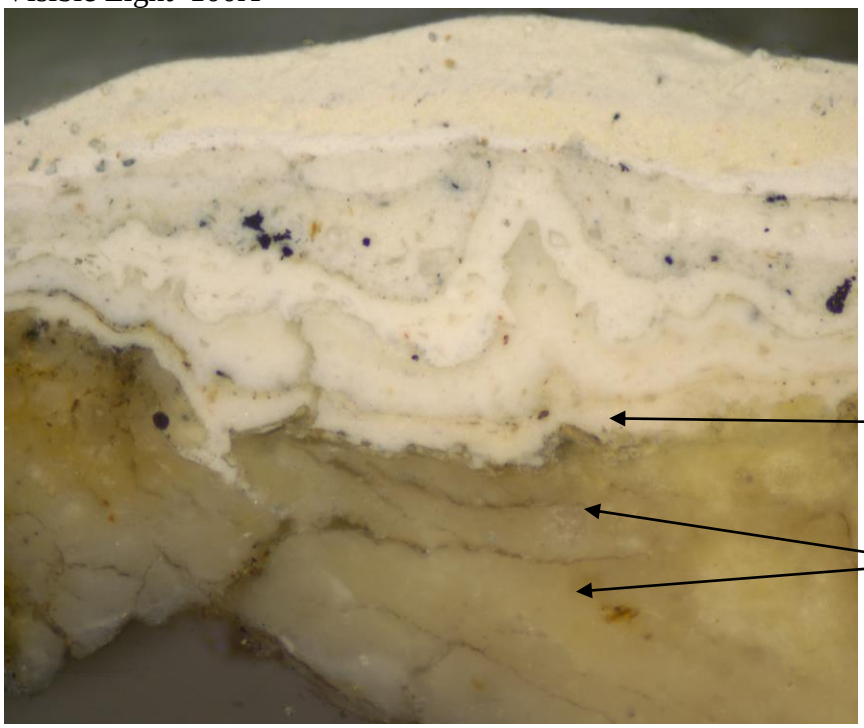
Spotty positive reaction in the off-white paint in generation 2 suggests the presence of zinc white

UV Light & RHOB for the presence of oils 200X
All layers reacted positively, to varying degrees, for the presence of oil

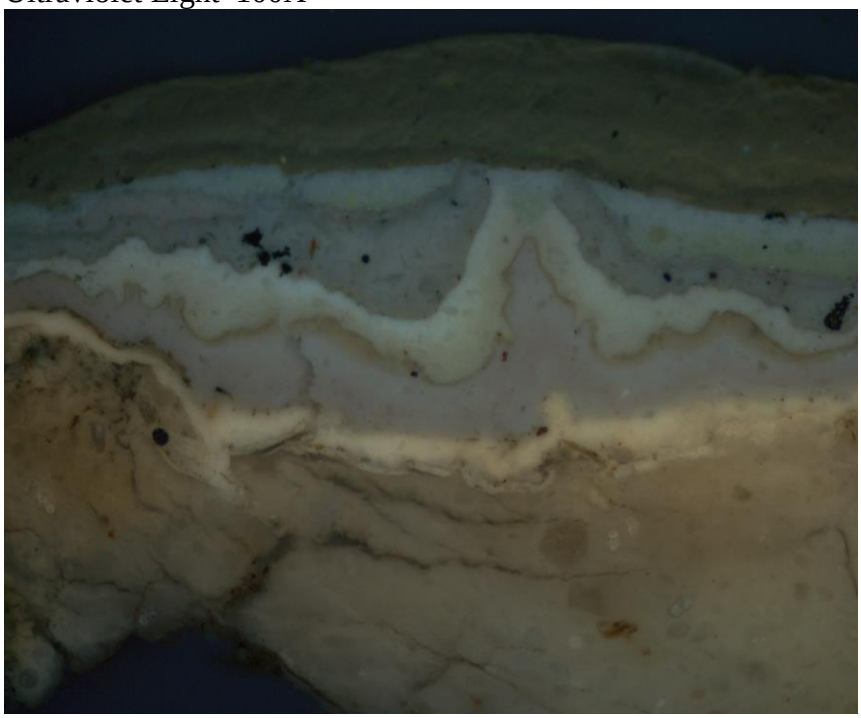


HS-10. Front 1st floor window, lower sash, putty from muntin (see diagram on sample bag).

Visible Light 100X

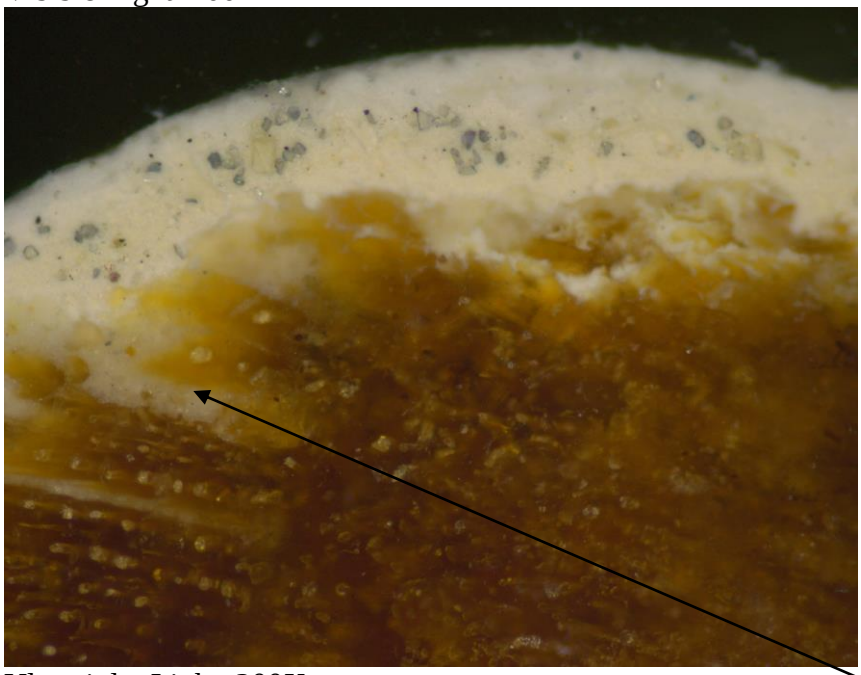


Ultraviolet Light 100X

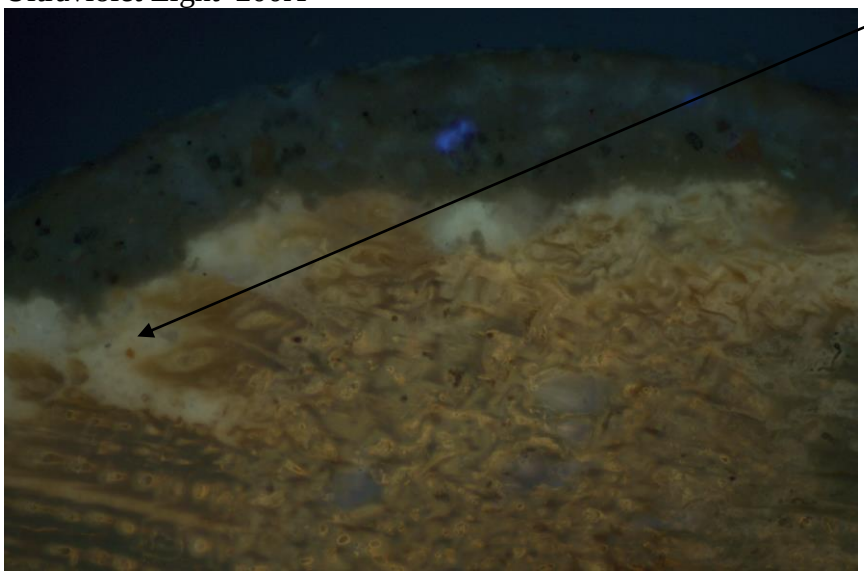


Sample HS-14. Front porch, left side pilaster, Greek Revival trim. Use to date Greek Revival remodeling vs. original trim. This cross-section represents an element that has been almost completely stripped of its early paints.

Visible Light 200X

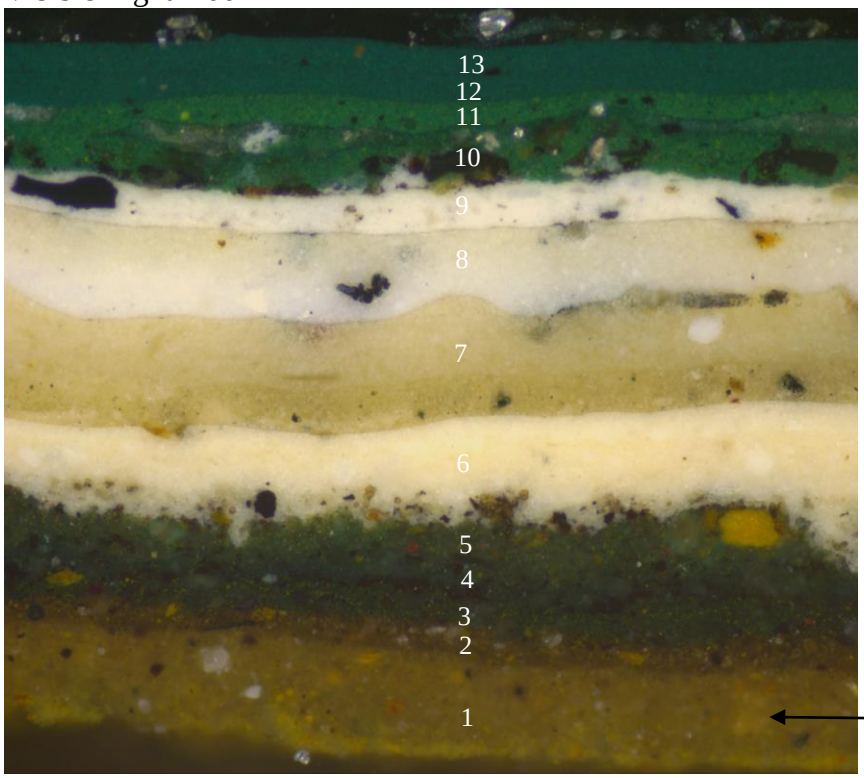


Ultraviolet Light 200X



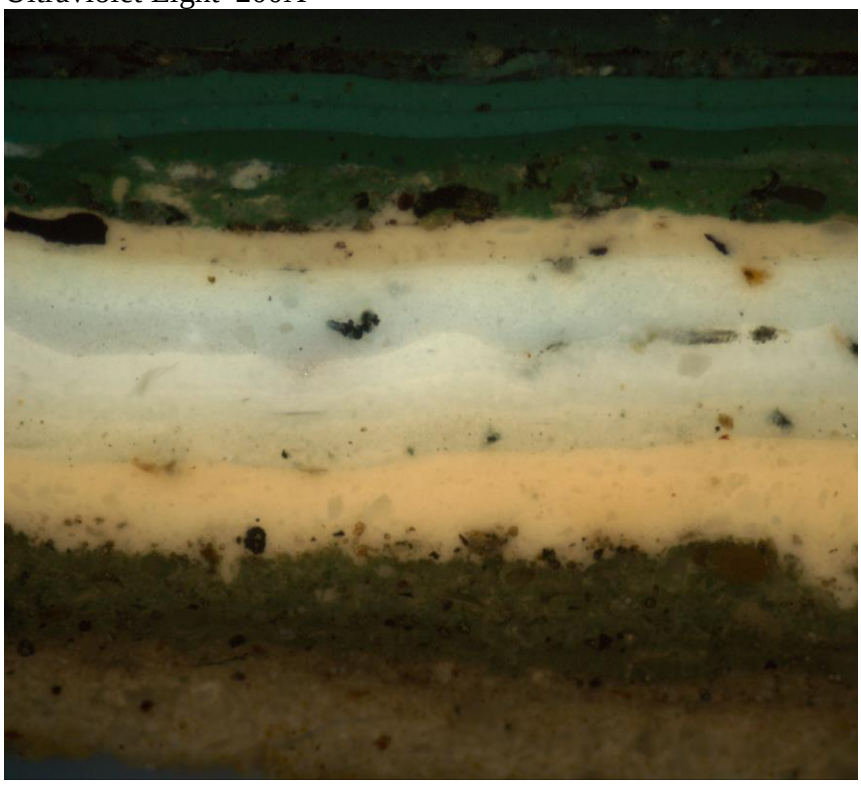
Remnants of early cream-colored paint trapped in the wood

Sample HS-15. North back 1st fl. window, loose paint, louvered blind, right of door.
Visible Light 200X

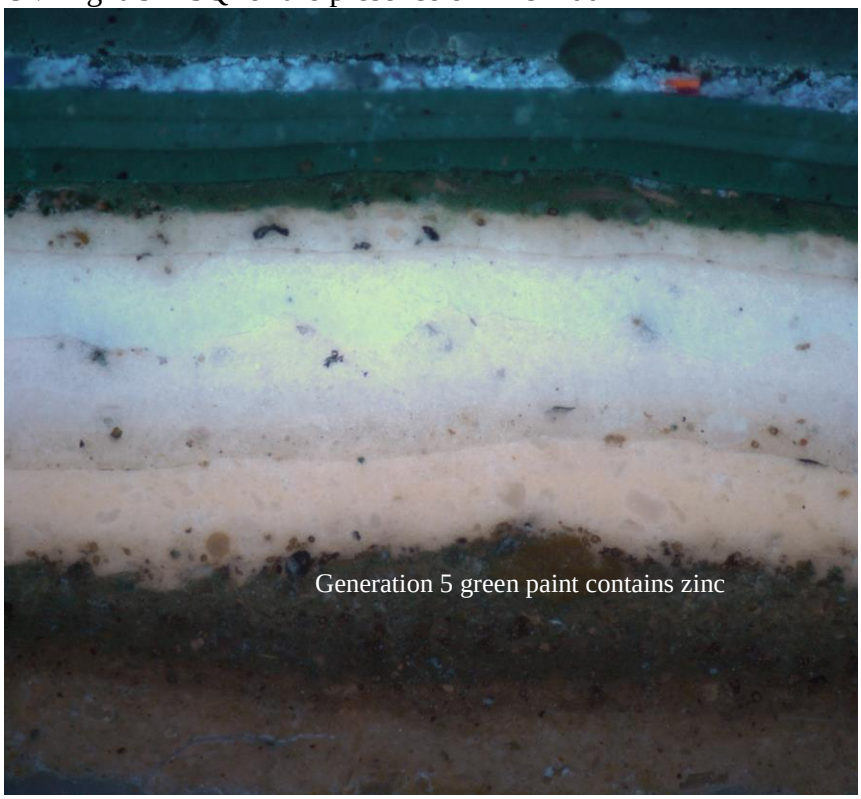


First paint layer is dark tan

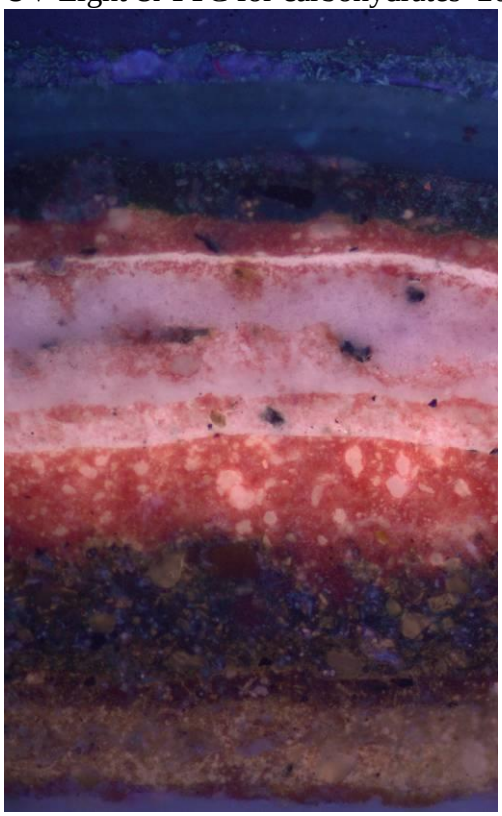
Ultraviolet Light 200X



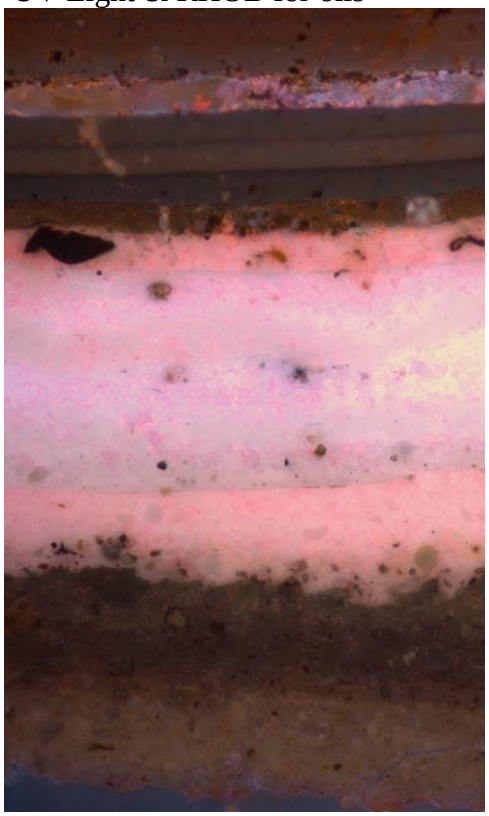
Sample HS-15. North back 1st fl. window, loose paint, louvered blind, right of door.
UV Light & TSQ for the presence of zinc 200X



UV Light & TTC for carbohydrates 200X



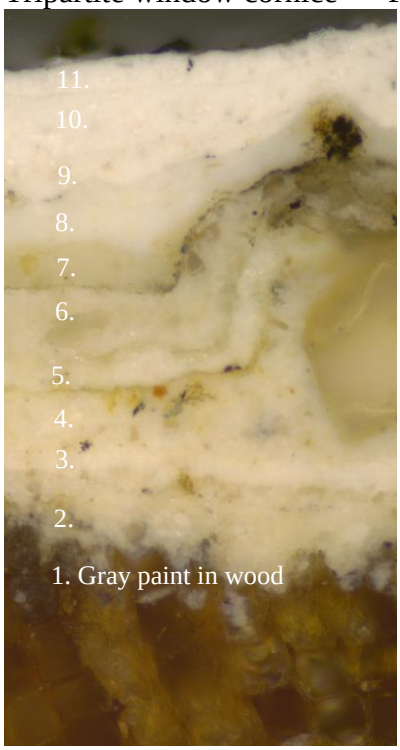
UV Light & RHOB for oils



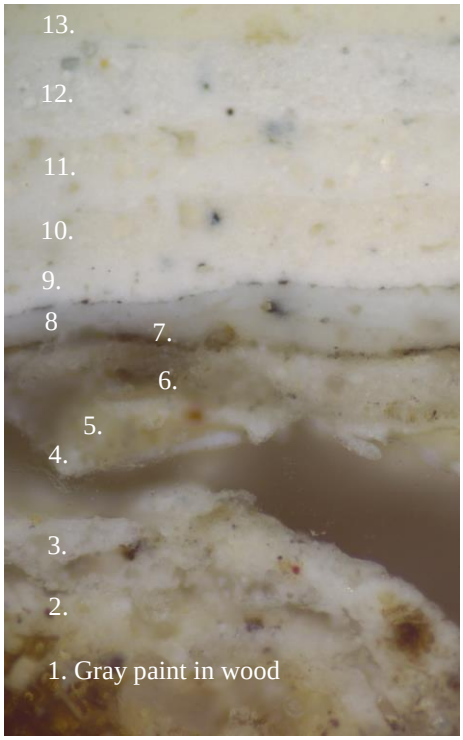
Conclusion:

The evidence found in this group of samples clearly indicates that the trim elements were consistently painted in light colors – primarily off-whites – from the first paint generation to the present. It is not possible to be absolutely sure which of the early off-white paints represents the 1860s color, but it seems likely that generations 3, 4 or 5 of the thirteen generations identified falls into the right time frame. The early trim paints are quite dirty and degraded so it is not possible to use these aged layers for color-matching. But, the 1860s off-white trim paint could be replicated by choosing a paint that accurately represents a traditional white lead in linseed oil exterior paint.

HS-4 Side porch 200X
Tripartite window cornice



HS-6 Side porch doorway 200X
Frieze block below cornice

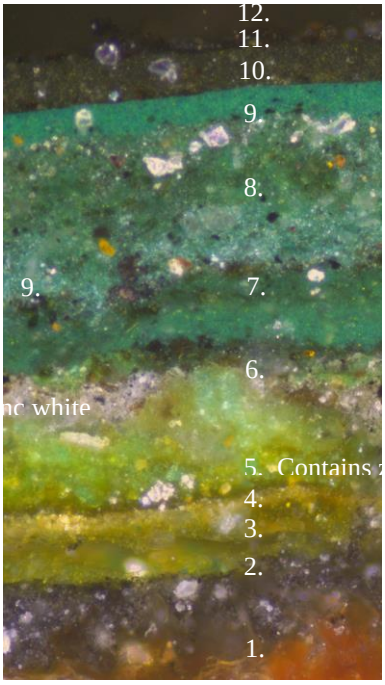


It is somewhat more problematic to determine the appropriate 1860s color(s) for the louvered shutters. If generation 5 is selected to represent the approximate interpretation period, the evidence suggests that the tripartite window shutter (HS-2) was a considerably brighter green than the window shutter on the north elevation (HS-15). A direct comparison of the two cross-sections from the shutters shows the color differences between the two shutters (see page 13).

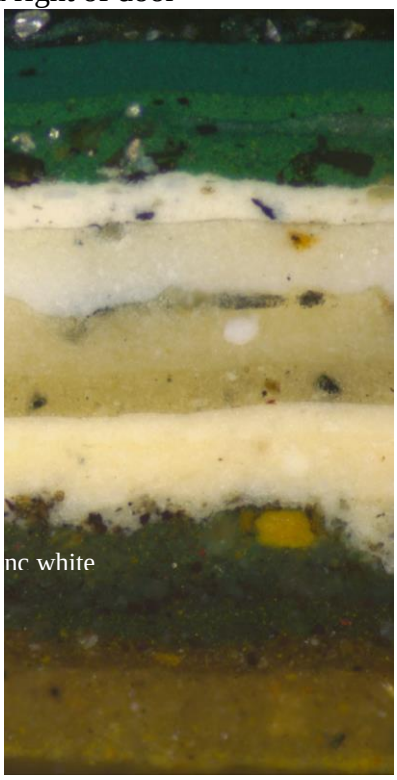
It is often quite difficult to find any early paints on exterior shutters as these elements are exposed to extreme weathering and use, so it is fortuitous that so many paint layers remain in these two samples. But this comparative evidence does not provide insight into how the other shutters on the house might have been painted. It is most likely that the shutters on each elevation were painted to match each other, and it is also possible that

the shutters on the rear elevation were not repainted as often as those on the front of the house. So one question for the replication is which shutters should be painted to match the paints found in sample HS-2 and which should be painted to match the paints in sample HS-15.

HS-2 Side porch
Tripartite window blind



HS-15 North back first-floor window
Louvered blind right of door



COLOR MEASUREMENT PROCEDURES

Uncast portions of the most intact areas of samples HS-2 and HS-15 were measured and matched using a Minolta Chroma Meter CR-241, a tristimulus color analyzer/microscope with color measurement area of 0.3mm, to determine the appropriate 1860s shutter colors. This instrument has an internal, 360-degree pulsed xenon arc lamp and provides an accurate color measurement in a choice of five different three-coordinate color systems. The target off-white paint layer in the trim samples HS-4 and HS-6 are so cracked, darkened and dirty that it was not possible to provide an accurate match to show how the off-white paint appeared when it was freshly applied. So, the color match was made to a reference sample of hand-ground lead white in linseed oil, which is an excellent representation of the 1860s paint found in samples HS-4 and HS-6.

The measurements were first generated in the Munsell color system (a color standard used in the architectural preservation field), and after the measurements were taken the closest Munsell color swatches from a standard Munsell Book of Color (gloss paint standards) were compared under 30X magnification to the actual samples. The measurements were also generated in the CIE L*a*b* color space system, which is currently one of the most widely accepted industry color space measuring systems.

Appropriate commercial matches were calculated and selected from the Benjamin Moore Color Preview collection and the Williamsburg Color Collection (www.prattandlambert.com and www.martinsenour.com).

1860s Period Paint on the Trim Elements

Match for Samples HS-4 and HS-6
Hand-ground linseed oil and lead white mock-up (mixed 11-1-04)

Color System*		Coordinates	
Munsell	Hue	Value	Chroma
	4.0Y	8.9	1.2
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L90.36	a-0.81	b+8.52

Benjamin Moore #OC-120 "seashell"

Color System*		Coordinates	
Munsell	Hue	Value	Chroma
	5.6Y	9.0	1.2
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L 90.59	a-1.45	b+8.41

The color difference (Delta E) in the CIE L*a*b* measurement system between the commercial match OC-120 and the hand-ground mock-up of linseed oil and lead white is 0.68, which is an excellent numerical match. The Benjamin Moore match #OC-120 is a very good visual match to the best-preserved areas of the 1860s wood trim paint when examined in full spectrum light both at 30X magnification. The composition of this fifth-generation off-white paint layer suggests it was originally moderately glossy.

1860s Shutter Color the Tripartite Window Blind

Sample HS-2 Fifth Generation Green Paint
Williamsburg Color Collection #CW423 "Buffet Green"

Color System*	Coordinates		
Munsell	Hue	Value	Chroma
	3.3G	3.3	4.8
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L34.11	a-26.13	b+11.08

The fifth generation bright green paint on the shutter was matched by eye at 40X under a color-corrected light source because the green paint was too uneven and degraded to allow accurate color measurement. CW 423 is a very good visual match to the best-preserved areas of the 1860s shutter. The composition of this verdigris-based paint layer suggests it was originally quite glossy.

1860s Bright Green Shutter Color the North Back First-floor Window

Match Fifth Generation Dark Green Paint in HS-15

Color System*			Coordinates
Munsell	Hue	Value	Chroma
	2.5G	3.4	1.3
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L34.89	a-6.44	b+2.87

Benjamin Moore #HC-134 " Tarrytown Green

Color System*			Coordinates
Munsell	Hue	Value	Chroma
	2.8BG	3.4	1.5
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L34.93	a-8.09	b-0.41

The color difference (Delta E) in the CIE L*a*b* measurement system between the commercial match HC-134 and the fifth generation of green paint is 3.68, which is a very good numerical match. The Benjamin Moore match #HC-134 is a very good visual match to the best-preserved areas of the 1860s shutter when examined in full spectrum light both at 30X magnification The composition of this green paint layer suggests it was originally moderately glossy.

*** COLOR SYSTEMS** – Derived from the Minolta CR-241 Instruction Manual and Minolta Precise Color Communication

Chroma Meter CR-241 offers five different color systems for measuring absolute chromaticity: CIE Yxy (1931), L*a*b* (1976), and L*C*H* (1976) colorimetric densities DxDyDz; Munsell notation and four systems for measuring color differences.

For two colors to match, three quantities defining color must be identical. These three quantities are called tristimulus values X, Y, and Z as determined by CIE (Commission Internationale de l'Eclairage) in 1931.

Color as perceived has three dimensions: hue, chroma and lightness. Chromaticity includes hue and chroma (saturation), specified by two chromaticity coordinates. Since these two coordinates cannot describe a color completely, a lightness factor must also be included to identify a specimen color precisely.

Munsell Color System: The Munsell color system consists of a series of color charts which are intended to be used for visual comparison with the specimen. Colors are defined in terms of the Munsell Hues (H; indicates hue), Munsell Value (V; indicates lightness), and Munsell Chroma (C; indicates saturation) and written as H V/C.

CIE Yxy (CIE 1931): In the Yxy (CIE 1931) color system, Y is a lightness factor expressed as a percentage based on a perfect reflectance of 100%, x and y are the chromaticity coordinates of the CIE x, y Chromaticity Diagram.

CIE L*a*b*: Equal distances in the CIE x,y Chromaticity Diagram do not represent equal differences in color as perceived. The CIE L*a*b* color system, however, more closely represents human sensitivity to color … Equal distances in this system approximately equal perceived color differences. L* is the lightness variable; a* and b* are the chromaticity coordinates

ΔE (Delta E) is the industry measure used to determine how closely two colors match in the CIE L*a*b*. The symbol Δ means "the change in". It is based on calculating the sum of the differences between each measure. The calculation is: $\Delta E = \sqrt{(L^*)^2 + (a^*)^2 + (b^*)^2}$, or, the color difference equals the square root of the squared sums of the differences between each of the three L* a* b* tristimulus values. Industry color standards indicate a ΔE of 1 is barely perceptible to the human eye, and ΔE of 6 to 7 is acceptable for color matches in the printing industry.

REFERENCES

Cross-section Preparation Procedures:

The samples were cast into mini-cubes of polyester resin (Excel Technologies, Inc., Enfield, CT). The resin was allowed to cure for 24 hours at room temperature and under ambient light. The cubes were then ground to expose the cross-sections, and dry polished with 400 and 600 grit wet-dry papers and Micro-Mesh polishing cloths, with grits from 1500 to 12,000.

Cross-section microscopy analysis was conducted with a Nikon Eclipse 80i epi-fluorescence microscope equipped with an EXFO X-Cite 120 Fluorescence Illumination System fiberoptic halogen light source and a polarizing light base using SPOT Advanced software (v. 4.6) for digital image capture and Adobe Photoshop CS for digital image management. Photographs and digital images of the best representative cross-sections are included in this report. UV photographs were taken with the UV-2A filter in place (330-380 nanometers excitation with a 400 nm dichroic mirror and a 420 nm. barrier filter). Please note that the colors in the printed photomicrographs may not accurately reflect the actual color of the samples because the colors in the digital images are affected by the variability of color printing.

The following fluorescent stains were used for examination of the samples:

> Alexafluor 488 0.02% in water, pH 9, 0.05M borate and 5% DMF to identify the presence of proteins. Positive reaction color is yellowish-green under the B-2A filter.
>
> Triphenyl tetrazolium chloride (TTC) 4.0% in ethanol to identify the presence of carbohydrates (starches, gums, sugars). Positive reaction color is dark red or brown under the UV filter.
>
> 2, 7 Dichlorofluorescein (DCF) 0.2% in ethanol to identify the presence of saturated and unsaturated lipids (oils). Positive reaction for saturated lipids is pink and unsaturated lipids is yellow under the UV filter.
>
> Rhodamine B (RHOB) 0.06% in ethanol to identify the presence of oils. Positive reaction color is bright orange under the UV filter.
>
> N-(6-methoxy-8-quinolyl)-p-toluenesulfonamide (TSQ) 0.2% w/v in ethanol for the presence of zinc (Zn^{2+}). Positive reaction color is bright sparkly blue.

Information Provided by Ultraviolet Light Microscopy:

When viewed under visible light, cross-sections which contain ground, paint and varnish may often be difficult to interpret, particularly because clear finish layers look uniformly brown or tan. It may be impossible using only visible light to distinguish between multiple varnish layers. Illumination with ultraviolet light provides considerably more information about the layers present in a sample because different organic, and some inorganic, materials autofluoresce (or glow) with characteristic colors.

There are certain fluorescence colors which indicate the presence of specific types of materials. For example: shellac fluoresces orange (or yellow-orange) when exposed to ultraviolet light, while plant resin varnishes (typically amber, copal, sandarac and mastic) fluoresce bright white. Wax does not usually fluoresce; in fact, in the ultraviolet it tends to appear almost the same color as the polyester casting resin. In visible light wax appears as a somewhat translucent white layer. Paints and glaze layers which contain resins as part of the binding medium will also fluoresce under ultraviolet light at high magnifications. Other materials such as lead white, titanium white and hide glue also have a whitish autofluorescence.

There are other indicators which show that a surface has aged, such as cracks which extend through finish layers, accumulations of dirt between layers, and sometimes diminished fluorescence intensity, especially along the top edge of a surface which has been exposed to light and air for a long period of time.

Sample Locations: Exterior
Samples Removed May 1, 2009 by Travis MacDonald

HS-1. Side porch, doorway/addition, top right architrave, "frieze" block (see diagram on sample bag).

HS-2. Side porch, tripartite window blind, right, top louver-(in).

HS-3. Side porch, tripartite window blind, left, top louver (in).

HS-4. Side porch, tripartite window "cornice," left side, back corner.

HS-5. Side porch, 1st per. doorway, right side "cornice," flaking paint.

HS-6. Side porch, 1st per. doorway, right side architrave, "frieze" block below cornice, front edge, (same location as HS-1).

HS-7. Front window, 1st floor, right of portico, peeling paint at juncture of sill (bottom) and brick (wash and penciling on mortar).

HS-8. Front 1st floor window, left of portico, left blind, lower stile at bottom (in) (part filler).

HS-9. Front cellar window frame, left of portico, upper inner edge of solid frame (once barred) under reveal of jack arch.

HS-10. Front 1st floor window, lower sash, putty from muntin (see diagram on sample bag).

HS-11 Back, porch, main block, closet window, solid frame, 2 samples from bead.

HS-12. Front doorway, right, under "sill" below sidelight, under rail/sill (see diagram in sample bag).

HS-13. Front door, right side plinth (see diagram in sample bag).

HS-14. Front porch, left side pilaster, Greek Revival trim. Use to date Greek Revival remodeling vs. original trim.

HS-15. North back 1st fl. window, loose paint, louvered blind, right of door.

HS-16. Loose louver from #10 (see diagram on main sample bag), "island" of paint.

Scanned diagram of sample locations from sample bag