Cross-section Paint Microscopy Report

Green-Painted Table
Enfield Shaker Village
Enfield, New Hampshire

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Date: February 27, 2014

Green Table Before 1978

Purpose:

The goal of this project is to use cross-section and polarized light microscopy analysis techniques to investigate the composition and stratigraphy of coatings remaining on a table that was aggressively stripped of its paint in 1978. If the original paint survives in protected areas of the table it will be color-matched for replication with the help of a colorimeter/microscope.

Procedures:

The table was delivered to Susan Buck for examination, sampling and analysis. It was first examined with a 30X monocular microscope to identify the best potential areas from which to remove samples. Samples were removed from areas where drips of green and whitish paint remain, and from paint remnants trapped deep in the joinery. Before casting the samples were examined at 45X magnification and the most intact flakes (about 300 microns across), were selected and cast into polyester resin cubes for permanent mounting. In some cases the embrittled paints separated from the wood substrates so the paint flakes and associated wood fibers were cast together in the same cubes for analysis. 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 photographs of the best representative cross-section images are included in this report. Please note that the colors in the digital images are affected by the variability of capture and color printing and do not accurately represent the actual colors.

Cross-section Microscopy Analysis Results

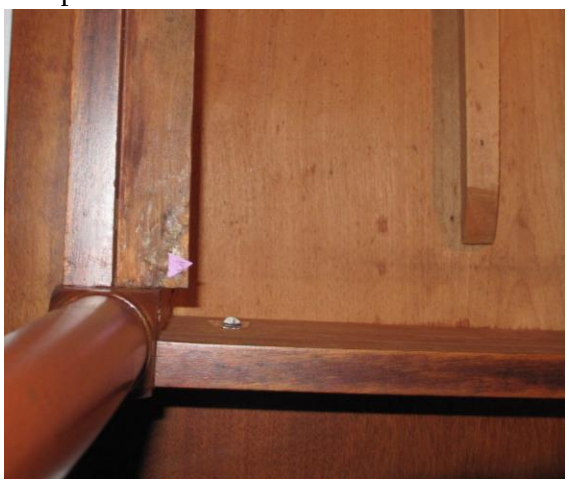
Sample Locations

1. Green splotch on inside of bottom of drawer.
2. Green paint drip on Proper Right (PR) drawer side.
3. Rear edge of Proper Left (PL) drawer runner, trapped green and white paint remnants.
4. Paint trapped in corner of join of top of PR leg with top rail at front.
5. Whitish drip of paint on PL side of drawer.
6. Paints trapped in join at underside of rear rail where it joins rear PL leg.

Sample 1

Sample 2

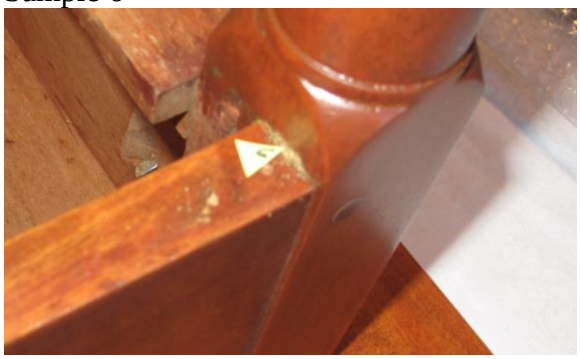
Sample 3



Sample 4

Sample 5

Sample 6



Photographs of the table taken before it was stripped show a mottled dark green paint on all the elements, but the cuffs of the feet seem to be whitish in color, not green. There is also a scrape on the Proper Right (PR) side of the table top that seems to reveal whitish paint. Virtually all that paint is gone now, with the exception of some drips and splashes of whitish and green paints on the drawers and in the interstices of the joinery.

The two cross-sections taken from the green drips of paint (1 and 2) contain only one oil-bound green paint layer on top of the wood substrate. Similarly, the sample taken from

the whitish drip of paint (5) contains one thin layer of oil-bound, cream-colored paint (sample 5) on top of the wood. The most important paint evidence was found in the samples taken from paint trapped in the joinery. In samples 3 and 4 there is definitely a thin layer of cream-colored paint on top of the wood. This paint also penetrated deep into the wood substrate, confirming that it was the original coating applied to the wood.

There is a thin film of dirt on top of some areas of this first cream-colored paint (see sample 3), which shows that this paint was a finish coat, not a primer. It would also be unusual to find a priming coat on this side table as that is not a typical Shaker painting practice, although often a resinous or natural gum sealant was applied to the wood to seal it before painting.

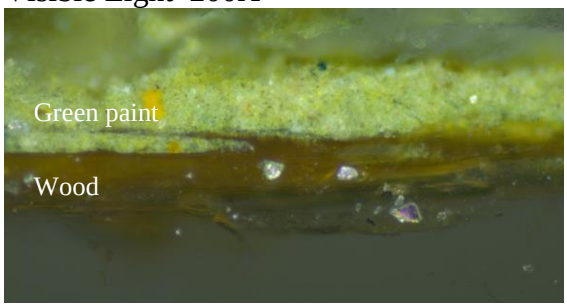
The second generation of green paint in samples 3 and 4 is the same green paint observed in the samples from the splashes and drips on the drawer bottom and drawer sides. Sample 6 contains the green and cream-colored paints, but they are only uneven lumps that must have been trapped deep in the joinery. Sample 6 also retains remnants of a red-pigmented stain or paint, as well as the most recent synthetic resin varnish.

Binding media analysis with biological fluorochrome stains shows that the cream-colored paint contains only oil in its binding medium. The green paint contains oil and protein components, suggesting it could be an emulsion paint. Examples of patent recipes for emulsion paints from the second half of the nineteenth century are included in the reference section of this report. This paint layer also contains zinc, based on the positive reactions with the fluorochrome tag TSQ. The presence of zinc white means this green paint has to date to after 1845 when the pigment zinc white became commercially available.

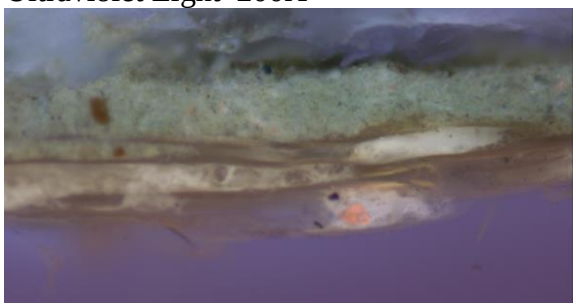
Polarized light microscopy analysis shows that the cream-colored paint is composed primarily of white lead, with calcium carbonate and widely dispersed yellow ochre and red ochre pigments. The green paint contains white lead, green earth (terre verte), yellow ochre, zinc white, chrome green, and calcium carbonate.

Sample 1. Green splotch on inside of bottom of drawer.

Visible Light 200X

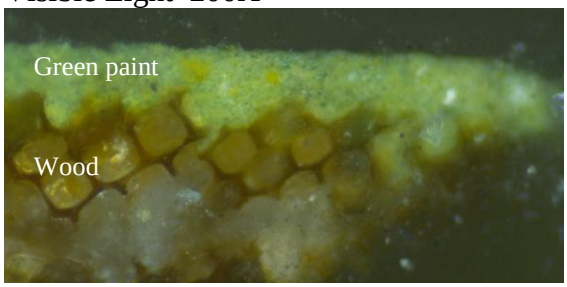


Ultraviolet Light 200X

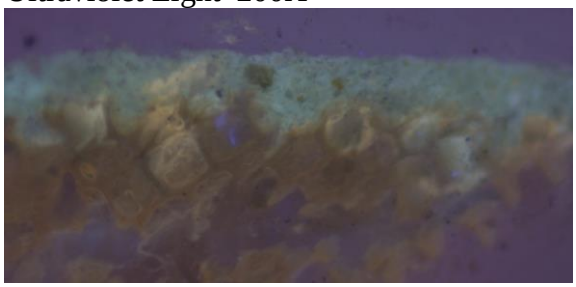


Sample 2. Green paint drip on Proper Right (PR) drawer side.

Visible Light 200X

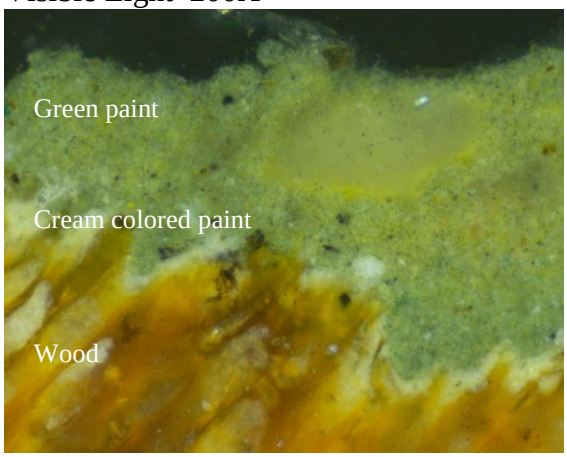


Ultraviolet Light 200X

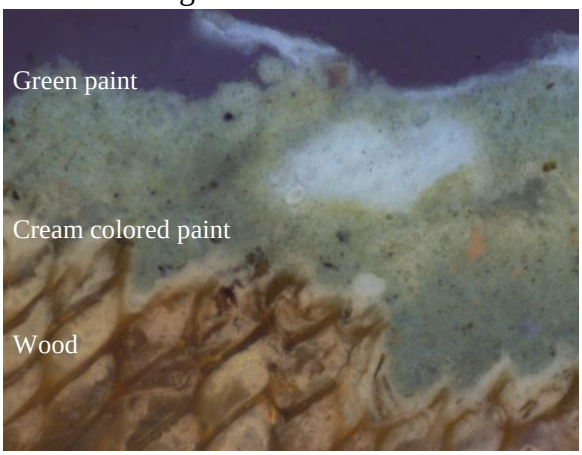


Sample 3. Rear edge of Proper Left (PL) drawer runner, trapped green and white paint remnants.

Visible Light 200X

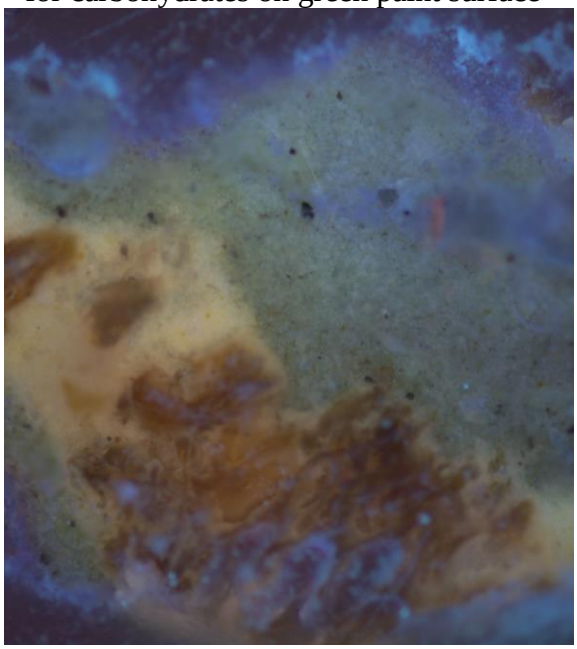


Ultraviolet Light 200X



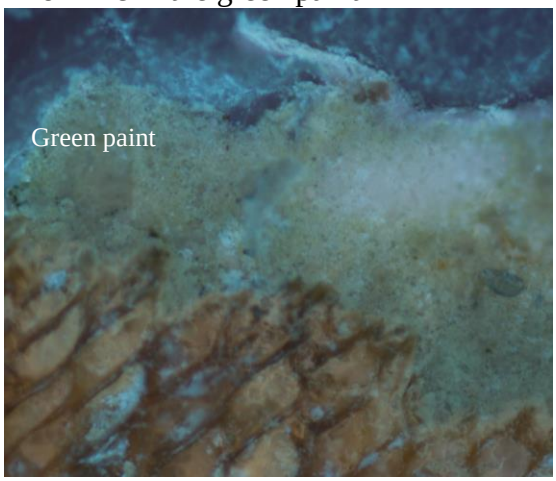
UV Light (repolished sample) 200X

UV Light & TTC for carbohydrates 200X + for carbohydrates on green paint surface

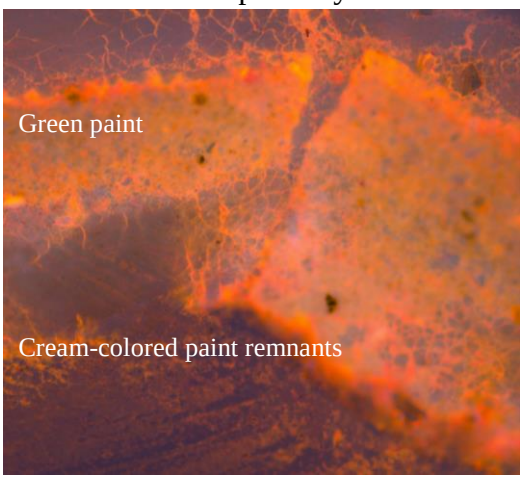


Sample 3. Rear edge of Proper Left (PL) drawer runner, trapped green and white paint remnants.

UV Light & TSQ for zinc 200X
+ for zinc in the green paint

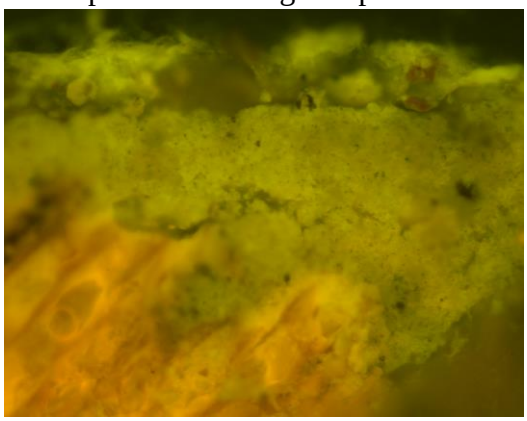


UV Light & RHOB for oils 200X
+ for oils in both paint layers

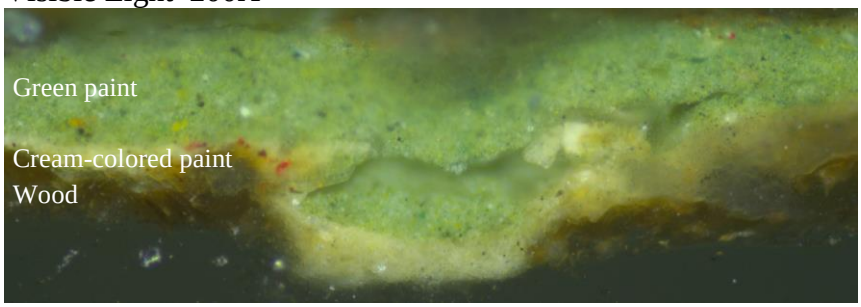


B-2A filter 200X

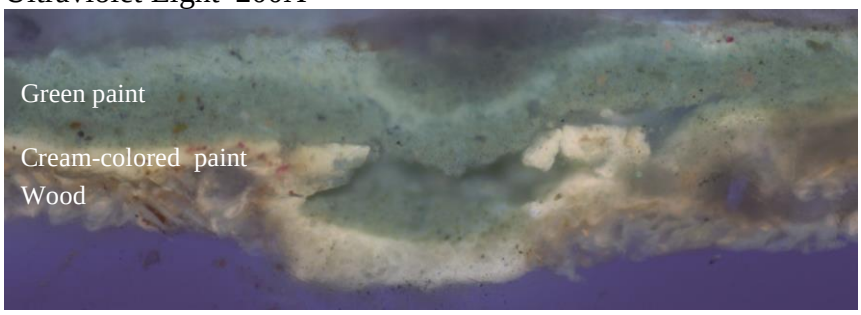
B-2A filter & FITC for proteins 200X
+ for proteins in the green paint



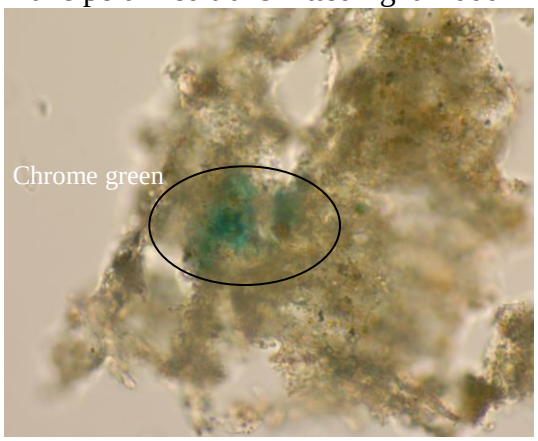
Sample 4. Paint trapped in corner of join of top of PR leg with top rail at front.
Visible Light 200X

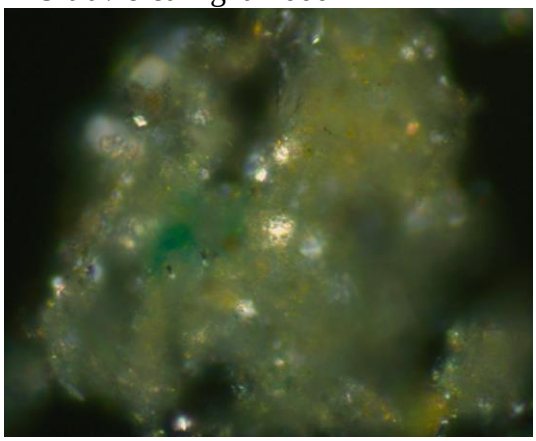


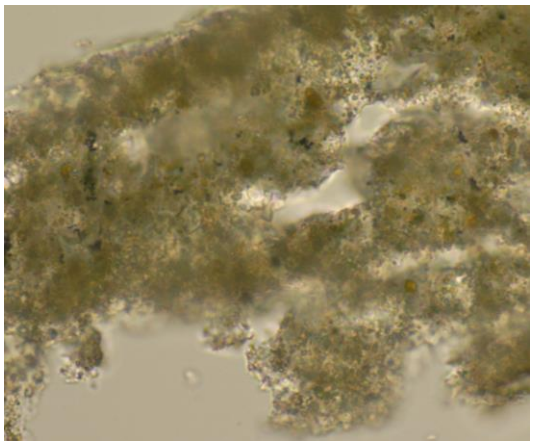
Ultraviolet Light 200X

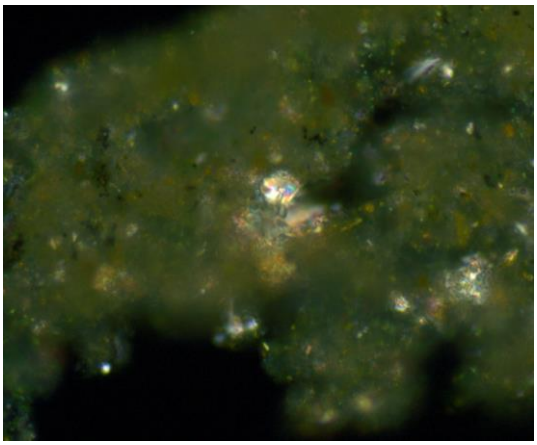


Pigments in the green paint layer. White lead, green earth (terre verte), chrome green, yellow ochre, zinc white, calcium carbonate.
Plane polarized transmitted light 1000X Ultraviolet Light 1000X

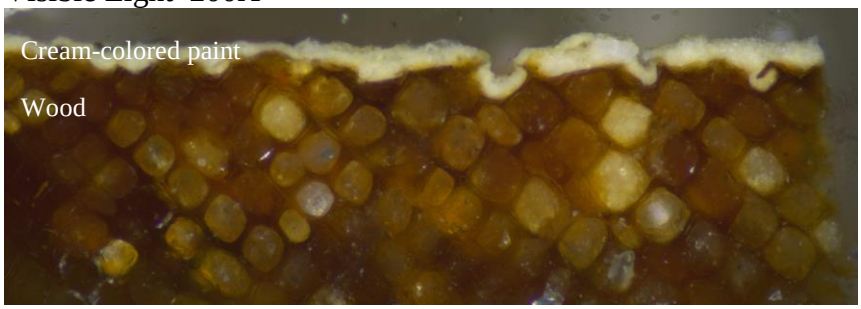




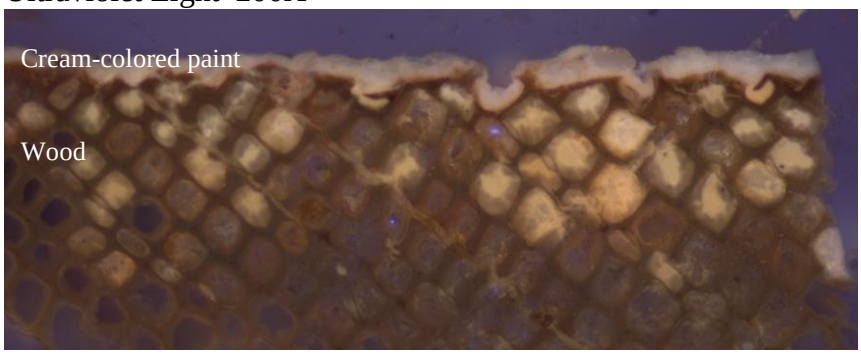




Sample 5. Whitish drip of paint on PL side of drawer.
Visible Light 200X

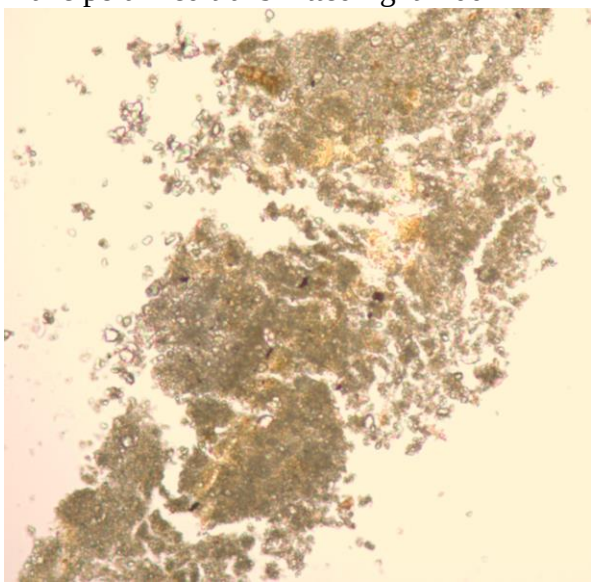


Ultraviolet Light 200X

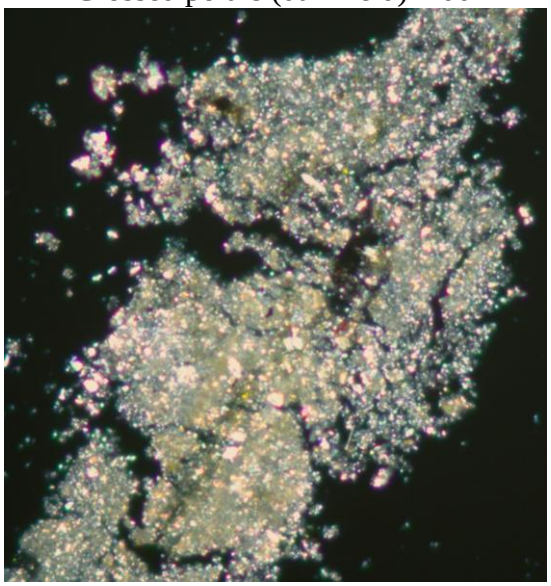


Pigments in the cream-colored paint layer. White lead, scattered yellow ochre and red ochre pigments, with calcium carbonate.

Plane polarized transmitted light 400X

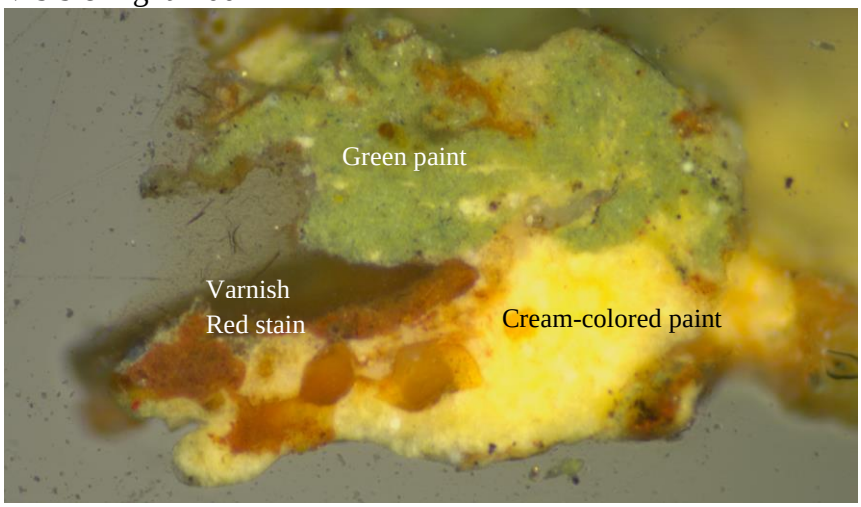


Crossed polars (darkfield) 400X

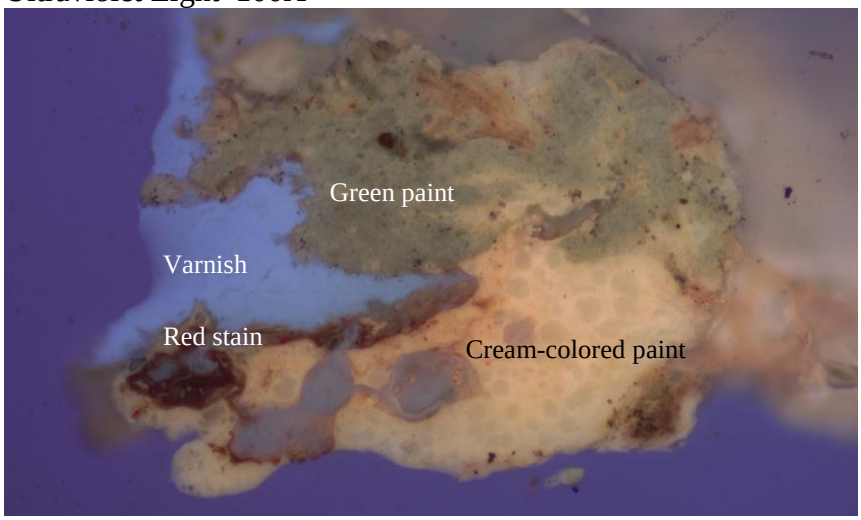


Sample 6. Paints trapped in join at underside of rear rail where it joins rear PL leg. Lump of whitish and green paint, with modern deep red stain and varnish. Paints were softened and disrupted by chemical stripping.

Visible Light 100X



Ultraviolet Light 100X

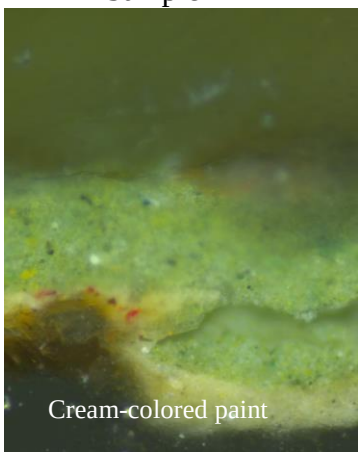


Conclusion:

Comparative cross-section analysis suggests that the table was originally painted with a thinly applied, oil-bound, cream colored paint. This is an unusual finding for New England Shaker furniture, but perhaps this light color turned out not to be practical so it was covered over with a darker paint. The cream-colored paint on this table collected some dirt and became slightly eroded before it was repainted green. The second-generation green paint contains zinc white, which means it could not have been applied before about 1845 when zinc-based paints became commercially available. The comparative cross-sections below show how the first cream-colored paint is related in three of the six samples. Color matches for both paints are provided for reference and possible replication.

Sample 3

Sample 4



Sample 5

COLOR MATCHING PROCEDURES

The degraded remnants of the first cream-colored paint and the second green paint were matched with the help of a Minolta Chroma Meter CR-241, a tristimulus color analyzer/microscope with color measurement area of 0.3mm. 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 period paints were exposed with a scalpel at 30X magnification to provide clean areas for color matching. The exposed layers were measured three times in three different areas of the exposed target layers to establish the color coordinates. 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) was 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.

In the areas where the target period paints were too degraded or translucent to allow accurate color measurement, a second round of color matching was done by eye comparing the Munsell swatches to the samples under 30-45X magnifications and a color-corrected light source. The best visual matches for the Munsell swatches were then used to generate close commercial paint matches.

The best commercial swatches are provided for reference.

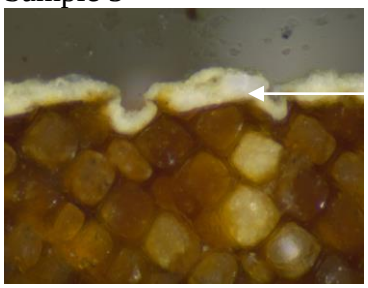
Generation 1. Original Cream-colored Paint on the Table

Color-matched February 26, 2014

Benjamin Moore #OC-44 "Misty Air"

Color System*		Coordinates	
Munsell	Hue	Value	Chroma
	6.8Y	8.6	1.6
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L87.15	a-2.58	b+11.93

Sample 5



The first generation cream-colored paint was too uneven and degraded accurately measure with a colorimeter/microscope, so a color match was made by eye at 30X under a color-corrected light source. The commercial match #OC-44 is an excellent visual match. Binding media analysis and the surface qualities of this paint suggest it was slightly glossy and could be replicated in a "satin" gloss level.

Generation 2. Second-generation Green Paint on the Table

Color-matched February 26, 2014

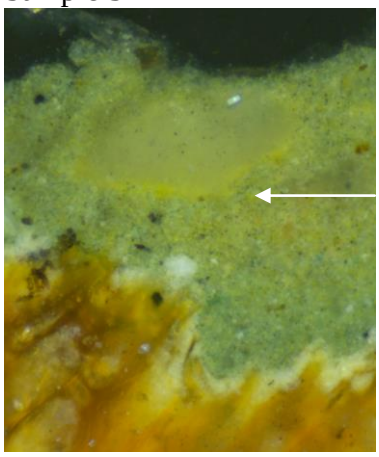
Samples 3, 5, 6

Color System*			Coordinates
Munsell	Hue	Value	Chroma
	4.7GY	4.5	2.0
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L46.30	a-7.40	b+12.0

Benjamin Moore #HC-126 "Avon Green"

Color System*			Coordinates
Munsell	Hue	Value	Chroma
	8.4GY	5.0	2.0
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L50.64	a-9.47	b+9.97

Sample 3



The second generation of green paint was matched with the colorimeter/microscope and checked by eye at 30X under a color-corrected light source. The commercial match #HC-126 is an excellent visual match, although it is slightly lighter (the L value) and slightly less yellow (the b value) than the measurements from the best preserved areas of the green paint. Binding media analysis and the surface qualities of this green paint suggest it was somewhat glossy and could be replicated in a semigloss gloss level.

*** 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.

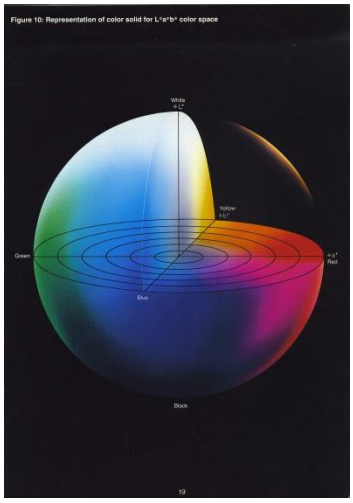
For two colors to match, three quantities defining color must be identical. These three quantities are called tristimulus values X, Y, and Z as determined by CIE (Commission Internationale de l=Eclairage) in 1931.

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: 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: $\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$, 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.

Cross-section Preparation Procedures:

The samples were cast in 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.

The cast samples were analyzed and photographed using 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. The samples were photographed in reflected visible and ultraviolet light using a UV-2A filter with 330-380 nm excitation, 400 nm dichroic mirror and a 420 nm barrier filter and a B-2A filter with 450-490 excitation and a 520 nm barrier filter. Photographs were taken at 100X, 200X and 400X magnifications.

The following fluorescent and visible light 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 yellow and unsaturated lipids is pink 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% in ethanol to mark the presence of Zn in the cast cross-section. Positive reaction color is bright blue-white.

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.

Pigment Preparation

Pigments from individual paint layers were dispersed and crushed onto microscope slides with a scapel. These dispersed samples were permanently mounted under cover slips with Cargille MeltMount with a refractive index of 1.66. The samples were examined under plane polarized transmitted light and crossed polars (darkfield) at 400X and 1000X, and the unknown pigments were compared to standard pigment reference samples.

APPENDIX

Emulsion Paints – U.S. Patent Recipes
Research Conducted by Richard C. Wolbers

Ca. 1850 Emulsion Paint

Water	200
Linseed oil	80
Caustic soda	20
Potato starch	6

Ca. 1860-70 Emulsion Paint

Water	200
Linseed oil	130
White spirit	30
Caustic soda	20
Copal	20
Potato starch	10
Casein	6
Manganese abietate	0.1

End of the 19th Century Emulsion Paint

Lithopone	380
Water	65.5
Linseed oil	30
Shellac	30
Ammonium bisulfate	4.5

Beginning of the 20th Century Emulsion Paint

Water	32
Varnish 16	
Hide glue	10
Naptha	4
TEA linoleate	0.6
Phenol	0.1

1930s Emulsion Paint		
Dehydrated castor oil		33.41
Lithopone		39.81
Casein		3.31
Phenol	0.06	
Ammonium hydroxide	23.41	

Modern PVA Emulsion Paint		
50% Everflex G	353	
Titanox	225	
Water		300
3% Methocel 4000		80
Mica C-3000		50
Celite 281		25
Carbitol acetate	20	
20% Dowicide A	11.5	
Aerosol OT-B		2.6
Emulphor EL-719		2.2
Polyglycol P-1200		

Modern PVA Emulsion Paint		
UCAR Latex 180	541	
Titanox RA-45	167	
Water		94
Hydroxy ethyl cellulose	82	
ASP-100		60
Safflower oil		26.8
Ethylene glycol	29.5	
Carbitol	21.1	
Temol 731		7
Bubble Breaker 746		5.3
Surfactol 318		2.3
Tectronic 504		2.3
Cobalt drier		0.11
Lead drier		0.03