

CROSS SECTION MICROSCOPY ANALYSIS RESULTS

Light Tower Interior Paints
Burnt Coat Harbor Light Station

Swan's Island, Maine



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March 7, 2014

Executive Summary:

Constructed in 1872 by the U.S. Light-House Board, the Burnt Coat Harbor Light Station came under the U.S. Coast Guard in 1939. The station was automated in 1975 and continues to house an active aid to navigation in the light tower. The Burnt Coat Harbor Light Station is owned by the Town of Swans Island and since 2000 the Friends of Swans Island Light have been working on the restoration of the light station.

The goal of this project is to document the existing paint layers on the interior surfaces of the Burnt Coat Harbor Light Tower and to determine to the greatest extent possible the paint colors on the interior surfaces during the period of interpretation for the Light Station, which has been identified as the 1930s. The Maine Historic Preservation Commission requested that documentation of the interior finishes be undertaken in response to anticipated paint removal in the near future to address failing paint and lead hazard issues.

Paint samples were taken from the interior of the light tower in July 2013 in order to document the remaining layers on the interior of the tower. Cross-section microscopy has been utilized to analyze the paint and coating layers and digital photomicrographs have been created to photo-document the remaining finish layers. In order to cross reference paint layers to historic documentation to the greatest extent possible, documentation on file with the Maine Historic Preservation Commission for the Burnt Coat Harbor Light Station was reviewed and copies of painting instructions and manuals published by the federal government from 1871 – 1952 for use at light stations were gathered for reference. In December 2013, Amy Cole Ives had the opportunity to photograph some of the Burnt Coat Harbor Light Station's Keeper's Logs at the National Archives in Washington, D.C.

The Burnt Coat Harbor Light Tower is an unheated masonry structure exposed to a harsh coastal climate on Swans Island in Hancock County, Maine. As a consequence of these factors, the coatings on the interior surfaces of the masonry portion of the tower are annually exposed to high levels of humidity and temperatures ranging from moderate to very cold, while the coatings on the interior surfaces of the metal lantern area on top of the masonry tower are exposed to a wider range from very cold to hot due to solar gain. Maintenance of the coatings on the interior surfaces of the tower since its construction has been dictated by the painting standards of the Light-House Service and U.S. Coast Guard, the availability of personnel to undertake the work and often by limited budgets or availability of materials. As a result, the general practice has been incremental recoating of surfaces as necessary rather than total repainting of all interior surfaces during cyclical comprehensive renovation projects.

Despite the harsh climate and weather conditions the interior surfaces have been subjected to, as well as the variety of circumstances relating to surface preparation and repainting, the paint samples document the presence of many layers of paints and coatings on the interior elements. While there are some traditional oil based paints visible in the samples, the paint layers are predominantly made up of modern paints that likely date from the middle of the 20th century and later. In many cases, the paint layer histories for different elements from the interior of the tower are consistent with the painting instructions for the interior of towers as published by the Light-House Service and the U.S. Coast Guard.

Evidence in the paint samples suggests a major repainting and or possibly renovation to the tower in the second half of the 20th century. The Keeper's Logs kept by Light Station Keeper Roscoe Chandler from January 1930 - July 1941 illustrate how maintenance of the station included constant touch-up painting. The logs do not, however, document any major renovation projects in the tower in this time period and therefore appear to post-date 1941. It is possible a renovation project was undertaken following WWII in response to deferred maintenance at stations or limited availability of paints during the war. Further research in Keeper's logs and Coast Guard records may clarify or confirm this theory.

Repainting Recommendations:

Based on the evidence in the paint samples and cross referenced with the painting manuals and Keeper's logs, the interior surfaces of the light tower appear to have had the following coatings during the 1930s.

Lantern – wood wainscoting on parapet wall, window frames and mullions and dome ceiling were all painted white.

Lantern – Fresnell lens pedestal was painted green.

Lantern – iron floor / deck was likely painted dark reddish brown based on the paint evidence on the iron stairs of the tower.

Service Room – wood floor was the upper-layer of flooring and was either unpainted and oiled or painted the same dark reddish brown as the iron tower stairs.

Service Room – wood surround for entrance door was painted white.

Service Room and Tower – brick walls were white washed.

Tower – iron stairs were painted dark reddish brown with a shellac or varnish top coating.

Tower – windows likely would have been painted white.

Purpose:

The goal of this project is to document the existing paint layers on the interior surfaces of the Burnt Coat Harbor Light Tower and to determine to the greatest extent possible the paint colors on the interior surfaces during the period of interpretation for the Light Station, which has been identified as the 1930s. The Maine Historic Preservation Commission requested that documentation of the interior finishes be undertaken in response to anticipated paint removal in the near future to address failing paint and lead hazard issues.

Procedures:

Amy Cole Ives of Sutherland Conservation and Alfred Hodson of Resurgence Engineering made a site visit to the Burnt Coat Harbor Light on July 31st, 2013 for the purpose of continuing structural investigation and water infiltration mitigation, and to study the extant paint layers on the interior of the tower and lantern and remove samples for cross section casting and analysis.

Eighteen paint samples were removed from the interior of the lighthouse tower. Specifically, samples were taken in the lantern room, watch room and in the masonry tower structure and metal stairs. Samples were removed with a scalpel and placed in labeled sample bags. Sampling locations were selected based on visual examination of building elements to identify the greatest remaining accumulation of paint layers. Visual examination was assisted with a 10X DermLite DL100 Pocket Epi-luminescence Microscopy Device and a 20X Nikon binocular field microscope. Where possible, samples were taken in locations where the paint layers were protected from weathering, abrasion or light damage. Samples were removed with some substrate (wood, plaster, metal, etc.) attached to the paint layers when possible. Sample numbers were written on the sample location and photographed for reference.

The samples were examined at 10X – 45X magnification with a binocular microscope. The sample pieces with the

most complete stratigraphies were selected for casting for cross-section analysis at 40X, 100X, 200X and 400X magnification in reflected visible and UV light. 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 fiber optic halogen light source and a polarizing light base using SPOT Advanced software (v. 4.6) for digital image capture and Adobe 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 color printing and do not accurately represent the actual colors.

Overview of historic property:

The Burnt Coat Harbor Light Station was constructed in 1872 by the U.S. Light-House Board, J.C. Duane 1st District Engineer. Originally constructed as a range light station with a small light tower in front of the taller rear tower, the front range light was discontinued and removed by 1884. The Burnt Coat Harbor Light Station came under the U.S. Coast Guard in 1939, remaining a manned station until it was automated in 1975. The Light Station is owned by the Town of Swans Island and since 2000 has been in the process of being restored by the Friends of Swans Island Light. The light tower continues to house an active aid to navigation maintained by the U.S. Coast Guard.

Historic context of the painting of U.S. Light Stations:

The construction and administration of light stations came under the authority of the new federal government in 1789 and shortly thereafter the U.S. Lighthouse Establishment was assigned to the Secretary of the Treasury. In 1852 light station administration was transferred to the U.S. Light-House Board who promulgated detailed written instructions to the people employed in the U.S. Lighthouse Establishment. Included in the 1871 *United States Lighthouse Establishment Instructions to Light-Keepers* were detailed instructions for painting that addressed preparation of surfaces, mixing and applying paint, as well as specifications for colors to be “used in painting light-house structures.”

Congress replaced the U.S. Light-House Board in 1910 with the Bureau of Lighthouses under the Department of Commerce, which became known as the Lighthouse Service. Like its predecessor, the Lighthouse Service circulated *Instructions to Employees* that included detailed painting instructions for surface preparation, mixing paint, paint application and specifications for color use on light station buildings. Administration of light stations was returned to the Treasury Department in 1939 when the Lighthouse Service was discontinued and placed under the United States Coast Guard. Similar to the *Instructions* circulated by the Lighthouse Establishment and the Lighthouse Service, the Coast Guard published *Instructions for United State Coast Guard Stations* in 1921 that included directions for painting the buildings at their stations. However, the 1934 *Instructions for United States Coast Guard Stations* references *Painting Instructions for Coast Guard Stations* (I have not been able to get a copy of this yet) instead of including the specific instructions in that publication. The United States Coast Guard Historian’s Office has just recently scanned and posted on their website the complete 1952 U.S. Coast Guard *Paint and Color Manual (CG-263)* which is an extensive period reference on materials, methods and specifications for color application.

Ready-mixed paints were commercially available in this country in the late nineteenth century, however their variability in quality and the tendency of painters accustomed to using traditional job mixed paints to add thinners and driers to the ready mixed paints often resulted in under-performing products.¹ Therefore it is not surprising the 1881 and 1902 *Instructions to Light-Keepers* published by the U.S. Light-House Establishment as well as the 1927 *Instructions to Employees by the Lighthouse Service* provide specific directions for job mixing paints

¹Standeven, Harriet A.L., *House Paints 1900-1960: History and Use*, (Los Angeles, CA: Getty Conservation Institute, 2011), Chapter 1.

for outside and inside work utilizing traditional recipes based on pigments in linseed oil mixed with spirits of turpentine and drying varnish.² However, the 1927 *Instructions* reflect the greater availability, improved general quality, and widespread use of ready mixed paints in the early 20th century by starting the instructions for inside work referencing ready mixed paint followed by the same instructions for job mixed paints used in the 1881 and 1902 *Instructions* if the paints for interior use were not ready mixed.

The 1930s period of interpretation selected for the Burnt Coat Harbor Light Station coincides with widespread advances in the development and use of synthetic resin paints from the 1920s – 1940s, which had a “dramatic impact on the paint industry”.³ However, natural paint ingredients continued to be available throughout the first half of the 20th century and coupled with wartime materials shortages, resulted in a wide range of paint materials being used throughout this period. By 1952, the Coast Guard was focusing on standardization of colors and materials to reduce painting costs by stocking the “best available material for each use” and maintaining a “reduced variety of materials.”⁴ According to the 1952 U.S. Coast Guard *Paint and Color Manual (CG-263)*, job-mixing paints was prohibited and “only ready-mixed paints available through Navy and Coast Guard supply channels” were authorized to be used (it is possible this practice was established earlier but without copies of Coast Guard paint manuals from the 1930s and 1940s this cannot be confirmed).

The 1952 paint manual specifies the use of synthetic rubber emulsion paint, which is roughly equivalent to modern latex paint, for general purpose interior use on properly primed plaster, wallboard, wood, masonry and metal surfaces.⁵ According to Standeven these paints “were first introduced to the U.S. paint market in the late 1940s”.⁶ Amendments and re-issues of CG-263 from the 1960s and 1970s have not yet been accessed to identify changes in specified colors for different interior lighthouse spaces and components which may help date later color changes in the paint stratigraphies from various samples taken at the Burnt Coat Harbor Lightstation tower.

Paint colors specified for use on the interior of light house towers 1871 – 1952:

The 1871 *Regulations, Instructions, Circulars, and General Orders of the Light-House Establishment of the United States* only specified colors for the interior of light-house lanterns as follows:

The whole interior of the light-house lanterns (dome, astragals, ventilators, smoke-conductor, &c.) is to be painted white, and must be kept clean, free from soot and grease, and the white paint renewed as often as necessary.

However, instructions for using black paint for inside work was included, along with general instructions for mixing colors typically used by the general public for painting as well during this period of time as documented in *Every Man His Own Paint. A Guide to Victorian House Painting* and other published period painting manuals. Refined coal tar was issued “for use on all iron-work which is not necessarily to be of another color, and no black paint is to be used where coal-tar will answer in color as a substitute.” Also at this time it was noted that hereafter “no green paint will be issued to light-keepers, and black paint or lamp-black will be issue only when it is required to mix with white paint to make lead color.”

The 1891 and 1909 Amendments to the 1881 and 1902 *Instructions to Light-Keepers* by the United States Light-House Establishment specified inside colors as follows:

²I would like to extend a sincere note of appreciation to James W. Claflin of Kendrick A. Claflin & Son Antiques for generously sharing copies of these three publications for this report.

³Standeven, 14-15.

⁴U.S. Coast Guard, *Paint and Color Manual (CG-263)*, 1952, Letter of Promulgation.

⁵U.S. Coast Guard, 1952, 23.

⁶Standeven, 92.

White --- For the interior of lanterns, and generally for all interior woodwork except hard wood.

Green --- For pedestals and service tables.

Lead color --- For floors, staircases, and walls when authorized to be painted. Hard-pine floors and hard woods generally are not to be painted, but shall be kept well oiled or scrubbed.

Black --- For iron staircases and railings, and for interior ironwork in general, except pedestals and service tables.

Black or white --- Underside of tower stairways.

Whitewash --- For walls, cellars, and outhouses, and rough-board work, when painting has not been authorized.

The use of coal tar and asphaltum varnish in painting light-house structures is prohibited, also lantern and lantern decks.

All ironwork shall be well primed with red lead before the application of other paint.

The 1927 *Instructions to Employees of the United States Lighthouse Service* specified inside colors as follows:

Interior of lanterns and generally all interior woodwork except hardwood – White.

Wooden floors, staircases, rails, and walls – Grained or lead color.

Iron floors, staircases, and railings, and interior ironwork in general, pedestals – Brown.

The complete 1935 Coast Guard painting manual, including later amendments and revisions, as well as issues of the “Painting Instructions Memorandum” series, have not yet been located for comparison with the cross-section paint layers. However, given the predominance of layers which fall into the category of modern synthetic resin paints based on their visual characteristics when viewed in uv light, there is little doubt paint layers in the samples date from this period. Based on the cross-section analysis it appears likely that the red lead primer layer present in samples with a metal substrate is a marker for a significant repainting effort that took place c. 1935 or later. Given the scarcity of materials during WWII, it is possible this undertaking did not happen until the end of the war.

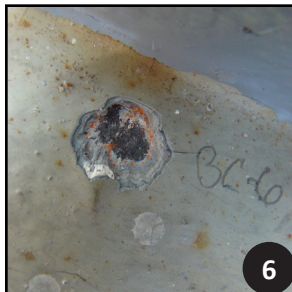
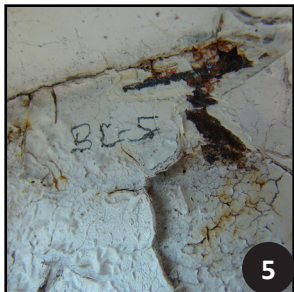
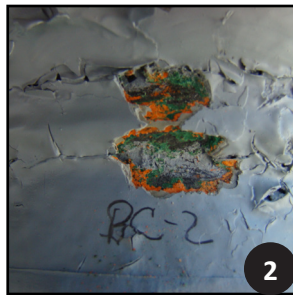
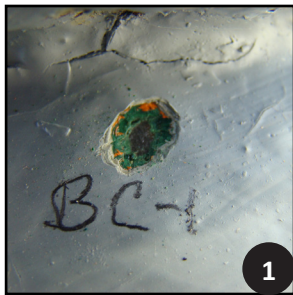
The existing application of color on the interior of the tower (including the lantern / lens room) pretty nearly follows the Coast Guard painting manual from 1952 which prescribes:

The light house tower interior, including the lens room, shall be white. The metal ladder shall be No. 19 Light Gray. Miscellaneous metal railings, metal sash, lens frames and supports shall also be No. 19 Light Gray. As an alternate No. 12 Spruce Green may be used. . . Painted floors shall normally be No. 19 Light Gray. Where maintenance is difficult, such as in shops, No. 20 Medium Gray may be used as an alternate. Painted floors of galleys, heads, furnace rooms, generator rooms and locker rooms shall be No. 29 Tile Red.⁷

⁷ U.S. Coast Guard, 1952, 28.

Cross-section analysis results:

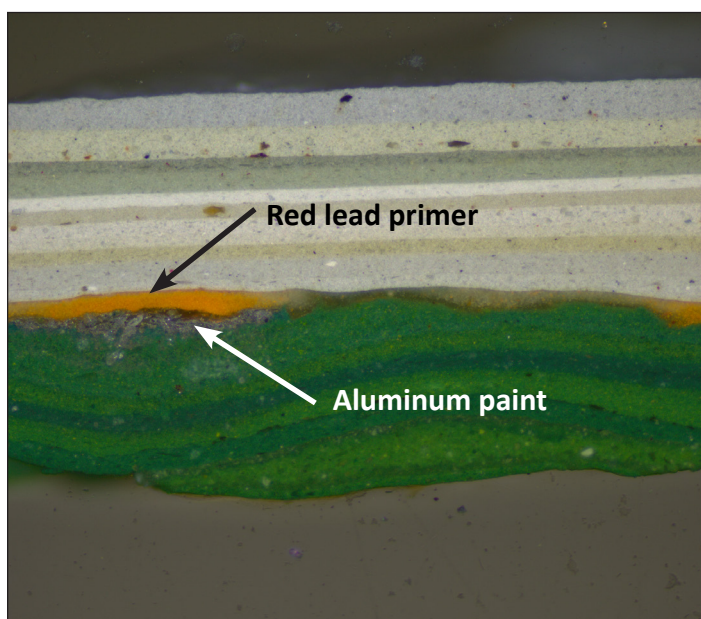
Lantern: Samples 1-7 were taken in the lantern from the original Fresnel lens pedestal, the metal floor, wood wainscoting, metal window frames and metal ceiling.



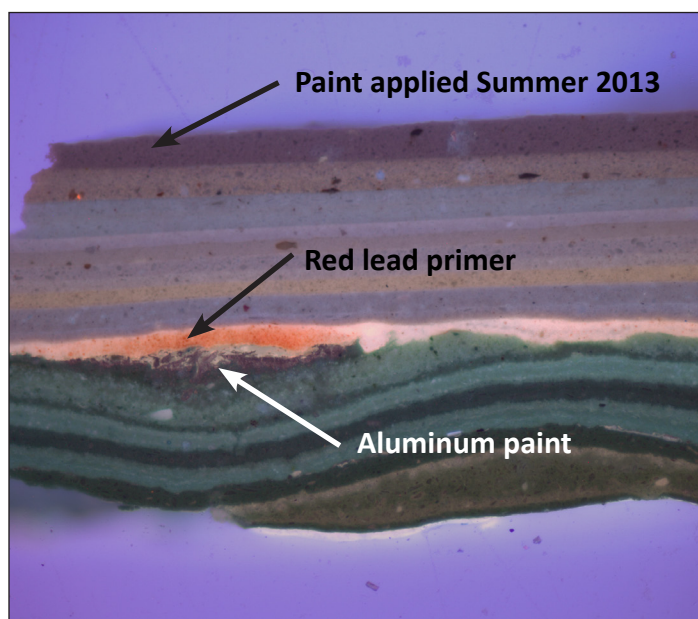
Fresnel Lens Pedestal: The combined stratigraphies of sample 1 taken from the base of the lens pedestal and sample 2 from the neck of the lens pedestal documents roughly 12-13 generations of green paint layers under roughly 7 generations of light to medium gray paint layers, ending with the gray paint applied during the summer of 2013. A red lead primer layer in a varnish separates the green paints from the gray paint layers. The pedestal base sample has more gray layers than the pedestal neck sample, and the pedestal neck sample has more green layers than the pedestal base sample. The earliest remaining paint on the pedestal neck sample (sample 2) appears as a partial layer of a granular dark gray paint in the cross section. This layer is readily visible in the uncast pieces of the sample as a thick, granular very dark gray / black layer. Sample 3 has the same gray generations (14-20) as sample 1 from the pedestal base.

The published 1891 and 1902 *Instructions by the Light-House Establishment* specified green paint for lens pedestals. The 1927 *Lighthouse Service Instructions* specified brown paint for lens pedestals. There is, however, no brown paint evidence in the pedestal paint samples. The 1952 *Coast Guard Paint Manual* specified No. 19 Light Gray for pedestals but also lists No. 12 Spruce Green as an alternate. As such, the documentary sources currently available for this analysis do not give us enough information to date the existing paint layers on the lens pedestal from these sources. An entry in a keeper's log or access to painting specifications between 1927 and 1952 could help provide more documentary evidence.

The thick red lead primer in sample 2 for the upper gray paint layers seeps down into the fragmented and broken top green layers which have the appearance of being disturbed by scraping or sanding. This disruption may indicate that paint layers are missing from the middle of the paint history due to a paint removal campaign prior to repainting. In sample 1, there is a partial layer of aluminum paint under the same orange colored red lead primer layer. Aluminum paint was widely used as a primer in the middle of the 20th century. The earliest reference for its use as a priming coat I have seen, however, is in the 1935 *Instructions for Painting United States Coast Guard Vessels, Boats, and Stations* intended for "all types of floating equipment." Section 4 – Use of Aluminum Paint explains it may "be used as a priming coat in lieu of red lead" and that aluminum paint "composed of aluminum powder in water-resisting spar varnish" should not be mistaken for the "ready-mixed bronzing paints" that had been used up until that time. As such it is likely the primer layer dates from the late 1930s or later (keeping in mind the Lighthouse Service was transferred over to the U.S. Coast Guard in 1939). While it cannot be unequivocally proven the green layers under this primer layer date from the 1930s (because the disturbed appearance of the top green layers seem to indicate paint layers were removed prior to the application of the primer coat) it may be a reasonable to say the pedestal could have been painted green at some point in the early 1930s because the dark autofluorescence of the middle and upper green layers in UV light indicate these are modern paints, which would have been available in the 1930s.

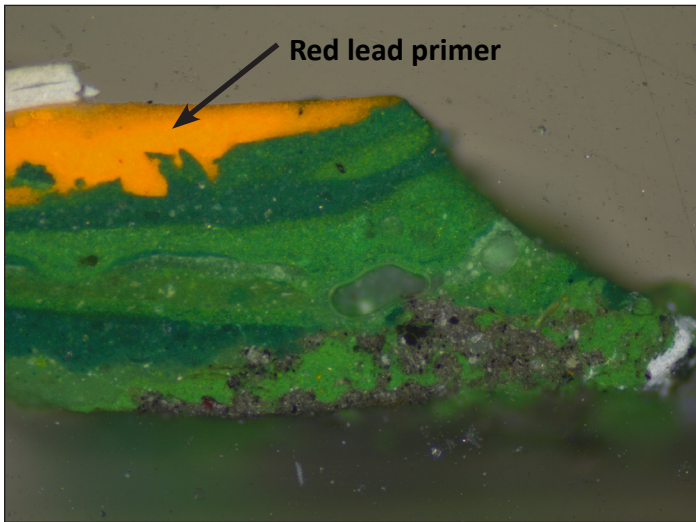


Sample bc-1, Lantern: lens pedestal, base of pedestal, 100x vis

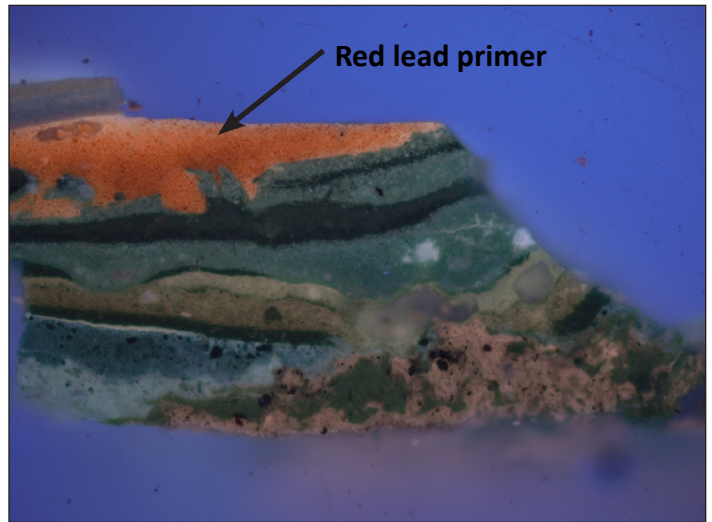


Sample bc-1, Lantern: lens pedestal, base of pedestal, 100x uv

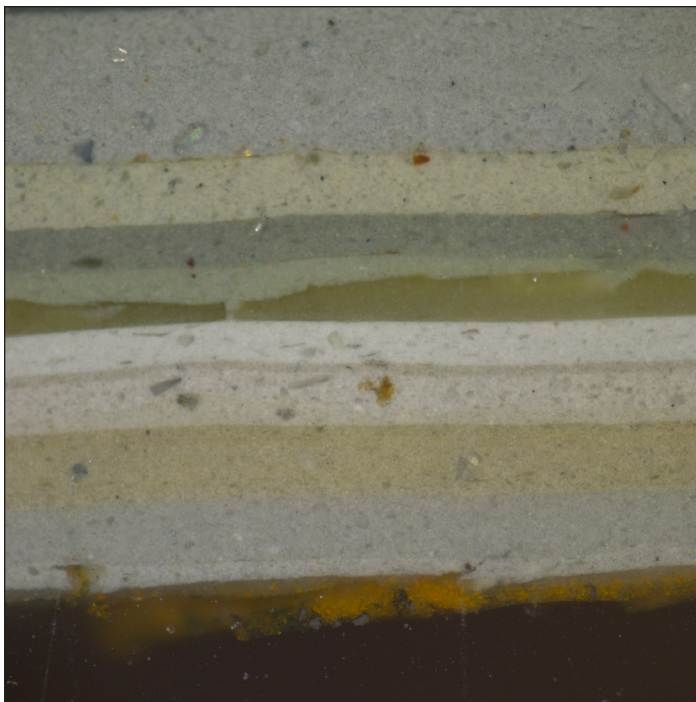
The dark gray paint at the bottom of sample 2 appears granular with medium and large black and white pigments visible in the gray matrix. The 1902 Instructions for mixing gray or lead color paint for outside work prescribe adding “lampblack (or black paint ground in oil) in small quantities to white paint, ground in oil, until the desired shade is obtained”.¹ It does not appear the directions for inside work were followed in this instance because the following recipe would have a different appearance in UV light. “Black paint for inside work may be prepared with dry lampblack, mixed with copal or coachmaker’s varnish and then thinned to the consistency of cream with spirits of turpentine”.² Interestingly, both the 1902 Instructions and the 1891 amendment to the 1880 Instructions prescribe the use of green for pedestals, with black being prescribed for “iron staircases and railings, and for interior ironwork in general, except pedestals and service tables.”



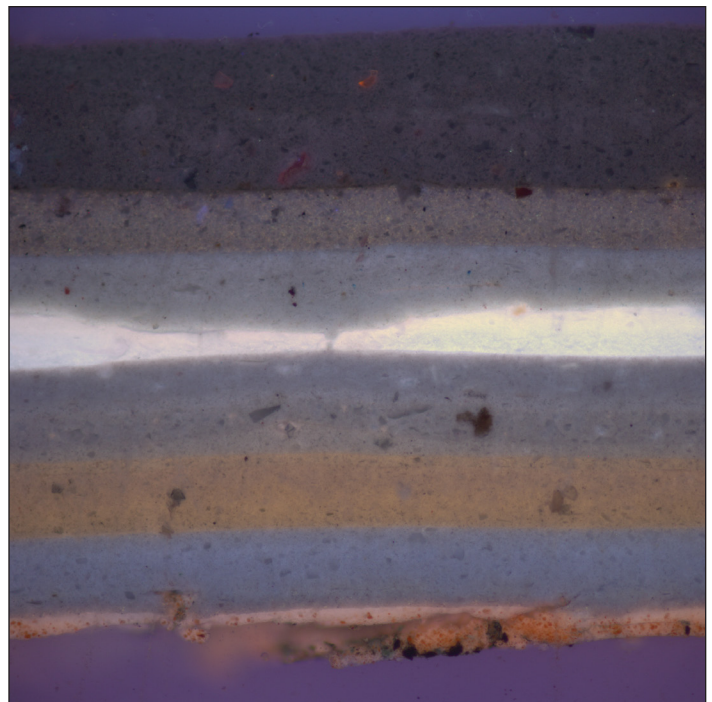
Sample bc-2, Lantern: lens pedestal, top of pedestal neck, 100x vis



Sample bc-2, Lantern: lens pedestal, top of pedestal neck, 100x uv



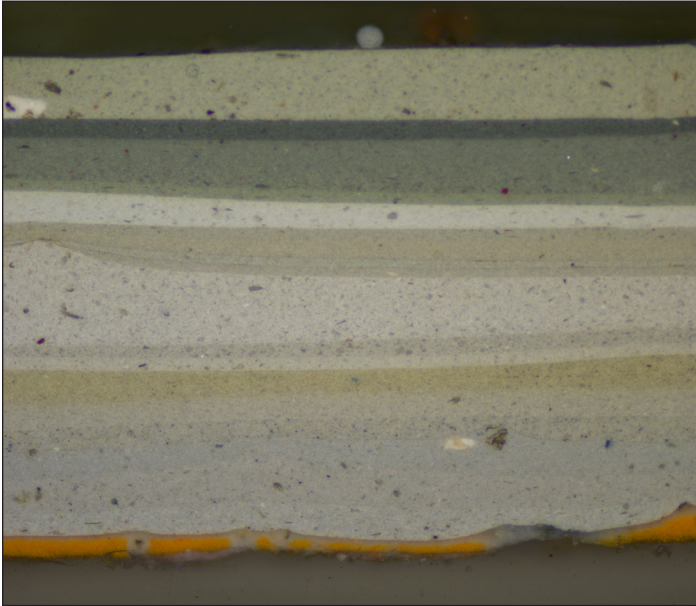
Sample bc-3, Lantern: lens pedestal shelf, 200x vis



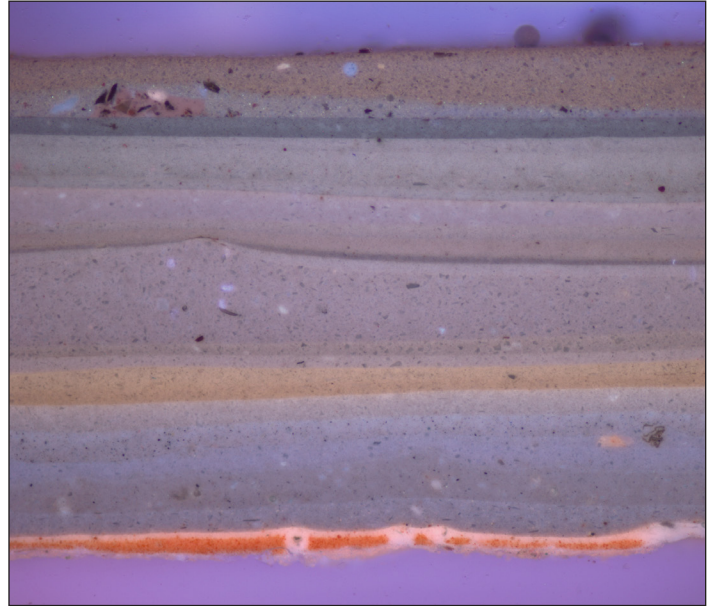
Sample bc-3, Lantern: lens pedestal shelf, 200x uv

1 United States Light-house Establishment, *Instructions to Light-Keepers and Masters of Light-House Vessels*, (Washington: Government Printing Office, 1902), 51.
2 United States Light-house Establishment, 1902, 51.

Lantern Floor: The paint layers for sample 6 from the metal lantern floor start with the same (orange colored) red lead primer visible at the beginning of the gray paint layers on the Fresnel lens pedestal. The metal floor sample has seven more gray layers than the pedestal samples. These layers are interspersed with the middle of the gray layers on the pedestal and likely represent more frequent repainting of the floor, which would have experienced greater abrasion from traffic and weathering due to it being a horizontal surface vs. a vertical one.



Sample bc-6, Lantern: floor, 100x vis

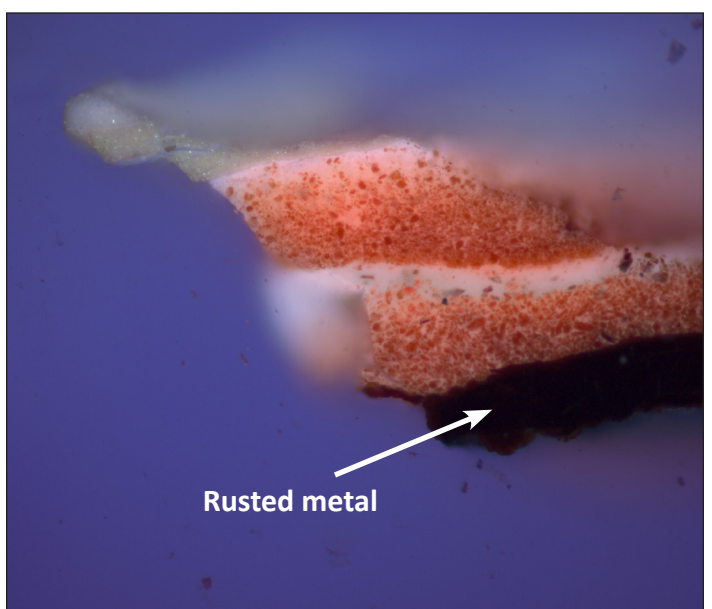


Sample bc-6, Lantern: floor, 100x uv

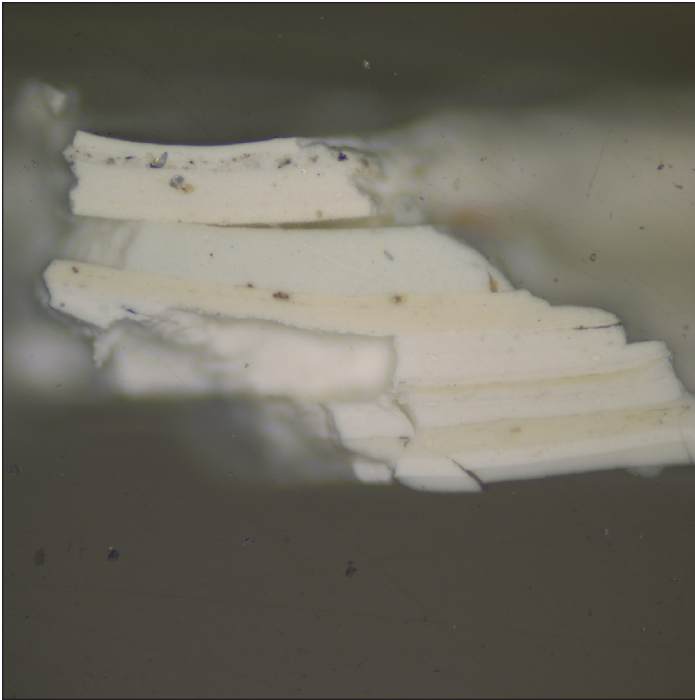
Lantern Windows and Ceiling: The lantern window frame with mullions (sample 5) and ceiling (sample 4) has paint stratigraphies comprised entirely of white paints which follow the prescribed painting instructions from 1871 – 1952. Sample 4 from the ceiling also starts with the same thick orange red lead primer as the floor sample. It is interesting to note there are two distinct layers of primer over deteriorated metal substrate. This evidence seems to reinforce the theory that a major repainting campaign of the entire tower took place in the early to post-WWII at a time when the paint layers may have substantially deteriorated.



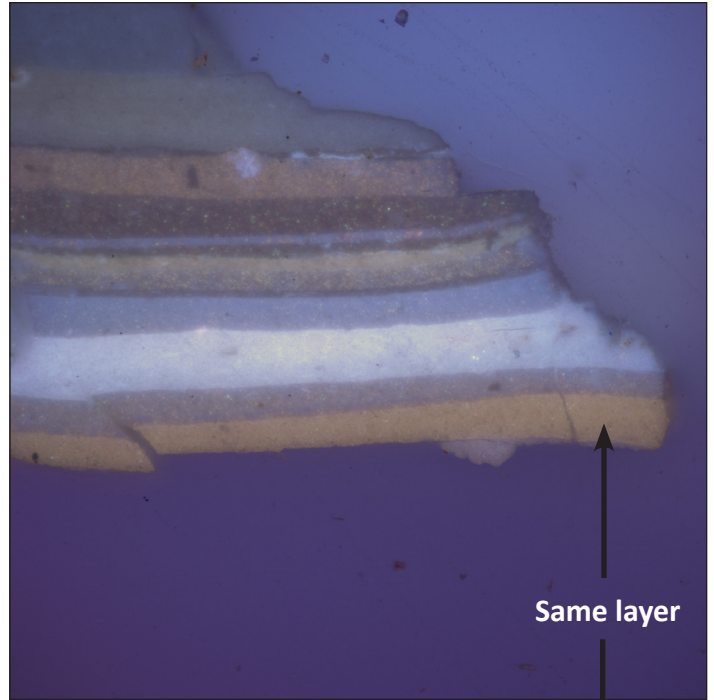
Sample bc-4.1, Lantern: ceiling, 200x vis



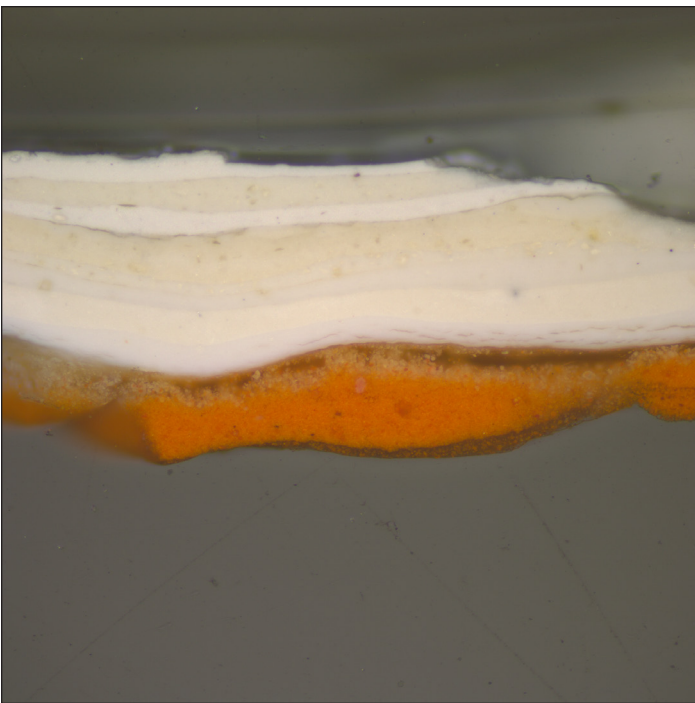
Sample bc-4.1, Lantern: ceiling, 200x uv



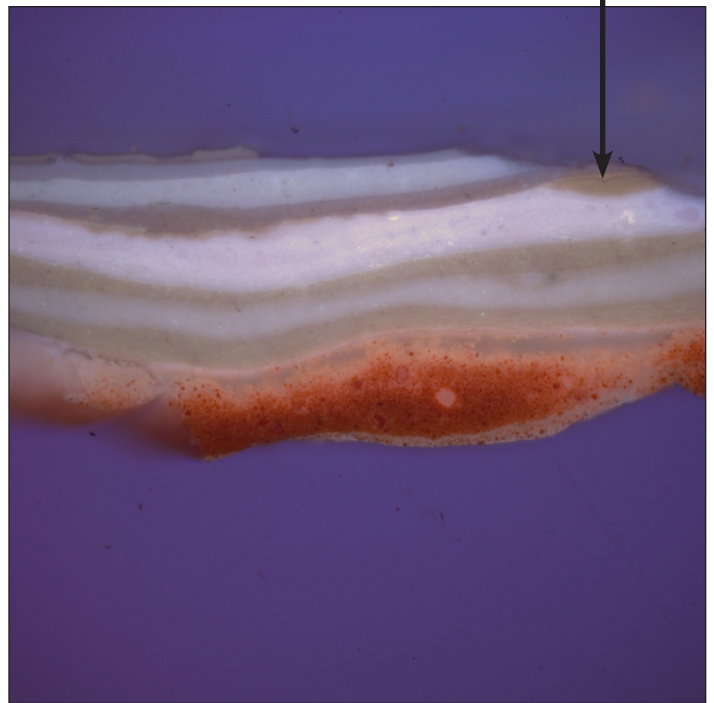
Sample bc-4.3, Lantern: ceiling, 100x vis



Sample bc-4.3, Lantern: ceiling, 200x uv

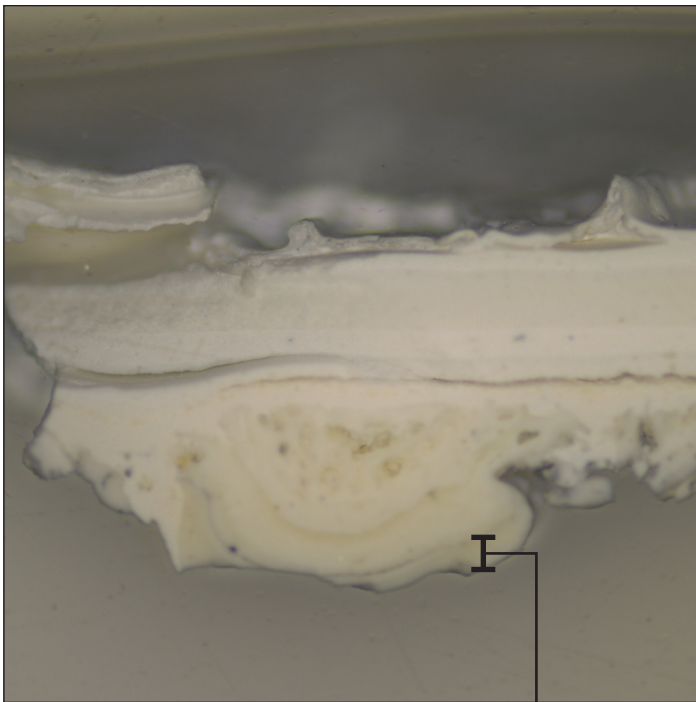


Sample bc-4.2, Lantern: ceiling, 100x vis

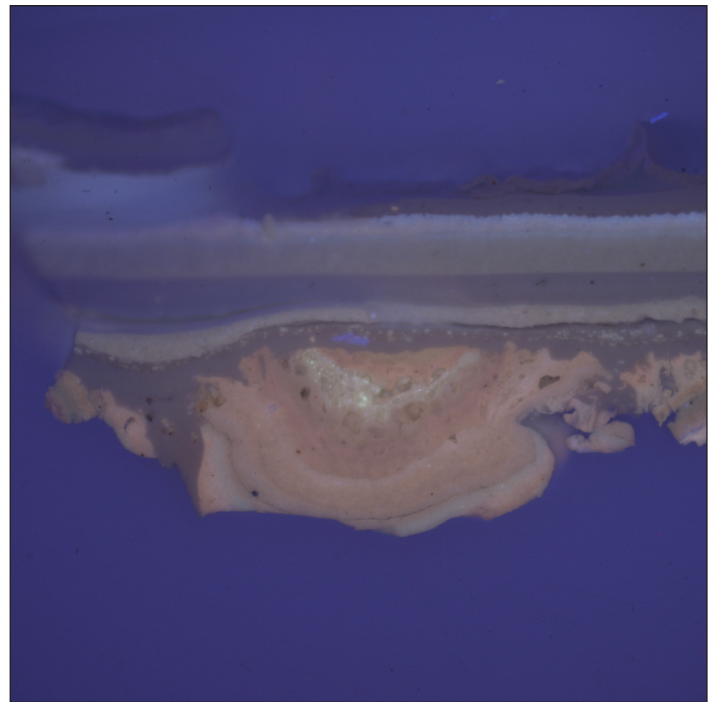


Sample bc-4.2, Lantern: ceiling, 100x uv

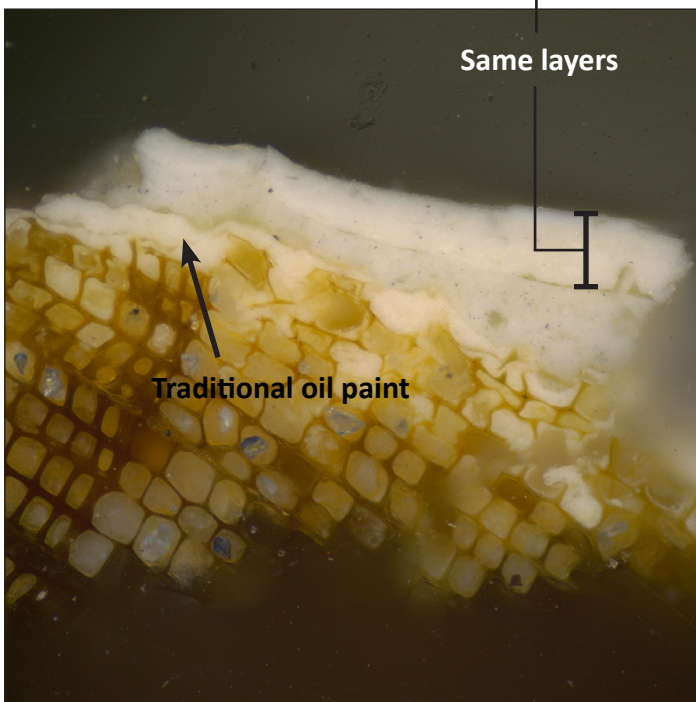
Wood Wainscoting: The sample 7 paint layering on the vertical beaded board parapet wainscoting is comprised of all white layers and includes what appears to be a traditional linseed oil and lead white layer as the earliest generation remaining visible in the fibers of the wood.



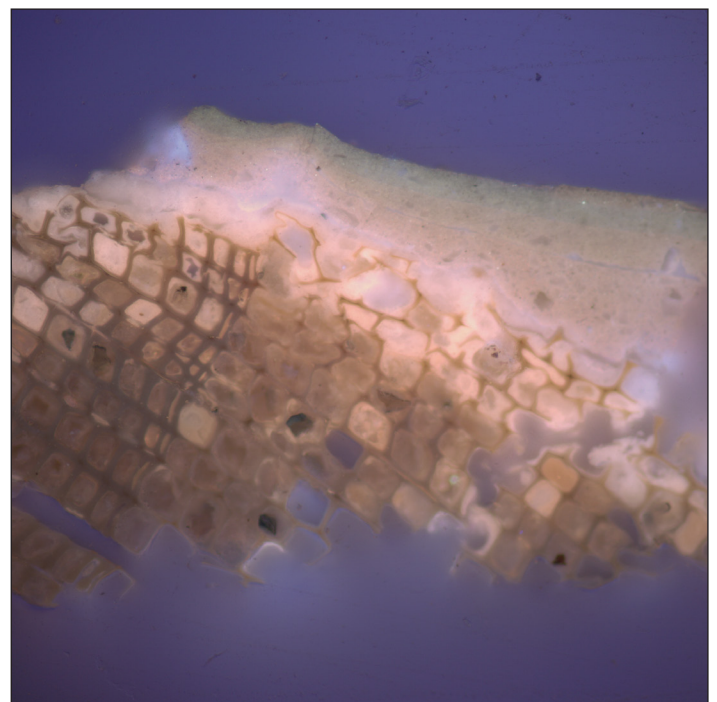
Sample bc-7.3, Lantern: wainscot, 40x vis



Sample bc-7.3, Lantern: wainscot, 40x uv



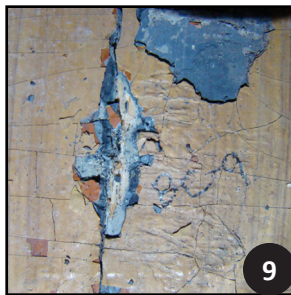
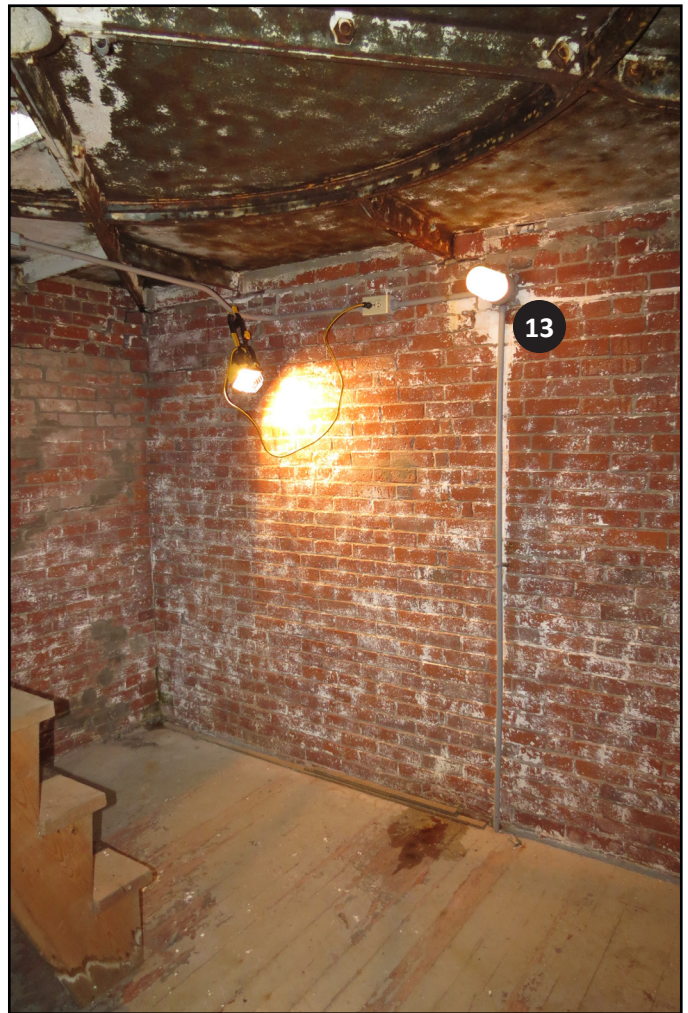
Sample bc-7.1, Lantern: wainscot, 200x vis



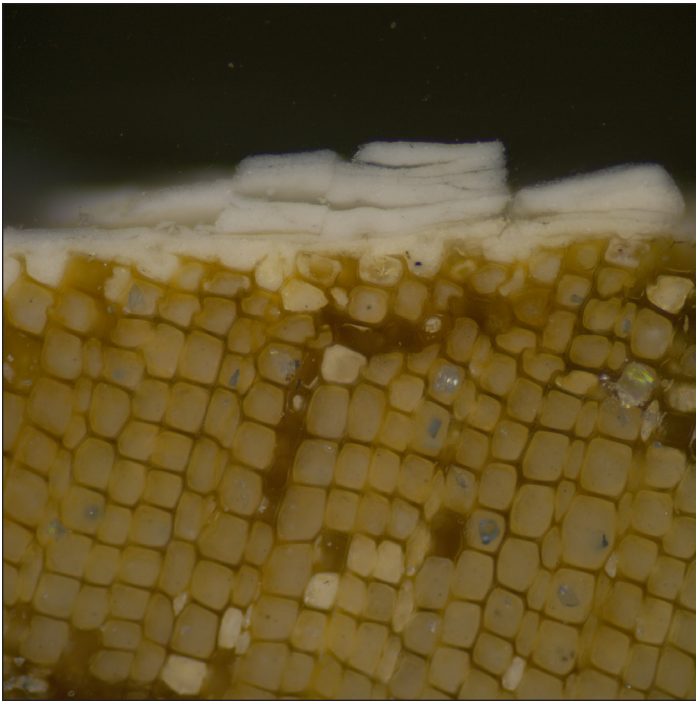
Sample bc-7.1, Lantern: wainscot, 200x uv

Cross-section analysis results:

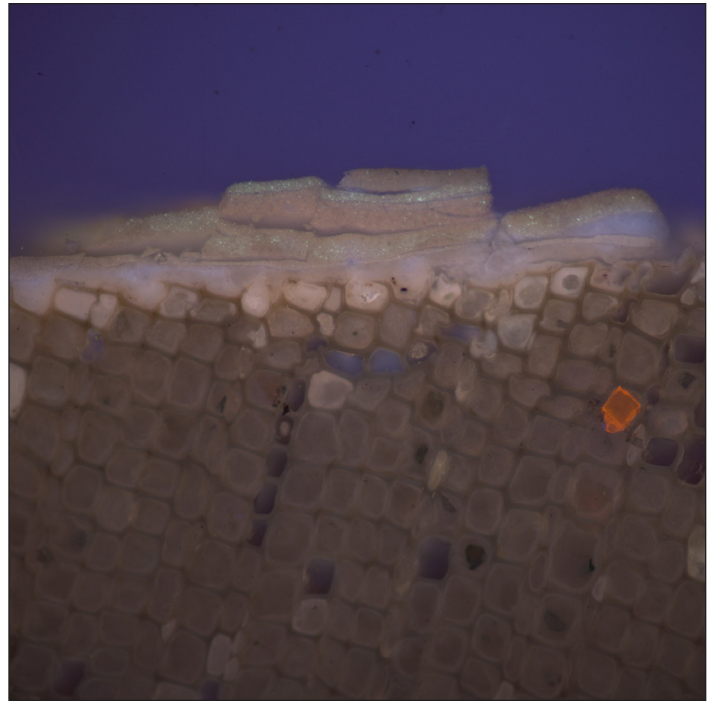
Watch Room: Samples 8-13 were taken in the watch room from the wood entrance partition wall, upper and lower floor boards and brick wall.



Door Frame and Partition: The door frame and the partition wall for the watch room (samples 11 and 12) contain only white paint layers. The earliest layer on the door frame appears to be a traditional linseed oil and white lead layer that is both in the pores of the wood and on top of the wood.

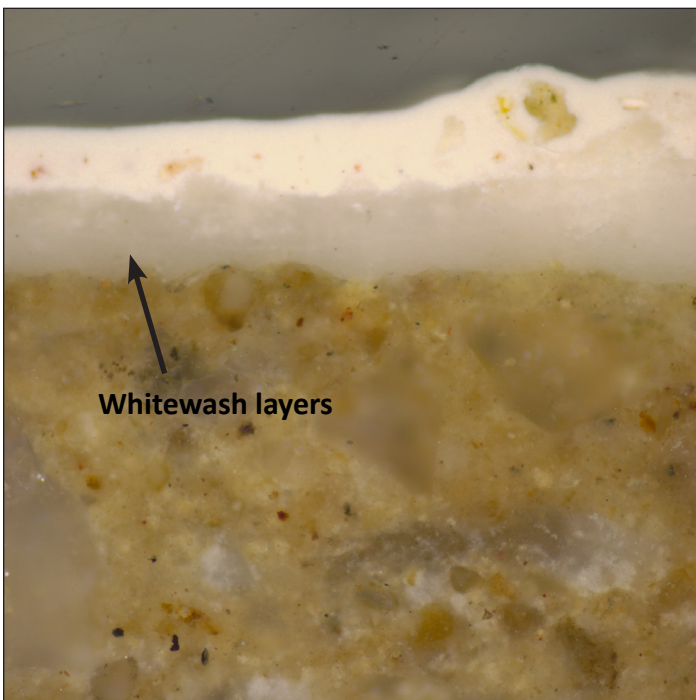


Sample bc-11c.1, Watch Room: door frame, 200x vis

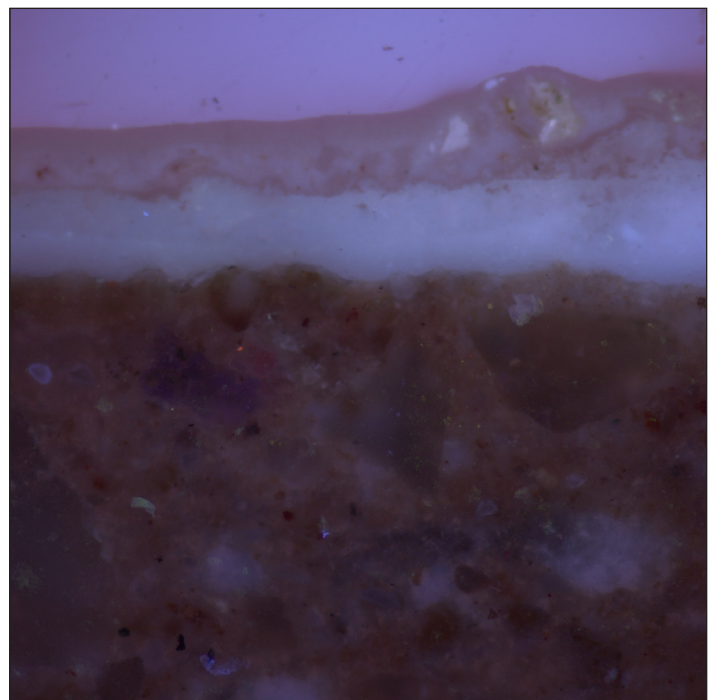


Sample bc-11c.1, Watch Room: door frame, 200x uv

Brick Wall: The brick walls of the tower have been sand blasted to removal all paint layers. However, thin strips of paint do remain on the brick behind surface mounted conduits for light bulbs. The sample from the brick wall in the watch room (sample 13) was taken behind the conduit and appears to retain a couple layers of whitewash below a layer of oil based paint.

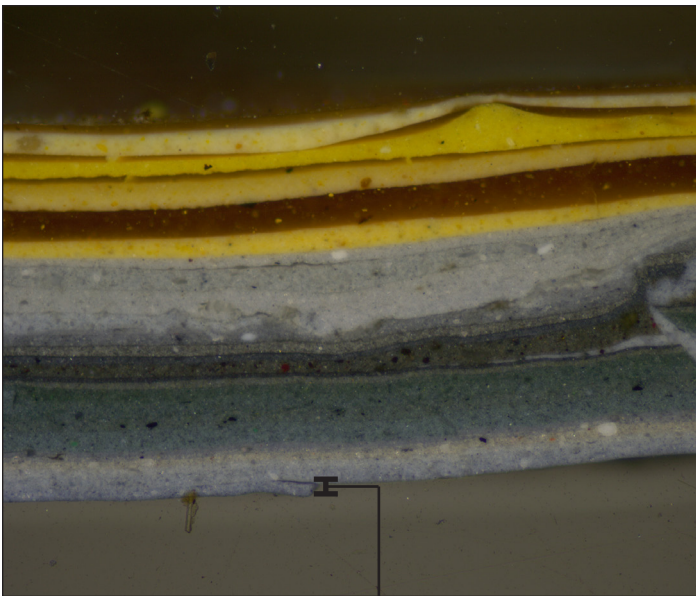


Sample bc-13, Watch Room: brick wall at light, 200x vis

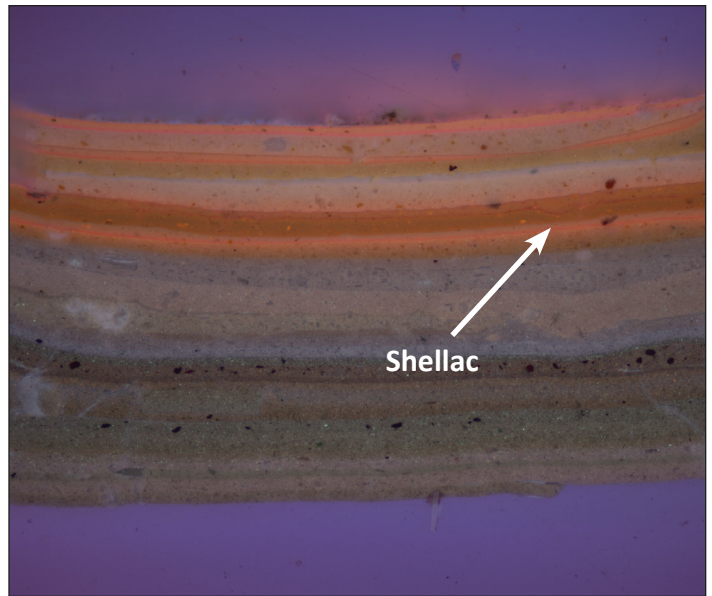


Sample bc-13, Watch Room: brick wall at light, 200x uv

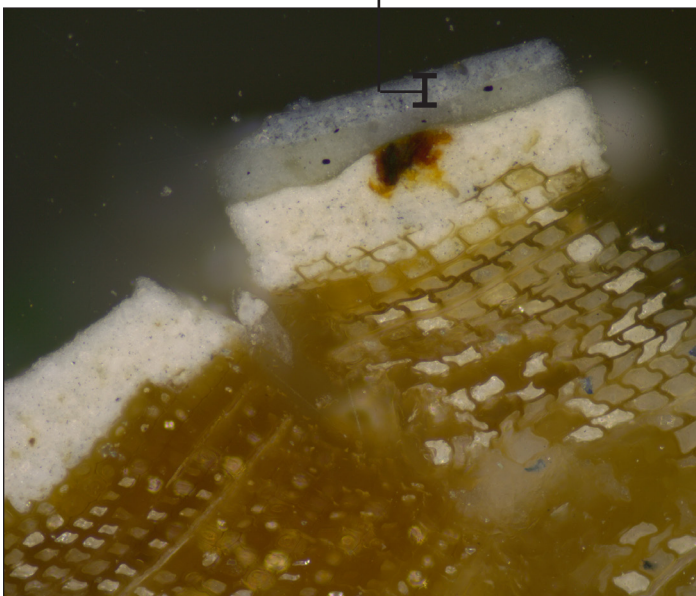
Watch Room Flooring: The watch room floor is comprised of two layers of floor boards. The lower layer is painted floor boards typical of 1870s construction and the upper layer is a tongue and groove hardwood floor installed perpendicular to the lower layer of flooring. The upper and lower floor boards of the watch room each provide a distinct set of paint layers and colors. At this time the date for the installation of the upper floor boards is not known. It is likely the upper hardwood flooring was installed in the first quarter of the 20th century and possibly as early as c.1900 when the keepers house interior was renovated. Unfortunately, the installation of this floor has not as yet been found in a keepers log entry. The nosing at the entrance step on the threshold to the watch room contains the nearly complete paint history of both layers of floor boards (plus additional layers). It does appear, however, that the upper flooring was added at the same time the iron stair paint color shifted from black to dark brown, as discussed further below in samples 10 and 15.



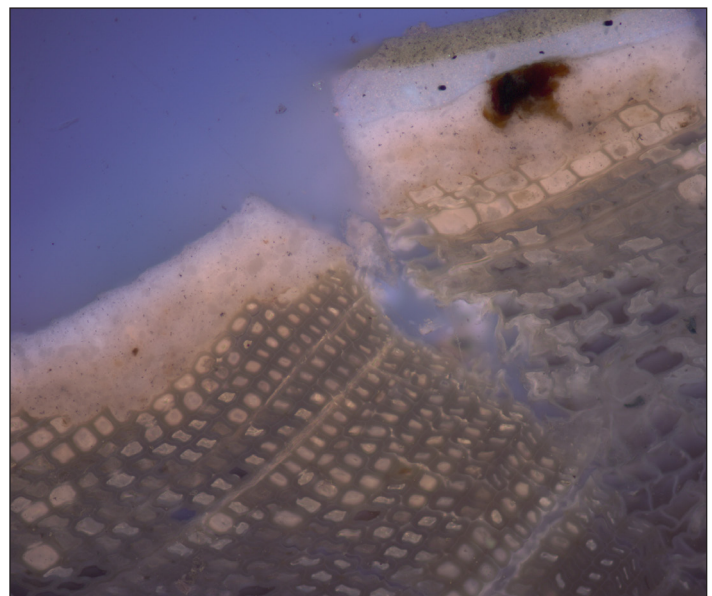
Sample bc-9.2, Watch Room: lower layer of flooring, 100x vis
Same layer



Sample bc-9.2, Watch Room: lower layer of flooring, 100x uv

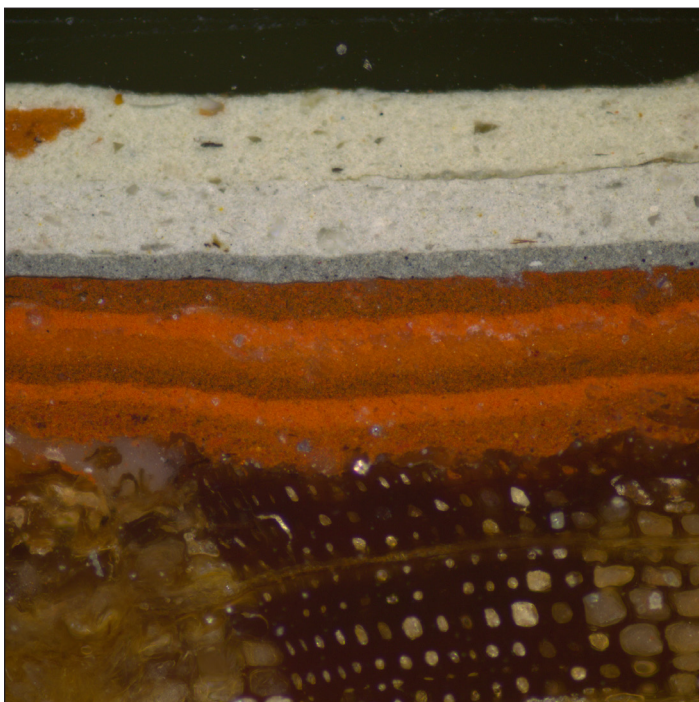


Sample bc-9.1, Watch Room: lower layer of flooring, 200x vis

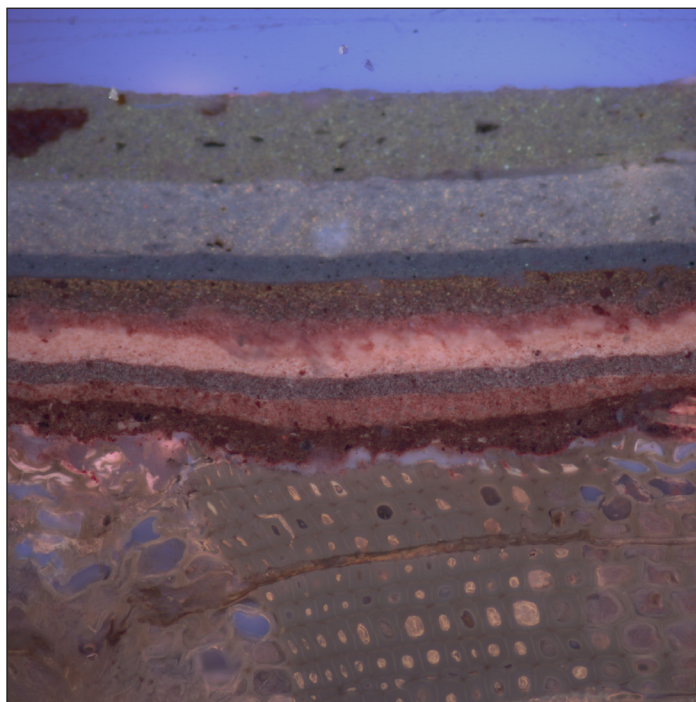


Sample bc-9.1, Watch Room: lower layer of flooring, 200x uv

Sample 9 from the lower floor boards first has a series of light blue-grays followed by medium grays and then light grays totaling 10 generations of paint (generations of paint are comprised of primer + top coat). The gray layers on the lower floor boards and are followed by 6 generations of yellow colored paint topped with shellac. If the lower floor was covered early in the 20th century, the thick accumulation of paint on the lower floor boards would indicate the floor was repainted about every 1-2 years, which is believable given how much this softwood floor would have been worn over the course of a year by the keepers constant attention to the lamp in the Fresnel lens in the lantern above. A keeper's log entry from July 18, 1874 – just shy of two years after the Burnt Coat was placed in service says “Painted the upper room floor in the rear tower.”



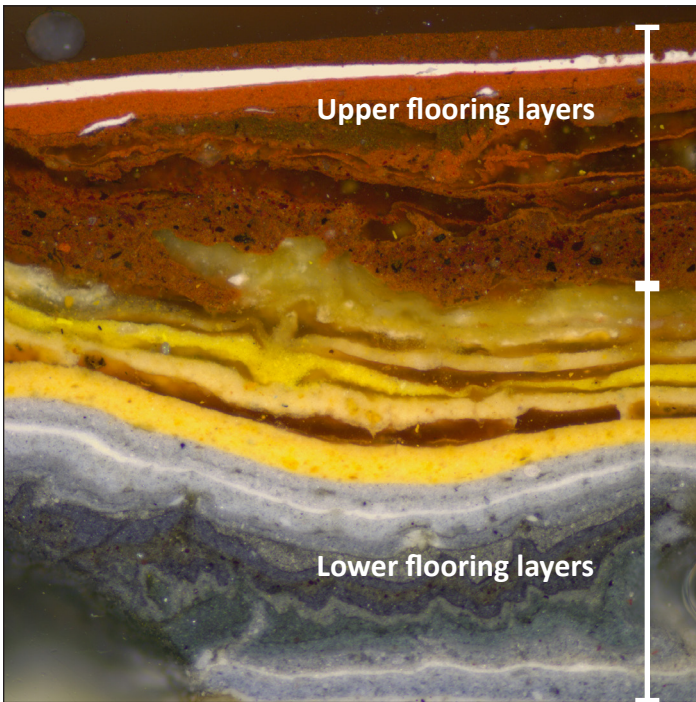
Sample bc-8, Watch Room: upper layer of flooring, 200x vis



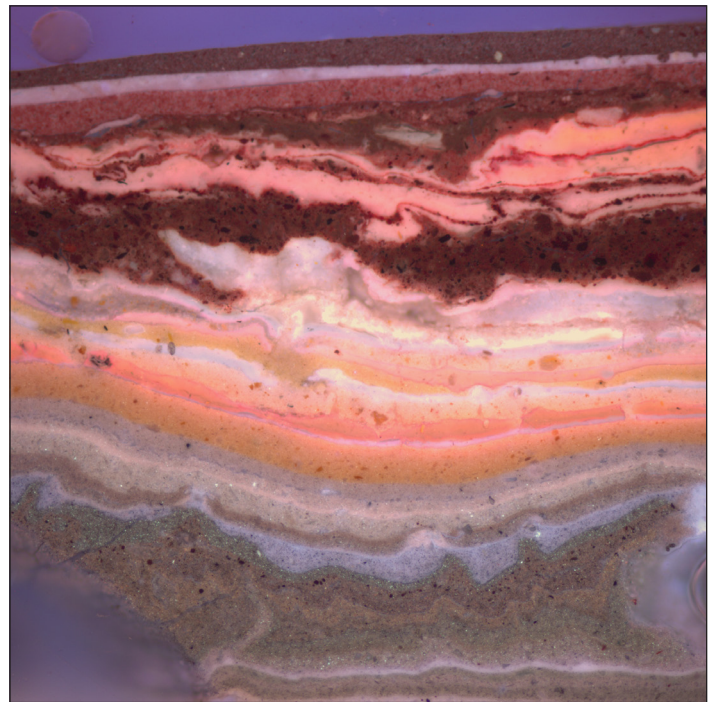
Sample bc-8, Watch Room: upper layer of flooring, 200x uv

Sample 8 from the upper floor boards has noticeably fewer extant layers of paint than sample 9 from the lower floorboards. This sample only has four generations of reddish-brown paint and two generations of light gray paint. However, the wood is weathered and the fibers are compressed in this sample indicating the wood was unpainted, abraded by foot traffic or aggressively prepped prior to repainting. Page 53 of the 1902 Instructions to Light Keepers dictates “hard-pine floors and hard woods generally are not to be painted, but shall be kept well oiled and scrubbed.” If the upper floor was installed when the keeper's house was renovated at the turn the 20th century and the new floor was not painted for some time, it would account for the lack of earlier red-brown paints that are present in the threshold sample 10. The dark red-brown paints that are present in sample 8 are more finely ground paints like the later red-brown paints in sample 10. The early and middle red paints on threshold sample 10 include shellac and varnish layers over the red paints that are not surviving on floor sample 8 with the exception of a partial shellac layer on the wood and below the first red paint.

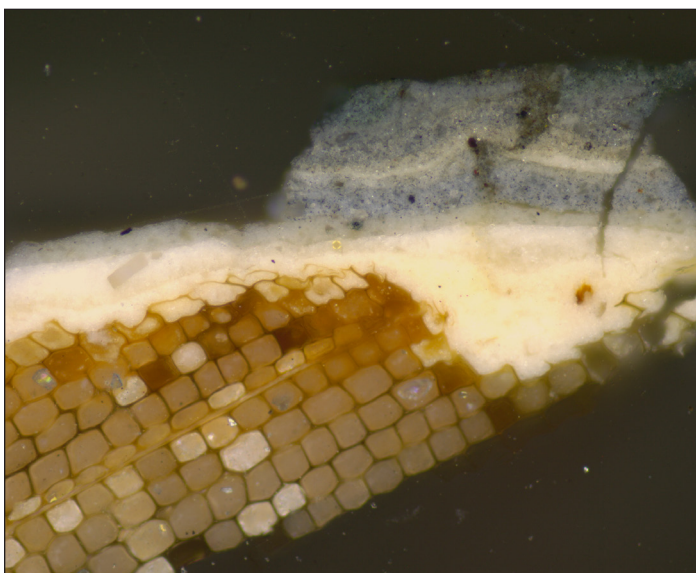
Sample 10 from the Watch Room door threshold is notable because it contains 26 generations of paint without the late 20th century gray paints, which the sample is missing. It is also notable the threshold was painted the same color as the lower floor boards until the iron stair paint color changed to dark brown, at which time the threshold was changed to the iron stair color. This is apparent because the first layer of dark reddish brown paint in sample 10 matches the first layer of dark reddish brown paint in sample 15 from the iron stairs. This may, in fact, be the strongest evidence to date the installation of the top flooring, to coincide with the shift of the iron stair color from black to dark brown.



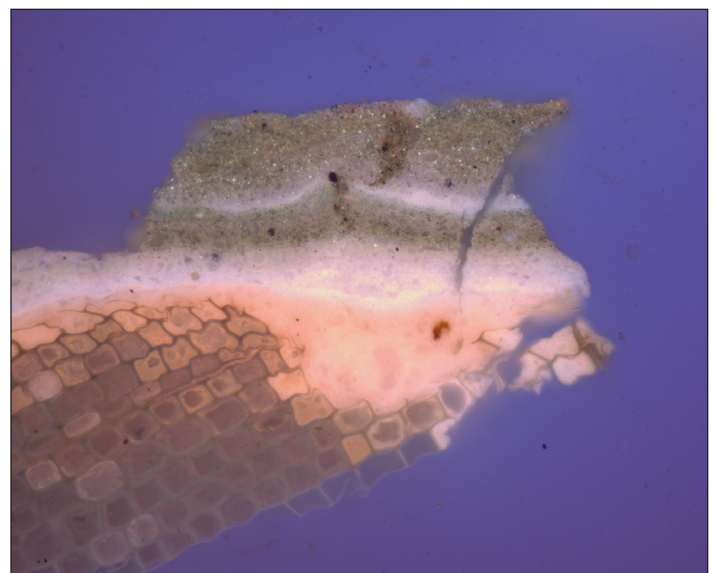
Sample bc-10.2b, Watch Room: door threshold, 100x vis



Sample bc-10.2b, Watch Room: door threshold, 100x uv



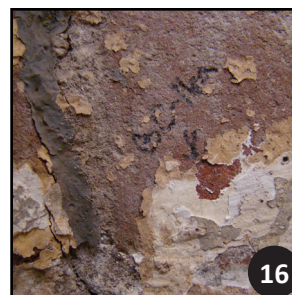
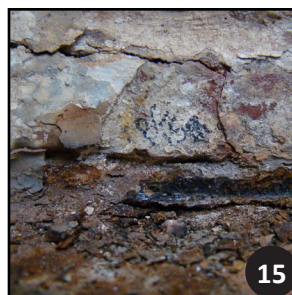
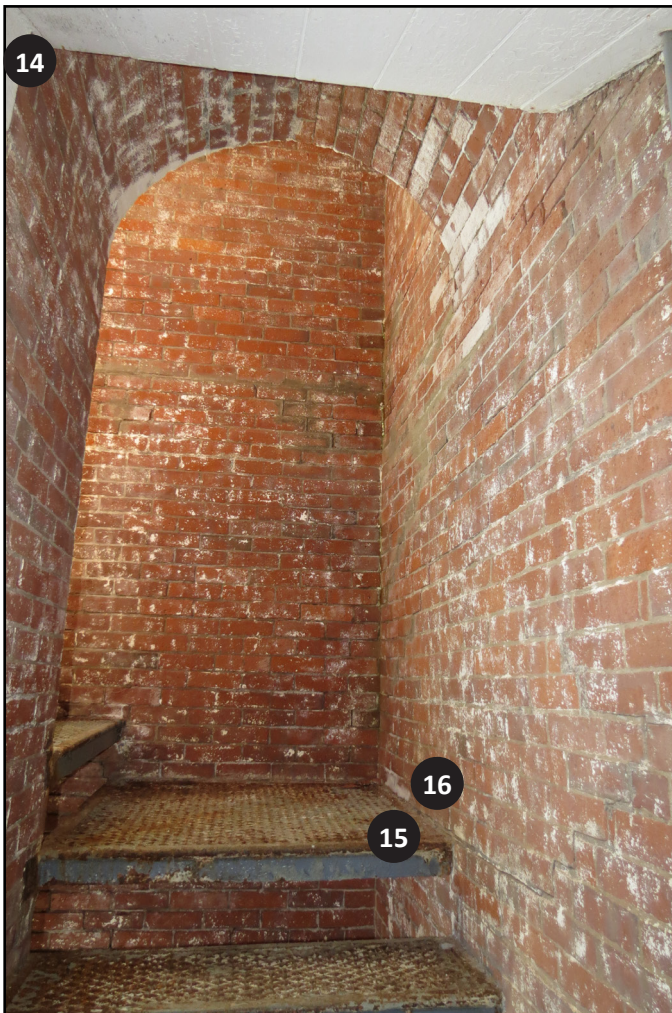
Sample bc-10.1, Watch Room: door threshold, 200x vis



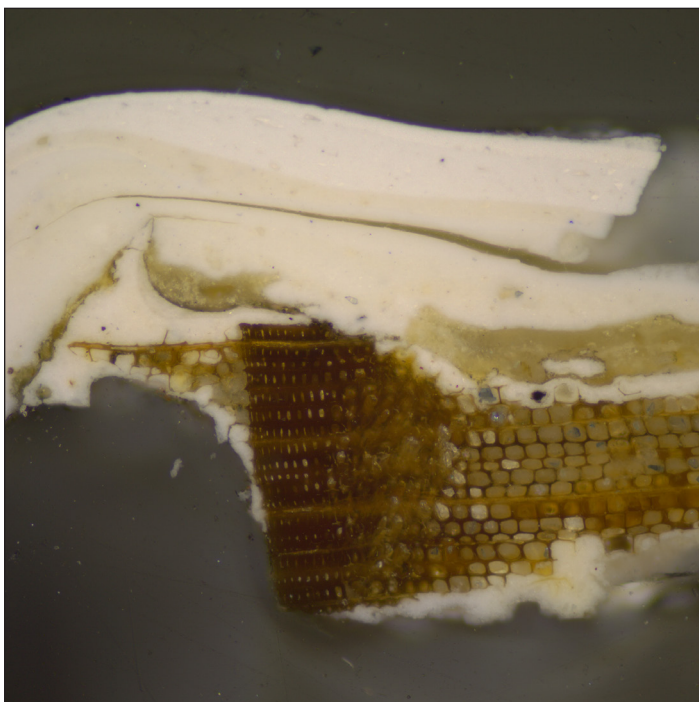
Sample bc-10.1, Watch Room: door threshold, 200x uv

Cross-section analysis results:

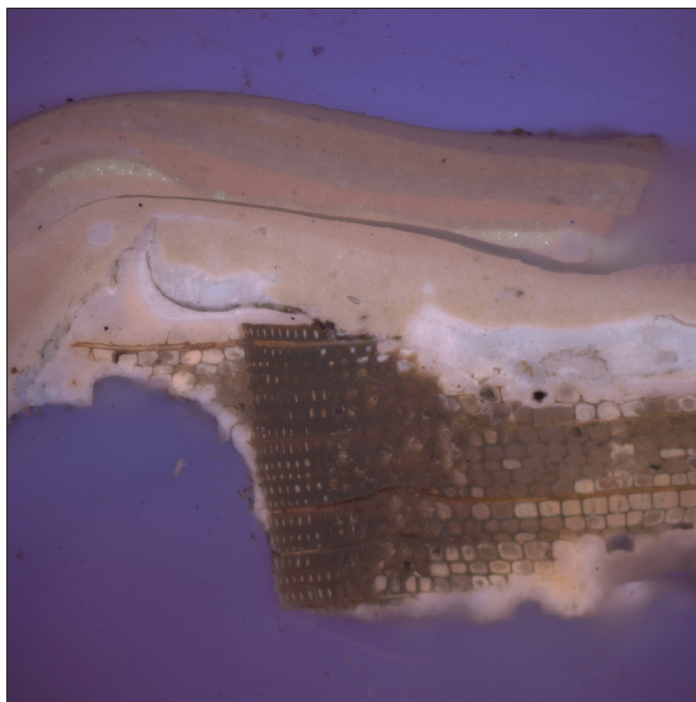
Tower: Samples 14-18 were taken in the tower from the underside of the watch room floor, the brick wall, iron stair treads and window openings.



Underside of Watch Room Floor: The watch room floor is wood joist construction set into the inner wythe of the exterior brick walls. On the west side of the tower a small brick barrel vault spans from the inner brick core of the tower to the exterior brick wall above the top run of stairs on the north side of the tower. On the east side of the brick vault is a rounded infill constructed with wood boards and a beaded board ceiling above the tower stairs adjacent to the watch room floor. This element appears to date from the original construction of the tower based on its materials and installation and because it is fastened to the wall with square headed nails. The paint layering on the wood elements above the stairway under the watch room floor (sample 14) is comprised of all white and off-white layers and includes what appears to be a traditional linseed oil and lead white layer as the earliest generation remaining visible in the fibers of the wood. Interestingly, the early oil paint also has a limewash above it in the layers, which is the finish historically used on the brick walls of the tower.

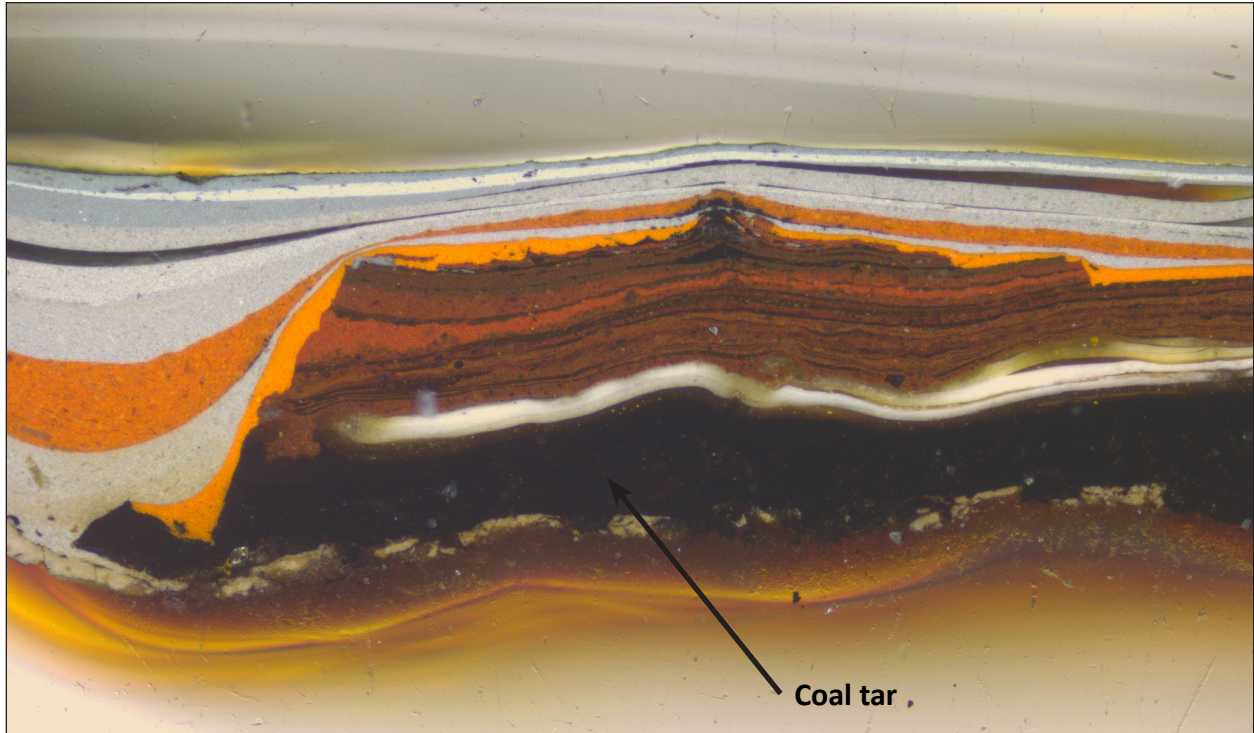


Sample bc-14a, Tower: underside of watch room floor, 100x vis

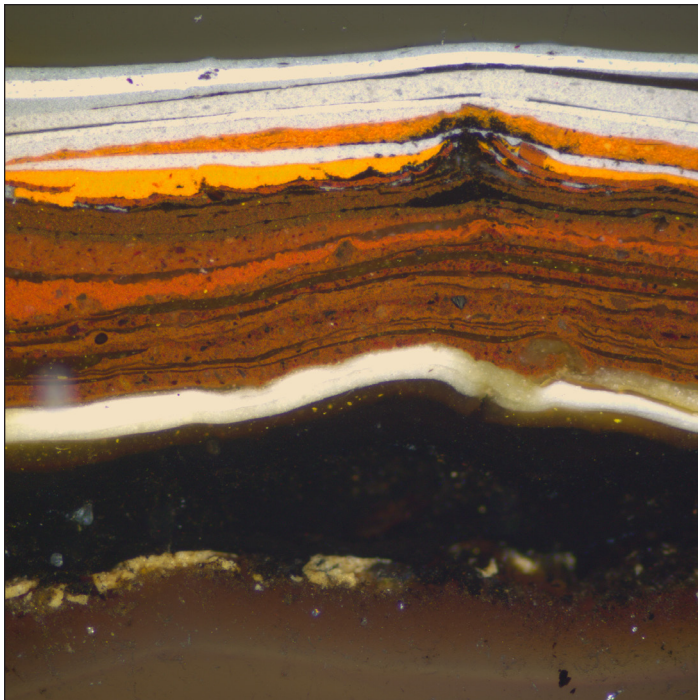


Sample bc-14a, Tower: underside of watch room floor, 100x uv

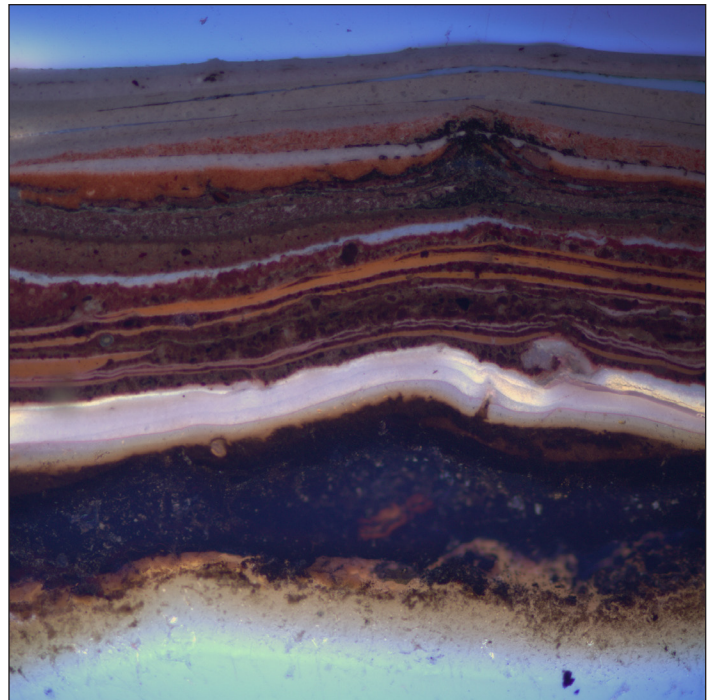
Iron Stairs in the Tower: Samples taken from the iron stair treads (samples 15a, b, c) are generally quite disrupted, exhibiting rust infiltration in the layers (especially 15a) and partial layers due to losses from abrasion and / or weathering. Sample 15b encompasses what appears to be a nearly complete stratigraphy for the stairs. The layering sequence starts with a thick layer of black coal tar seeping down around fragments of an oil based layer. There may also be a layer of black oil based paint above the coal tar. The coal tar layer is supported by documentation at the National Archives and in the published Light-House Establishment Instructions. In Light Station Keeper Allen's 1874 log book there are entries for: October 22, 1874 "Commenced to tar the rear tower steps but found it too cold" and November 2, 1874 "Finished coal taring the rear tower steps." Page 197 of the 1871 Regulations, Instructions, Circulars, and General Orders of the Light-House Establishment of the United States ordered the use of coal tar as follows: "Refined coal-tar will be issued for use on all iron-work which is not necessarily to be of another color, and no black paint is to be used where coal-tar will answer in color as a substitute." However, 1891 Amendment to the Light-House Regulations specified that "The use of coal tar and asphaltum varnish in painting light-house structures is prohibited, also lanterns and lantern decks."



Sample bc-15b 40x vis



Sample bc-15b, Tower: stair, 100x vis

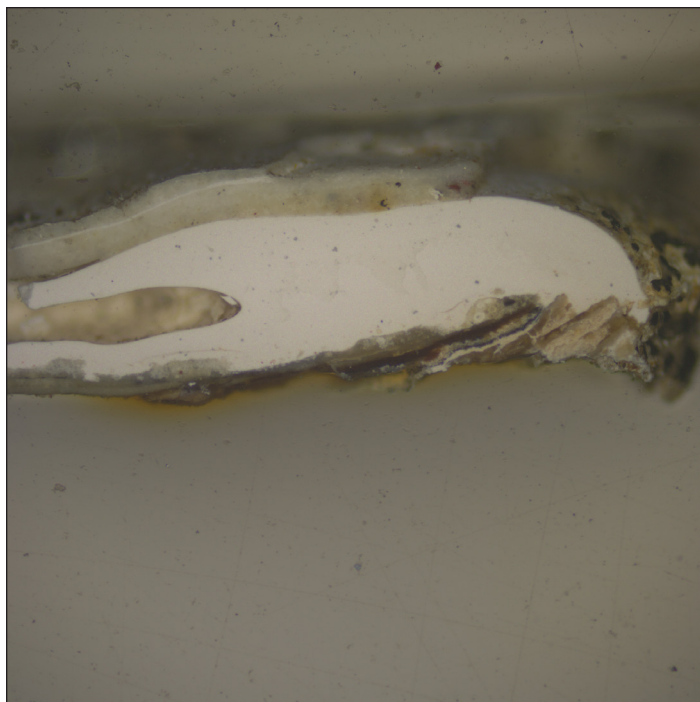


Sample bc-15b, Tower: stair, 100x uv

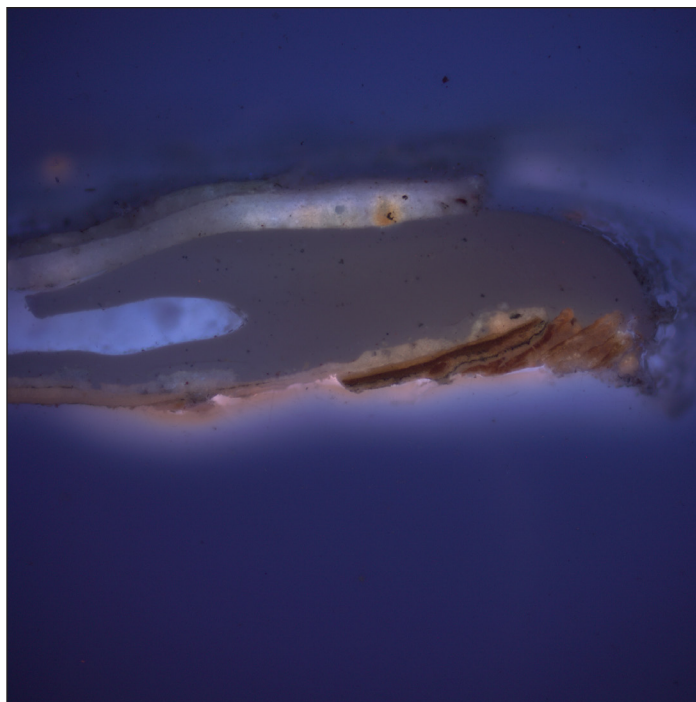
The black layers are followed by roughly 6-8 generations of varnish layers, which are then followed by a considerable accumulation of dark reddish brown paints (roughly 18 generations) with a shellac or varnish top coat. These dark reddish brown paints with shellac or varnish top coats match the dark reddish brown paints on the threshold to the service room (sample 10). The shift to brown paint for iron stairs is ordered in the 1927 Instructions to Light Keepers. The earliest reference to the use of shellac in the Light Keeper's Log Books is July

23, 1912 but the interior location is not specified. Entries from June 18, 1915 and September 25, 1916 note “Painted the steps in the tower” but they do not identify the color. The first specific reference to painting the steps in the tower during the 1930s is May 7, 1931, followed the next day by an entry that states “Shellacked steps in the tower.” Again, no paint color references are made. Specific references to painting the tower stairs (no color identified) are made again in 1932, 1937 and 1938. Given the frequency of repainting the steps noted in the keeper’s logs, it seems probable the 18 generations of dark brown paint likely span the c.1900 – c.1945 time period.

The bright orange red lead primer marking the start of the gray paint layers noticeably spreads over the dark brown layers where were standing proud of the adjacent surface of the step which would have been scraped or abraded down to near bare metal. The weathered appearance of the top brown layer and the presence of mold spores on top of that layer appear to be evidence that more time and weathering elapsed between the application of the last brown paint and the new red lead primer than between the repainting of the earlier dark brown layers. The sequence of gray paints at the top of the sample follows the gray paints sequence of the lantern floor and pedestal paints.



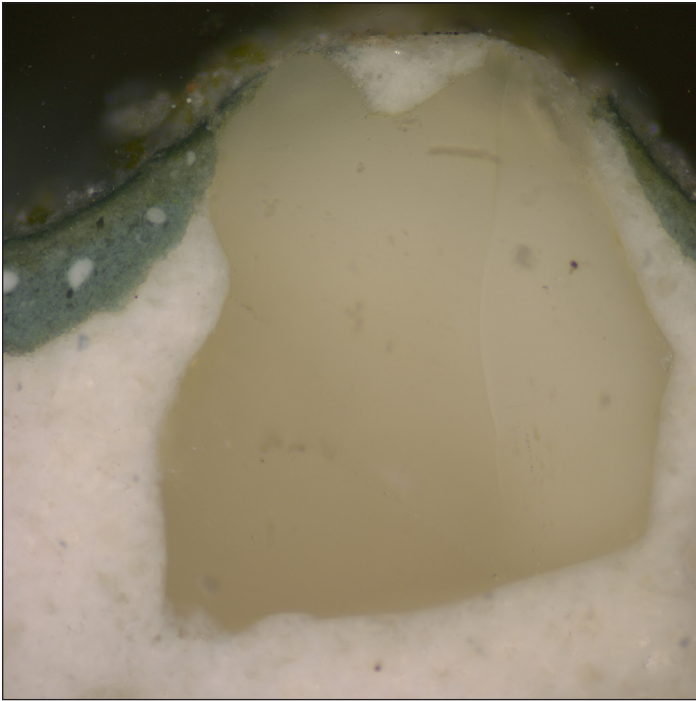
Sample bc-16a, Tower: wall, 40x vis



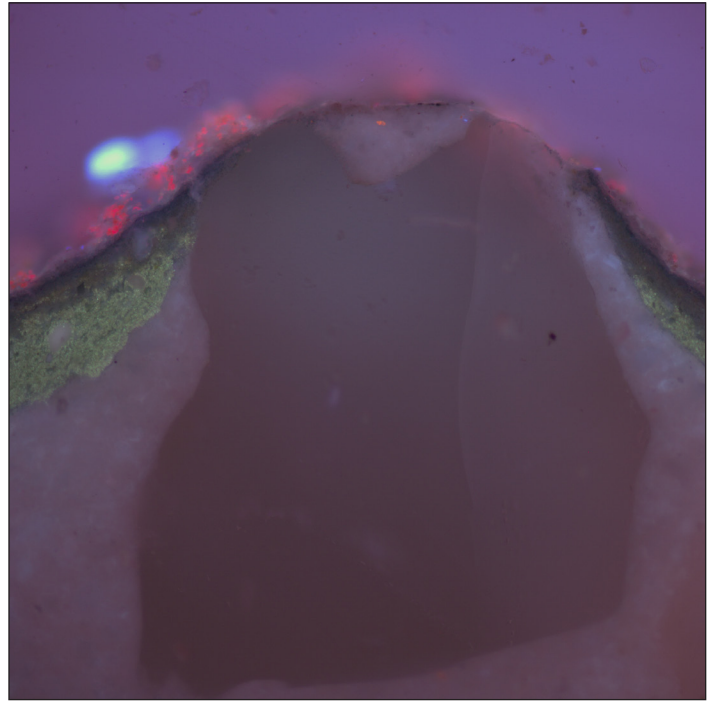
Sample bc-16a, Tower: wall, 40x uv

Wall: Samples taken from the brick wall (samples 16a, b, c) have lime wash on the bottom of the sample with modern white paint on top. Sample 16a, taken next to the stair sample 15a, appears to have stair paint over lapping the (rust infused) whitewash wall layer. There is a very thin black layer under a brown layer which correlates with the late 19th century color specification for stairs followed by the 1927 color specification for stairs.

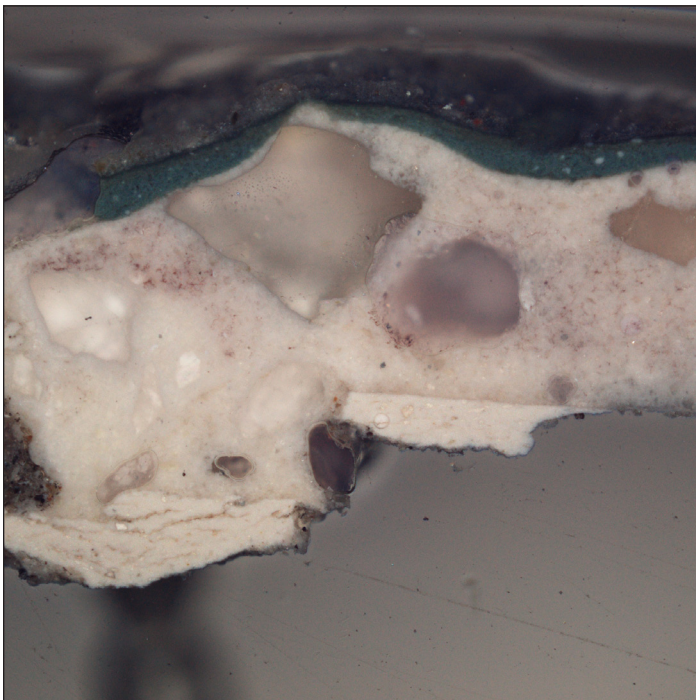
Window Frame: Sample 18 was taken from the masonry window opening. It is presumed that the wooden windows were removed and replaced with the current glass block c.1975 when the aid to navigation was automated. The sample was removed from where I estimated the wooden window would have been located in the masonry opening and based on a faintly visible paint ridge. The sample does have multiple layers of white paint as would be expected, but it also has some green paint layers (some of the green in the cross-section is actually bio-growth). The 1952 *Coast Guard Paint Manual* specified white for interior surfaces of windows and No. 12 Spruce Green for exterior window frames and sash.



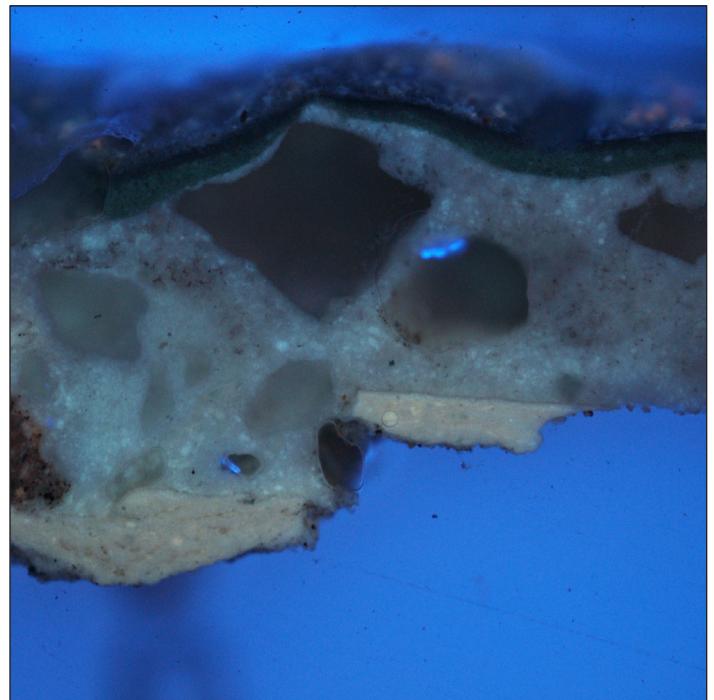
Sample bc-18.1, Tower: window frame, 200x vis



Sample bc-18.1, Tower: window frame, 200x uv



Sample bc-18.1, Tower: window frame, 40x vis



Sample bc-18.1, Tower: window frame, 40x uv

REFERENCE

Paint Samples location list:

Sample	Location
bc-1	Lantern: Lens pedestal, base of pedestal
bc-2	Lantern: Lens pedestal, top of pedestal neck
bc-3	Lantern: Lens pedestal shelf, top surface of shelf
bc-4	Lantern: Ceiling
bc-5	Lantern: Window mullion
bc-6	Lantern: Floor
bc-7	Lantern: Wainscot
bc-8	Watch Room: Floor, upper layer of flooring
bc-9	Watch Room: Floor, lower layer of flooring
bc-10	Watch Room: Door threshold
bc-11	Watch Room: Door frame
bc-12	Watch Room: Partition wall
bc-13	Watch Room: Brick wall at light
bc-14	Tower: Underside of watch room floor
bc-15	Tower: Stair
bc-16	Tower: Wall
bc-17	Tower: Wood frame inside tower core
bc-18	Tower: Window frame

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U.S. Coast Guard, Treasury Department. *Instructions for United States Coast Guard Stations*. Washington: Government Printing Office, 1921, 1934.

U.S. Coast Guard, Treasury Department. *Paint and Color Manual (CG-263)*. 1952

U.S. Light-House Establishment. *Circular No. 11 of 1909. Inside Paint Colors*. May 17, 1909.

U.S. Light-House Establishment. *Instructions to Light-Keepers*. Washington: Government Printing Office, 1881, 1902

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U.S. Treasury Department. *Coast Guard Instructions for Painting United States Coast Guard Vessels, Boats, and Stations*.

Washington: United States Government Printing Office, 1935.

U.S. Treasury Department. *Organization and Duties of the Light-house Board; and Regulations, Instructions, Circulars, and General Orders of the Light-house Establishment of the United States*. Washington: Government Printing Office, 1871.

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 1,500 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. Photographs were taken at 40X, 100X, and 200X magnifications.

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.W