Eames House Conservation Project: Investigations 2011 to 2016

Research Report

Edited by Laura Matarese
with Chandler McCoy and Gail Ostergren

The Getty Conservation Institute

Eames House Conservation Project: Investigations 2011 to 2016

Edited by Laura Matarese
with Chandler McCoy and Gail Ostergren

THE GETTY CONSERVATION INSTITUTE
LOS ANGELES

The Getty Conservation Institute
1200 Getty Center Drive, Suite 700
Los Angeles, CA 90049-1684
United States
Telephone 310 440-7325
Fax 310 440-7702
E-mail gciweb@getty.edu
www.getty.edu/conservation

The Getty Conservation Institute (GCI) works internationally to advance conservation practice in the visual arts—broadly interpreted to include objects, collections, architecture, and sites. The Institute serves the conservation community through scientific research, education and training, field projects, and the dissemination of information. In all its endeavors, the GCI creates and delivers knowledge that contributes to the conservation of the world's cultural heritage.

ISBN: 978-1-937433-57-4 (online resource)

Cover: Contractors undertaking conservation treatment on the wood paneling in the Eames House living room.
Photo: Arlen Heginbotham, 2012

Contents

CHAPTER 3

Wood Panel Investigation and Conservation Treatment

Arlen Heginbotham

CHAPTER 4

Environmental Assessment of the Eames House Residence

Shin Maekawa

CHAPTER 5

Geotechnical Evaluation

Leighton Consulting

CHAPTER 6

Eames House Landscape Survey and Assessment

Carlberg Associates

Preface

In 2011, the Getty Conservation Institute (GCI) began working with the Charles and Ray Eames House Preservation Foundation (Eames Foundation) on the Eames House Conservation Project. It is the first field project under the GCI's Conserving Modern Architecture Initiative (CMAI), which seeks to advance the practice of conserving twentieth-century heritage. The project was developed to demonstrate the practical application of international best practices at the Eames House. The first step for the Eames House Conservation Project was to understand the conditions of the house, focusing on areas where deterioration was evident or was suspected.

Over the next five years, the GCI conducted on-site investigations and assessments on a variety of topics, either by conducting its own work or hiring consultants with expertise in specialized fields. This volume presents the results of those investigations. These investigations are compiled into this compendium as an example of sound conservation methodology, which always begins with understanding the place. Being able to perform multiple scientific investigations and condition assessments at the beginning of a project is indeed a luxury that many projects cannot afford, but when it is possible, it is the best approach. We share these reports in order to demonstrate a variety of testing and investigation techniques, and to share results and recommendations that may be of use to others who, like the Eames Foundation, are charged with maintaining a building from the modern era.

The GCI wishes to acknowledge the extensive commitment of the Eames Foundation to our partnership and to the conservation and stewardship of the Eames House for future generations. In particular we would like to thank Lucia Dewey Atwood, Director of the 250 Year Project, for her resolve in championing the use of international best practice conservation approaches to the care and management of the Eames House. We extend our thanks to the Eames Foundation staff for their assistance during the on-site investigations.

Between 2011 and 2016, many experts from a number of fields were brought together to carry out the investigations and conservation work at the Eames House, reflecting the interdisciplinary nature of conservation. They include conservators, architects, scientists, arborists, geologists, surveyors, and heritage conservation professionals. We gratefully acknowledge the contributions of Getty staff members in the preparation of investigations and treatments at the Eames House, in particular the late Shin Maekawa, senior scientist at the GCI, for his thorough environmental investigation and monitoring. He passed away before this work could be published but is remembered for the professional rigor and for the clear methodology he brought to this project.

Thanks also go to GCI Science staff for paint and wood analysis, as well as environmental and climatic condition monitoring, and to the J. Paul Getty Museum Decorative Arts Conservation Department staff for wood paneling investigation and conservation. The GCI thanks the consultants who carried out a number of specialist studies including Leighton Consulting, who prepared a geotechnical evaluation and topographical survey; Escher

GuneWardena Architecture, who provided architectural guidance and prepared drawings of the site for the Eames Foundation; and Carlberg Associates, who prepared an arborist's report, landscape survey, and tree assessment. We also thank Michael Henry for his careful review and input into the Environmental Assessmment. Finally, we acknowledge the contributions of GCI staff members Cynthia Godlewski, Alison Reilly, Megan DiNoia, Chelsea Bingham, and Ana Paula Arato Gonçalves in finalizing this document and readying it for publication.

Introduction

The Eames House, an internationally renowned work of modern architecture, was designed by Charles and Ray Eames and constructed in 1949. The Eameses conceived their house as a place for both living and working. It comprises two buildings—a residence and a studio—arranged around three courtyards, all of which are connected by a concrete retaining wall. This building complex is nestled between a steep hillside and a mature row of eucalyptus trees. It faces out to a meadow with views to the Pacific Ocean beyond. The residence features a remarkable interior that still contains the furnishings, household items, and collections assembled by the Eameses. Following Ray's death in 1988, ownership of the house passed to Charles's daughter, Lucia, who together with her five children felt a keen responsibility to preserve it as Charles and Ray had left it. In 2004, the family established the nonprofit Charles and Ray Eames House Preservation Foundation (Eames Foundation) to preserve and protect the Eames House, providing visitor access and creating educational experiences that celebrate the Eameses' creative legacy.

From September 2011 to June 2012, the entire contents of the Eames House living room were loaned to the Los Angeles County Museum of Art for a major exhibition on California modern design. This gave the Eames Foundation a rare opportunity to make repairs in this space to address general wear and tear that had accrued since the house's construction in 1949. The Eames Foundation approached the Getty Conservation Institute (GCI) asking for technical assistance and conservation guidance at the onset of their proposed repair projects. The GCI was thrilled to take part in conservation efforts for this iconic modern house, and eagerly agreed to help, catalyzing the foundation's partnership with the GCI. Almost immediately the GCI began physical investigations, scientific analysis, and conservation projects at the site, beginning by investigating sources of water intrusion and elevated humidity levels inside the house. This compendium comprises reports of the investigations and assessments undertaken at the Eames House by the GCI and its consultants between 2011 and 2016.

These investigations of the buildings, landscape, and collections at the Eames House demonstrate how best practice conservation methodologies are applied to conserving modern heritage sites. They also demonstrate the first step in applying an internationally recognized conservation methodology: understanding the site and its cultural significance, through historic research and scientific investigations, prior to intervening.

The reports supply technical expertise, scientific analysis, and research on specific material issues of the Eames House, providing guidance for immediate conservation needs, as well as long-term maintenance. *Eames House Conservation Project: Investigations 2011 to 2016* includes an analysis of the paint colors and stratigraphy at the residence and studio (chapters 1 and 2); and an analysis of the residence's wood paneling and its finishes, and the related conservation treatments (chapter 3). In addition, a three-year environmental monitoring program at the Eames House built upon the GCI's existing work on managing collections in hot, humid, and marine climates. An environmental assessment of the Eames House (chapter 4) has enabled us to understand the current environment in and around the residence for the specific purpose of developing ideal conservation conditions that also meet the interpretive and public preservation needs of the Eames Foundation. The final two chapters provide technical expertise and research on the landscape of the Eames House by the GCI's consultants. The investigations include a geotechnical study of the site (chapter 5) and a landscape inventory and survey and arborist's report (chapter 6).

This compendium demonstrates, through practice, how conservation methodologies are fundamental to conserving sites of modern heritage. By first understanding the site—its materials, condition, and vulnerabilities—and assessing its cultural significance, we are able to develop appropriate solutions to conserve the site and its significance.

CHAPTER 1

Analysis of Paint Stratigraphies, Pigments, and Organic Binders at the Residence of the Eames House

Alan Phenix, Wendy Lindsey, Rachel Rivenc, Emily MacDonald-Korth

1.1 Introduction

1.1.1 Objectives and Methods

This chapter presents the findings of microscopic examination and chemical analysis of paint samples taken from the interior and exterior of the Pacific Palisades residence of the Eames House and from archival sample paint-outs on metal plates. In late September 2011 during a visit to the residence by a group of GCI staff, GCI scientist Alan Phenix took samples from the buildings, and GCI project specialist Emily MacDonald-Korth took samples from painted plates. The purpose of the study was to look for stratigraphic and compositional evidence within the paint samples that might contribute to the understanding of the painting history of the residence, particularly with regard to discrepancies between the extant colors and the original appearance.

The history of painting campaigns at the residence and studio were investigated by researching the Eames Foundation records. This information was used to correlate results of the paint analysis with particular dates, where possible. The samples from the residence of the Eames House were taken strategically with this broad goal in mind, but choice of sampling locations was also strongly influenced by the availability of suitable sample sites.

Fifteen samples were taken from the paintwork at the residence for microscopic examination and chemical analysis, with particular focus on matters of stratigraphy and pigment composition insofar as those things might inform an understanding of the history of painting of the building. The set of samples taken from the building itself included six samples from the exterior metalwork (all facades), five samples from the interior metalwork (east and north facades), and four samples from the exterior painted panels. In some instances, because of sample fragmentation or variability within the stock material, multiple fragments from a single stock of sample were prepared as cross sections.

Additionally, samples were obtained and analyzed from seven painted reference plates and a series of old paint cans retained at the Eames House. Two fragments of putty (original locations unknown), reportedly detached in the 1994 Northridge earthquake, provided paint samples that could not have included any layers after that specific date, so they offered a specific chronological reference point.

Paint samples were prepared as polished cross sections, examined and photographed by optical microscopy, and analyzed by environmental scanning electron microscopy with energy-dispersive X-ray spectroscopy (ESEM-EDS) for spatially resolved elemental composition. Selected samples were analyzed for organic binder identification by Pyrolysis-GCMS and FTIR-spectroscopy (findings are described in appendix 1.1 of this report).

The residence is a large structure that has had several painting interventions that added material or, possibly, took material away. The event history at any given location may be very specific. The limited number of samples may not give a complete picture of the global event history. Samples from interior and exterior metalwork were mostly taken from areas of putty, and consequently may not include original preparatory coating treatments to the metal of the frame itself.

1.1.2 Results

The samples from both the interior and exterior metalwork trim of the residence show good evidence for repeated campaigns of puttying, priming, and painting. The interior and exterior metalwork has been treated quite differently in terms of the patterns of repainting campaigns. In many instances, samples from the metalwork reveal complex stratigraphies consisting of many layers (putty, primer, paint), but stratigraphies are often inconsistent across a specific group (i.e., interior and exterior metalwork).

1.1.2.1 EXTERIOR METALWORK

The cross section samples from the now-black metalwork are illustrated together in figure 1.1, with each sample annotated to show the layer structure. Of the samples from the building itself, only samples East Exterior_2b and North Exterior_10 show complex stratigraphies that include what could be interpreted as the earliest layers of paint applied to the structure. Samples of paint from selected fragments of putty detached in the 1994 Northridge earthquake also show complex stratigraphies that, while lacking the most recent strata, have definite correspondences to the samples taken from the building.

The same pattern of two adjacent paint layers—dense black over dark gray—at the uppermost level appears in all of the samples from the exterior metalwork of the building, but not in the putty fragments, suggesting that these two uppermost layers derive from a recent (post–1994) repainting intervention, or, possibly indicating two separate interventions. The uppermost (black) paint layer can be securely connected to the known painting campaign by Dan Elliot in 2003. Whether the underlying dark gray layer immediately beneath derives from that campaign (i.e., as undercoat to the black) or from an earlier, immediately post-earthquake repair campaign cannot be said from the evidence provided by the samples.

The uppermost two layers in sample Eames House_putty#1b-2 (black paint over red primer) have direct correspondences with layers in sample North Exterior_10; these strata represent the most recent coatings prior to the 1994 earthquake. Accordingly, given their position in the stratigraphy and their composition, these layers can be linked to the first repainting campaign by Clayton Coatings, commissioned in 1989 by the family after the death of Ray Eames. These paints are identified as Ameritone Alkyd Enamel Satin black over Dunn-Edwards Bloc-Rust #43-4. In 1989–90, therefore, the metal framework of the residence was black in color, with satin finish. Alkyd was identified as the binder for uppermost black paint layer by Py-GCMS (fig. 1.1).

In samples East Exterior_2b, North Exterior_10, and Eames House_putty#1b-2, immediately beneath the 1989 paint and primer layers lies a dark brown, chlorine-rich coating, the status and dating of which are relatively uncertain. This layer is interpreted as possibly a mastic or sealant layer, or a similar coating applied for protective, water-repellant purposes. In each of these samples, lying directly beneath the dark brown mastic/sealant is a sequence of black paint layers, seemingly representing two different campaigns; the earlier campaign appears to have involved repeat applications of similarly-composed paint. The dates of these two painting campaigns cannot be deduced with any certainty from the evidence, nor can they be dated in relation to Charles Eames's death in 1978, when a repair campaign is recorded. It seems probable, however, that the exterior metalwork was painted black at the time of Ray Eames's death in 1988. If, however, the upper stratum of

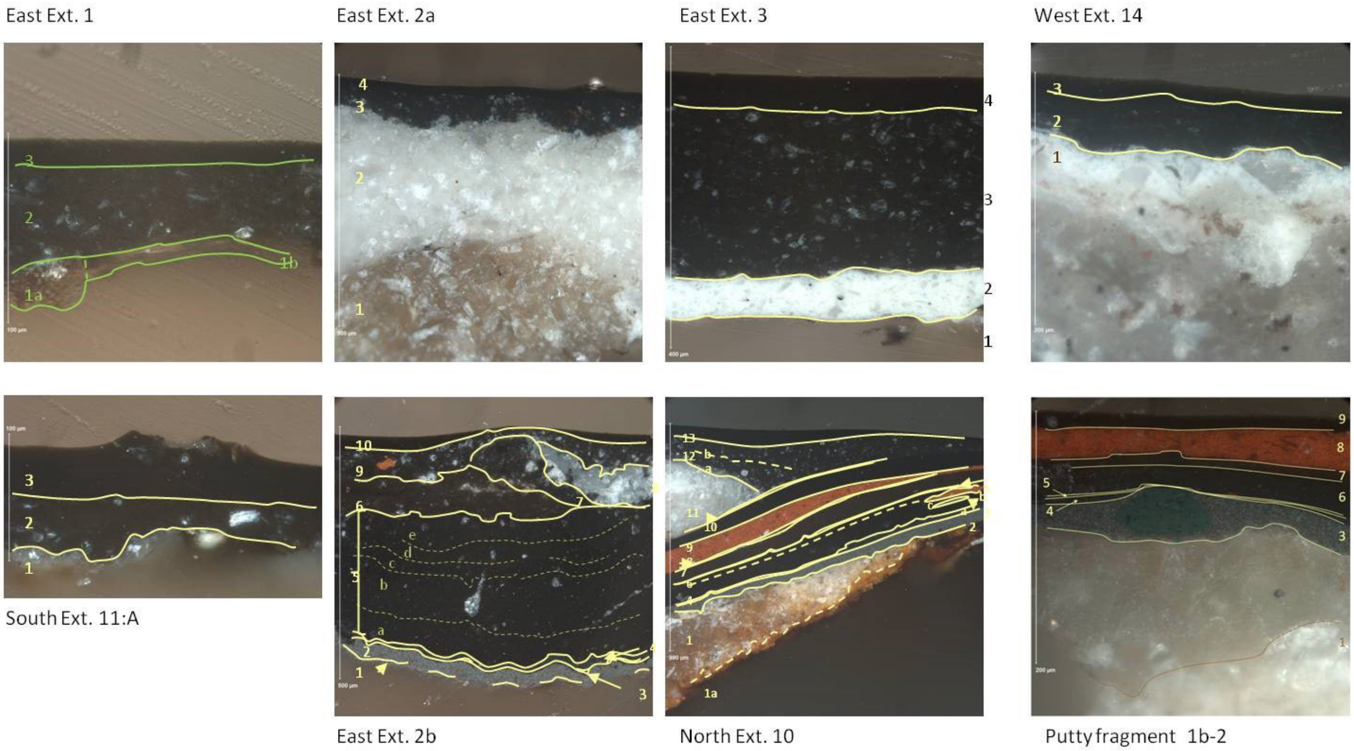


FIGURE 1.1
Set of cross section samples from the exterior black metalwork and putty fragment detached during the 1994 Northridge earthquake.

this early black sequence is tentatively linked to the 1978 repair campaign, then the lower stratum, which consists of multiple substrata, must be earlier, predating Charles Eames's death, leading to the conclusion that the exterior metalwork was painted black during Charles Eames's lifetime.

Samples East Exterior_2b, North Exterior_10, and Eames House_putty#1b-2 have a common sequence for the lowest two paint layers in the stratigraphy of each: a very dark gray over a lighter and more opaque warm gray. In each of these samples, the upper dark gray layer is uneven in thickness to the point of being discontinuous in places, suggestive of physical erosion, perhaps by sanding. In samples East Exterior_2b and North Exterior_10, these two paint layers lie over putty, and no primer is evident. In Eames House_putty#1b-2 the corresponding layers lie over a zinc-rich layer that may represent a zinc metal-based primer in which the original zinc particles have disappeared over time. A similar pair of layers—very dark gray over a lighter and more opaque warm gray—can also be observed at the same location in the stratigraphy in the excavation of the metal framework conducted by Emily MacDonald-Korth and in the associated sample from that location on the east facade (see appendix 1.1). In this last case, the upper dark gray layer is continuous, even, and of comparable thickness to the lower lighter warm gray paint, which in turn is applied over a pale gray zinc dust primer.

In all probability, this pair of paint layers—very dark gray over a lighter and more opaque warm gray—represents the first two applications of paint to the exterior metalwork. A high degree of certainty can be attached to dating the lower layer to 1949, which is almost certainly the first coat of paint applied to the frame. The temporal relationship of the upper layer is uncertain, however. It could be contemporaneous with the lower, warm gray, representing an intentional darkening of the color scheme at the initial painting stage, or separated by a number of years, representing a later revision. Although they are quite different in color, these two paint layers have compositional similarities: distinctively, they are tinted with red (iron oxide), blue-green (chrome green = Prussian blue + chrome yellow), and yellow (chrome yellow) pigments, in addition to white and probably carbon black. These colored pigments, especially the red iron oxide, are more abundant in the lower layer of lighter warm gray paint. The lower warm gray paint is similar in conception to other subtractive color mixing gray paints on the interior metalwork. This composition has connections to the original "dark warm gray" or "dark neutral gray" color for the metalwork that is mentioned in early accounts of the Eames House (Eames and Entenza 1949a). Although it is quite different in tonality to the layer beneath it, the upper dark gray paint layer has a similar composition, and it seems reasonable to associate that painting campaign, too, with the direct influence of the Eameses, even if the exact date of its application is uncertain. The binder of these lowest two strata in samples Eames House_putty#1a, Eames House_putty#1b-2 is identified as synthetic styrene/butadiene rubber, which is consistent with the documentary evidence of the original painting with a rubber-based paint made by A.C. Horn. Py-GCMS analyses of scrapings of the lower strata (pre-1989) of black and dark gray paints provide a similar finding of a styrene/butadiene rubber binder. The scrapings were taken during the excavation of the exterior metalwork, as noted above.

1.1.2.2 INTERIOR METALWORK

The samples of paint from the interior metalwork all have quite complex stratigraphies that illustrate repeated cycles of priming and painting (fig. 1.2). The stratigraphies are somewhat variable across the sample set. Although no two samples have exactly the same layer structure, some correspondences and commonalities do occur. The differences in the stratigraphies across the group suggest a degree of specific local variation in the paint treatments. There are few, if any, temporal reference points to allow reliable dating of any of the layers in the interior metalwork samples, with the exception, perhaps, of the uppermost, most recent one in each.

Apart from occurrences of red primer and two isolated instances of black paint, all the paint and primer layers in the samples are gray. Two different gray primers occur that are based on metallic zinc: a lower pale gray primer that may be original, and an upper dark gray zinc primer that must be from a later repainting intervention. The lower gray zinc-based primer may be the same as the A.C. Horn product Galvanide that was reportedly used originally to prime the metalwork.

The paint, as opposed to the primer layers, in the samples are dark grays, not black, that vary somewhat in tonality and hue. There is a considerable degree of compositional overlap between the different layers: they generally share similar elemental profiles, featuring most of the elements: Mg, Al, Si, S, Cl, Ca, Ti, Cr, Fe, Zn, and Pb, with occasional specific omissions, mainly Fe or Pb, or distinctive high abundances, mainly Ba, Cl, and Fe. The general similarity of the composition of the various paint layers might point to a common formulation concept, with some variation over time of specific ingredients. The basis for dark gray interior paints is essentially titanium white (TiO_2) and carbon black, which is presumed by observation, though not positively identified chemically, with the addition of colorless extenders of different types, and small, variable amounts of colored pigments: red (iron oxide), yellow (chromate), and possibly blue-green (chromium-containing).

All the interior samples share a common uppermost paint layer. A distinctive feature of this layer is the super-abundance of chlorine, associated with the presence, probably, of a chlorinated rubber paint binder. It is reasonable to connect this paint layer to the 2003 painting campaign by Dan Elliott.

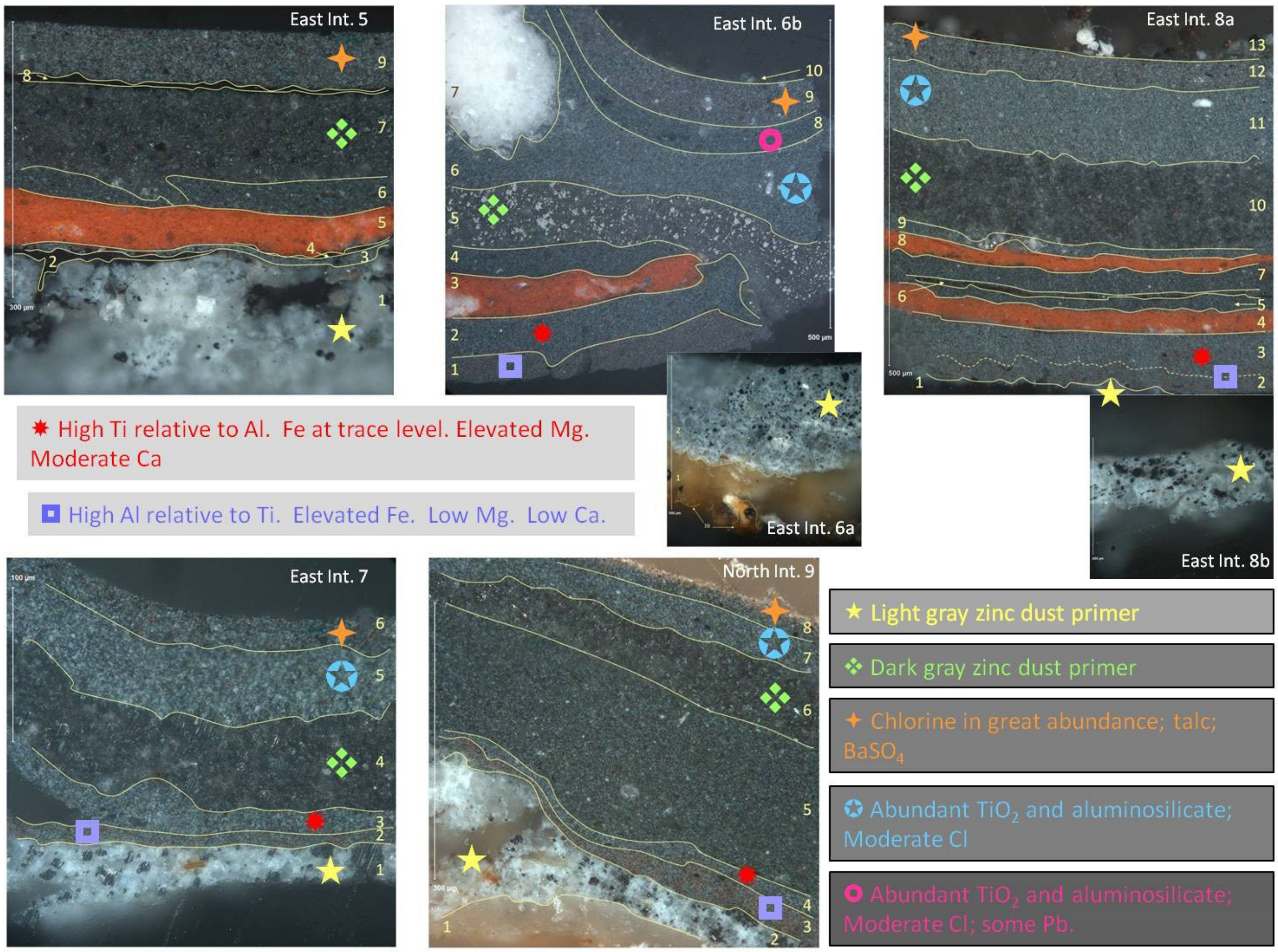


FIGURE 1.2
Samples from interior metalwork showing commonalities across the sample set.

As already noted, the upper dark gray zinc-based primer can be confidently identified as non-original, as can the paint layers above. The paint layers beneath the 2013 dark gray zinc-based primer are obviously more significant in terms of the early history of the interior paint scheme. Most of the interior metalwork samples show commonalities in the lowest two paint layers that lie directly above the pale gray zinc-based primer. These paints are both mixed, or subtractive, grays of the type described above; the upper one is cooler (i.e., less red) than the lower, which can be seen to be more abundant in red (iron oxide) particles. The composition of these two early paint layers is quite similar, but there are some distinctive differences that allow them to be positively correlated across the sample set.

The lower warm gray paint is probably original, and appears to coincide with written references to “dark warm gray” (Eames and Entenza 1949a). It is a subtractive gray, made in part by mixing red, yellow, and blue-green colorants, and is similar in concept and composition to the lowest paints on the exterior metalwork, also warm gray. The status and dating of the cooler gray of the two under consideration here, meaning the second lowest in the stratigraphy, are uncertain, however. There is insufficient evidence to say whether this is an “original” layer, that is, applied around the time of the Eames House construction, or is from one of the later repainting campaigns, such as those of 1969 and 1972, which are mentioned in the records kept by the Eames Foundation.

The elemental profiles that are characteristic of the first two paint layers in this group of samples do not correspond perfectly with the paints on any of the reference plates that are associated with the interior metalwork/trim.

1.1.2.3 PAINTED EXTERIOR PANELS

Four samples were obtained from the painted exterior paneling: three from the west facade (West Exterior_12: blue; West Exterior_13: blue; West Exterior_15: silver metallic) and one from the east facade (East Exterior_4: orange-red). The constraint of having to take samples from the very edges of the painted panels limited the number of samples and limits the conclusions that can be drawn about the repainting history.

Evidence for repainting of the blue and aluminum metallic panels on the west wall is observed in paint cross sections from those areas. The colorant in both blue paint samples has not been positively identified, but it is probably organic. The metal-flake constituent of the silver paints is identified as aluminum.

No complex stratigraphy is observed in the sample from the orange-red panel (East Exterior_4), which comprises a single paint layer directly on the panel support. This paint was found to contain probably two different orange-red colorants: lead chromate and an organic pigment, the identity of which has not been determined.

A more comprehensive evaluation of the restoration history of the painted panels would require the taking of more samples.

1.1.2.4 CAVEAT

The appearance (absolute color, tonality) of a paint layer in a cross section sample viewed microscopically cannot be directly translated to the likely perceived color of that paint surface when viewed macroscopically. In optical terms, the situations are fundamentally different. It is reasonable, however, to make broad comparative evaluations of color differences between layers observed in a cross section sample.

1.2 Paint Stratigraphies and Pigments

This part of the study presents the findings of microscopic examination and chemical analysis of paint samples taken from the interior and exterior of the residence (fig. 1.3), and from archival sample paint-outs on metal plates. During a visit to the Eames House in late September 2001, GCI scientist Alan Phenix took samples from the building, and GCI project specialist Emily MacDonald-Korth took samples from painted plates and paint cans (fig. 1.4).

The purpose of this study is to look for stratigraphic and compositional evidence within the paint samples that might contribute to the understanding of the painting history of the residence, particularly with regard to discrepancies between the extant colors and the original appearance. The history of painting campaigns at the residence and studio were investigated by researching the Eames Foundation records. This information was used to correlate results of the paint analysis with particular dates, where possible.

The samples from the building were taken strategically with this broad goal in mind, but choice of sampling locations was also strongly influenced by the availability of suitable samples sites. The fifteen samples taken from the residence are described as follows:

- East Exterior_1 Flake from window frame in the location where new glass has been fitted.

FIGURE 1.3
Emily MacDonald-Korth carrying out paint investigations at the Eames House, 2011.
Photo: Scott Warren

FIGURE 1.4
Emily MacDonald-Korth taking a paint sample from paint cans stored at the Eames House, 2011. Photo: Scott Warren

- East Exterior_2 Sample taken from window frame, adjacent to windowpane, in an area of historic glass; visible putty/white layer in places beneath black paint.
- East Exterior_3 Sample taken from edge of loss on window frame at location of historic glass; white layer visible beneath the black layer.
- East Exterior_4 Sample taken from a crack near the edge of the orange panel where it meets the black frame; white layer visible beneath; possibly some panel fibers included in the sample.
- East Interior_5 Sample taken from the edge of the frame, from an area with a thick buildup of paint.
- East Interior_6 Sample taken from window frame. Sample broke into two fragments during mounting; each fragment was embedded separately. Cross section East Interior_6a is the lower fragment that consists of gray primer, possibly also some putty, and corrosion products on its underside. Cross section East Interior_6b includes the upper paint layers of dark gray, red, and near-black.
- East Interior_7 Sample taken from an area of flaking paint next to the windowpane.
- East Interior_8 Sample taken from a thick buildup of paint next to the windowpane. Sample broke into two fragments during mounting; each fragment was embedded separately for preparation as cross sections.
- North Interior_9 Sample of gray paint taken from the window frame adjacent to the pane.
- North Exterior_10 Sample taken from corner of window frame, black paint bubbled up from failed putty/corrosion; sample may include a red primer and putty.
- South Exterior_11 Sample of black paint taken from edge of loss on window frame; putty failing. Three separate subfragments from the fragment selected as

cross section. Uppermost fragment A includes the paint layer(s); lower fragments B and C are essentially putty material.

- West Exterior_12 Blue paint from panel frame, possibly includes some caulk, taken from an edge of a repainted area.
- West Exterior_13 Blue paint from edge of repainted area, possibly includes caulk.
- West Exterior_14 Loose fragment from edge of loss in black paint on metal frame.
- West Exterior_15 Metallic paint at location of impact damage site on silver-painted panel. Sample also includes some of the underlying panel material.

The locations of the samples taken from the structure are shown on the drawings of the respective elevations given in figures 1.5–1.8. Samples from the exterior are indicated by magenta font; samples from the interior by green font. The samples were all taken from areas of existing damage (cracking, flaking, etc.) in the paintwork. It should be stressed that the sample material taken at any specific location may not be wholly representative of the general surrounding area and that the local stratigraphy may be influenced by the

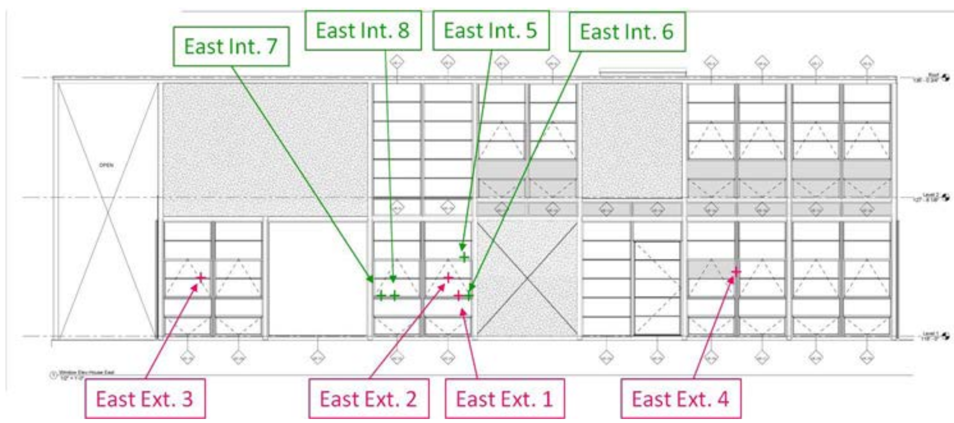


FIGURE 1.5
Eames House, Pacific Palisades. Drawing of east elevation showing locations of sample sites East Exterior #1–4 and East Interior #5–8. Drawing: Adapted from drawing by Escher GuneWardena Architecture, © Eames Office.

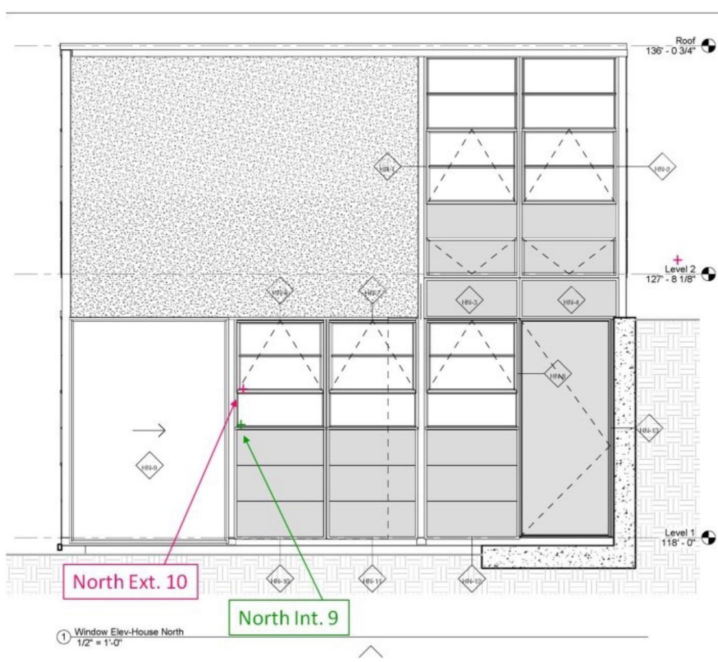


FIGURE 1.6
Eames House, Pacific Palisades. Drawing of north elevation showing locations of sample sites North Interior #9 and North Exterior #10. Drawing: Adapted from drawing by Escher GuneWardena Architecture, © Eames Office.

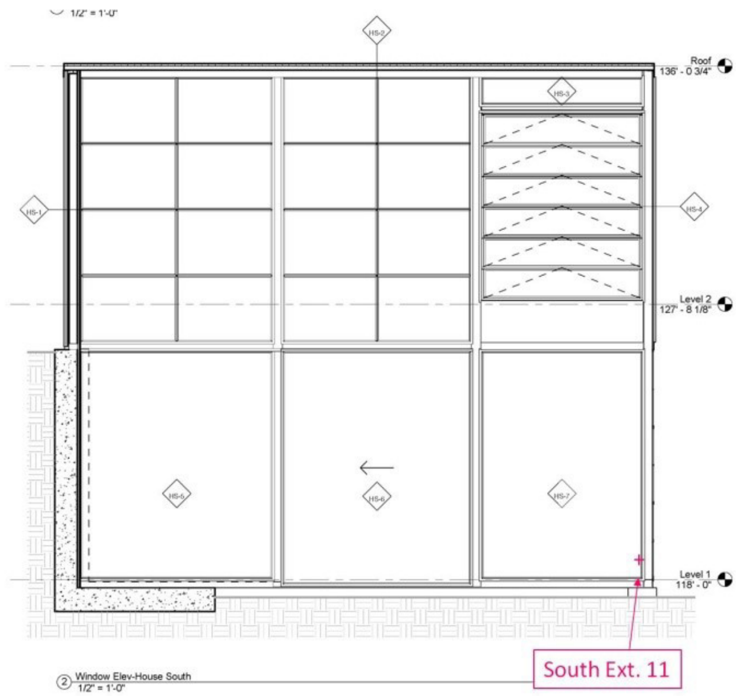


FIGURE 1.7
Eames House, Pacific Palisades. Drawing of south elevation showing locations of sample site South Exterior #11. Drawing: Adapted from drawing by Escher GuneWardena Architecture, © Eames Office.

FIGURE 1.8
Eames House, Pacific Palisades. Drawing of west elevation showing locations of exterior sample sites West Exterior #12–#15. Drawing: Adapted from drawing by Escher GuneWardena Architecture, © Eames Office.

specific event history at that location. Indeed, within a batch of material collected from a sample site, some degree of variability could sometimes be discerned even by low-power stereomicroscopy. The East Exterior_2 sample is perhaps the most notable instance of this occurrence. In such cases, multiple fragments from the stock of sample material were prepared as cross sections in order to gain a fuller perspective on the representative stratigraphy at that location.

1.3 Paint Campaigns at the Eames House

The Eames Foundation's records were reviewed to establish a timeline of painting campaigns undertaken at the Eames House. The records date from 1958 to 2003 and include invoices, paint cans, quotes, notes, and maintenance logs. It is not known if the records are complete. The following paint campaigns were identified, and several are referred to in this report:

- 1949 The residence and studio were painted at the completion of construction. Source: Entenza and Eames, 1949a: 29–30.

- 1958 The Eames House was painted. Source: Note by Dan Osloff, no other supporting documentation.
- 1966 The Eames House studio and residence were painted by Paul Isley in October 1966. Source: Notes from Paul Isley.
- 1968–1973 Several partial painting campaigns of the residence and studio, touch ups. Source: Paul Isley invoices and notes, 1968; 1972; 1973.
- 1974 The Eames House studio and residence were painted on the exterior and interior in July and August 1974. Source: Dan's Painting Company invoice dated October 9, 1974.
- 1977–1978 Several partial painting campaigns of the residence and studio, touch ups. Source: Eames House maintenance log.
- 1989 Eames House painted by Clayton Coatings. Source: Quotations, notes, and recollections of Foundation staff.
- 2003 Eames House exterior painted by Dan Elliott. Source: Invoice by Dan Elliott dated November 2003.

According to the Eames Foundation, no further painting campaigns have been undertaken since 2003.

1.4 Preparation and Examination of Cross Section Samples

The fragments of samples selected for examination as cross sections were mounted in Technovit 2000 LC resin (a UV-curing acrylic), and were ground and polished by hand without any liquid lubricant. The prepared cross section samples were examined under visible light (crossed polarizing filters) and by ultraviolet fluorescence using a Leica DM4000 microscope. Digital images were captured using a Diagnostic Instruments Flex camera. Elemental analysis was subsequently performed on the cross section samples using environmental scanning electron microscopy with energy-dispersive X-ray spectroscopy (ESEM-EDS).

1.5 Environmental Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (ESEM-EDS)

ESEM-EDS was performed on selected cross section samples using a Philips XL30 ESED-FEG instrument fitted with an Oxford INCA EDS analysis system. The EDS analysis was done under standard ESEM conditions: H20 mode, 10mm, 20kV accelerating voltage, 0.8-1.0 torr water vapor. ESEM-EDS analysis is capable of providing data on the elemental composition of target sites in samples, which may be single points or larger areas of interest. The INCA software can map the distribution of specific elements, if desired. ESEM-EDS analysis allows identification of the elemental composition of the sample and visualization of the distribution of elements within the sample. In many instances, the presence of indicative elements, or combination thereof, can, by inference, provide a reliable indication of the identity of a constituent pigment. In the following summary, the inferences made for particular pigments/inerts should not be taken as absolutely conclusive, since they are not all confirmed by multiple analytical techniques.

Back-Scattered Electron (BSE) images of the samples obtained by ESEM-EDS analysis are useful for comparison with the optical images of the cross sections. The BSE images are grayscale images that reflect local variations in atomic number/density within the sample: dark areas generally represent zones composed predominantly of low atomic mass, while light areas correspond to the presence of elements with a high atomic number.

Caution is always required in the interpretation of ESEM-EDS spectra, not least due to the overlap of the X-ray emission peaks of certain elements. Most commonly, this difficulty applies to the overlap of lead M peaks with sulfur K peak at ca. 2.4 keV. Peak overlaps also occur for barium and titanium. When overlaps do occur, the INCA analysis software may not be able to reliably differentiate the respective contributions to the spectrum of the elements concerned. This lack of elemental differentiation may also manifest itself in the elemental maps, which may consequently show erroneous elemental distributions.

1.6 Analysis of Paint Samples from the Residence

1.6.1 Sample East Exterior_1

Sample is a flake from window frame taken from a location where new glass has been fitted.

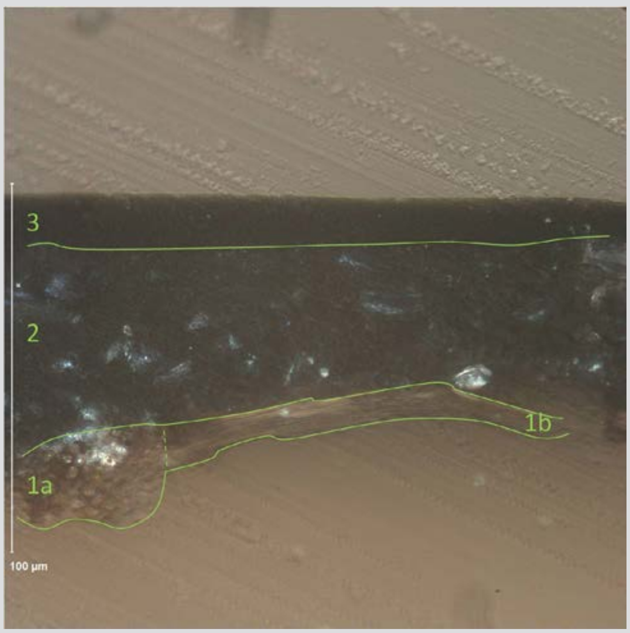


FIGURE 1.9A
Cross section of sample East Exterior_1. Crossed polarizing filters with added sidelight. 50× objective + 1.5× magnifier (= 75×). Annotated to show layer structure.

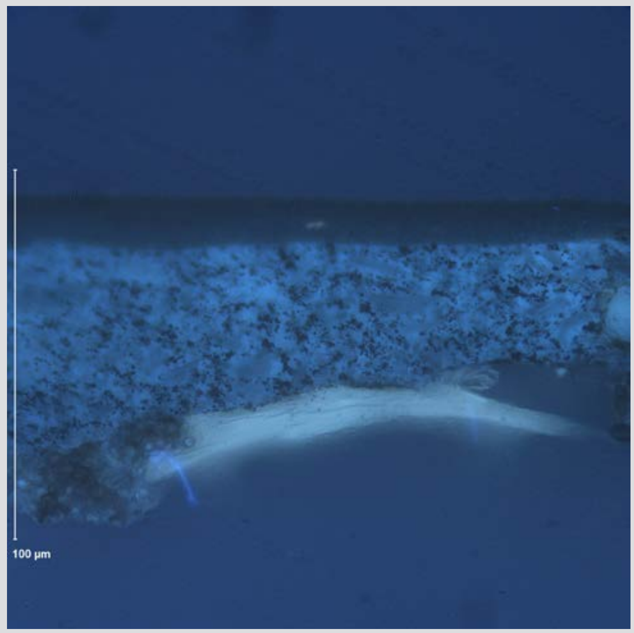


FIGURE 1.9B
Cross section East Exterior_1. UV fluorescence. 50× objective + 1.5× magnifier (= 75×).

TABLE 1.1
Description of cross section East Exterior_1.

Layer	Description	Observations / Types of pigment particles present
3	Dense black paint	Predominantly very fine black particles effectively imperceptible by optical microscopy; plus a few larger transparent colorless particles.
2	Gray paint	Composed mostly of fine black particles and large transparent grains of a colorless extender. Some fine particles higher atomic mass material evident in ESEM backscattered electron images.
1	Probably mostly corrosion products, possibly with some amorphous organic material.	Two zones (1a, 1b) evident. Zone 1a is a nodular aggregate; zone 1b is more homogeneous/amorphous.

(continued on next page)

1.6.1 Sample East Exterior_1 *(continued)*

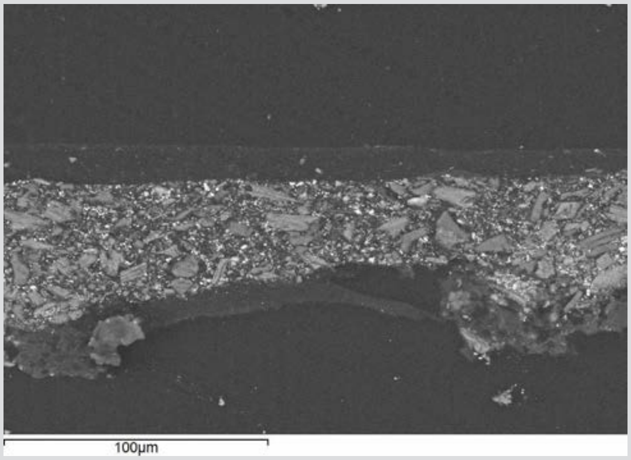


FIGURE 1.9C
Cross section East Exterior_1. Backscattered electron image.

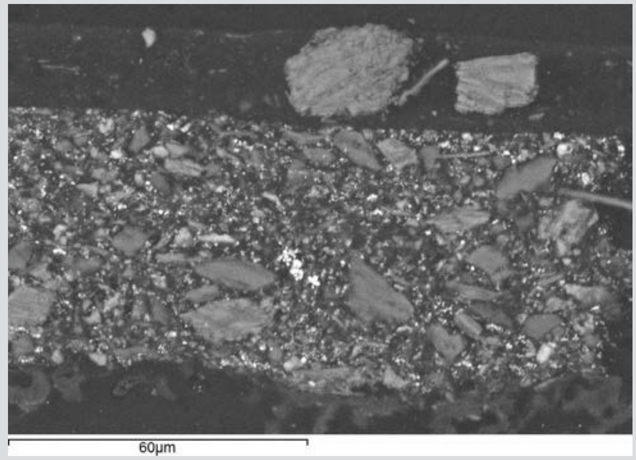


FIGURE 1.9D
Cross section East Exterior_1. Backscattered electron image.

TABLE 1.2
ESEM-EDS of cross section East Exterior_1.

Layer	Description	Elements	Inferences
3	Dense black paint	Predominantly organic (C + O), with *(Na), (Mg), Al, Si, (Cl), (Ca), (Fe)*	**Carbon black** Magnesium and aluminium silicates
2	Gray paint	*(Na),* **Mg,** *Al,* **Si,** *P, (K), Ca, Fe, (Zn)*	**Carbon black** **Talc** Minor amount iron oxide (black?) Trace zinc oxide
1	Corrosion products and/or amorphous organic material.	Predominantly organic (C + O), with *(Na), (Mg), Al, (P), Si, (S), Cl, Ca, (Fe)*	

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = (very slight trace).* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.6.2 Sample East Exterior_2

Sample taken from window frame, adjacent to windowpane, in an area of historic glass; visible putty/white layer in places beneath black paint.

This sample location was selected for comparison with that of East Exterior_1. The sample contains multiple fragments among which there is seemingly some variation in stratigraphy, with some fragments showing more complex layer structure than others. Accordingly, for preparation as cross sections, two fragments were selected that appeared to represent the differences in stratigraphy. These two subsamples were identified as East Exterior_2a and East Exterior_2b. Cross section 2a has a much simpler layer structure, which may indicate some isolated loss of original material at this location.

1.6.3 East Exterior_2a

Cross section sample East Exterior_2a has a simple stratigraphy similar to that observed in several other samples from the exterior metalwork, in particular East Exterior _1, East Exterior_3, South Exterior_11, and West Exterior_14. In this, as in the other samples, the paint consists of just

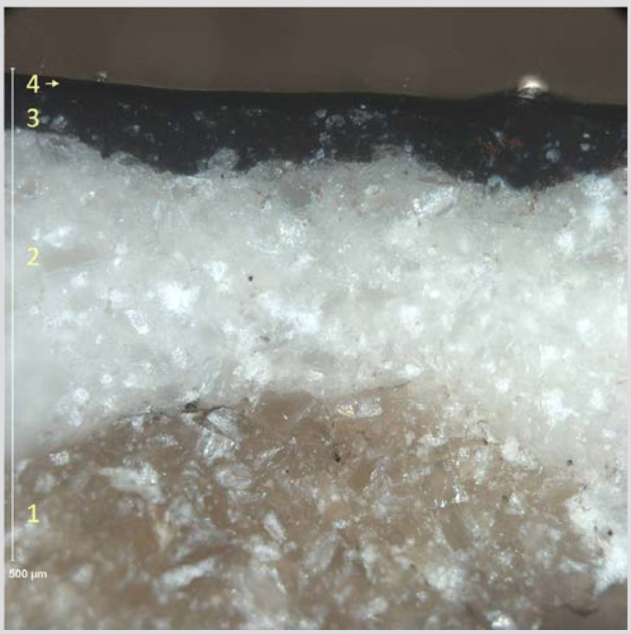


FIGURE 1.10A
Cross section East Exterior_2a. Crossed polarizing filters. 20× objective. Annotated to show layer structure.

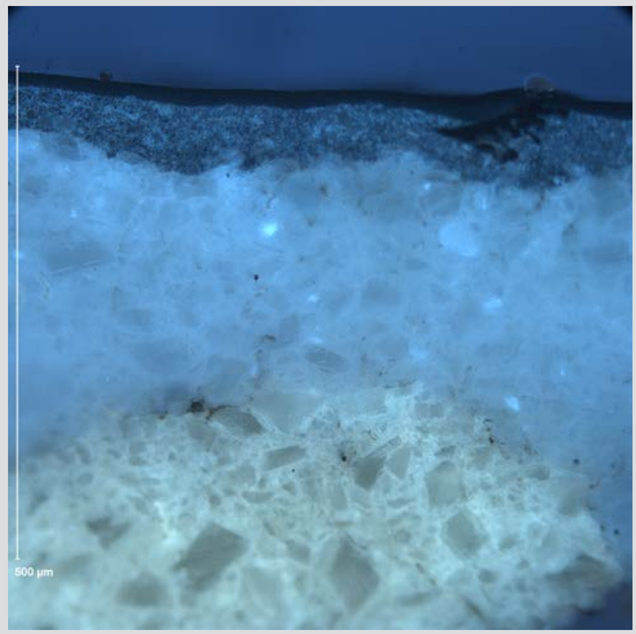


FIGURE 1.10B
Cross section East Exterior_2a. UV fluorescence. 20× objective.

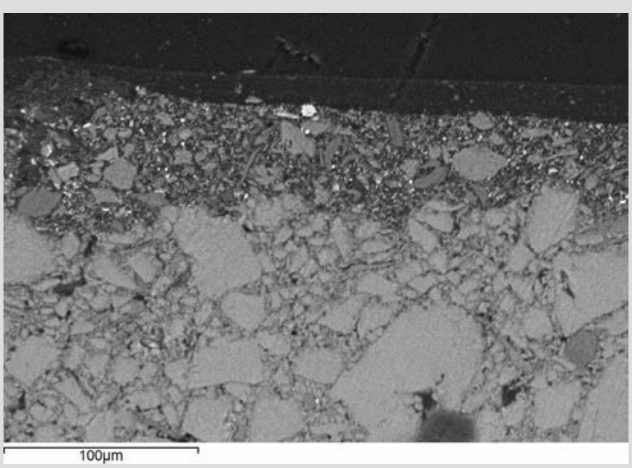


FIGURE 1.10C
Cross section East Exterior_2a.
Backscattered electron image.

two layers: an upper layer of dense black (here, layer #4), which is carbon-rich, probably carbon black, is largely devoid of inorganic particulates, and which lies over a gray paint composed of carbon black extended with a magnesium- and silicon-rich colorless pigment, probably talc.

The simplicity of the stratigraphy of sample East Exterior_2a compared to East Exterior_2b is explained by the local loss, at some point in the past, of older layers of paint that remain in the latter sample.

(continued on next page)

1.6.3 East Exterior_2a *(continued)*

TABLE 1.3
Description of cross section East Exterior_2a.

Layer	Description	Observations / Types of pigment particles present
4	Dense black paint	Predominantly very fine black particles effectively imperceptible by optical microscopy; plus a few larger transparent colorless particles. Comparable with layer #3 in sample East Exterior_1.
3	Gray paint	Composed mostly of fine black particles and large transparent grains of a colorless extender. Some fine particles higher atomic mass material evident in ESEM backscattered electron images. Comparable with layer #2 in sample East Exterior_1.
2	Coarse white putty	Particles: coarse transparent colorless grains.
1	Coarse off-white putty	Particles: coarse transparent colorless grains.

TABLE 1.4
ESEM-EDS of cross section East Exterior_2a.

Layer	Description	Elements	Inferences
4	Dense black paint	Predominantly organic (C + O), with *(Na), (Mg), Al, Si, (Cl), (Ca), (Fe)*	**Carbon black** Magnesium and aluminium silicates
3	Gray paint	*(Na),* **Mg,** *Al,* **Si,** *P, (K), Ca, Fe, (Zn)*	**Carbon black** **Talc** Minor amount iron oxide (black?) Trace zinc oxide
2	Coarse white putty	*Mg, (Al), Si,* **Ca,**	**Calcium carbonate**
1	Coarse off-white putty	*(Mg), (Al), Si, (S), (Cl),* **Ca,** *(Ba)*	**Calcium carbonate** Trace barium sulfate

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.*
These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.6.4 East Exterior_2b

East Exterior_2b has a much more complex stratigraphy. It includes older paint layers not present in East Exterior_2a, and the two uppermost paint layers—dark gray (#9) and dense black (#10)—are relatively recent and consistent with the uppermost two paint layers in all other samples from the exterior metalwork. Immediately beneath these recent paint layers is a series of discontinuous strata: white putty (#8) composed of calcium carbonate; disrupted black coating (#7) the status of which is ambiguous; and dark brown coating (#6). Discontinuous dark brown coating (#6) is distinctively rich in chlorine with lesser amounts of Fe and Mg. It remains uncertain, however, if this is a paint layer, or another type of coating material such as mastic/sealant.

Layer #5 is a thick black paint in which several substrata (a–e) are visible, both by optical and electron microscopy. The boundaries between the substrata are somewhat uneven and indistinct. In terms of elemental compositional, all the substrata of layer #5 appear similar—aluminum and silicon are by far the most abundant elements besides carbon—and an aluminosilicate extender is indicated as being present throughout, possibly also with some alumina. Layer #5 in sample East Exterior_2b is comparable with layer #4 in sample North Exterior_10.

Beneath thick black paint layer #5 is a dark gray paint (#4) with an uneven surface. This layer was not analyzed specifically for elemental composition, but elemental mapping indicates the presence of titanium, probably in the

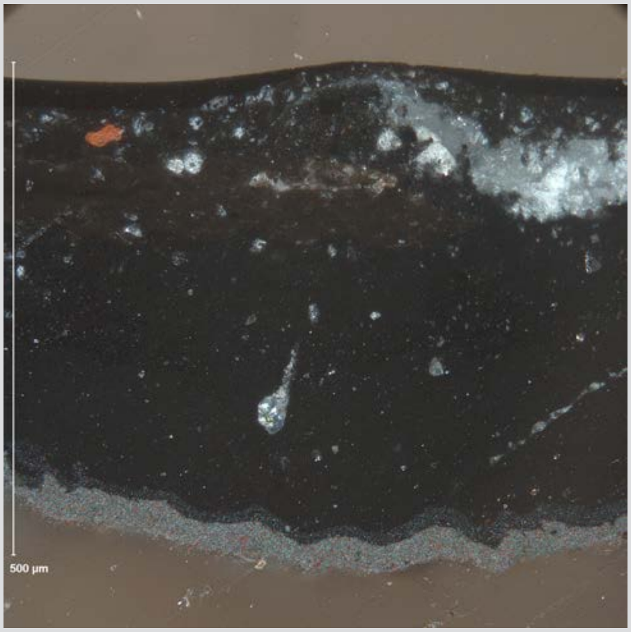


FIGURE 1.11A
Cross section East Exterior_2b. Crossed polarizing filters with added sidelight. 20× objective.

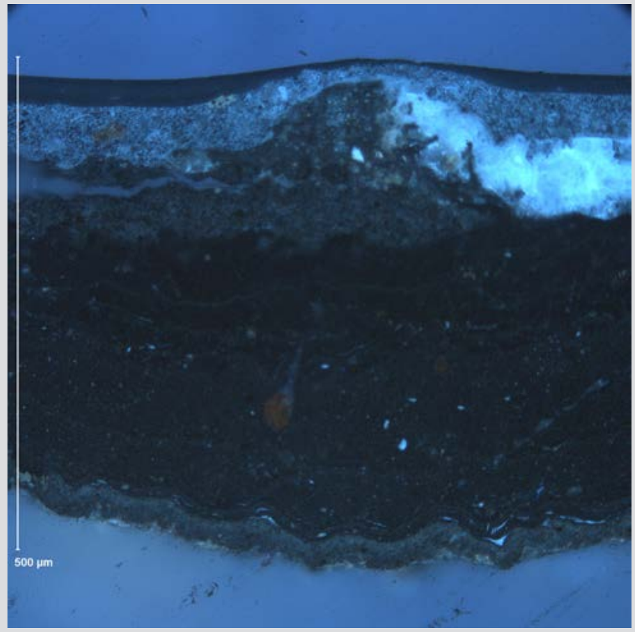


FIGURE 1.11B
Cross section East Exterior_2b. UV fluorescence. 20× objective.

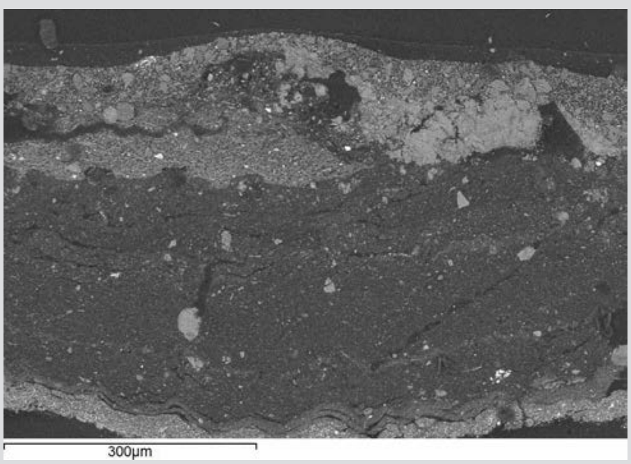


FIGURE 1.11C
Cross section East Exterior_2b. Backscattered electron image.

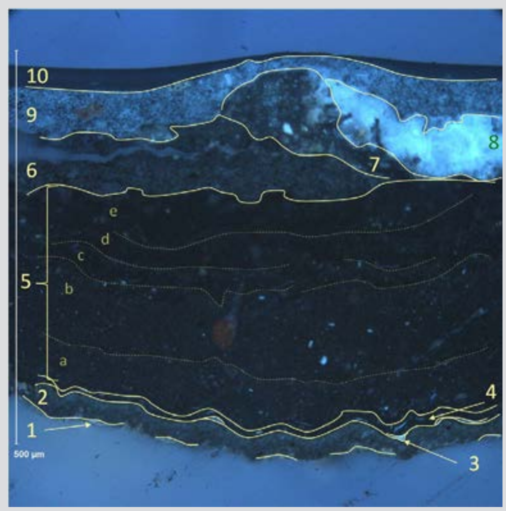


FIGURE 1.11D
Cross section East Exterior_2b. UV fluorescence. 20× objective. Annotated to show layer structure.

form of titanium white pigment, with aluminosilicates and a trace of iron oxide red. Unidentified discontinuous deposits of organic material (#3), which is strongly fluorescent under UV, underlie dark gray paint layer #4.

Titanium (as titanium white) is also relatively abundant in the medium gray paint layer #2 that underlies the dark gray paint (#4), but iron, chromium, and lead are also present in the former layer. Optical microscopy shows red, blue-green, and yellow particulates in medium gray paint layer #2. These pigments are interpreted respectively as synthetic red iron oxide, chrome green (i.e., a mixture of lead chromate yellow and Prussian blue), with lead chromate possibly also occurring as an independent (yellow) colorant. Medium gray paint layer #2, therefore, is a mixed gray color achieved in part by subtractive color mixing of red, blue-green, and yellow pigments, rather than just an

(continued on next page)

1.6.4 East Exterior_2b *(continued)*

TABLE 1.5

Description of cross section East Exterior_2b.

Layer	Description	Observations / Types of pigment particles present
10	Dense black paint	Predominantly very fine black particles effectively imperceptible by optical microscopy; plus a few larger transparent colorless particles. Comparable with: layer #3 in sample East Exterior_1. layer #4 in sample East Exterior_2a. layer #4 in sample East Exterior_3. layer #3 in sample South Exterior_11:A.
9	Dark gray paint	Composed mostly of fine black particles and large transparent grains of a colorless extender. Some fine particles higher atomic mass material evident in ESEM backscattered electron images. Comparable with: layer #2 in sample East Exterior_1. layer #3 in sample East Exterior_2a. layer #3 in sample East Exterior_3. layer #2 in sample South Exterior_11:A.
8	Bright white putty. Discontinuous.	
7	Black paint (?). Discontinuous and uneven; possibly disrupted	
6	Dark brown coating; possibly mastic. Discontinuous	Comparable with: layer #6 in sample North Exterior_10.
5	Thick coating of black paint, with substructure evident.	Several substrata (a-e) evident under UV fluorescence and by electron microscopy. Compositions of substrata are very similar and probably represent repeat applications of similarly-formulated paint. Comparable with: layer #4 in sample North Exterior_10.
4	Dark gray paint	Contains fine black particles, plus fine opaque white and red. Comparable with: layer #3 in sample North Exterior_10.
3	Discontinuous deposits of organic material, strongly fluorescent under UV.	Identity obscure.
2	Medium-gray paint	Composed mostly of fine black and fine opaque white, with some red, blue-green, and a minor amount of opaque yellow grains. Comparable with: layer #2 in sample North Exterior_10.
1	Discontinuous deposits of material, weakly fluorescent under UV.	Identity obscure. Possibly residues of putty.

admixture of black and white. Layers #2 and #4 of this sample seemingly correspond with layers #2 and #3 in sample North Exterior_10.

At the base of sample East Exterior_2b are discontinuous deposits (#1) of material that is weakly fluorescent under UV. Elemental mapping shows this material to be rich in calcium, and it is probably residue of putty (figs. 1.12a–1.12i and figs. 1.13a–1.13i).

TABLE 1.6
ESEM-EDS of cross section East Exterior_2b.

Layer	Description	Elements	Inferences
10	Dense black paint	Predominantly organic (C + O), with *(Na), (Mg), Al,* Si, *(Cl), (Ca), (Fe)*	**Carbon black** Magnesium and aluminum silicates
9	Dark gray paint	*(Na),* **Mg,** *Al,* **Si,** *P, (K), Ca, Fe, (Zn)*	**Carbon black** **Talc** Minor amount iron oxide (black?) Trace zinc oxide
8	Bright white putty. Discontinuous.	*Mg, (Al), Si,* **Ca,** *Fe*	**Calcium carbonate**
7	Black paint (?). Discontinuous and uneven; possibly disrupted	Not analyzed	–
6	Dark brown coating; possibly mastic. Discontinuous	Cl-rich, with Fe and Mg.	
5	Thick coating of black paint, with substructure evident.	**Al, Si,** *(S), Cl, Ca, Ti, (Fe)*	**Carbon black** **Aluminosilicate** (kaolin?) Alumina?
4	Dark gray paint	**Al, Si,** *(S), Cl, (Ca),* Ti, *Fe*	**Carbon black** **Aluminosilicate** Titanium dioxide Trace Iron oxide red
3	Discontinuous deposits of organic material, strongly fluorescent under UV.	Not analyzed	–
2	Medium-gray paint	**Al, Si,** *S, Cl, Ca,* Ti, *Cr*, Fe, *Pb*	**Aluminosilicate** Titanium dioxide Iron oxide red✱ Lead chromate yellow chrome green (lead chromate and Prussian blue)❖
1	Discontinuous deposits of material, weakly fluorescent under UV.	Calcium-rich	Possibly calcium carbonate

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table:
✱ Indicated by localized abundance of iron in red particles.
❖ Both small-area analyses and elemental mapping show the coincident abundance of lead and chromium particles of blue-green together with some iron. This finding points towards the green being chrome green (ie., a mixture of lead chromate yellow and Prussian blue) rather than a chromium oxide green (ie., viridian or opaque oxide of chromium). See elemental maps below.

1.6.4 East Exterior_2b *(continued)*

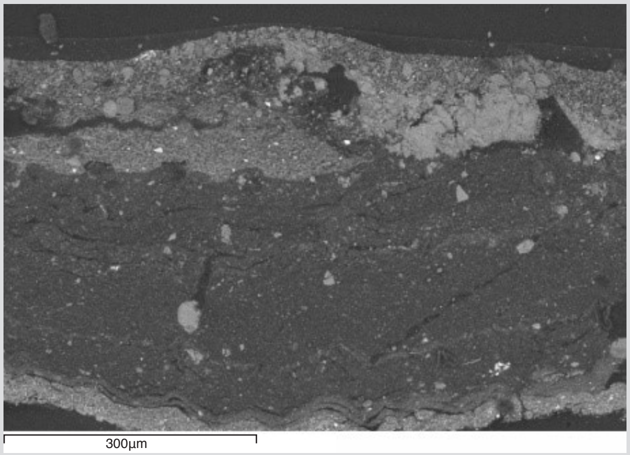


FIGURE 1.12A
Selected elemental sample maps – Sample East Exterior_2b. Backscattered electron image.

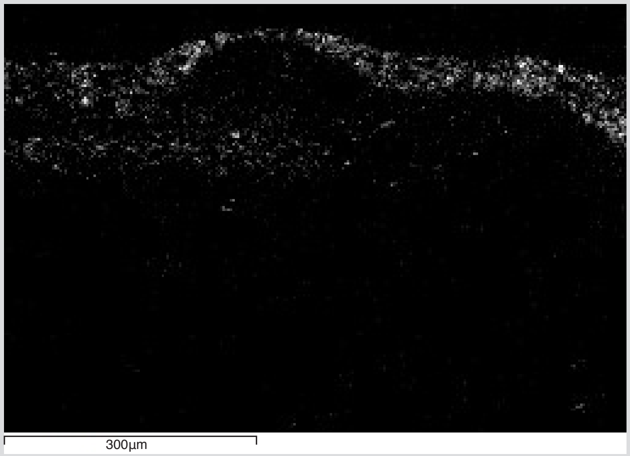


FIGURE 1.12B
Magnesium

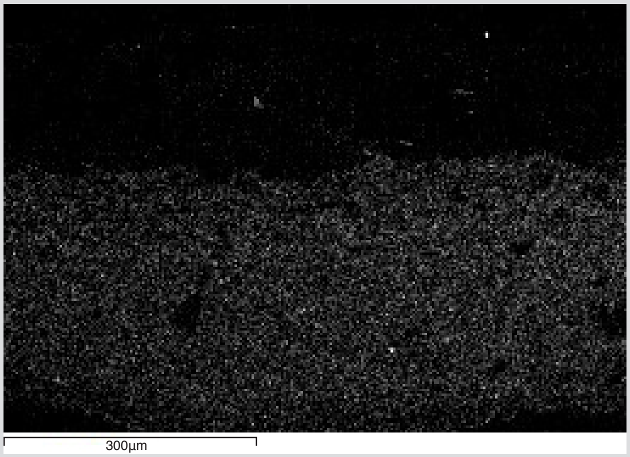


FIGURE 1.12C
Aluminum

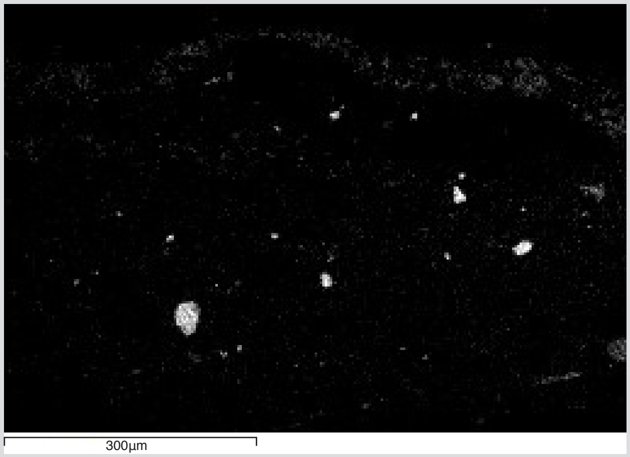


FIGURE 1.12D
Silicon

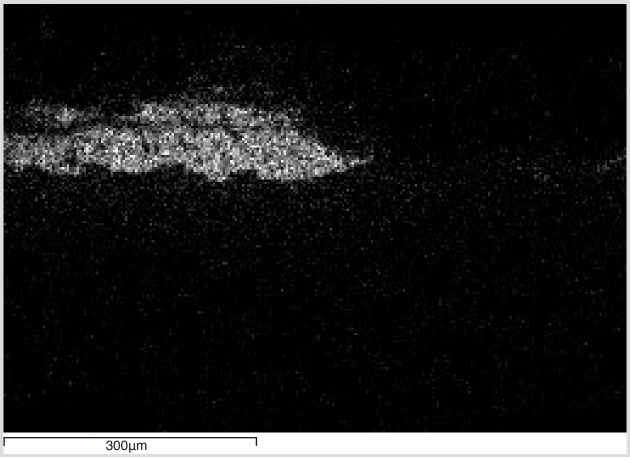


FIGURE 1.12E
Chlorine

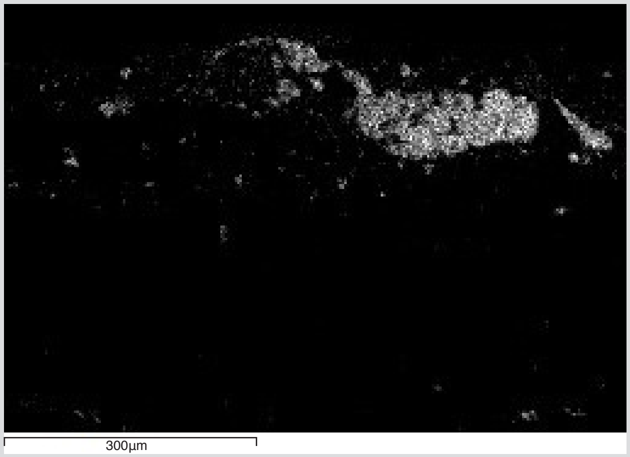


FIGURE 1.12F
Calcium

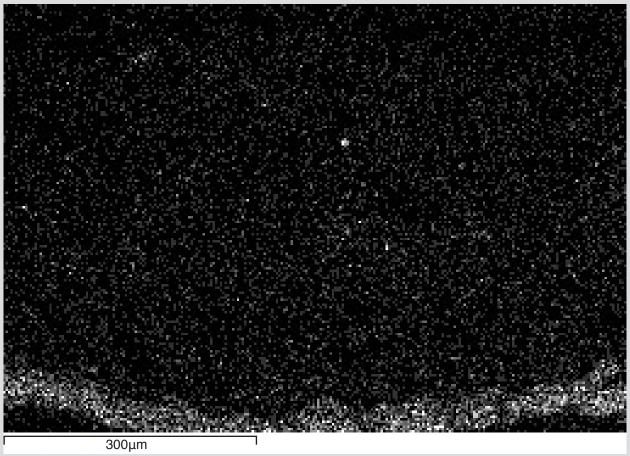


FIGURE 1.12G
Titanium

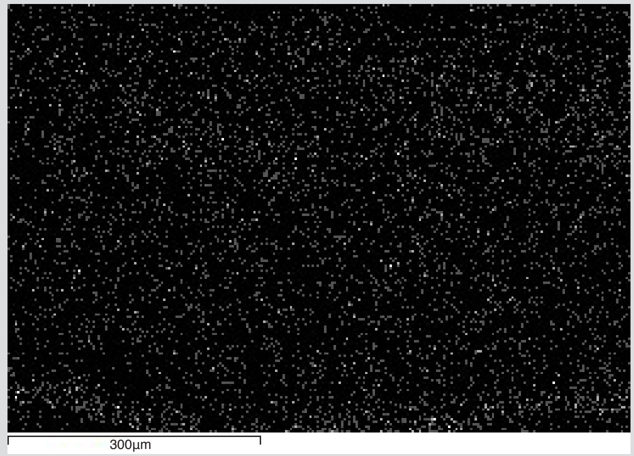


FIGURE 1.12H
Chromium

FIGURE 1.12I
Iron

(continued on next page)

1.6.4 East Exterior_2b *(continued)*

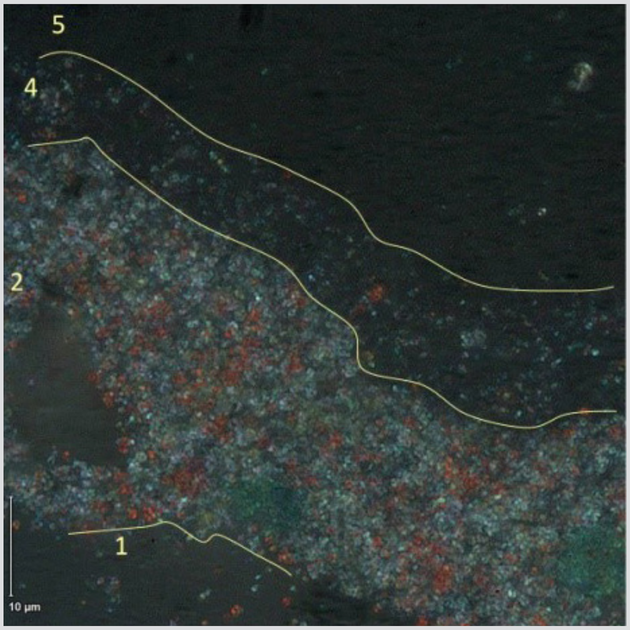


FIGURE 1.13A
Cross section East Exterior_2b at high magnification. Crossed polarizing filters. 100× objective + 2× magnifier (= 200×).

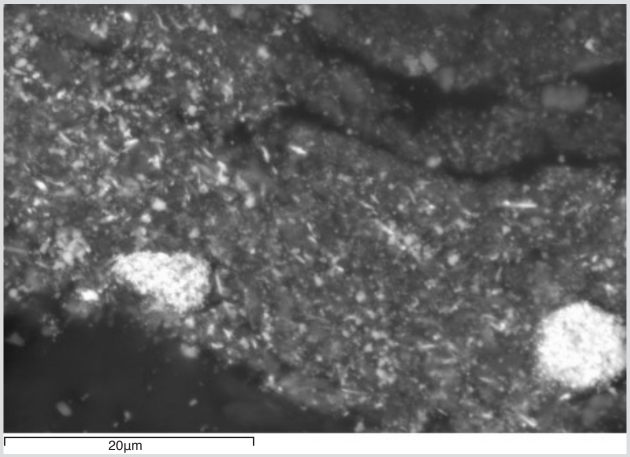


FIGURE 1.13B
Cross section East Exterior_2b at high magnification. Backscattered electron image.

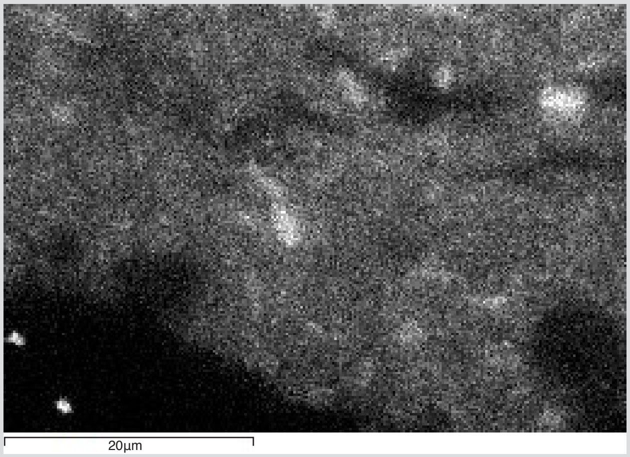


FIGURE 1.13C
Aluminum

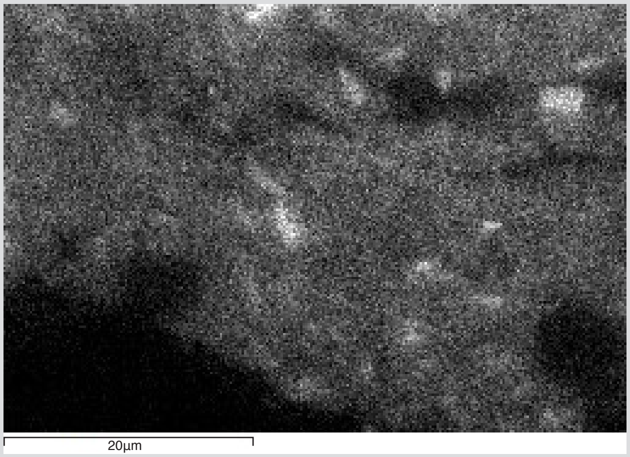


FIGURE 1.13D
Silicon

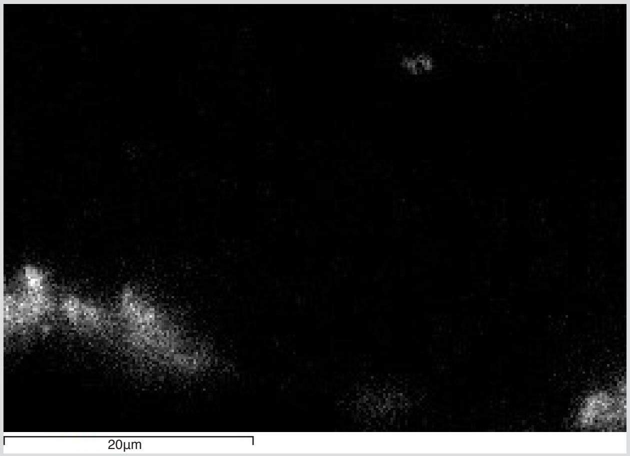


FIGURE 1.13E
Calcium

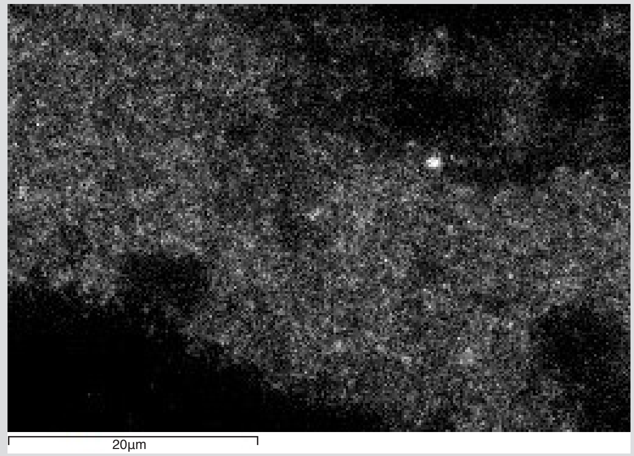


FIGURE 1.13F
Titanium

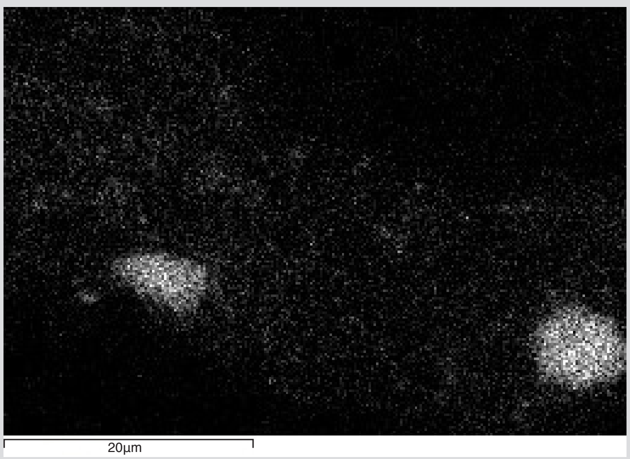


FIGURE 1.13G
Chromium

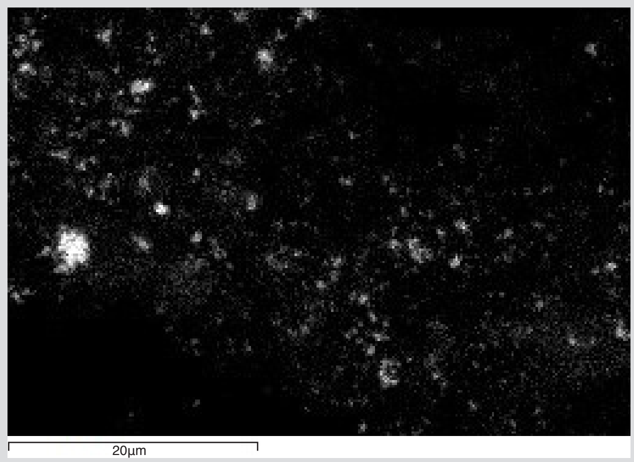


FIGURE 1.13H
Iron

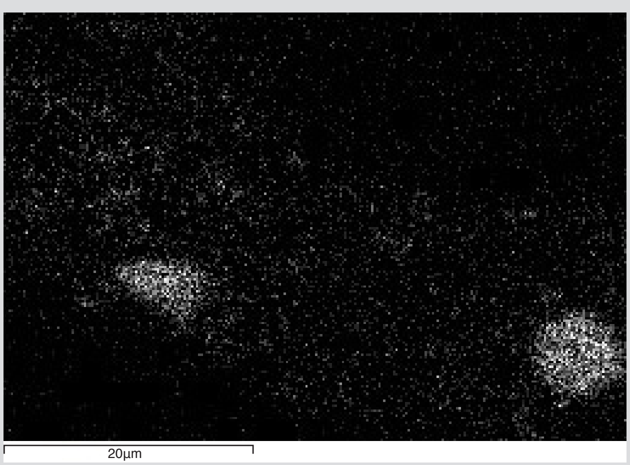


FIGURE 1.13I
Lead

1.6.5 Sample East Exterior_3

Sample taken from edge of loss on window frame at location of historic glass; white layer visible beneath the black paint.

FIGURE 1.14A
Cross section East Exterior_3. Crossed polarizing filters with added sidelight. 20× objective + 1.5× magnifier (= 30×).

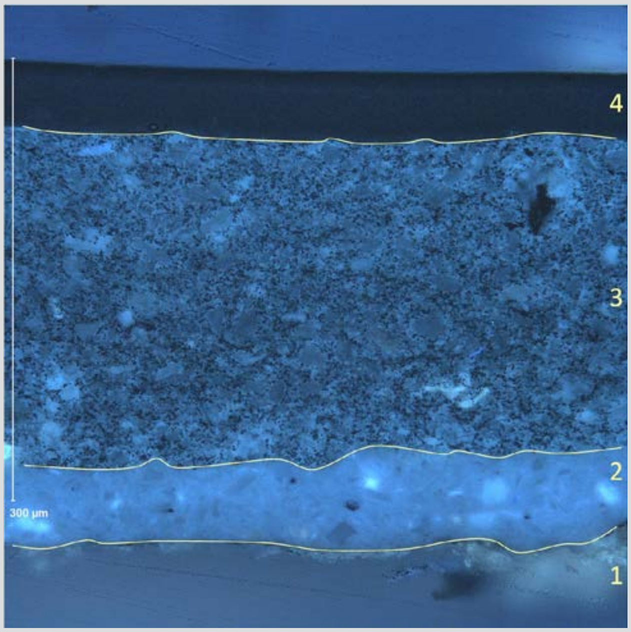


FIGURE 1.14B
Cross section East Exterior_3. UV fluorescence. 20× objective + 1.5× magnifier (= 30×). Annotated to show layer structure.

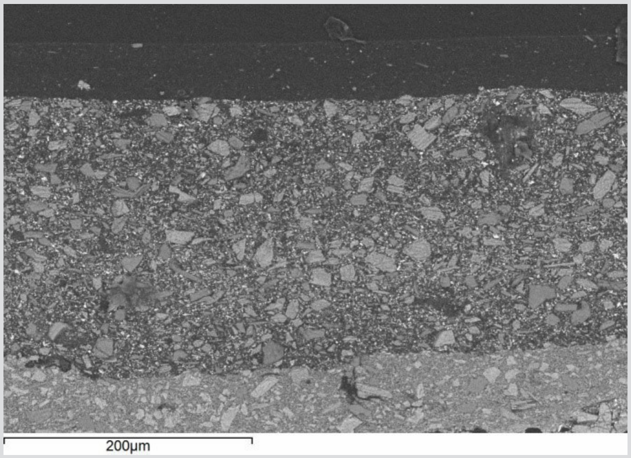


FIGURE 1.14C
Cross section East Exterior_3. Backscattered electron image.

TABLE 1.7
Description of cross section East Exterior_3.

Layer	Description	Observations / Types of pigment particles present
4	Dense black paint	Predominantly very fine black particles effectively imperceptible by optical microscopy; plus a few larger transparent colorless particles. Comparable with: layer #3 in sample East Exterior_1 layer #4 in sample East Exterior_2a
3	Gray paint	Composed mostly of fine black particles and large transparent grains of a colorless extender. Some fine particles higher atomic mass material evident in ESEM backscattered electron images. Comparable with: layer #2 in sample East Exterior_1 layer #3 in sample East Exterior_2a
2	Bright white putty	Particles: coarse transparent colorless grains.
1	Residue of off-white putty	Particles: coarse transparent colorless grains.

TABLE 1.8
ESEM-EDS of cross section East Exterior_3.

Layer	Description	Elements	Inferences
4	Dense black paint	Predominantly organic (C + O), with *(Na), (Mg), Al, Si, (Cl), (Ca), (Fe)*	**Carbon black** Magnesium and aluminum silicates
3	Gray paint	*(Na),* **Mg,** *Al,* **Si,** *P, (K),* *Ca,* Fe, *(Zn)*	**Carbon black** **Talc✹** Minor amount iron oxide (black?) Trace zinc oxide
2	Bright white putty	*(Na), Mg, Al,* **Si, Ca,** Ti, *(Fe)*	**Calcium carbonate** **Silica** Titanium dioxide
1	Residue of off-white putty	Not analyzed	–

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table
✹ Indicated by coincident abundance of magnesium and silicon.

1.6.6 Sample East Exterior_4

Sample taken from a crack near the edge of the orange panel where it meets the black frame; white layer visible beneath; possibly some panel fibers included in the sample.

FIGURE 1.15A
Cross section East Exterior_4. Crossed polarizing filters. 20× objective. Annotated to show layer structure.

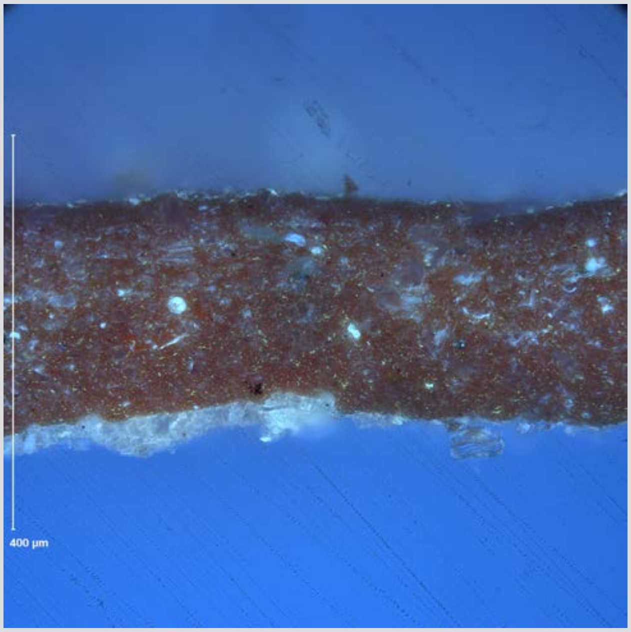


FIGURE 1.15B
Cross section East Exterior_4. UV fluorescence. 20× objective.

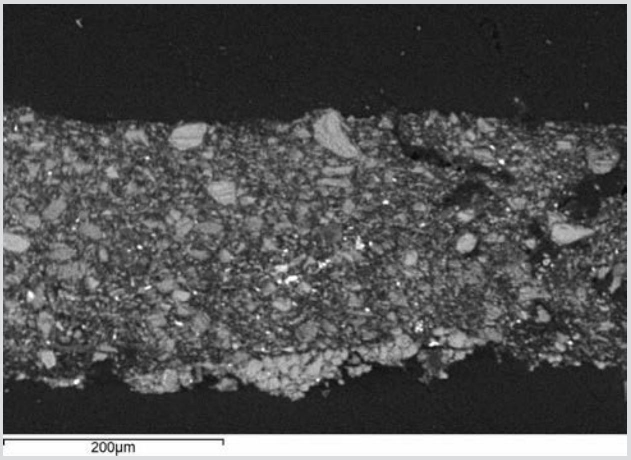


FIGURE 1.15C
Cross section East Exterior_4. Backscattered electron image.

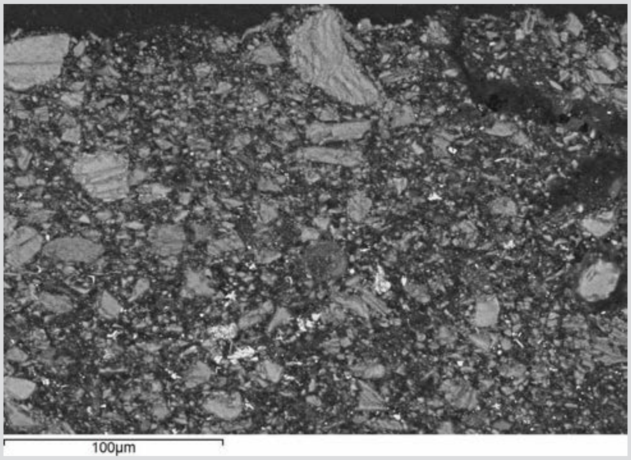


FIGURE 1.15D
Cross section East Exterior_4. Backscattered electron image.

FIGURE 1.15E
Cross section East Exterior_4. Crossed polarizing filters. 50× objective.

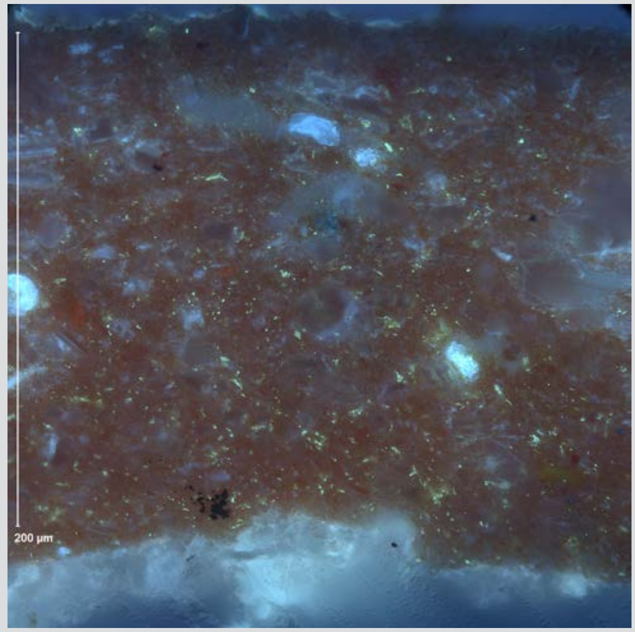


FIGURE 1.15F
Cross section East Exterior_4. UV fluorescence. 50× objective.

TABLE 1.9
Description of cross section East Exterior_4.

Layer	Description	Observations / Types of pigment particles present
2	Orange paint	Colorless transparent particles; dense orange-red particles with no UV fluorescence; fine acicular particles with strong yellowish fluorescence
1	Residues of putty panel material or putty	

TABLE 1.10
ESEM-EDS of cross section East Exterior_4.

Layer	Description	Elements	Inferences
2	Orange paint	*Na, (Mg),* Al, **Si,** *(S), (Cl), K, (Ti), Ca, (Cr), (Fe), Zn, (Pb)*	**Potassium-rich alumino-silicate❖** Silica Lead chromate✶ Zinc oxide□ Organic colorant possible
1	Residues of panel material or putty?	*Na, Mg,* Al, **Si,** *S, (Cl), (K),* **Ca**, *Ba, (Fe), (Zn)*	Calcitic siliceous substances

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table
❖ suggested by coincident abundance of K, Al, and Si in single particles.
✶ suggested by coincident abundance of Pb and Cr in single particles.
□ suggested by coincident abundance of Zn and O in single particles.

1.6.7 Sample East Interior_5

Sample taken from the edge of the frame, from an area with a thick buildup of paint.

Sample East Interior_5 was analyzed mostly by ESEM-EDS mapping; its stratigraphy and composition are summarized in table 1.11.

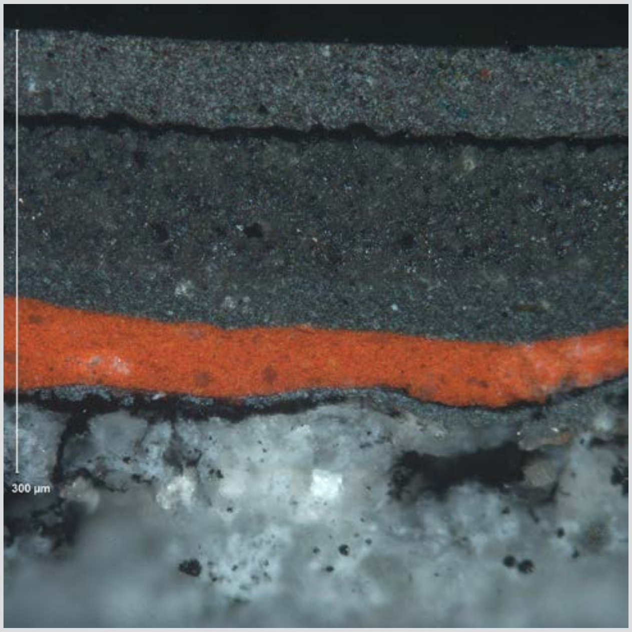


FIGURE 1.16A
Cross section East Interior_5. Crossed polarizing filters. 20× objective + 1.5× magnifier (= 30×).

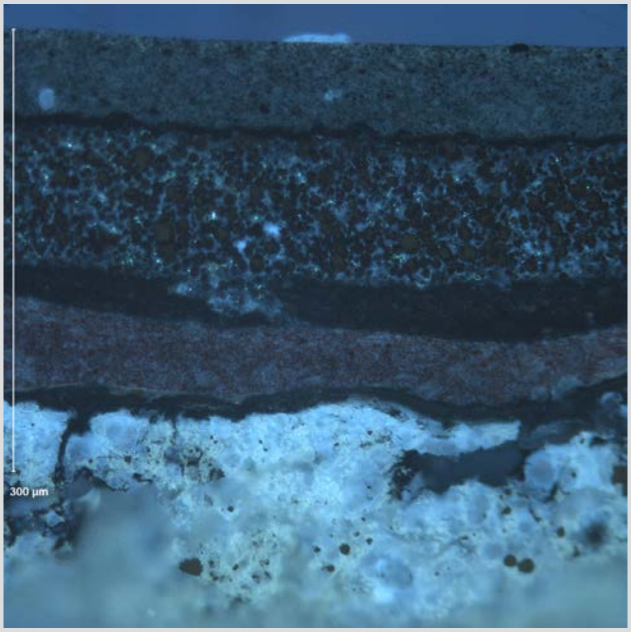


FIGURE 1.16B
Cross section East Interior_5. UV fluorescence. 20× objective + 1.5× magnifier (= 30×).

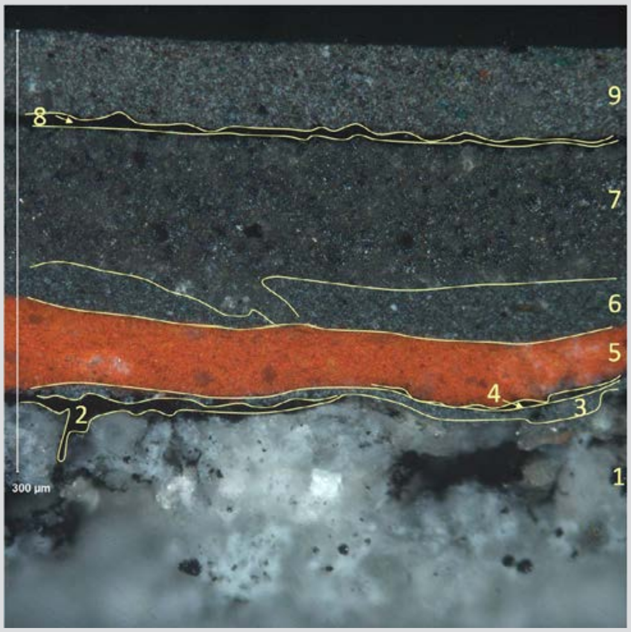


FIGURE 1.16C
Cross section East Interior_5. Crossed polarizing filters. 20× objective + 1.5× magnifier (= 30×). Annotated to show layer structure.

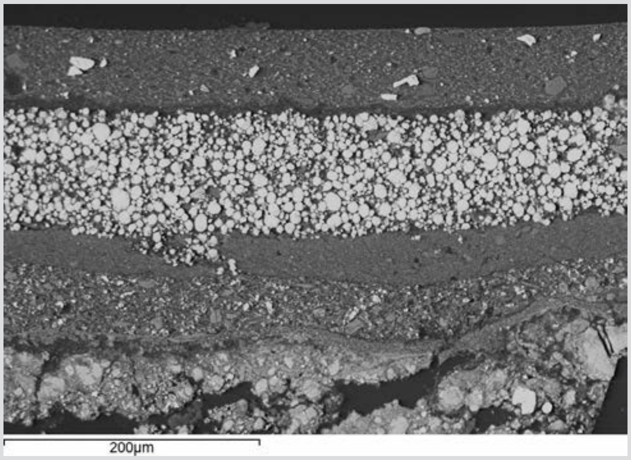


FIGURE 1.16D
Cross section East Interior_5. Backscattered electron image.

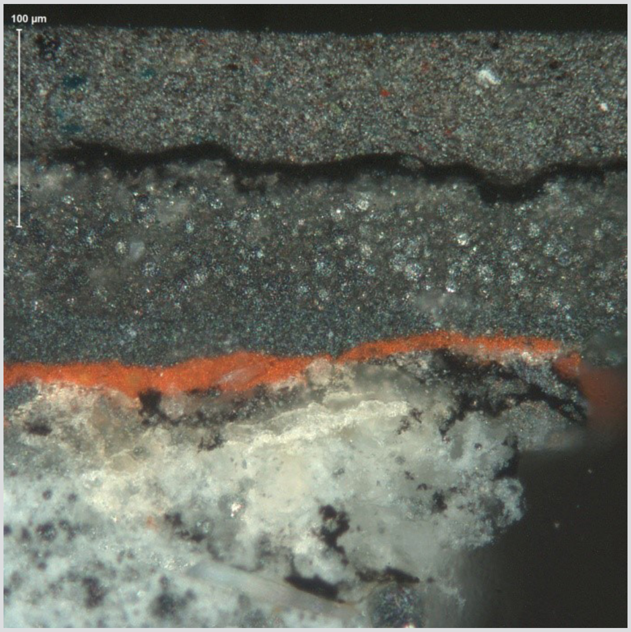


FIGURE 1.16E
Cross section East Interior_5. Crossed polarizing filters. 20× objective + 2 magnifier (= 40×).

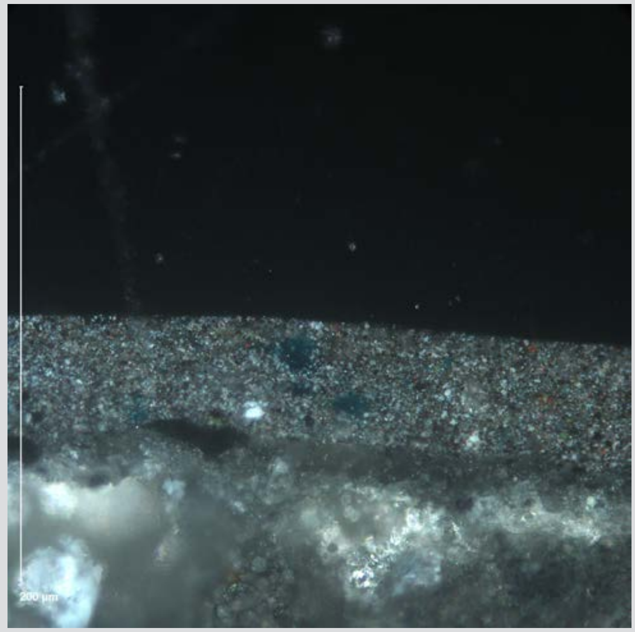


FIGURE 1.16F
Cross section East Interior_5. Crossed polarizing filters. 50× objective. Detail showing transparent blue-green pigment in uppermost layer #9.

TABLE 1.11
Description and ESEM-EDS of cross section East Interior_5.

Layer	Description	Observations
9	Mixed gray paint. Particulates: opaque white, transparent colorless, orange-red; transparent blue-green and yellow.	Chlorine-rich Fe-rich [iron oxide red❖] Titanium-rich [as TiO_2] Cr-rich [chromate pigment(s) including viridian✶]. Ca-rich Mg-rich [talc□] Si-rich BaSO4 present◆
8	Thin black paint	Aluminum-rich
7	Neutral gray primer Contains abundant rounded opaque grains that show metallic reflection under partially uncrossed polarizing filters.	Zinc abundant
6	Cool gray paint; fine-grained.	Titanium-rich Low Cr Fe-rich Aluminum-rich
5	Red primer	Fe-rich Ca-rich Mg-rich
4	Discontinuous black paint	
3	Thin gray paint	Titanium-rich
2	Discontinuous black paint	Aluminum-rich
1	Pale gray primer	Zinc abundant. Some phosphorus.

Notes to table
❖ suggested by localized abundance of Fe in red particles.
✶ Viridian (hydrated chromium oxide) is indicated as the transparent blue-green pigment on grounds of localized abundance in particles of that color abundance of Cr, in combination with low abundance/absence of other metals such as Pb, Sr, Ba and Zn.
□ suggested by coincident abundance of Mg and Si in single particles.
◆ suggested by coincident abundance of Ba and S in single particles.

1.6.8 Sample East Interior_6

Sample taken from window frame. Sample broke into two fragments during mounting; each fragment was embedded separately.

Cross section East Interior_6a is the lower fragment that consists of gray primer, possibly also some putty, and shows corrosion products on its underside. Cross section East Interior_6b includes the upper paint layers of dark gray, red, and near-black. The orientation of the upper fragment, East Interior_6b, as depicted below, has been determined to be correct through comparison with a macroscopic examination of the sample stock. It is understood that, taken together, the two separate fragments prepared from the main stock of sample East Interior_6 represent the full, continuous stratigraphy at this location.

1.6.8.1 SAMPLE EAST INTERIOR_6A: LOWER FRAGMENT CONSISTING OF GRAY PRIMER, WITH CORROSION PRODUCTS/PUTTY RESIDUE ON THE UNDERSIDE.

Pale gray primer layer #2 appears quite brittle, possibly degraded. It is clear that the paint layers above adhere only weakly to the primer, which is reflected in the separation at this interface of the sequence of paint layers that make up cross section sample East Exterior_6b. Very slight traces of the pale gray primer can be seen on the underside of paint fragments in the stock of sample material obtained at this location.

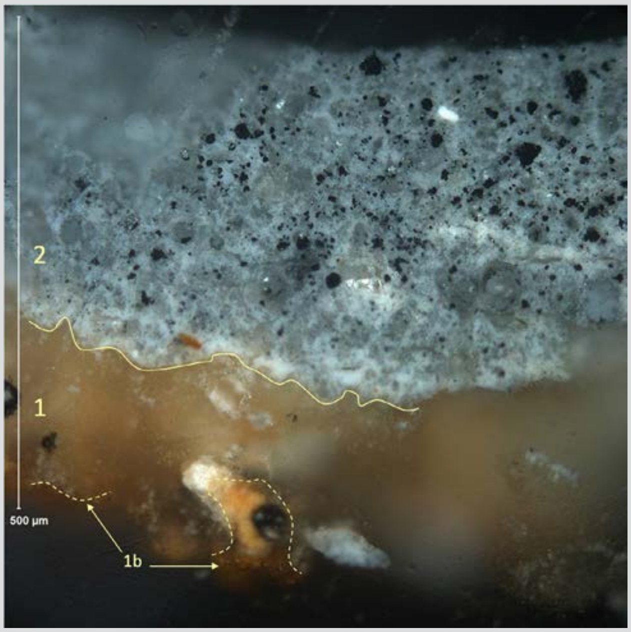


FIGURE 1.17A
Cross section East Interior_6a. Crossed polarizing filters. 20× objective. Annotated to show layer structure.

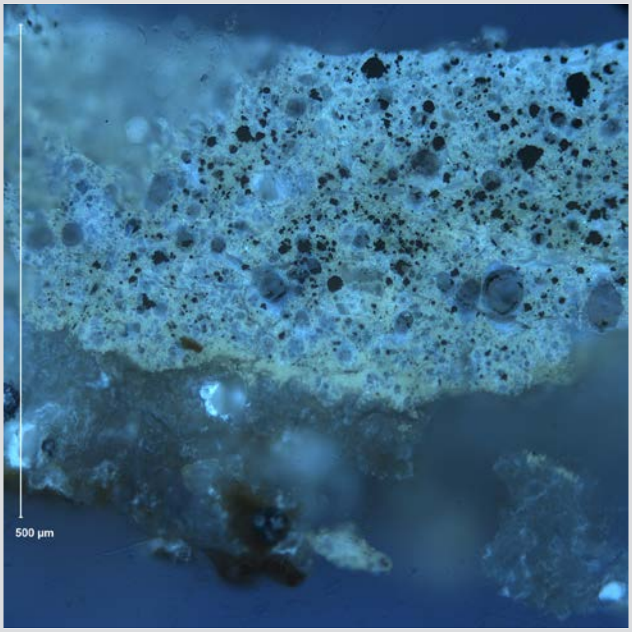


FIGURE 1.17B
Cross section East Interior_6a. UV fluorescence. 20× objective.

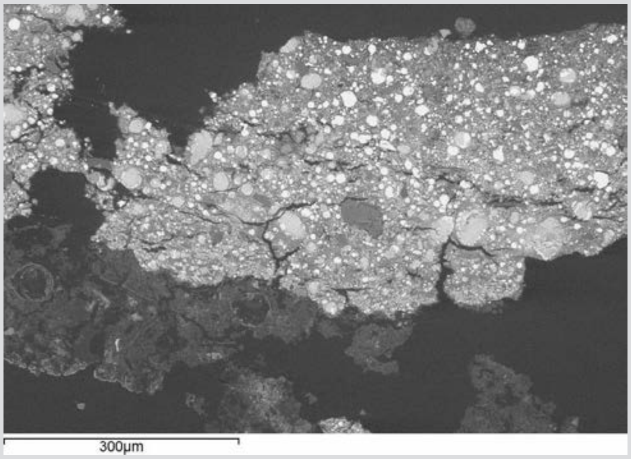


FIGURE 1.17C
Cross section East Interior_6a. Backscattered electron image.

TABLE 1.12
Description of cross section East Interior_6a.

Layer	Description	Observations / Types of pigment particles present
2	Pale gray primer	Some fine opaque white particulates, with isolated large black grains. Layer includes also large, relatively transparent particles many of which have rounded morphology. Some of these particulates show signs of internal substructure.
1	Corrosion products and possibly some residue of putty	Orange-red in color and transparent.

TABLE 1.13
ESEM-EDS of cross section East Exterior_6a.

Layer	Description	Elements	Inferences
2	Pale gray primer	*(Mg), (Al),* Si, *(S),* Cl, Ca, Ti, *(Fe),* **Zn**	Titanium dioxide (minor) Zinc dust/powder, possibly chemically altered.❖ Carbon black?
1	Corrosion products and possibly some residue of putty	*(Mg), (Al),* Si, *(S),* Cl, *(K),* Ca, *Fe,* Zn	

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table
❖ Zinc is the most abundant element throughout layer #2, and this layer is interpreted as a zinc-rich primer that was originally based on zinc dust or powder. Many of the rounded grains evident in layer #2 now show coincidentally high abundance of both zinc and chlorine. It is possible that this situation has arisen through reaction of the original zinc metal particulates with environmental chlorine.

1.6.8.2 SAMPLE EAST INTERIOR_6B: UPPER PAINT LAYERS OF DARK GRAY, RED AND NEAR-BLACK.

Cross section sample East Interior_6b has a complex stratigraphy, especially if one considers that in situ the paint layers indicated here were superimposed on the pale gray, zinc-rich priming that is the main component of sample East

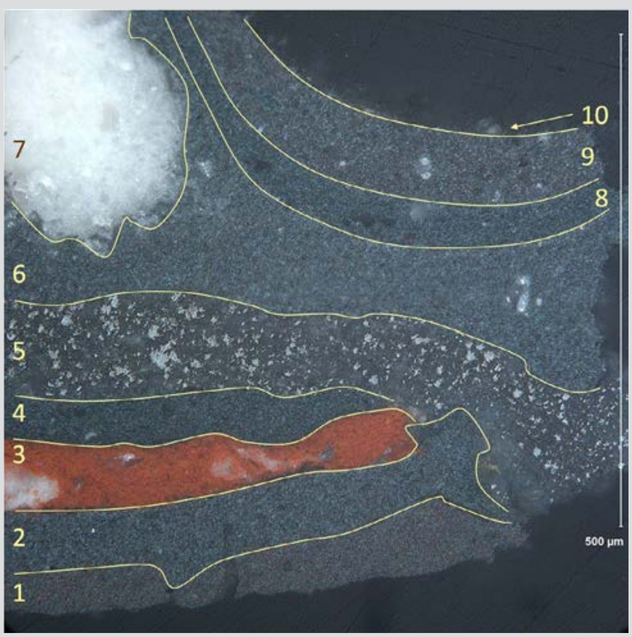


FIGURE 1.18A
Cross section East Interior_6b. Partially uncrossed polarizing filters. 20× objective. Annotated to show layer structure.

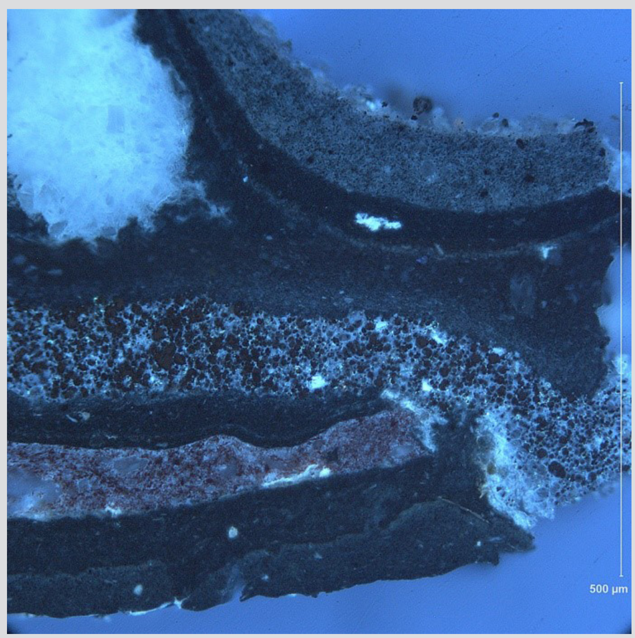


FIGURE 1.18B
Cross section East Interior_6b. UV fluorescence. 20× objective.

(continued on next page)

1.6.8 Sample East Interior_6 *(continued)*

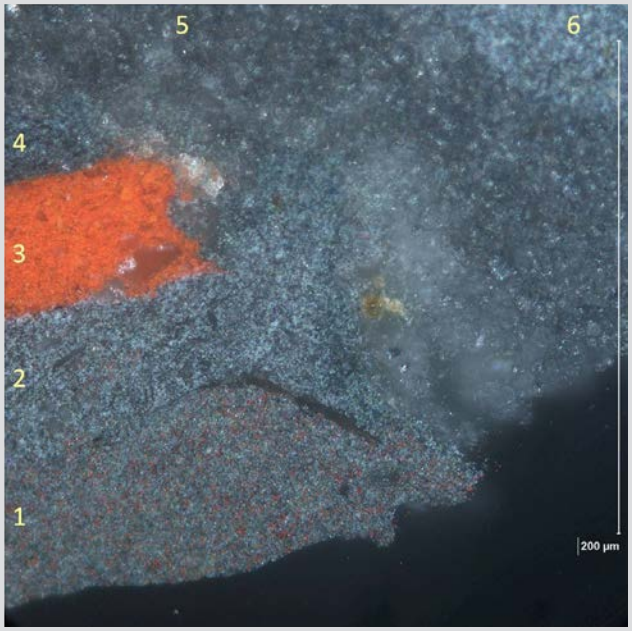


FIGURE 1.18C
Cross section East Interior_6b. Lower right of sample. Crossed polarizing filters. 50× objective. Annotated to show layers.

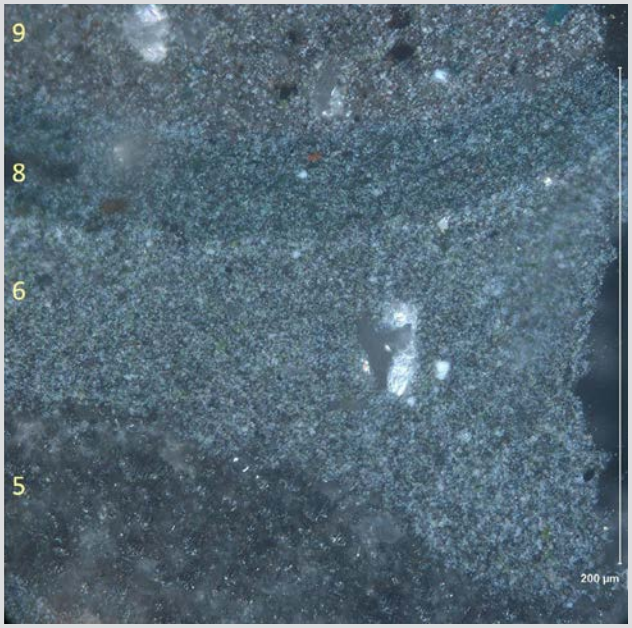


FIGURE 1.18D
Cross section East Interior_6b. Upper right of sample. Crossed polarizing filters. 50× objective. (Layer #7 out of view.) Annotated to show layers.

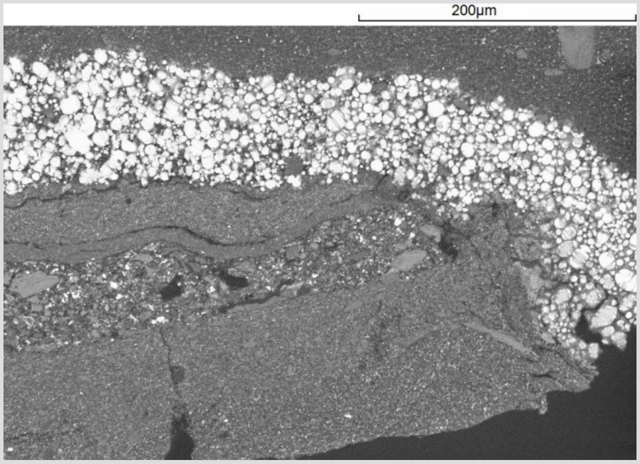


FIGURE 1.18E
Cross section East Interior_6b. Lower right of sample. Backscattered electron image.

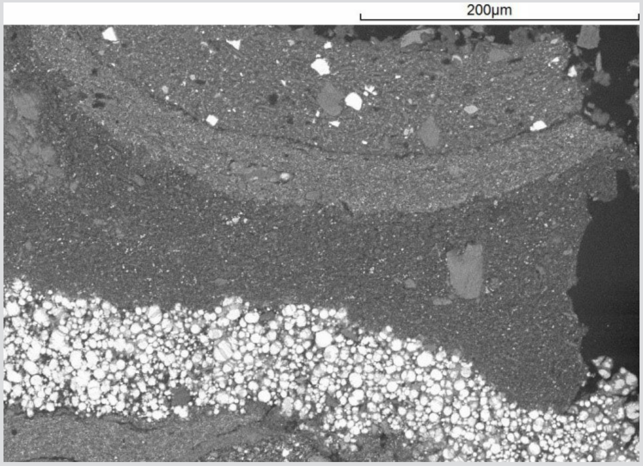


FIGURE 1.18F
Cross section East Interior_6b. Upper right of sample. Backscattered electron image.

Interior_6a. The various layers in sample East Interior_6b are summarized in the tables below. It can be noted that lower layers #1–4 are not continuous across the sample, but are truncated. The truncated edge of these layers at the right of the sample is overlaid by layer #5. The interface between layers #4 and #5, therefore, represents a distinct boundary in the history of the paint layers at this location.

Elemental analysis by ESEM-EDS of sample East Interior_6b shows that most of the gray paint layers have rather similar compositions, but with both subtle and in some cases distinctive differences in make-up. Before discussing those differences, it can be concluded from the elemental data that the bright white putty layer #7 is predominantly calcium carbonate; the neutral gray primer layer #5 is mostly zinc metal (presumably zinc powder/dust); and the red primer layer #3 is iron oxide with silicates and, possibly, lead or zinc chromate.

Regarding the gray paint layers (#1, #2, #4, #6, #8, and #9), the following observations can be made:

- They have similar elemental profiles consisting, in varying proportions, of magnesium, aluminum, silicon, chlorine, calcium, titanium, chromium, iron, and zinc. These elemental profiles point to generally similar pigment mixtures for the gray paints, which include mostly titanium dioxide, red iron oxide, and a chromium-based pigment (possibly a chromate yellow). Carbon black is not indicated in the elemental analysis, but it may also be present.
- Lead is present at trace levels in several of the mixed gray paint layers: #1, #2, #4, and #8. However, it is seemingly absent from gray paint layers #6 and #9.
- Iron, probably in the form of red iron oxide, is relatively abundant in lowest paint layer #1 and uppermost paint layer #9. These two paints are the warmest (reddest) in hue of the gray layers in the sample, almost certainly because of the greater relative proportion of iron oxide red.

TABLE 1.14
Description of cross section East Interior_6b.

Layer	Description	Observations / Types of pigment particles present
10	Surface deposits/accretions	
9	Warm gray paint layer	Particulates include: fine opaque white, fine orange-red, transparent blue-green. Possibly also some yellow and black. Similar in color to layer #1, but slightly less red. Some large, relatively opaque colorless particles also present.
8	Cool (greenish) gray paint layer	Very uniform, fine granularity. Similar in color and particulate composition to layers #2, #4, and #6, but slightly darker in tonality. Some isolated large transparent particles present.
7	Bright white putty	Coarse transparent colorless grains.
6	Cool (greenish) gray paint layer	Very uniform, fine granularity. Similar in color and particulate composition to layers #2 and #4
5	Neutral gray primer	Contains abundant rounded opaque grains that show metallic reflection under partially uncrossed polarizing filters.
4	Cool (greenish) gray paint layer	Similar in color and particulate composition to layer #2
3	Red primer	Fine red particles plus larger transparent colorless grains.
2	Cool (greenish) gray paint layer	Particulates include: fine opaque white, fine orange-red; possibly also transparent blue-green, yellow and black. Transparent colorless particles also relatively abundant in this layer
1	Warm gray paint layer	Particulates include: fine opaque white, fine orange-red, transparent blue-green. Possibly also some yellow and black

(continued on next page)

1.6.8 Sample East Interior_6 *(continued)*

TABLE 1.15
ESEM-EDS of cross section East Exterior_6b.

Layer	Description	Elements	Inferences	Remarks
10	Surface deposits/accretions	Not analyzed	—	
9	Warm gray paint layer	*Mg, (Al),* **Si,** *(S),* **Cl,** *Ca, Ti, Ba, (Cr),* Fe, *(Zn),*	Titanium dioxide Red iron oxide★ Chromate pigment(s)	Cl-rich Si-rich Low Al BaSO4❖ No Pb Moderate Ca; large chalk particles. Rel. low Ti Rel. high Fe
8	Cool (greenish) gray paint layer	*Mg,* Al, **Si,** Cl, *Ca,* **Ti,** *(Cr), (Fe), (Zn), (Pb)*	**Titanium dioxide** silicates Red iron oxide Chromate yellow (Pb or Zn?)	Ti-rich Si-rich Moderate Cl Trace Pb present
7	Bright white putty	*Mg, (Al), Si, Cl,* **Ca,** *Ti, (Fe), (Zn)*	Calcium carbonate	
6	Cool (greenish) gray paint layer	*Mg,* **Al, Si,** Cl, *Ca,* **Ti,** *Cr, (Fe), (Zn)*	**Titanium dioxide** **Aluminosilicate** Red iron oxide Chromate yellow (Zn?)	Ti-rich Al-rich Si-rich No Pb Moderate-Cr
5	Neutral gray primer	*(Al), Si, Cl, (Ca),* (*Ti,) (Fe),* **Zn**	Zinc metal	
4	Cool (greenish) gray paint layer	*Mg,* Al, **Si,** *Cl, Ca,* **Ti,** *Cr, Fe, Zn, (Pb)*	**Titanium dioxide** silicates Red iron oxide Chromate yellow (Pb or Zn?)	Ti-rich Si-rich low Cl Trace Pb present Moderate-Cr
3	Red primer	Mg, *Al,* **Si,** *P, Cl,* Ca, *Ti, Cr,* Fe, *Zn, Pb*	Red iron oxide Silicates inc. calcium silicates✶ Chromate yellow (Pb and/ or Zn)	high Fe
2	Cool (greenish) gray paint layer	*Mg,* Al, **Si,** *(P), Cl,* Ca, **Ti,** *Cr,* Fe*, (Zn), (Pb)*	Titanium dioxide Red iron oxide Chromate yellow (Pb and/ or Zn)	Ti-rich Si-rich Moderate Ca low Cl Trace Pb present P present
1	Warm gray paint layer	*(Mg),* **Al, Si,** *Cl, (Ca),* **Ti,** *Cr, Fe, (Zn), (Pb)*	Titanium dioxide Red iron oxide Chromate yellow (Pb and/ or Zn)	Ti-rich Al-rich Si-rich low Cl Trace Pb present Rel. high Fe

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to Table
❖ indicated by coincident abundance of barium and sulfur.
★ indicated by coincident abundance of iron and oxygen.
✶ indicated by coincident abundance of calcium, silicon and oxygen.

- Titanium, probably as titanium dioxide white, is relatively abundant in all the mixed gray paint layers, except in the uppermost layer #9, where there is less. Coincidentally, layer #9 includes moderately large particles of barium sulfate, which is absent from all other paints. Layer #9 also contains large particles of calcium carbonate, but these may derive from erosion of putty layer #7.
- Magnesium, aluminum, and silicon, probably as various siliceous minerals, feature in all mixed gray paints, but in differing proportions. Two paints—layers #1 and #6—are notably rich in aluminosilicates, which is suggested by an abundance of aluminum, while layer #9 is distinctively low in aluminum. Layers #2 and #8 show an abundance of silicon compared to other elements.
- Chlorine is present in relatively small amounts in all mixed gray paints with the exception of uppermost layer #9, where it is by far the most abundant element. The source of the chlorine in this layer remains uncertain, but it may come from the organic binder rather than from a pigment or extender.
- Cool (greenish) gray paint layer #8 does not have any analogues in other samples from the interior metalwork.

1.6.9 Sample East Interior_7

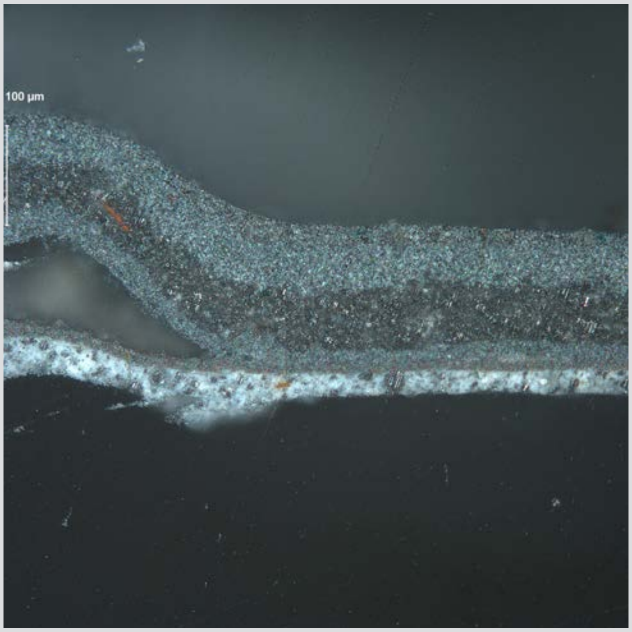


FIGURE 1.19A
Cross section East Interior_7. Crossed polarizing filters. 20× objective.

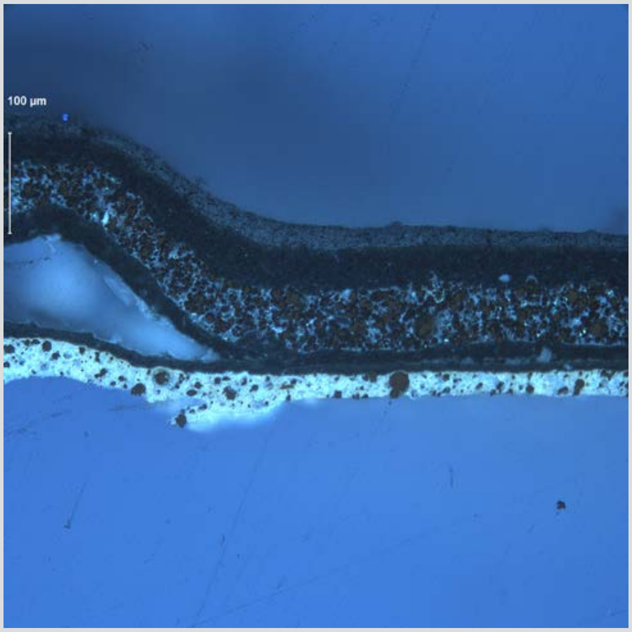


FIGURE 1.19B
Cross section East Interior_7. UV fluorescence. 20× objective.

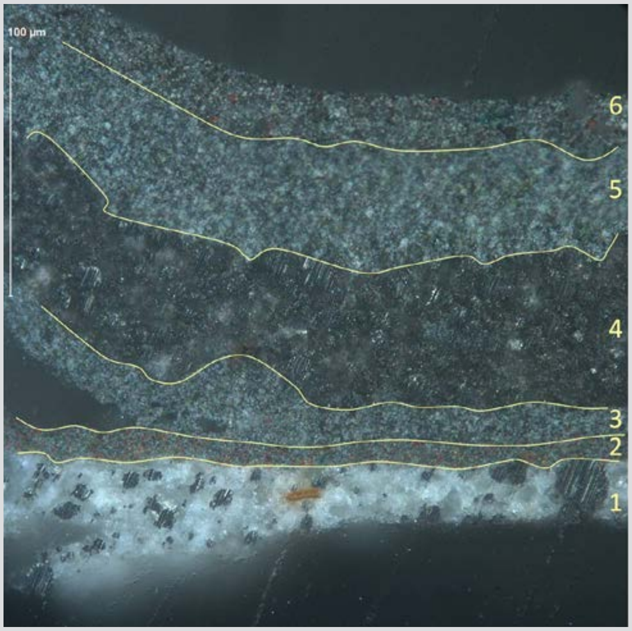


FIGURE 1.19C
Cross section East Interior_7. Crossed polarizing filters. 50× objective. Annotated to show layer structure.

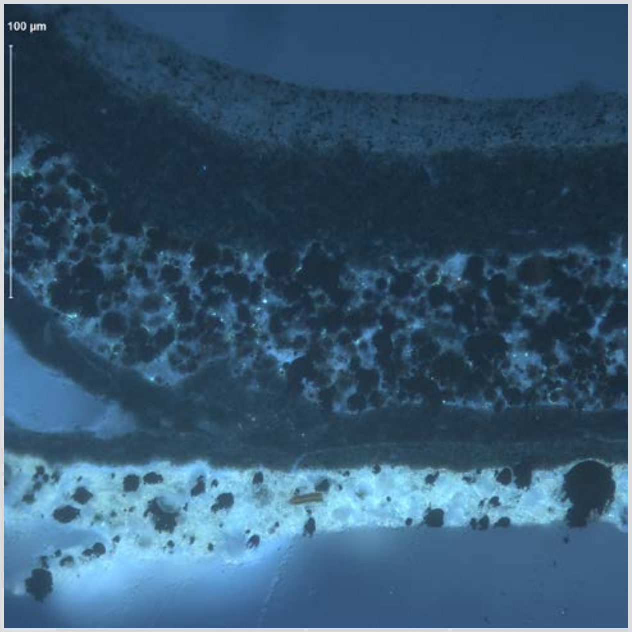


FIGURE 1.19D
Cross section East Interior_7. UV fluorescence. 50× objective.

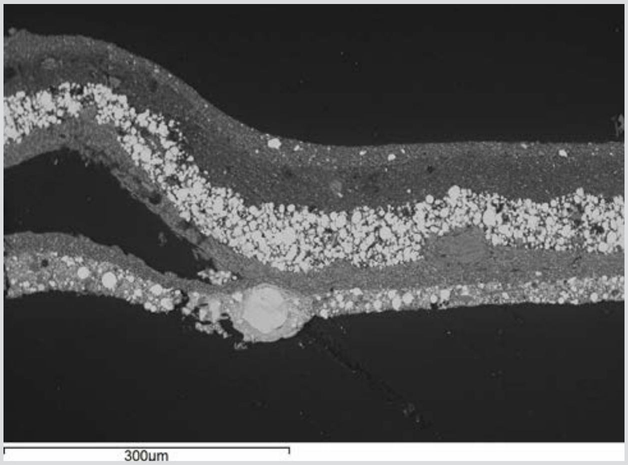


FIGURE 1.19E
Cross section East Interior_7. Backscattered electron image.

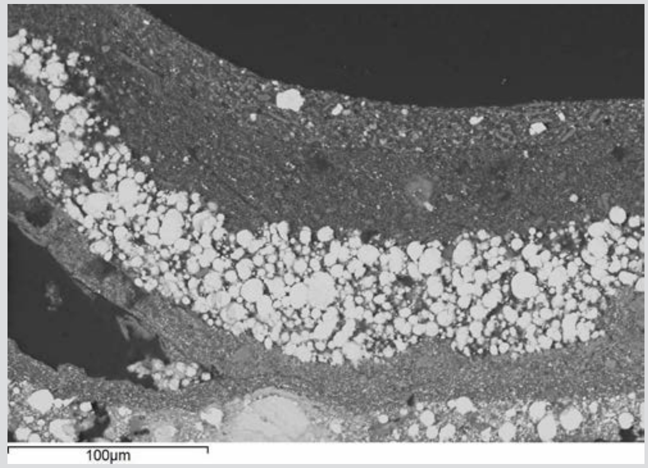


FIGURE 1.19F
Cross section East Interior_7. Backscattered electron image.

TABLE 1.16
Description of cross section East Interior_7.

Layer	Description	Observations / Types of pigment particles present
6	Warm gray paint layer	Particulates include: fine opaque white, fine orange-red, transparent blue-green. Possibly also some yellow and black. Similar in color to layer #2, but darker and slightly less red. Some large, relatively opaque colorless particles also present.
5	Cool (greenish) gray paint layer	Similar in color and particulate composition to layer #3. Yellow particles distinctly visible.
4	Neutral gray primer	Contains abundant rounded opaque grains that show metallic reflection under partially uncrossed polarizing filters.
3	Cool (greenish) gray paint layer	Particulates include: fine opaque white, fine orange-red; possibly also transparent blue-green, yellow and black. Some isolated larger transparent colorless grains.
2	Warm gray paint layer	Particulates include: fine opaque white, fine orange-red, transparent blue-green. Possibly also some yellow and black
1	Pale gray primer	White matrix containing isolated rounded opaque grains that show metallic reflection under partially uncrossed polarizing filters.

Sample taken from an area of flaking paint next to the windowpane. Some red primer visible macroscopically at the sample location, but no red primer is actually present in the sample material collected. During sampling, upper paint layers tended to delaminate from an underlayer of gray primer.

It appears that cool gray paint layer #3 is not strongly adhering to the underlying warm gray layer #2, and this defect may be responsible for the delamination of the upper paint layers from the priming that was noted during sample preparation. The sample shows some correspondence in stratigraphy with other samples from East Interior_6b, in that the lowest gray paint layer #2 and the uppermost gray paint layer #6 are both warm, reddish in color, compared to the intermediate gray paint layers #3 and #5, which are cooler or greener in color. As in all other samples from the interior metalwork, the sample includes two gray primer layers #1 and #4 that contain rounded metal (zinc) particles.

(continued on next page)

1.6.9 Sample East Interior_7 *(continued)*

TABLE 1.17
ESEM-EDS of cross section East Interior_7.

Layer	Description	Elements	Inferences	Remarks
6	Warm gray paint layer	Mg, *Al*, **Si,** *(S),* **Cl,** *(Ca),* Ti, *(Ba), (Cr), (Fe), Zn*	Barium sulfate✪ talc✶ trace aluminosilicates Titanium dioxide Trace iron oxide Chromate pigment	High Cl High Si Hi Mg BaSO4 present High Fe No Pb Low Al
5	Cool (greenish) gray paint layer	*Mg,* **Al, Si,** *(S),* Cl, *(Ca),* **Ti,** *Cr, (Fe), Zn*	Aluminosilicates Titanium dioxide Trace iron oxide Chromate pigment	High Ti High Al High Si Low Fe High Cr Moderate Mg No Pb
4	Neutral gray primer	*(Mg), (Al), Si, (P), (S), (Cl), (Ca), Ti,* **Zn**	Titanium dioxide (trace) **Zinc dust/powder** silica⦿	
3	Cool (greenish) gray paint layer	*Mg,* Al, **Si,** *S, Cl, Ca,* **Ti,** (*Cr), (Fe),* Zn✠, *(Pb)*	Aluminosilicates Titanium dioxide Trace iron oxide Lead chromate	High Ti Pb present High Mg High Si
2	Warm gray paint layer	*(Mg),* **Al, Si,** *Cl, Ca,* **Ti,** *Cr, Fe, Zn✠, (Pb)*	Aluminosilicates Titanium dioxide Trace iron oxide Lead chromate	High Ti High Si High Al Pb present High Fe
1	Pale gray primer	*(Mg), (Al),* Si, *(S), (Cl), (Ca),* (*Ti),* **Zn**	Titanium dioxide (minor) Zinc dust/powder	

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table
✠ intensity of signal for zinc probably influence by proximity of zinc primer layers above and below layer
⦿ indicated by coincident abundance of silicon and oxygen in single particles.
✶ indicated by coincident abundance of magnesium and silicon in single particles
✪ indicated by coincident abundance of barium and sulfur in single particles

1.6.10 Sample East Interior_8

Sample taken from a thick buildup of paint next to the windowpane. Sample broke into two fragments during mounting; each fragment was embedded separately. Cross section East Interior_8a consists of the upper paint layers of dark gray and red primer. Cross section East Interior_8b is the lower fragment that consists of gray primer only. The orientation of the upper fragment, East Interior_6b, as depicted below, has been determined as correct by comparison with macroscopic examination of the sample stock. It is understood that, taken together, the two separate fragments prepared from the main stock of sample East Interior_8 represent the full, continuous stratigraphy at this location.

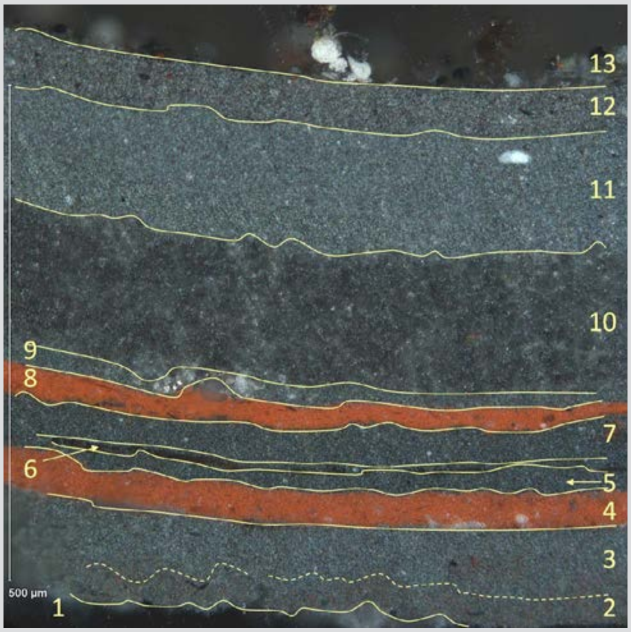


FIGURE 1.20A
Cross section East Interior_8a. Crossed polarizing filters. 20× objective. Annotated to show layer structure.

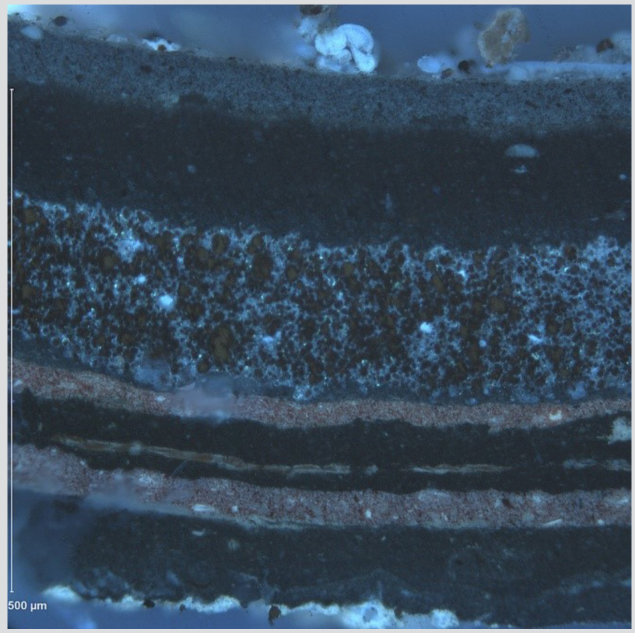


FIGURE 1.20B
Cross section East Interior_8a. UV fluorescence. 20× objective.

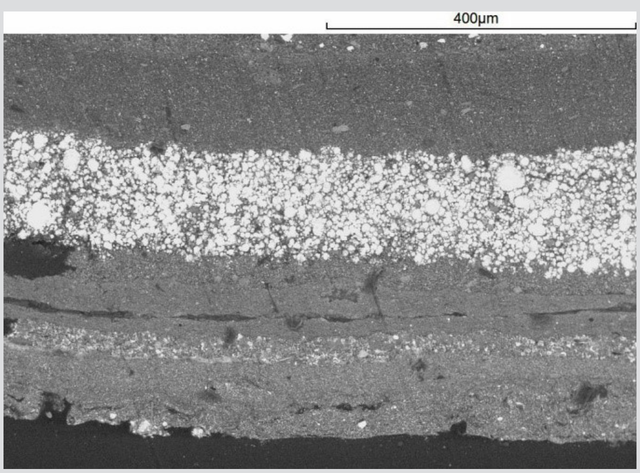


FIGURE 1.20C
Cross section East Interior_8a. Backscattered electron image.

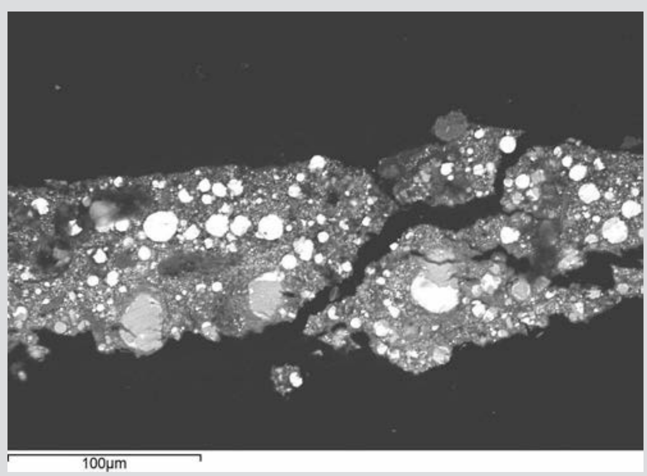


FIGURE 1.20D
Cross section East Interior_8b. Backscattered electron image.

(continued on next page)

1.6.10 Sample East Interior_8 *(continued)*

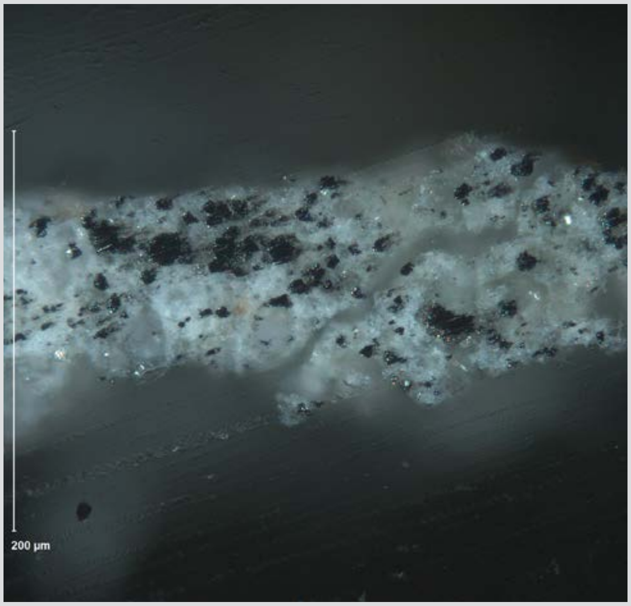


FIGURE 1.20E
Cross section East Interior_8b. Crossed polarizing filters. 20× objective + 2× magnifier (= 40×).

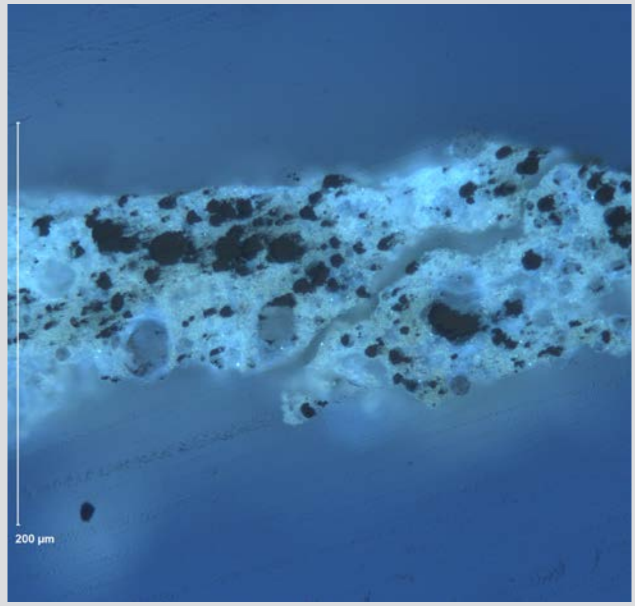


FIGURE 1.20F
Cross section East Interior_8b. UV fluorescence. 20× objective + 2× magnifier (= 40×).

TABLE 1.18
ESEM-EDS of cross section East Interior_8a.

Layer	Description	Elements	Remarks	
13	Surface deposits/debris			
12	Neutral gray paint	Mg, *Al*, **Si**, *(S)*, **Cl**, *(K)*, *Ca*, Ti, *(Cr), Fe, Zn*	Chlorine-rich Fe-rich Titanium-rich Ca-rich	Mg-rich Si-rich BaSO4 present. Low Al.
11	Cool gray paint	*Mg*, **Al**, **Si**, *(S)*, Cl, *Ca*, **Ti**, *Cr*, *(Fe), Zn*	Chlorine-rich Titanium-rich Cr-rich	Al-rich Si-rich
10	Neutral gray primer	**Zn**		
9	Thin gray paint			
8	Red primer			
7	Thin gray paint			
6	Discontinuous layer of dark, fluorescent organic medium	-	-	
5	Thin gray paint			
4	Red primer	Mg, *Al*, **Si**, **P**, *(S)*, *(Cl)*, Ca, *Ti*, *(Cr)*, Fe, *Zn*	Ca-rich Fe-rich Mg-rich	Si-rich P abundant
3	Gray paint, similar in appearance and color to layer #2)		Titanium-rich Si-rich Aluminum-rich	
2	Warm gray paint.			
1	Residue of pale gray primer (from sample East Interior_8a)		Zinc abundant. Some phosphorus.	

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.6.11 Sample North Interior_9

Sample of gray paint taken from the window frame adjacent to the panel.

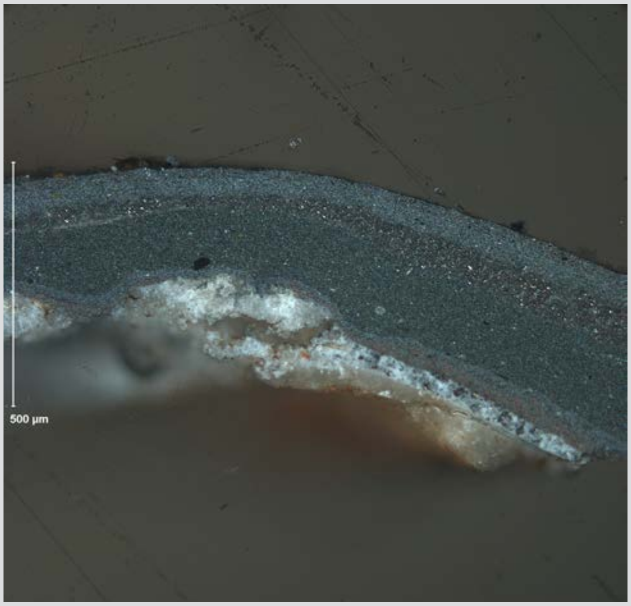


FIGURE 1.21A
Cross section North Interior_9. Crossed polarizing filters. 10× objective.

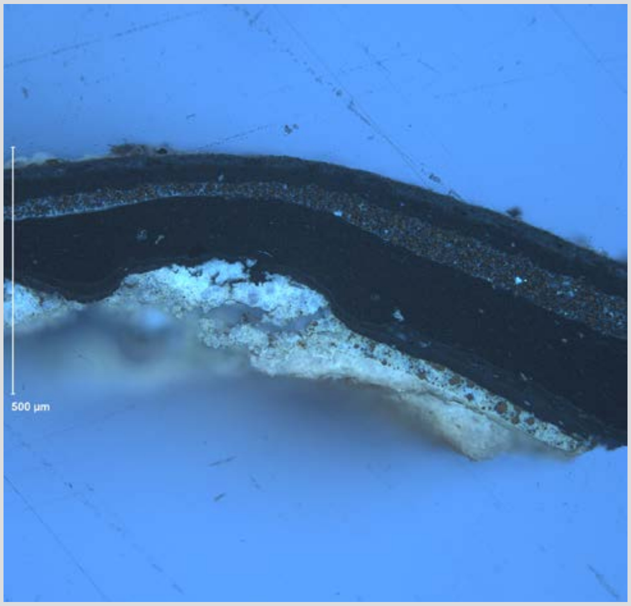


FIGURE 1.21B
Cross section North Interior_9. UV fluorescence. 10× objective.

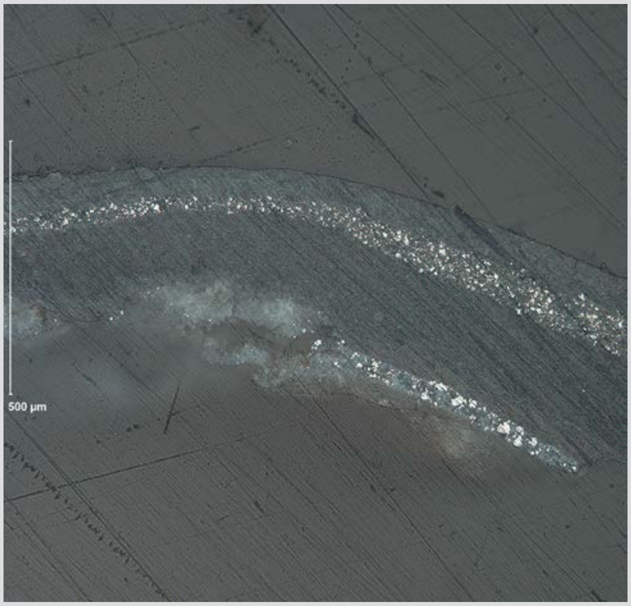


FIGURE 1.21C
Cross section North Interior_9. Partially uncrossed polarizing filters. 10× objective. Reflective metallic (zinc) particles are clearly indicated.

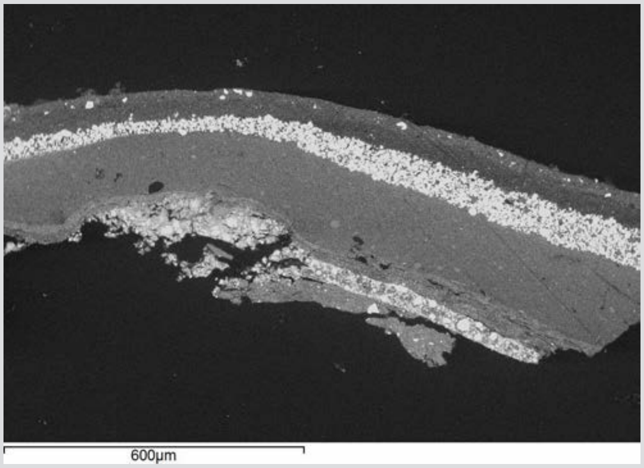


FIGURE 1.21D
Cross section North Interior_9. Backscattered electron image.

(continued on next page)

1.6.11 Sample North Interior_9 *(continued)*

The results of ESEM-EDS of cross section North Exterior_9 are summarized in table 1.20.

Cool, greenish gray paint layer #5, which is distinctively rich in iron, does not have any analogues in other samples from the interior metalwork. It may represent a unique repainting treatment of the north (kitchen) interior trim. Chlorine-rich uppermost layer #8 was shown by Py-GCMS to be based on an organic binder of chlorinated rubber.

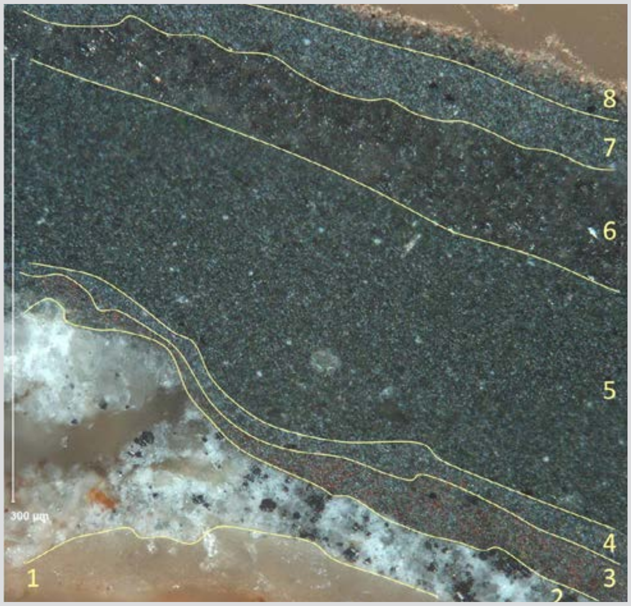


FIGURE 1.21E
Cross section North Interior_9. Crossed polarizing filters with additional sidelight. 20× objective + 1.5× magnifier (= 30×). Annotated to show layer structure.

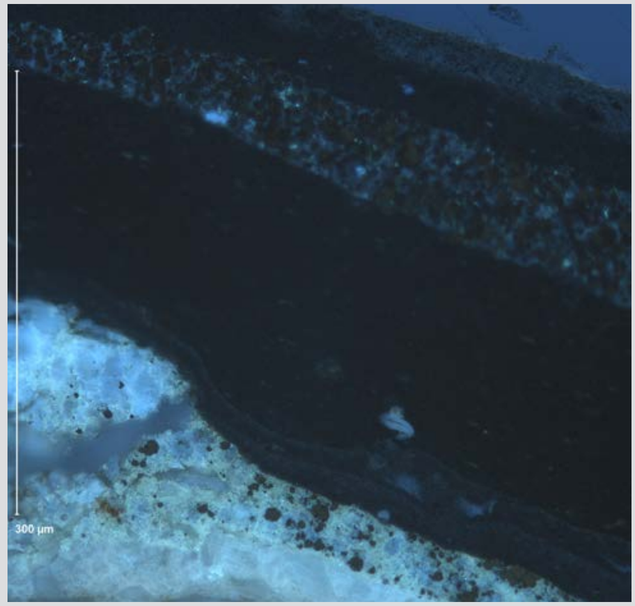


FIGURE 1.21F
Cross section North Interior_9. UV fluorescence. 20× objective + 1.5× magnifier (= 30×).

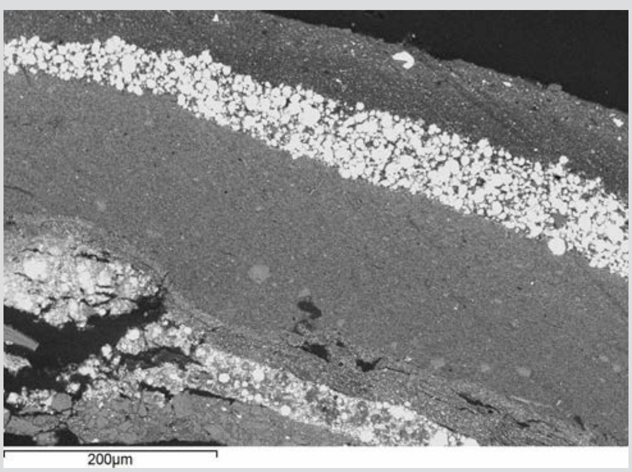


FIGURE 1.21G
Cross section North Interior_9. Backscattered electron image.

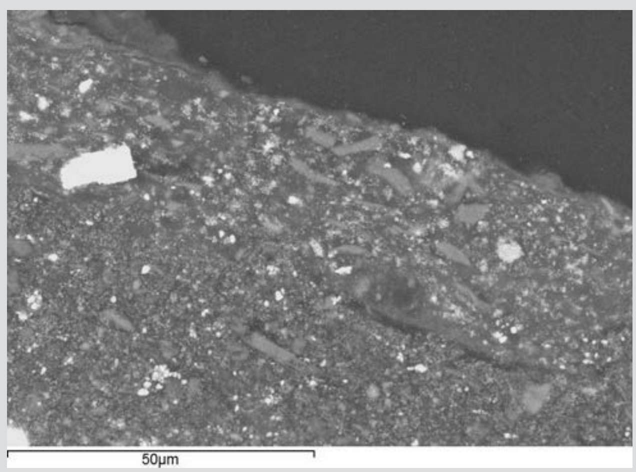


FIGURE 1.21H
Cross section North Interior_9. Backscattered electron image.

TABLE 1.19
Description of cross section North Interior_9.

Layer	Description	Observations / Types of pigment particles present
8	Cool gray paint layer	Similar in color and particulate composition to layers #5 and #6.
7	Cool (greenish) gray paint layer	Similar in color and particulate composition to layer #5.
6	Neutral gray primer	Contains abundant rounded opaque grains that show metallic reflection under partially uncrossed polarizing filters.
5	Cool (greenish) gray paint layer	Similar in color and particulate composition to layer #4, but slightly darker in tonality.
4	Cool (greenish) gray paint layer	Particulates include: fine opaque white, fine orange-red; possibly also transparent blue-green, yellow and black. Some isolated larger transparent colorless grains.
3	Warm gray paint layer	Particulates include: fine opaque white, fine orange-red, transparent blue-green. Possibly also some yellow and black
2	Pale gray primer	White matrix containing isolated rounded opaque grains that show metallic reflection under partially uncrossed polarizing filters.
1	Residue of putty	

TABLE 1.20
ESEM-EDS of cross section North Interior_9.

Layer	Description	Elements	Inferences	Remarks
8	Cool gray paint layer	*Mg*, *Al*, Si, *(S)*, **Cl,** *(K)*, *(Ca)*, Ti, *(Cr)*, *Fe, Zn*		Si-rich Cl-rich Low Al Moderate Mg Ba present No Pb
7	Cool (greenish) gray paint layer	*Mg*, **Al, Si,** *(S)*, Cl, *(K)*, *(Ca)*, *Cr*, *(Fe)*, *Zn*		Si-rich Ti-rich Al-rich Moderate Cr Moderate Mg No Pb
6	Neutral gray primer	*(Mg), Al, Si, (S), Cl, (Ca), Ti,* **Zn**	**Zinc dust/powder**	
5	Cool (greenish) gray paint layer	*Mg*, Al, **Si,** *(S)*, *Cl*, *Ca*, **Ti, Fe,** Zn		Si-rich Ti-rich Fe-rich No Pb Moderate Al Moderate Mg
4	Cool (greenish) gray paint layer	*Mg*, **Al, Si,** *(S?)*, *Cl*, Ca, **Ti,** *(Cr), Fe, Zn, (Pb)*		Si-rich Ti-rich Al-rich Pb present Moderate Ca
3	Warm gray paint layer	*(Mg)*, **Al, Si,** *(S?)*, *Cl*, *Ca*, Ti, *(Cr), Fe, Zn, (Pb)*		Si-rich Ti-rich Al-rich Pb present
2	Pale gray primer	*(Mg), Al, Si, (S), (Cl), Ca, Ti,* **Zn**	Titanium dioxide (minor) **Zinc dust/powder**	
1	Residue of putty	*(Mg), (Al), (Si), (S), (Cl),* **Ca,** *(Ti), (Fe), (Zn)*	Calcium carbonate	

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.6.12 Sample North Exterior_10

From corner of window frame, black paint bubbled up from failed putty/corrosion; sample may include a red primer and putty.

Cross section North Exterior_10 contains a complex stratigraphy, with several layers in common with sample East Exterior_2b, as noted earlier. The layer structure of sample North Exterior_10 is summarized in table 1.21.

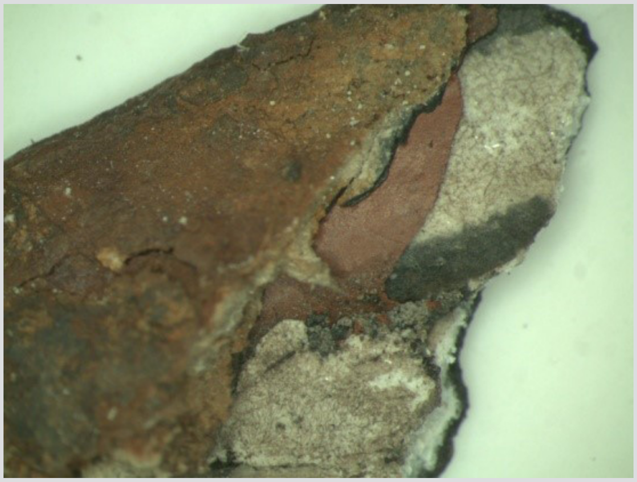


FIGURE 1.22A
Sample North Exterior_10; underside, unmounted.

FIGURE 1.22B
Cross section North Exterior_10. Crossed polarizing filters. 10× objective.

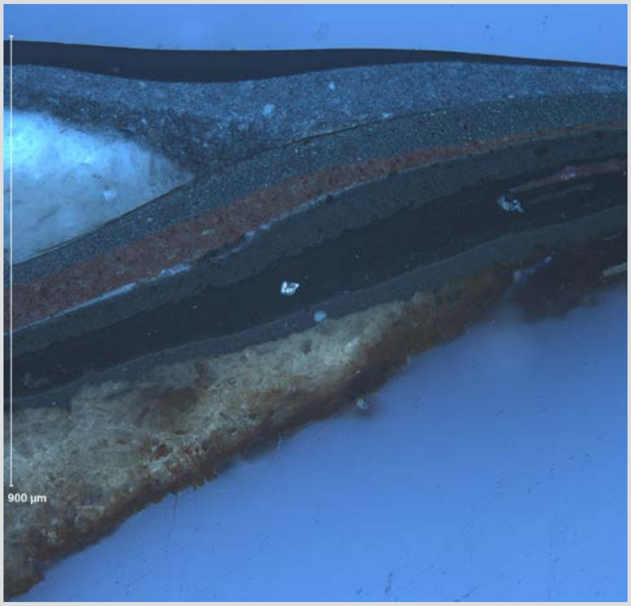


FIGURE 1.22C
Cross section North Exterior_10. UV fluorescence. 10× objective.

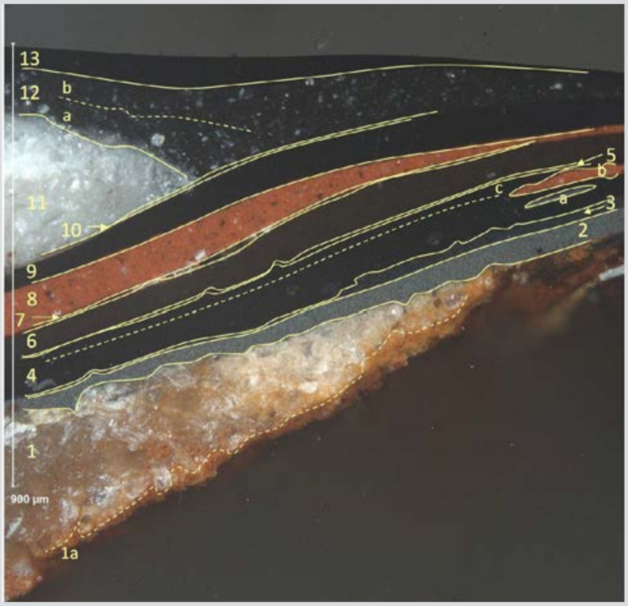


FIGURE 1.22D
Cross section North Exterior_10. Crossed polarizing filters. 10× objective. Annotated to show layer structure.

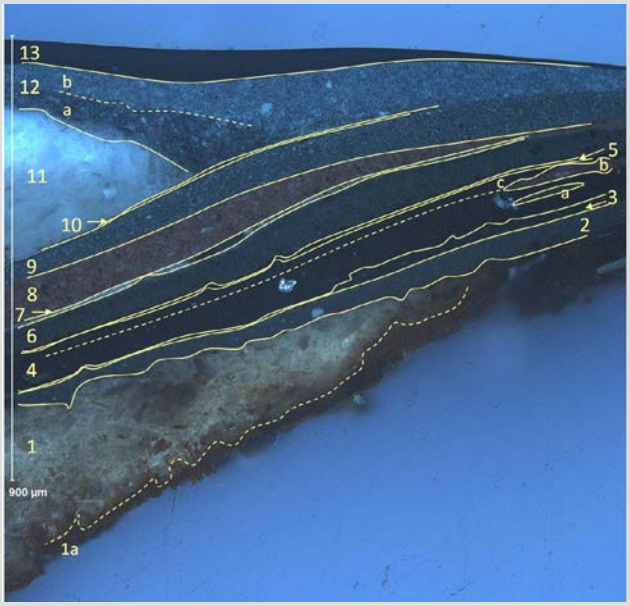


FIGURE 1.22E
Cross section North Exterior_10. UV fluorescence. 10× objective. Annotated to show layer structure.

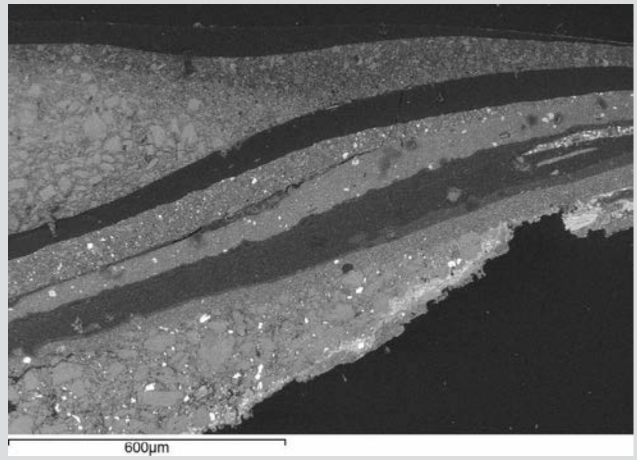


FIGURE 1.22F
Cross section North Exterior_10. Backscattered electron image.

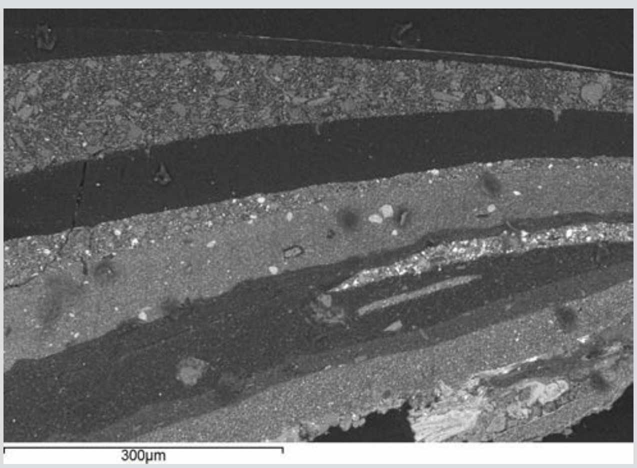


FIGURE 1.22G
Cross section North Exterior_10. Backscattered electron image.

(continued on next page)

1.6.12 Sample North Exterior_10 *(continued)*

TABLE 1.21
Description of cross section North Exterior_10.

Layer	Description	Observations / Types of pigment particles present
13	Dense black paint	Comparable with top-most layer in samples: East Exterior_1; East Exterior_2a; East Exterior_3; South Exterior_11:A
12	Dark gray paint	Two substrata (a, b) evident, suggesting repeat applications of similarly-formulated paint. Comparable with second top-most layer in samples East Exterior_1; East Exterior_2a; East Exterior_3; South Exterior_11:A
11	Bright white putty	
10	Very thin, dense black paint	No particulates visible
9	Black paint	Contains fine transparent colorless particles. Layer includes some particles of higher atomic mass.
8	Red primer	
7	Organic material	Fluorescent under UV
6	Dark brown coating; possibly mastic.	Comparable with layer #6 in sample East Exterior_2b
5	Uneven, thin layer of black paint	
4	Black paint, with some internal substructure evident and inclusions of red (b) and gray (a).	Comparable with layer #5 in sample East Exterior_2b
3	Dark gray paint	Contains fine black particles, plus fine opaque white and red. Comparable with: layer #4 in sample East Exterior_2b.
2	Medium-gray paint	Composed mostly of fine black and fine opaque white, with some red, transparent blue-green and, possibly, opaque yellow grains. Comparable with: layer #2 in sample East Exterior_2b.
1	Off-white putty with corrosion products (#1b) at lower interface.	

The results of ESEM-EDS of cross section North Exterior_10 are summarized in table 1.22.

TABLE 1.22
ESEM-EDS of cross section North Exterior_10.

Layer	Description	Elements	Inferences
13	Dense black paint	**C,** *O, (Mg), (Al), (Si), (Cl), (Ca), (Fe)*	Predominantly organic (**carbon black**)◆
12	Dark gray paint	*(Na),* **Mg,** *Al*, **Si,** *P, (Cl), (K), Ca, Fe, (Zn)*	**Carbon black** **Talc**★ Minor amount iron oxide (black?) Trace zinc oxide
11	Bright white putty	*Mg, Al, Si, (Cl),* **Ca,** *(Fe)*	**Calcium carbonate**
10	Very thin, dense black paint	Not analyzed	–
9	Black paint	**C,** *O, (Mg), (Al), Si, Cl, (Ca), (Fe), (Zn)*	Predominantly organic (carbon black)
8	Red primer	*(Na),* Mg, *(Al),* **Si,** *(P), Cl, (K), Ca, (Ba)* Fe, *(Ti), (Cr), (Zn)*	iron oxide red plus aluminosilicates, talc, dolomite; trace titanium dioxide or ilmenite trace barium sulfate zinc chromate?
7	Organic material	Not analyzed	–
6	Dark brown coating; possibly mastic.	*(Na),* (Mg), *(Al), Si, (P),* **Cl,** *Ca,* Fe, *(Ti),*	Chlorinated organic binder? Iron oxide?
5	Uneven, thin layer of black paint	Not analyzed	–
4	Black paint, with some internal substructure evident and inclusions of red (b) and gray (a).	*(Na), (Mg),* **Al, Si,** *(S),* Cl, *Ca, (Ti), (Fe)*	**Carbon black** **Aluminosilicate** (kaolin?)
3	Dark gray paint	*(Na), (Mg),* **Al, Si,** *(S),* Cl, *Ca,* Ti, *(Fe)*	**Carbon black** **Aluminosilicate** (kaolin?) Titanium dioxide
2	Medium-gray paint	*(Na),* (Mg)**, Al, Si,** *Cl, (K), Ca,* Ti, Fe, *Cr,*	**Aluminosilicate** Titanium dioxide, Red iron oxide Lead chromate yellow Chrome green (Lead chromate + Prussian blue)❖
1	Off-white putty with corrosion products (#1b) at lower interface.	*(Mg), Al, Si, (S), (Cl), (K),* **Ca,** *(Ba), Fe,*	**Calcium carbonate** Iron corrosion products. Trace barium sulfate.

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table
◆ carbon black suggested by the absence of any other characteristic elements.
★ suggested by coincident abundance of magnesium and silicon.
❖ Both small-area analyses and elemental mapping show the coincident abundance of lead and chromium particles of blue-green together with some iron. This finding points towards the green being chrome green (ie., a mixture of lead chromate yellow and Prussian blue) rather than a chromium oxide green (ie., viridian or opaque oxide of chromium).

(continued on next page)

1.6.12 Sample North Exterior_10 *(continued)*

Cross section North Exterior_10 was also analyzed by ESEM-EDS using the elemental mapping function of the INCA analysis system. The main elemental maps of the sample, obtained at low magnification, are presented below.

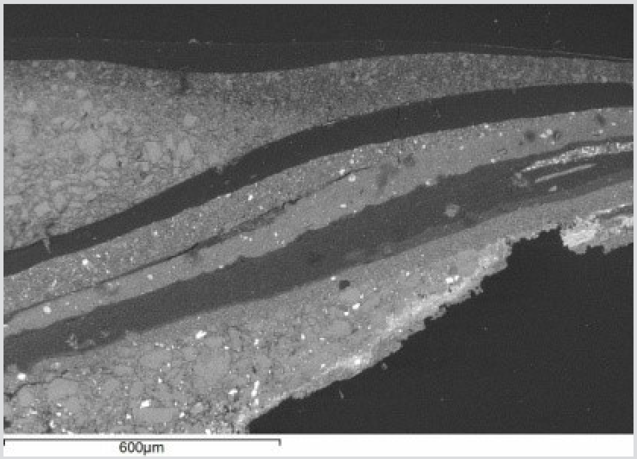


FIGURE 1.23A
Cross section North Exterior_10. Backscattered electron image.

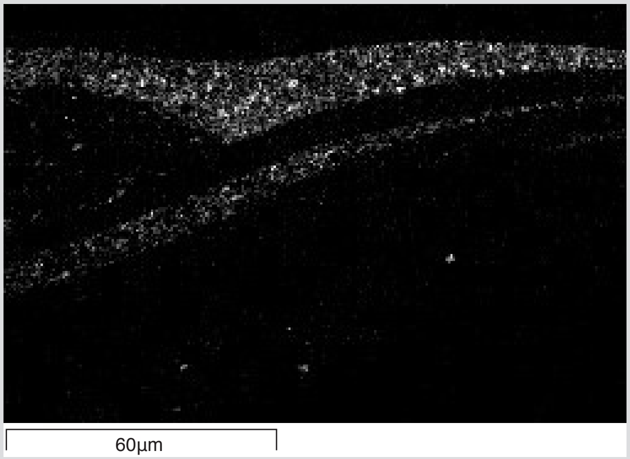


FIGURE 1.23B
Magnesium

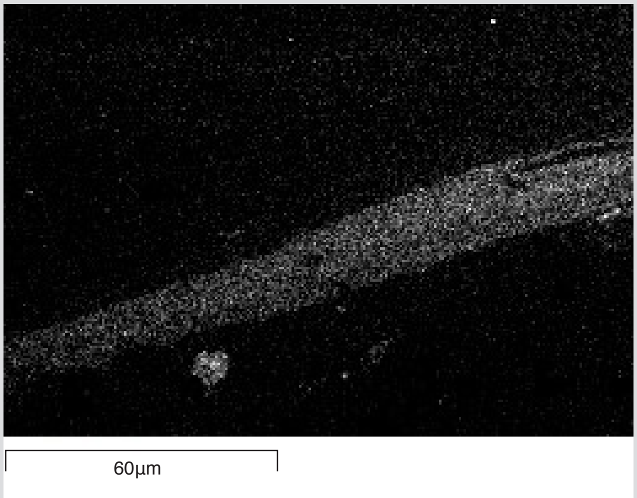


FIGURE 1.23C
Aluminum

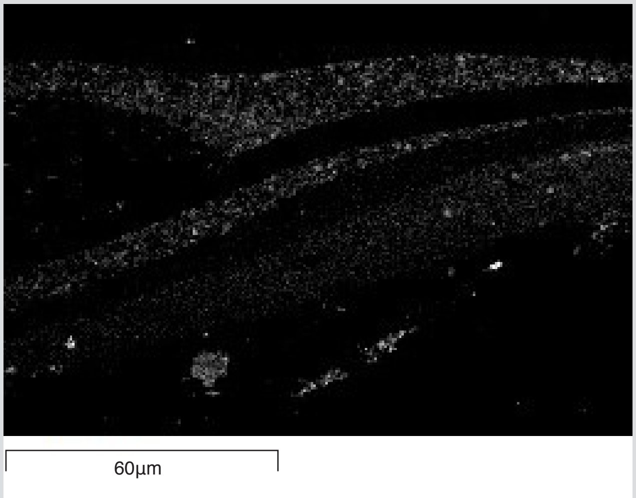


FIGURE 1.23D
Silicon

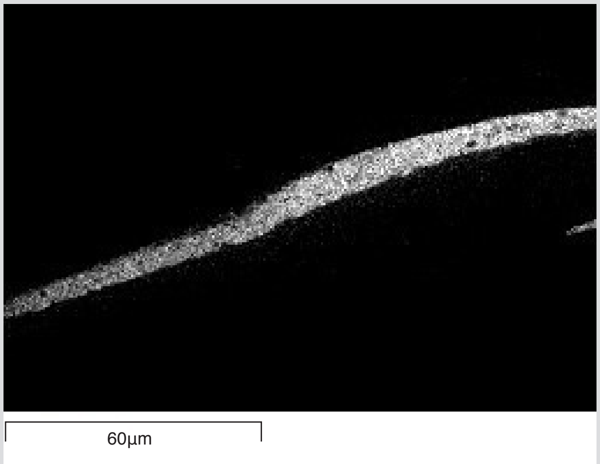


FIGURE 1.23E
Chlorine

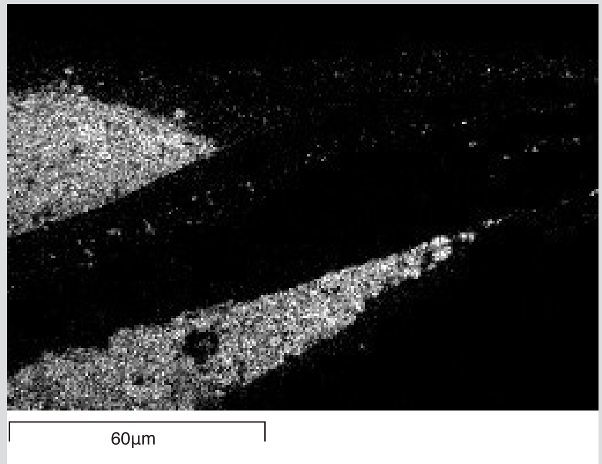


FIGURE 1.23F
Calcium

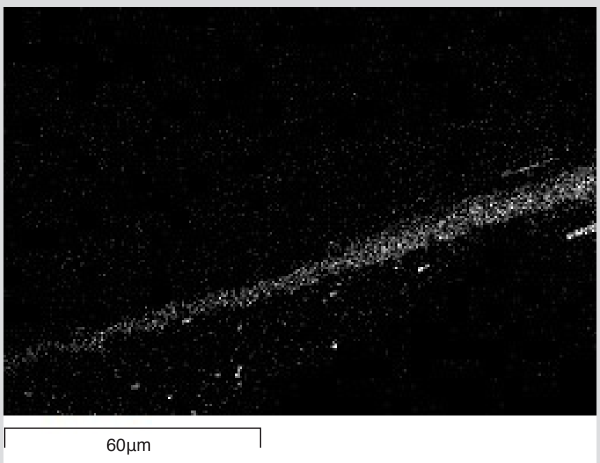


FIGURE 1.23G
Titanium

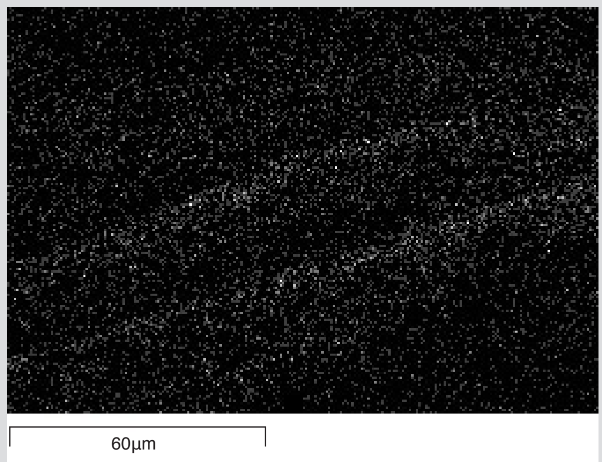


FIGURE 1.23H
Chromium

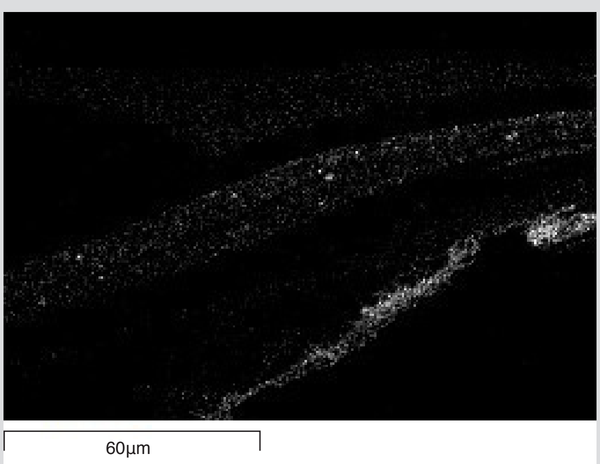


FIGURE 1.23I
Iron

(continued on next page)

1.6.12 Sample North Exterior_10 *(continued)*

High magnification optical and electron microscopy was performed on the lower strata of sample North Exterior_10 with a view to looking more closely at the correspondence with the lower layers of East Exterior_2b. A high magnification detail (100× objective) of sample North Exterior_10 is given in figure 1.24, which should be compared with figure 1.13a.

Medium gray paint layer #2 is composed of a mixture of white, red, blue-green, and yellow particles. The white particles are rich in titanium, indicative of titanium dioxide; the red particles are rich in iron (without Al or Si), indicative of synthetic iron oxide red; and the blue-green particles show coincident abundance of chromium and lead with some iron, which is indicative of chrome green (i.e., yellow

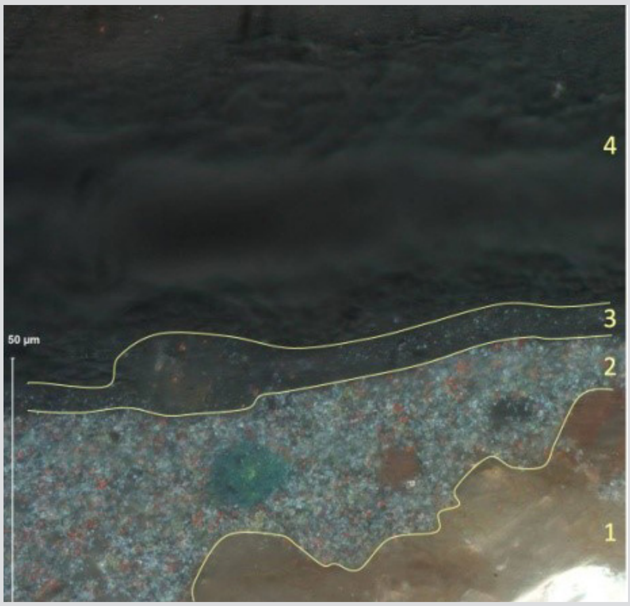


FIGURE 1.24
Cross section North Exterior_10 at high magnification. 100× objective

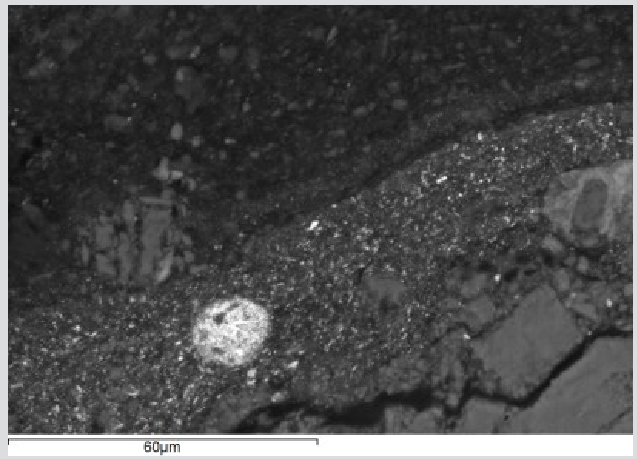


FIGURE 1.25A
Cross section North Exterior_10. Backscattered electron image.

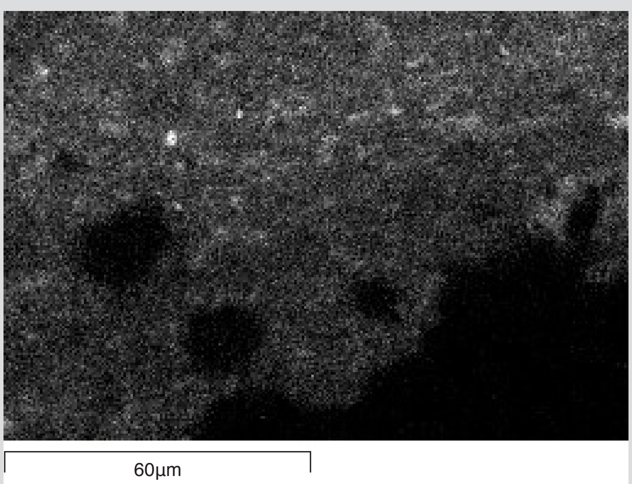


FIGURE 1.25B
Aluminum

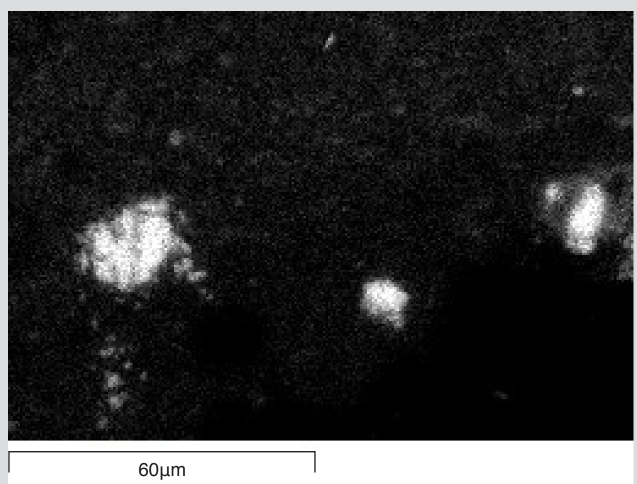


FIGURE 1.25C
Silicon

lead chromate with Prussian blue). Isolated particles of yellow, which are rich in lead and chromium, are probably yellow lead chromate as an independent pigment. The composition of paint layer #2 in sample North Exterior_10 is effectively the same as the corresponding layer in sample East Exterior_2b; they probably derive from the same campaign of painting. The same applies to the layer #3 above.

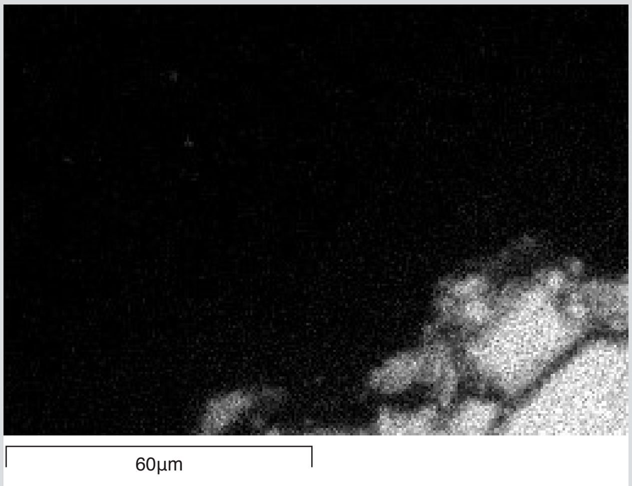


FIGURE 1.25D
Calcium

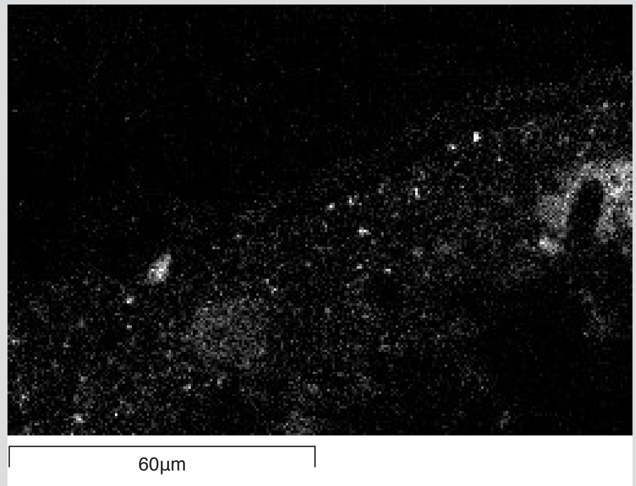


FIGURE 1.25E
Iron

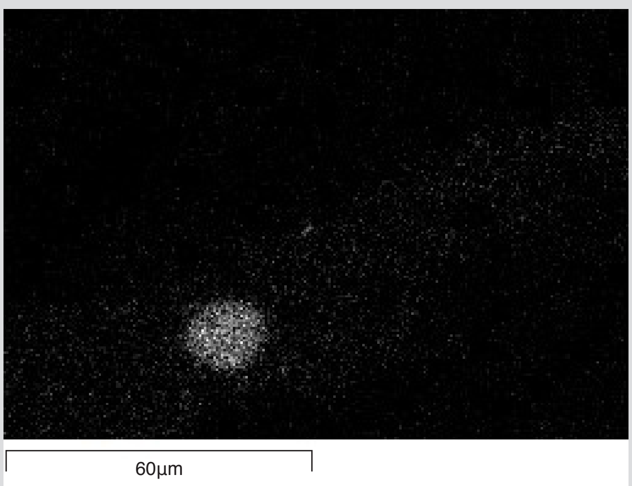


FIGURE 1.25F
Chromium

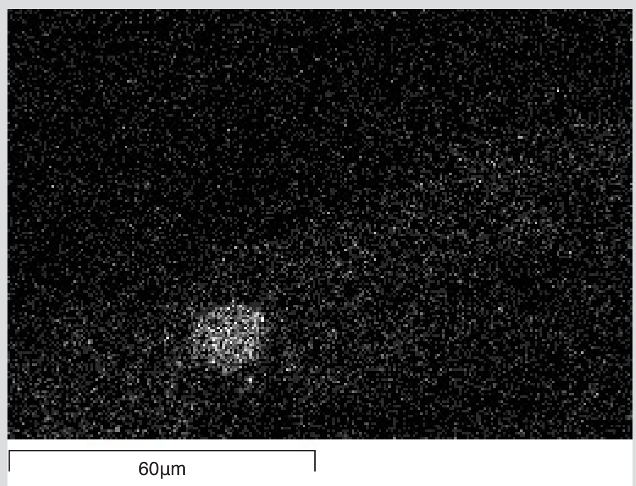


FIGURE 1.25G
Lead

1.6.13 Sample South Exterior_11

Sample of black paint taken from edge of loss on window frame shows the putty is failing. Three separate subfragments from the fragment selected as cross section. Uppermost Fragment A includes the paint layer(s); lower Fragments B and C are essentially putty material.

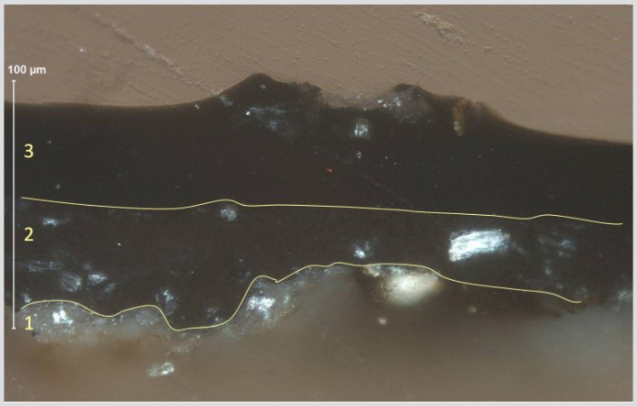


FIGURE 1.26A
Cross section South Exterior_11 Fragment A. Crossed polarizing filters. 50× objective. Annotated to show layer structure.

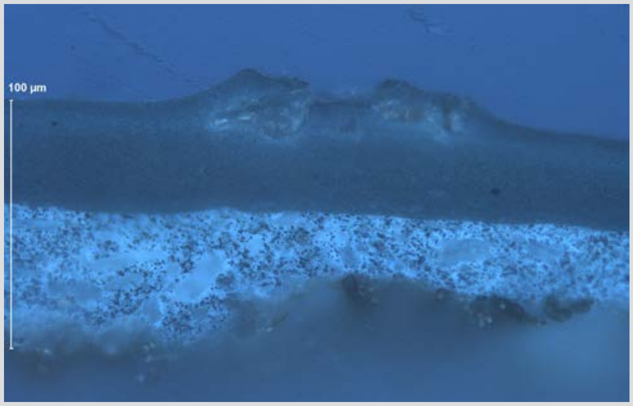


FIGURE 1.26B
Cross section North Exterior_11 Fragment A. UV fluorescence. 50× objective.

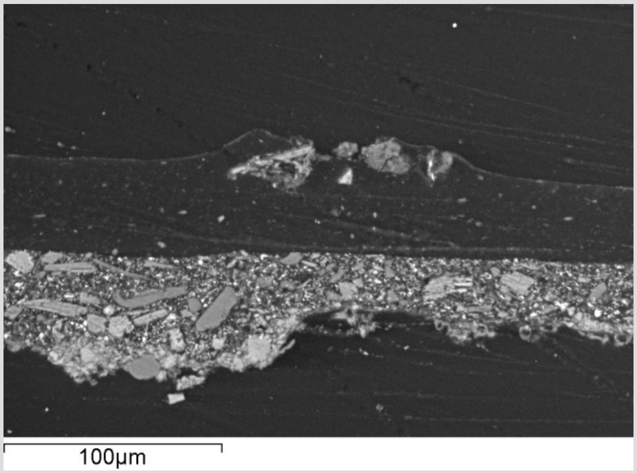


FIGURE 1.26C
Cross section South Exterior_11 Fragment A. Backscattered electron image.

1.6.14 South Exterior_11 Fragment A

TABLE 1.23
Description of cross section South Exterior_11 Fragment A.

Layer	Description	Observations / Types of pigment particles present
3	Dense black paint	Predominantly very fine black particles effectively imperceptible by optical microscopy; plus a few larger transparent colorless particles. Comparable with: layer #3 in sample East Exterior 1 layer #4 in sample East Exterior 2a layer #4 in sample East Exterior 3
2	Gray paint	Composed mostly of fine black particles and large transparent grains of a colorless extender. Some fine particles higher atomic mass material evident in ESEM backscattered electron images. Comparable with: layer #2 in sample East Exterior 1 layer #3 in sample East Exterior 2a layer #3 in sample East Exterior 3
1	Residue of putty	Particles: coarse transparent colorless grains.

Cross section South Exterior 11_Fragment A was analyzed by ESEM-EDS only using the elemental mapping function of the INCA analysis system. The main elemental maps are presented in figures 1.27a–1.27g.

The elemental distributions suggest the uppermost black paint layer #3 is mostly organic in composition, probably as carbon black. Gray paint layer #2 contains magnesium, silicon, iron and zinc, with the magnesium and silicon

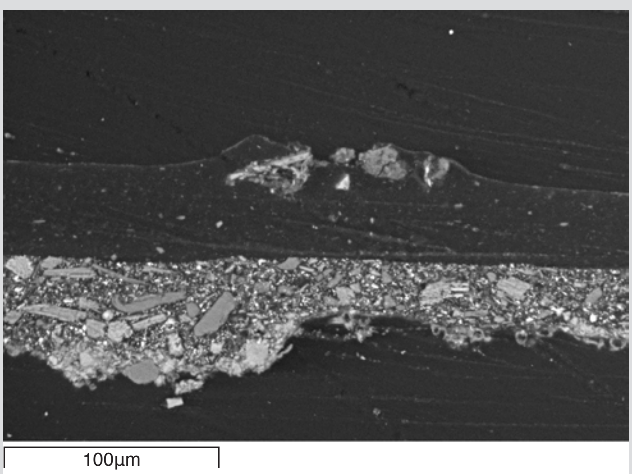


FIGURE 1.27A
ESEM-EDS of cross section South Exterior_11 Fragment A. Backscattered electron image.

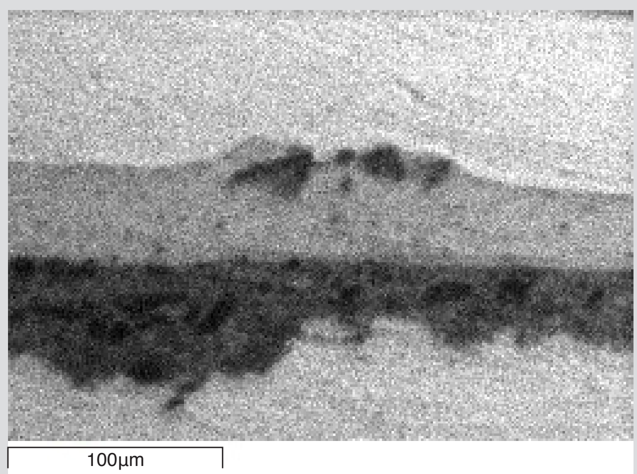


FIGURE 1.27B
Carbon

(continued on next page)

1.6.14 South Exterior_11 Fragment_A *(continued)*

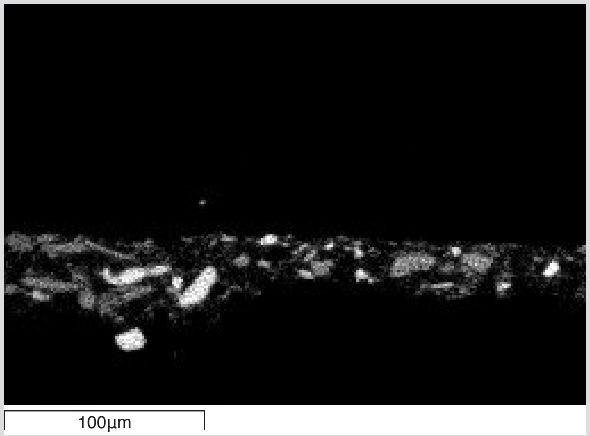


FIGURE 1.27C
Magnesium

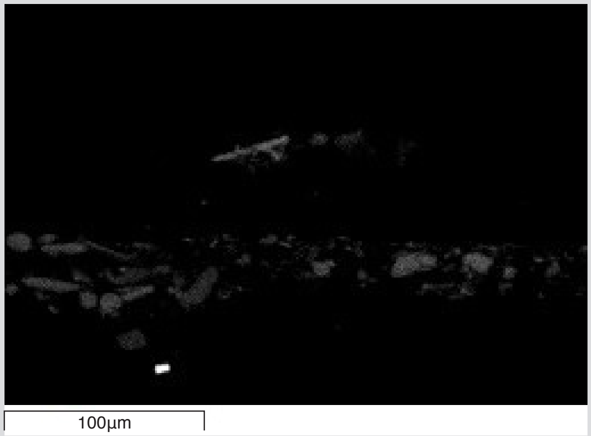


FIGURE 1.27D
Silicon

FIGURE 1.27E
Iron

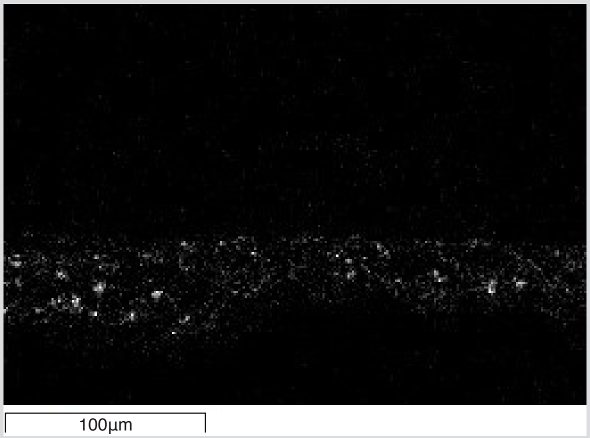


FIGURE 1.27F
Zinc

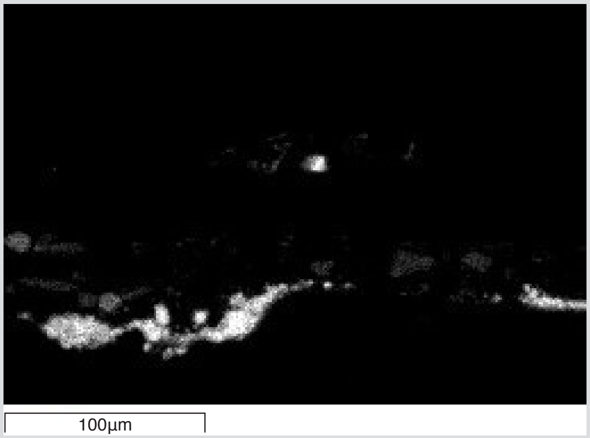


FIGURE 1.27G
Calcium

showing the kind of coincident abundance that is usually associated with talc. The iron may present as (possibly black) iron oxide, and the minor amount of zinc might suggest zinc oxide. Lowest putty layer #1 is abundant in calcium, probably in the form of calcium carbonate.

This stratigraphy is analogous to those observed in other samples of the exterior black paint, particularly East Exterior_1, East Exterior_2a, and East Exterior_3.

1.6.15 Description of Cross Section South Exterior_11 Fragment B

Fragment B of cross section sample South Exterior_11 comprises a detached fragment of putty (layer #1) that has isolated inclusions of red and black paint and corrosion products on its underside, and a thin surface layer (#2) of black or dark gray paint composed mostly of fine black organic particles, probably carbon black.

FIGURE 1.28A
Cross section South Exterior_11 Fragment B. Crossed polarizing filters. 10× objective + 1.5× magnifier (= 15×).

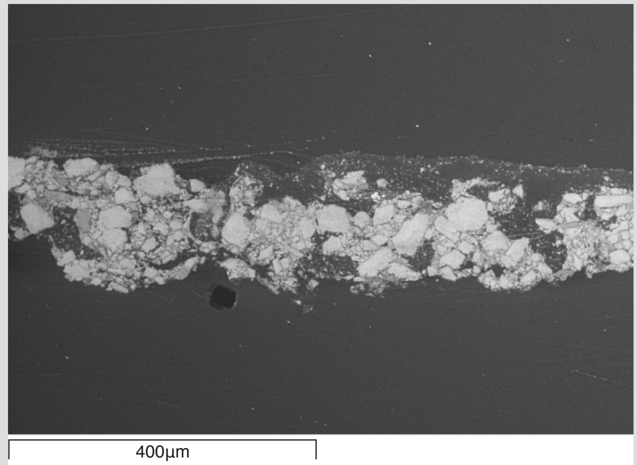


FIGURE 1.28B
Cross section South Exterior_11 Fragment B. Backscattered electron image.

1.6.16 Description of Cross Section South Exterior_11 Fragment C

Fragment C of cross section sample South Exterior_11 consists solely of white putty material composed of mostly of calcium carbonate, plus a minor proportion of calcium magnesium silicate.

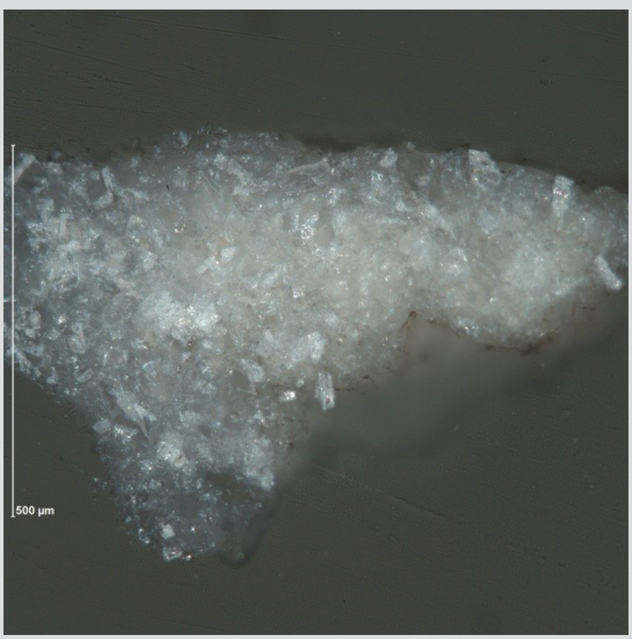


FIGURE 1.29A
Cross section South Exterior_11 Fragment C. Crossed polarizing filters. 10× objective + 1.5× magnifier (= 15×).

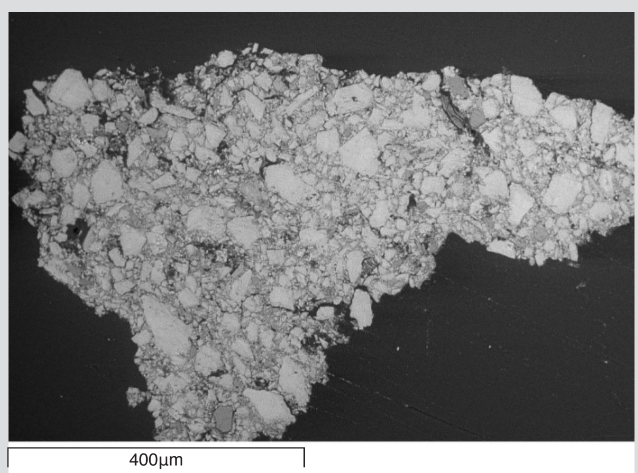


FIGURE 1.29B
Cross section South Exterior_11 Fragment C. Backscattered electron image.

1.6.17 Sample West Exterior_12

Blue paint from panel frame, possibly includes some caulk, taken from an edge of a repainted area.

Sample West Exterior_12 is difficult to interpret, in part due to the lack of a distinct layer sequence, discontinuous layers, and the presence of isolated domains of one material within another. These features are probably related to the particular location from where the sample originates, at the very edge of a painted blue panel at the boundary with the metal frame. A thick buildup of white material, pre-

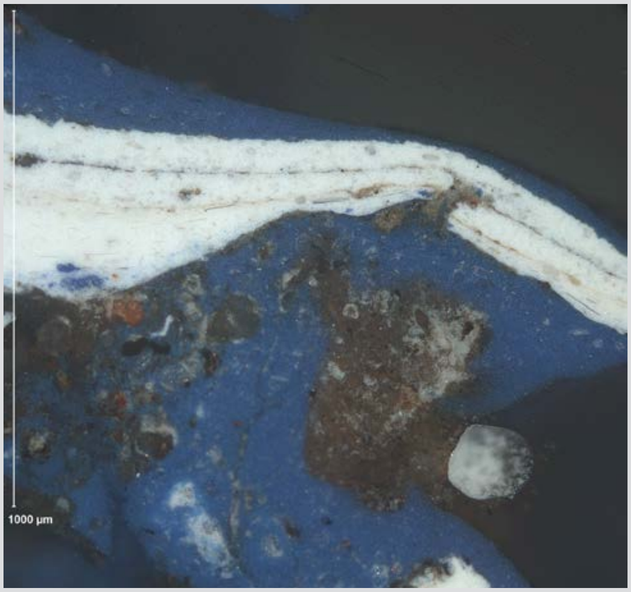


FIGURE 1.30A
Cross section West Exterior_12. Crossed polarizing filters. 10× objective.

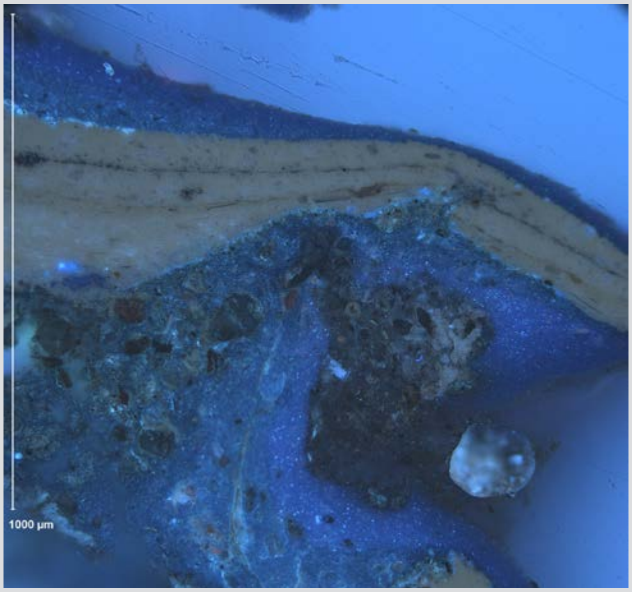


FIGURE 1.30B
Cross section West Exterior_12. UV fluorescence. 10× objective.

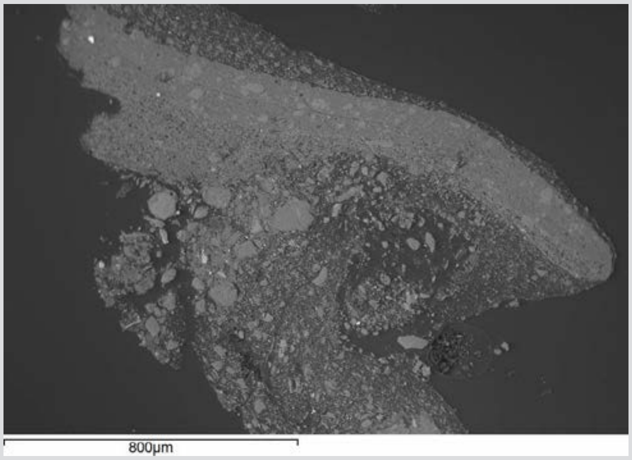


FIGURE 1.30C
Cross section West Exterior_12. Backscattered electron image.

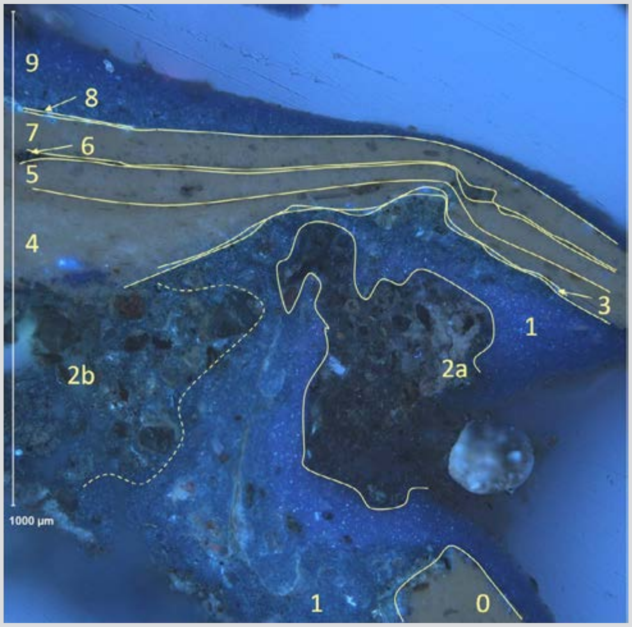


FIGURE 1.30D
Cross section West Exterior_12. UV fluorescence. 10× objective. Annotated to show layer structure.

TABLE 1.24
Description of cross section West Exterior_12.

Layer	Description	Observations / Types of pigment particles present
9	Blue paint	Possibly a continuation of layer #1
8	Thin, discontinuous vein of organic material	Fluorescent under UV illumination
7	white material, possibly caulk	Similar in appearance to layer #5. Contains also large transparent colorless particles.
6	Thin layer of dark material, possibly dirt	
5	white material, possibly caulk	Contains also large transparent colorless particles.
4	Fine-grained white material, possibly caulk	
3	Thin, discontinuous vein of organic material	Fluorescent under UV illumination
2	Isolated zones of coarse brownish material with whitish inclusions	Status uncertain
1	Blue paint	
0	Isolated inclusion of white material, possibly caulk	Possibly same material as layer #3, #5 or #7

sumed to be caulk, was noted at this location when the sample was taken. These considerations should be taken into account when reading the description of the sample that is outlined in table 1.24 (see fig. 1.30d).

Although presenting itself superficially as a superimposed layer, it appears that the uppermost zone of blue paint (#9) may be continuous with the blue paint of zone #1: these two zones, which appear to consist of similar paint, are almost connected at the extreme right of the sample, as seen here. Blue zones #1 and #9 are both similarly abundant in magnesium with silicon, which is suggestive of the presence of talc as an extender, and both contain zinc, possibly as zinc white (zinc oxide). The identity of the isolated zones (2a, 2b) of coarse brownish material with whitish inclusions within the blue paint (zone #1) remains obscure. They seemingly contain aluminosilicates. Three distinct layers (#4, #5, and #7) of opaque white material, possibly all caulk, are present in the sample, with a thin layer of dark material (#6), possibly dirt between the two upper white layers #5 and #7. All three white layers are abundant in titanium, which is indicative of titanium dioxide pigment, but both upper white layers #5 and #7 also contain particles that are abundant in calcium, probably as calcium carbonate. It is possible that layers #5 and #7 represent repeat applications of the same material. The layer (#0) of white material, occluded within blue paint layer #1 is probably an isolated part of one of the caulk layers #3, #5, or #7. Thin veins of unidentified fluorescent organic material (#3 and #8) can be seen above and below the white (caulk?) layers.

Cross section West Exterior_12 was analyzed by ESEM-EDS only using the elemental mapping function of the INCA analysis system. The main elemental maps are presented in figures 1.31a–1.31i.

In addition to the observations on pigment composition made in the preceding section, the main finding of the ESEM-EDS analysis is the lack of any elements that are indicative of any inorganic (mineral) blue pigments. Accordingly, an organic blue pigment is suspected as the colorant in layers #1 and #9.

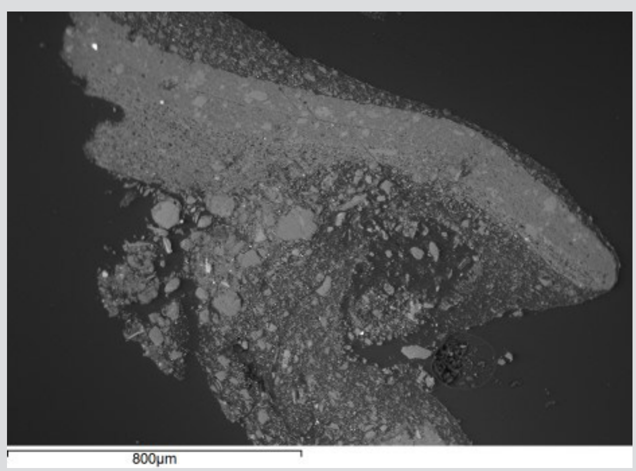


FIGURE 1.31A
Cross section West Exterior_12. Backscattered electron image.

(continued on next page)

1.6.17 Sample West Exterior_12 *(continued)*

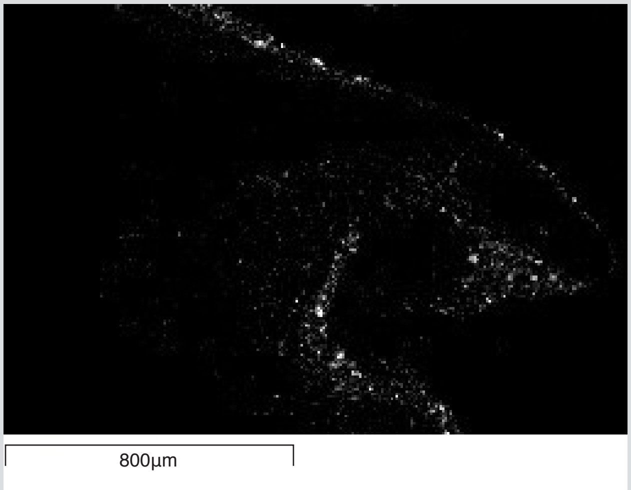


FIGURE 1.31B
Magnesium

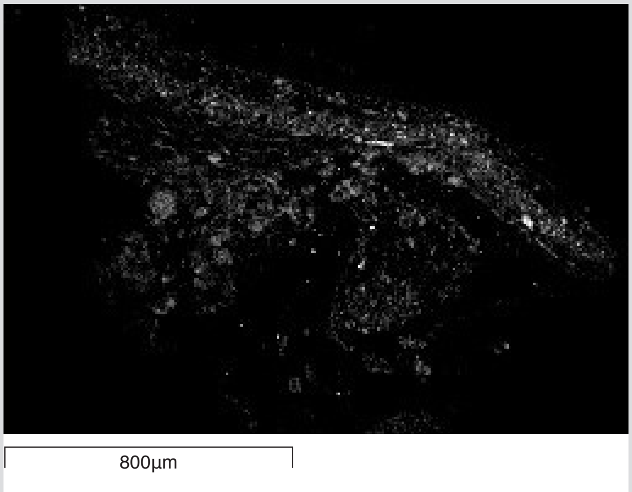


FIGURE 1.31C
Aluminum

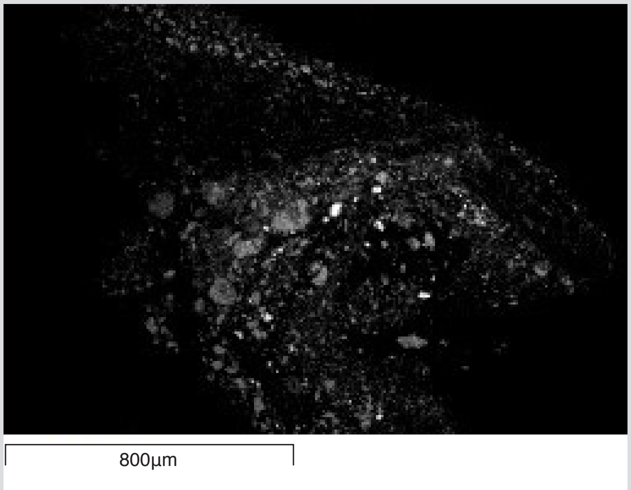


FIGURE 1.31D
Silicon

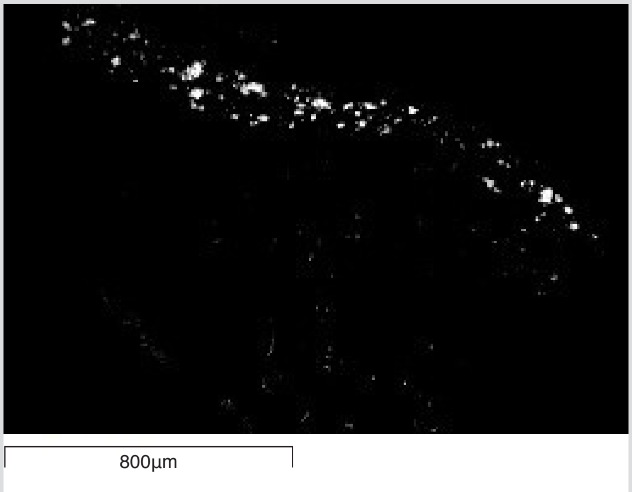


FIGURE 1.31E
Calcium

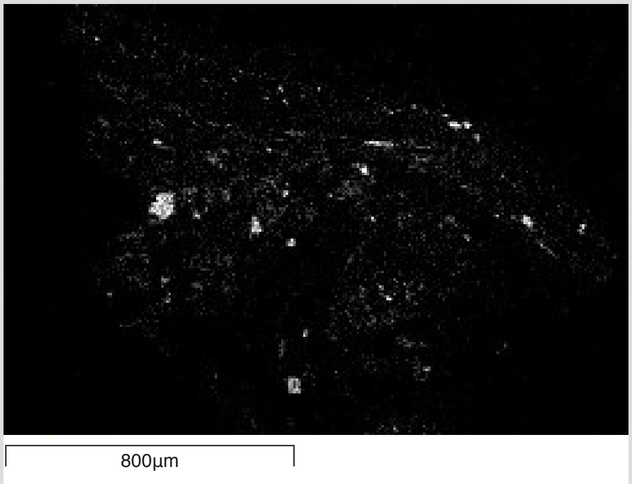


FIGURE 1.31F
Potassium

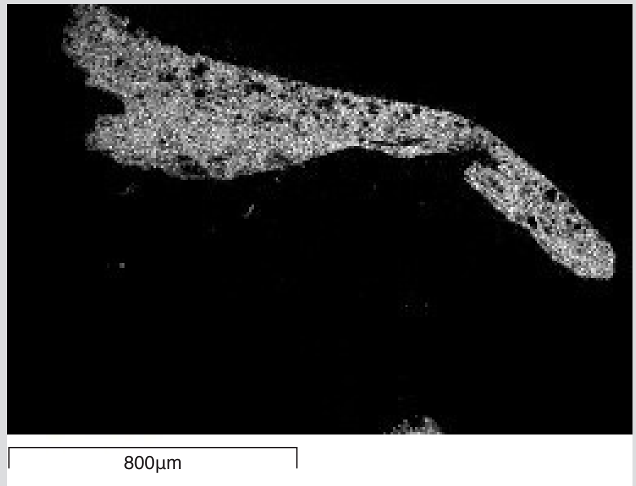


FIGURE 1.31G
Titanium

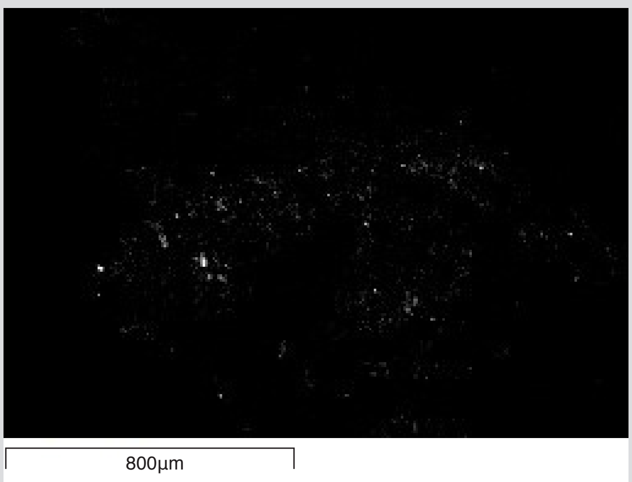


FIGURE 1.31H
Iron

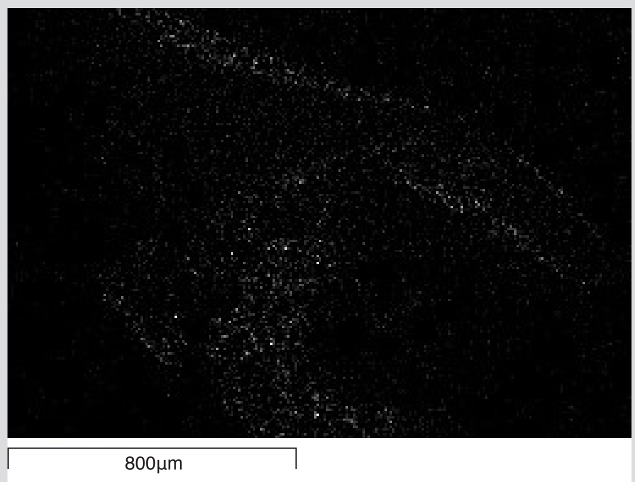


FIGURE 1.31I
Zinc

1.6.18 Sample West Exterior_13

Blue paint from edge of repainted area, possibly includes caulk.

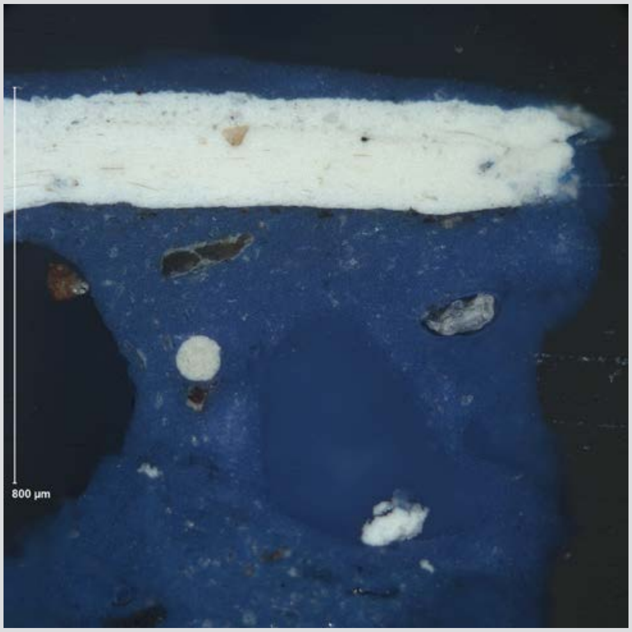


FIGURE 1.32A
Cross section West Exterior_13.Crossed polarizing filters. 10× objective.

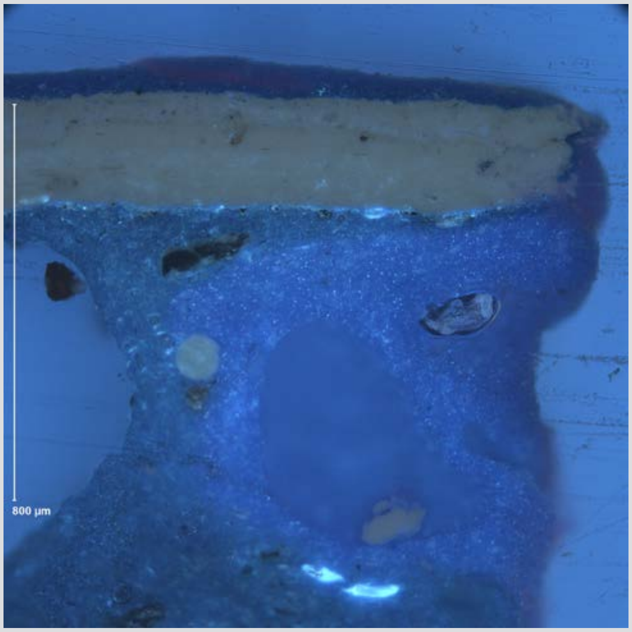


FIGURE 1.32B
Cross section West Exterior_13.UV fluorescence. 10× objective.

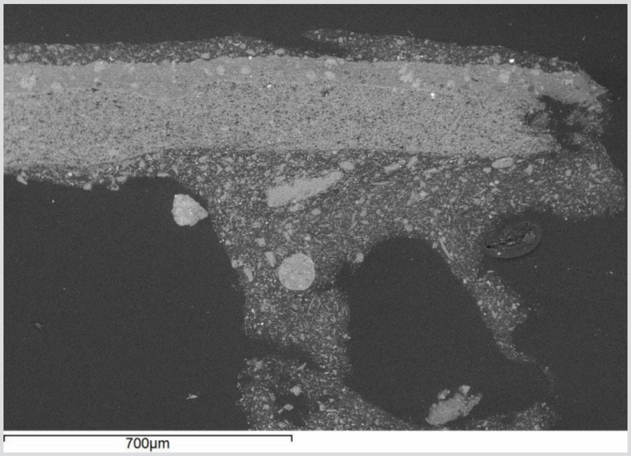


FIGURE 1.32C
Cross section West Exterior_13. Backscattered electron image.

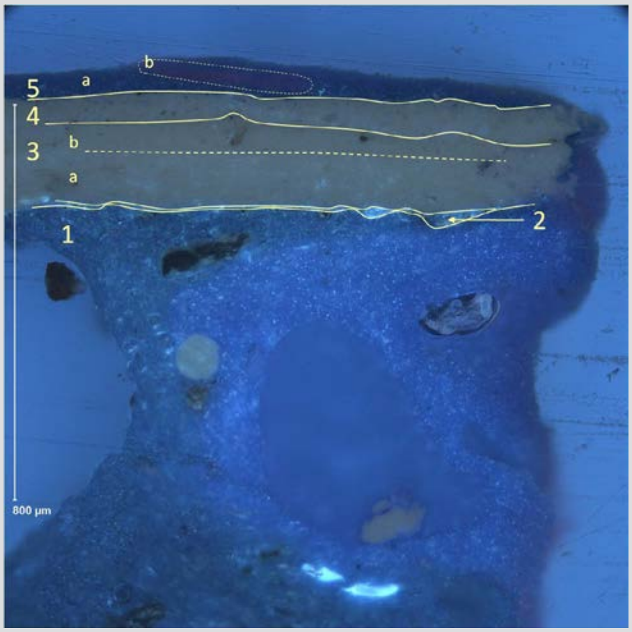


FIGURE 1.32D
Cross section West Exterior_13. UV fluorescence. 10× objective. Annotated to show layer structure.

Cross section sample West Exterior_13 shares several common features with sample West Exterior_12. As in the preceding sample, West Exterior_13 shows two layers of blue paint (#1 and #5) that have essentially the same elemental composition. In both cases, no elements are

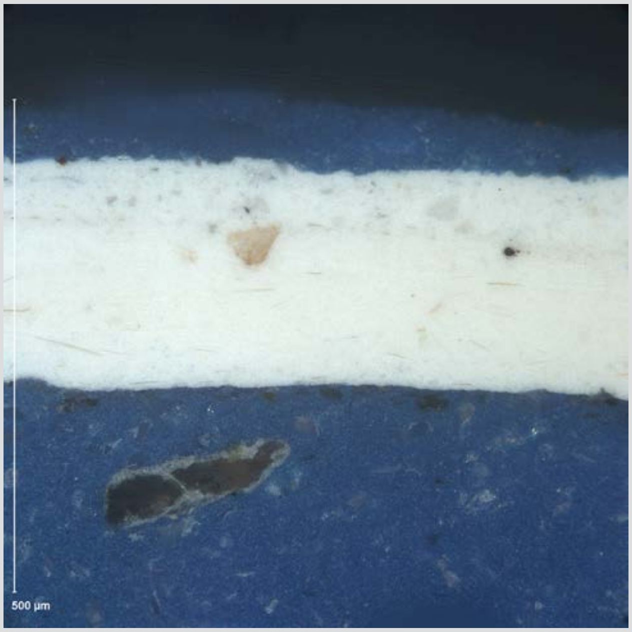


FIGURE 1.32E
Cross section West Exterior_13; Crossed polarizing filters. 20× objective.

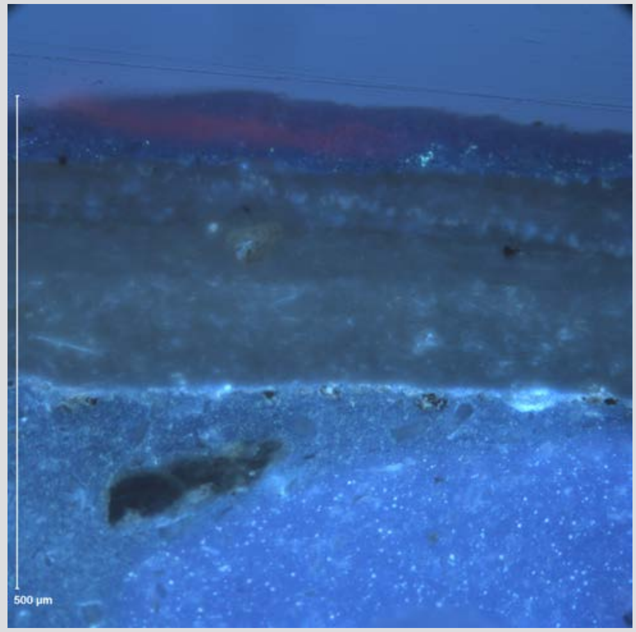


FIGURE 1.32F
Cross section West Exterior_13. UV fluorescence. 20× objective.

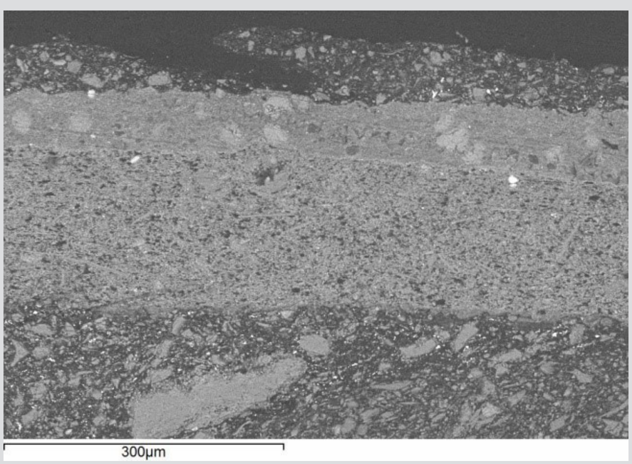


FIGURE 1.32G
Cross section West Exterior_13. Backscattered electron image.

present which would indicate an inorganic blue pigment; therefore, an organic blue colorant is suspected. Both blue paint layers are abundant in transparent colorless particles of an extender pigment. At the upper surface of the lower blue paint is a thin vein of organic material, strongly fluorescent under UV, the status of which is uncertain. Two dense white layers #3 and #4, follow, both of which may be caulk. These differ slightly in conformation: the upper layer #4 includes large transparent colorless particles in addition to fine opaque white; lower layer #3 appears to correspond with the lowest caulk layer #4 in sample West Exterior_12, while upper caulk layer #4 of West Exterior_13 corresponds with one or other of layers #5 and #7 of the preceding sample. The unidentified, unusual red-fluorescent feature (#5b) in upper blue paint layer #5 is carbon-rich (i.e., organic) and may represent an aggregate of organic colorant.

1.6.18 Sample West Exterior_13 *(continued)*

TABLE 1.25

Description of cross section West Exterior_13.

Layer	Description	Observations / Types of pigment particles present
5	Blue paint	Includes a zone (#5b) that shows distinct reddish fluorescence under UV illumination.
4	white material, possibly caulk	Contains also larger transparent colorless particles
3	Fine-grained white material, possibly caulk	Two substrata evident under UV illumination: upper substratum #3b shows weaker fluorescence. Layer #3, however, appears to represent a single application of material.
2	Thin, discontinuous vein of organic material	Fluorescent under UV illumination
1	Blue paint	

TABLE 1.26

ESEM-EDS of cross section West Exterior_13.

Layer	Description	Elements	Inferences
5	Blue paint	Mg, *Al,* **Si,** *Ca, Ti, (Zn)*	silica❖ organic blue colorant✸
4	white material, possibly caulk	*(Mg),* Al, **Si,** *K,* Ca **Ti,** *(Zn)*	Titanium dioxide Aluminosilicates Calcium carbonate★
3	Fine-grained white material, possibly caulk	*(Mg),* Al, **Si,** *K, (Ca)* **Ti,** *(Zn)*	Titanium dioxide aluminosilicates
2	Thin, discontinuous vein of organic material	Not analyzed	–
1	Blue paint	Mg, *Al,* **Si,** *Ca, Ti,*	silica❖ organic blue colorant✸

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table
❖ indicated by coincident abundance of Si and O.
✸ indicated by absence of elements characteristic of inorganic blue pigments.
★ indicated by dominant abundance of Ca in single particles.

1.6.19 Sample West Exterior_14

Loose fragment from edge of loss in black paint on metal frame.

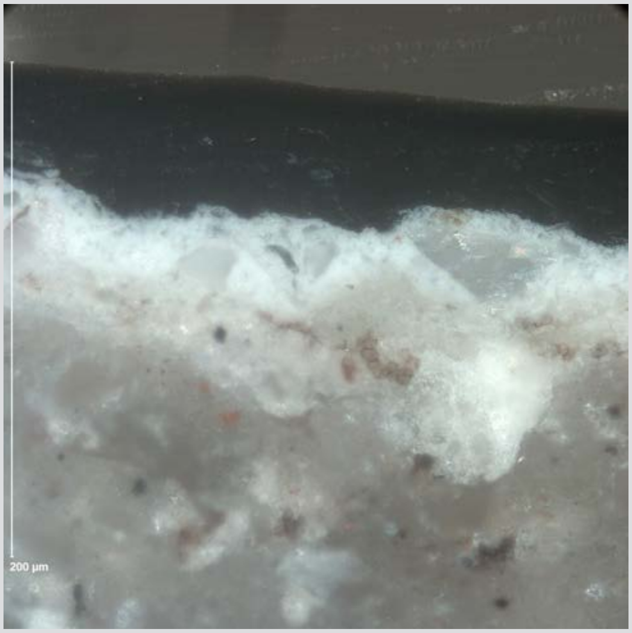


FIGURE 1.33A
Cross section West Exterior_14; Crossed polarizing filters. 50× objective.

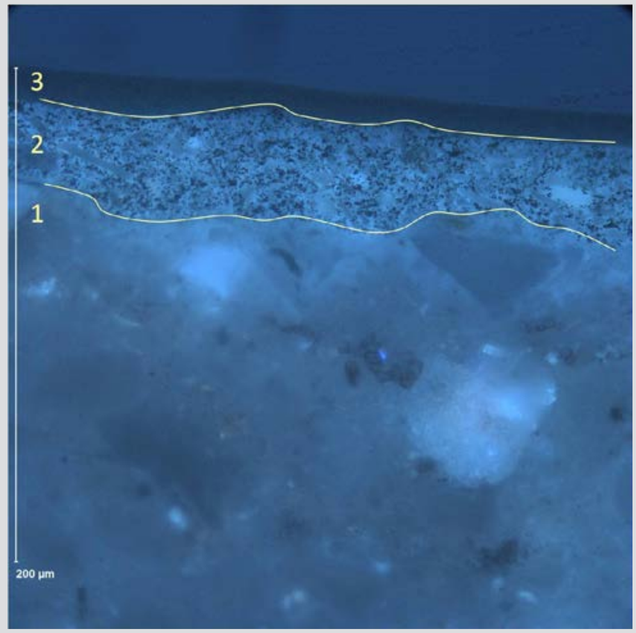


FIGURE 1.33B
Cross section West Exterior_14. UV fluorescence. 50× objective. Annotated to show layer structure.

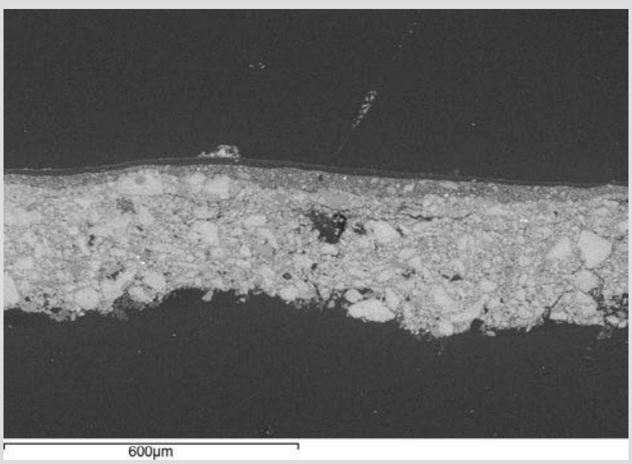


FIGURE 1.33C
Cross section West Exterior_14. Backscattered electron image.

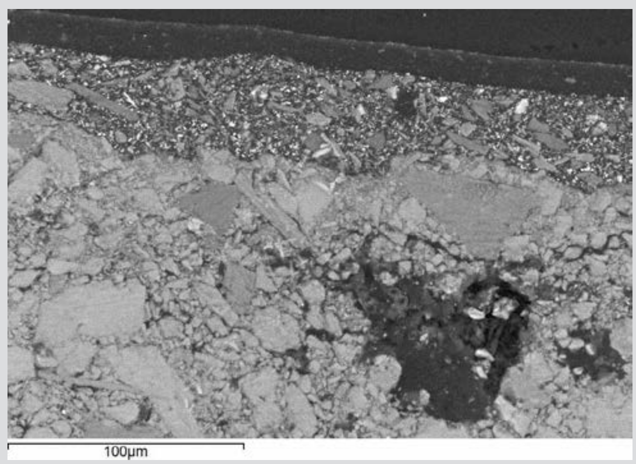


FIGURE 1.33D
Cross section West Exterior_14. Backscattered electron image.

Cross section sample West Exterior_14 has a simple stratigraphy that is essentially the same as East Exterior_2a, East Exterior_3, and South Exterior_11 Fragment A, with similarities also to sample East Exterior_1. The layer structure, accordingly, is described in table 1.27 and table 1.28.

(continued on next page)

1.6.19 Sample West Exterior_14 *(continued)*

TABLE 1.27
Description of cross section West Exterior_14.

Layer	Description	Observations / Types of pigment particles present
3	Dense black paint	Predominantly very fine black particles effectively imperceptible by optical microscopy; plus a few larger transparent colorless particles. Comparable with: layer #3 in sample East Exterior_1 layer #4 in sample East Exterior_2a layer #4 in sample East Exterior_3 layer #3 in sample South Exterior_11:A
2	Gray paint	Composed mostly of fine black particles and large transparent grains of a colorless extender. Some fine particles higher atomic mass material evident in ESEM backscattered electron images. Comparable with: layer #2 in sample East Exterior_1 layer #3 in sample East Exterior_2a layer #3 in sample East Exterior_3 layer #2 in sample South Exterior_11:A
1	Bright white putty	Particles: coarse transparent colorless grains.

TABLE 1.28
ESEM-EDS of cross section West Exterior_14.

Layer	Description	Elements	Inferences
3	Dense black paint	Predominantly organic (C + O), with *(Na), (Mg), Al, Si, (Cl), Ca, (Fe)*	**Carbon black** Magnesium and aluminum silicates
2	Gray paint	*(Na),* **Mg,** *Al,* **Si,** *P, (Cl), Ca, Fe, (Zn)*	**Carbon black** **Talc** Minor amount iron oxide (black?) Trace zinc oxide
1	Bright white putty	*Mg, Al, Si, (Cl),* **Ca,** *(Ti)*	**Calcium carbonate** with some dolomite

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.*
These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.6.20 Sample West Exterior_15

Metallic paint at location of impact damage site on silver-painted panel. Sample also includes some of the underlying panel material.

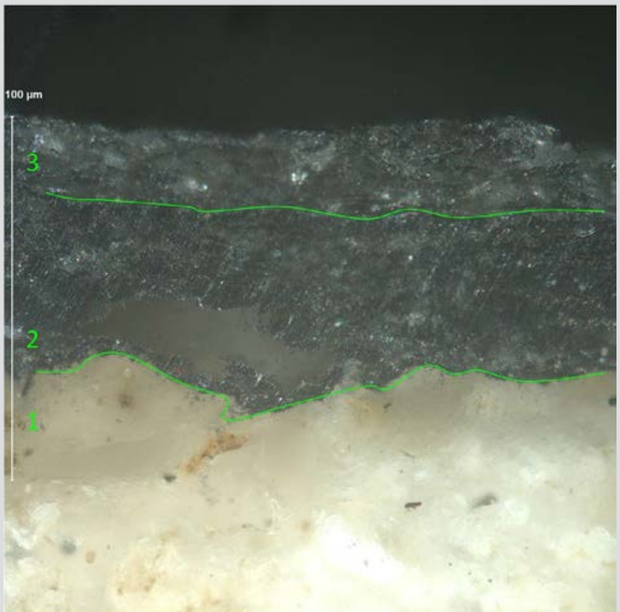


FIGURE 1.34A
Cross section West Exterior_15; Crossed polarizing filters. 50× objective + 1.5× magnifier (= 75×). Annotated to show layer structure.

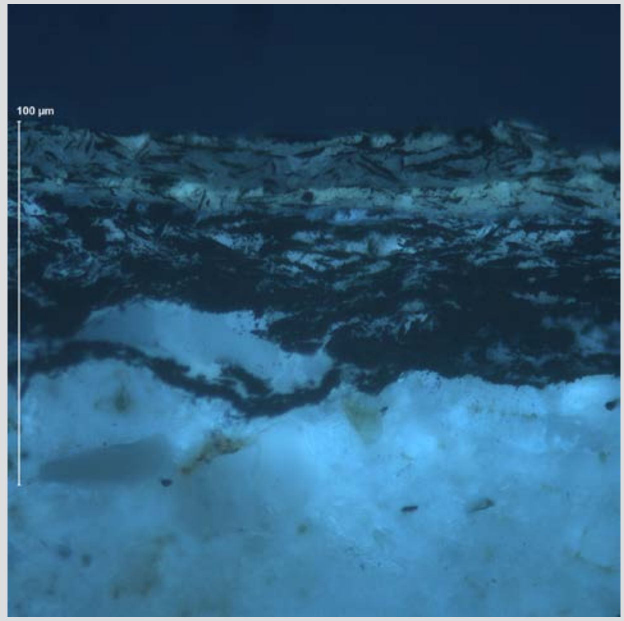


FIGURE 1.34B
Cross section West Exterior_15. UV fluorescence. 50× objective + 1.5× magnifier (= 75×).

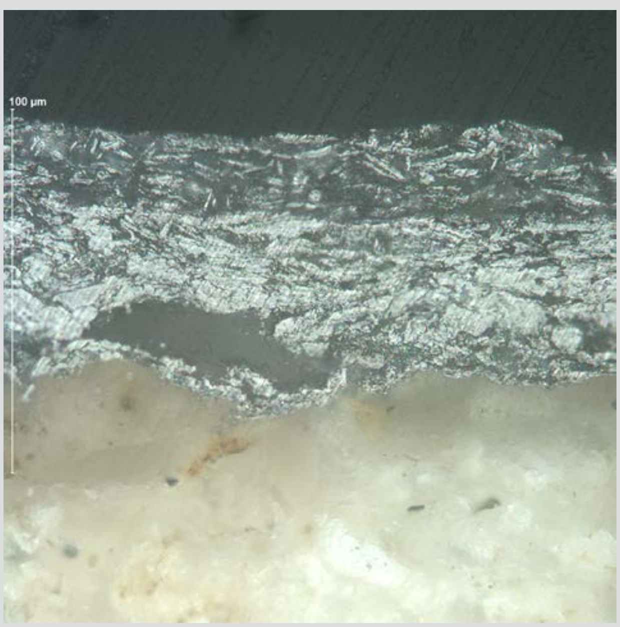


FIGURE 1.34C
Cross section West Exterior_15; Partially uncrossed polarizing filters. 50× objective + 1.5× magnifier (= 75×).

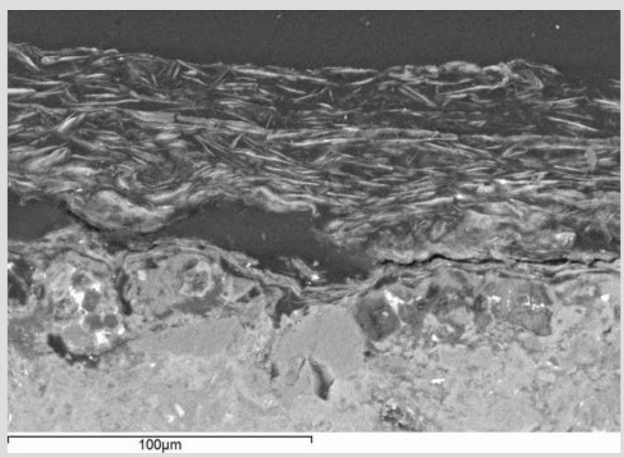


FIGURE 1.34D
Cross section West Exterior_15. Backscattered electron image.

Cross section sample West Exterior_15 shows a relatively simple stratigraphy as follows:

The lowest layer #1 in the sample is the material of the panel, which is composed of calcium magnesium silicate(s),

(continued on next page)

1.6.20 Sample West Exterior_15 *(continued)*

possibly asbestos. Two metallic paint layers are present, both similarly composed of aluminum flakes. Upper metallic paint layer #3 is slightly less densely packed with metallic particles than lower layer #2, and also shows a stronger fluorescence under UV. Whether the two metallic paint layers derive from the same painting campaign or represent a repainting of the panel cannot be determined from the evidence within the sample.

TABLE 1.29
Description of cross section West Exterior_15.

Layer	Description	Observations / Types of pigment particles present
3	Silver-colored metallic paint	Composed of metal flakes with a generally horizontal orientation.
2	Silver-colored metallic paint	Composed of metal flakes with a generally horizontal orientation.
1	Material of panel substrate; off-white in color	

TABLE 1.30
ESEM-EDS of cross section West Exterior_15.

Layer	Description	Elements	Inferences
3	Silver-colored metallic paint	*Mg,* **Al,** *Si, Ca*	Aluminum metal
2	Silver-colored metallic paint	*Mg,* **Al,** *Si, Ca*	Aluminum metal
1	Material of panel substrate; off-white in color	Mg, Al, **Si,** *S*, **Ca,** *Fe*	Calcium/magnesium silicate(s)

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.7 Analysis of Archival Samples of Painted Putty Reportedly Detached as a Consequence of 1994 Northridge Earthquake

The large samples taken from a container filled with putty fragments have a slightly different appearance—lighter and darker putty colors—probably from different putty campaigns. Two large putty fragments, respectively Eames House_putty#1a and Eames House_putty#1b, were collected, and samples from each were mounted as cross sections. Whether the samples of painted putty derive from the interior or exterior of the building is not indicated in any way on the box of material. Of these two main fragments, Eames House_putty#1b is the more informative in terms of stratigraphy, and the observations on that fragment only are reported here.

FIGURE 1.35A
Container of putty fragments from the Eames House residence or studio dated detached during the Northridge earthquake, 1994.

FIGURE 1.35B
Putty fragments detail.

Sample Eames House_putty#1b

Some variability within fragment Eames House_putty#1b was evident. Accordingly, two separate subfragments—Eames House_putty#1b-1 and Eames House_putty#1b-2—were prepared as cross sections in order to accommodate the internal variability of the larger stock fragment. Of the two subfragments, sample Eames House_putty#1b-1 has the fuller stratigraphy, and includes two light gray primers. There is sufficiently good correspondence between the paint layer structures of the two detached putty fragments, and also with sample North Exerior_10 (see fig. 1.51 in sect. 1.10.1 below), to indicate that the fragments come from the exterior metalwork of the house.

1.7.1 Sample Eames House_putty#1b-1

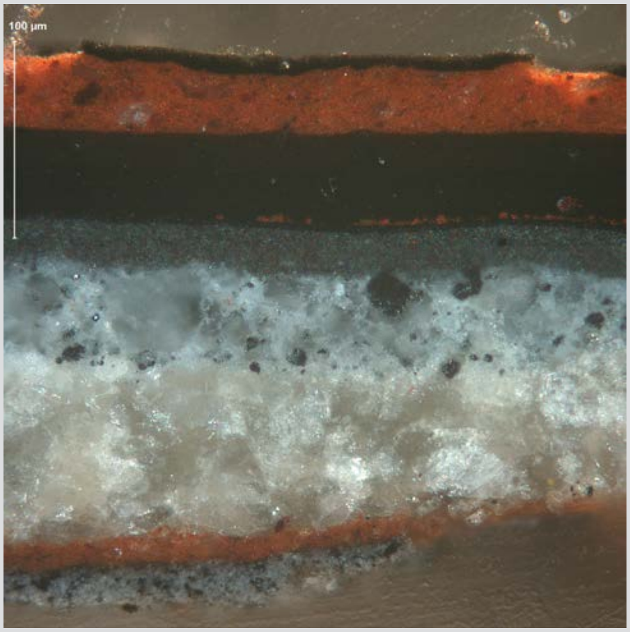


FIGURE 1.36A
Cross section Eames House_putty#1b-1; partially uncrossed polarizing filters. 40× objective.

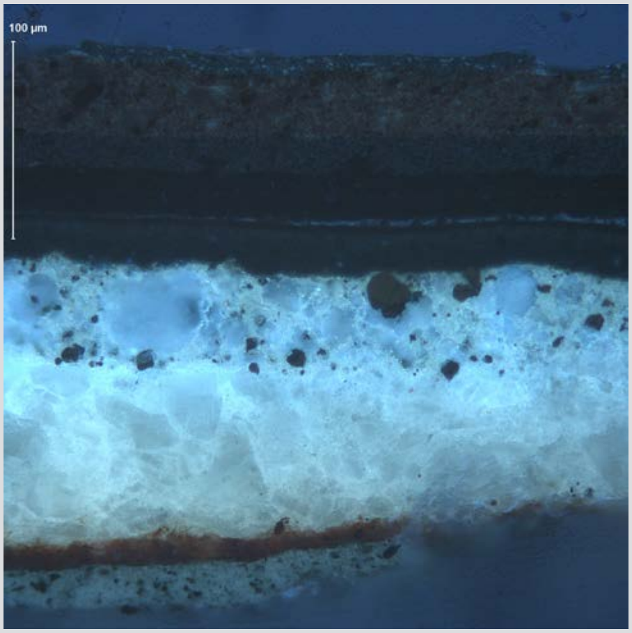


FIGURE 1.36B
Cross section Eames House_putty#1b-1. UV fluorescence. 40× objective.

1.7.2 Sample: Eames House_putty#1b-2

FIGURE 1.37A
Cross section Eames House_putty#1b-2; partially uncrossed polarizing filters. 10× objective.

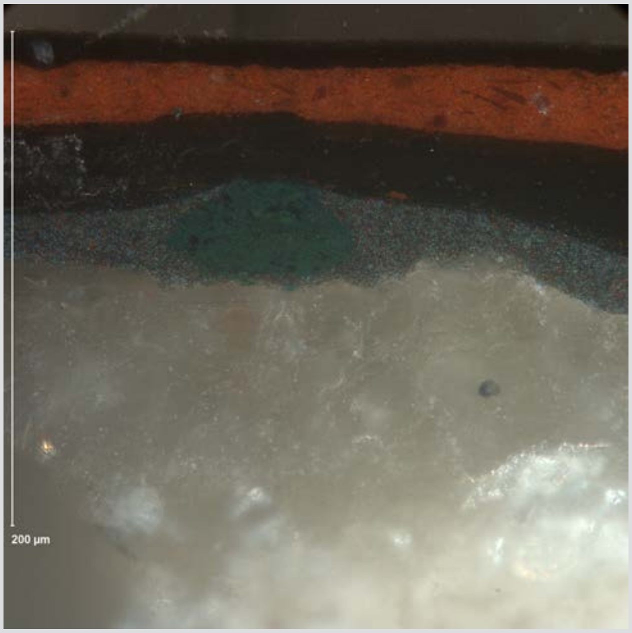


FIGURE 1.37B
Cross section Eames House_putty#1b-2; partially uncrossed polarizing filters. 50× objective.

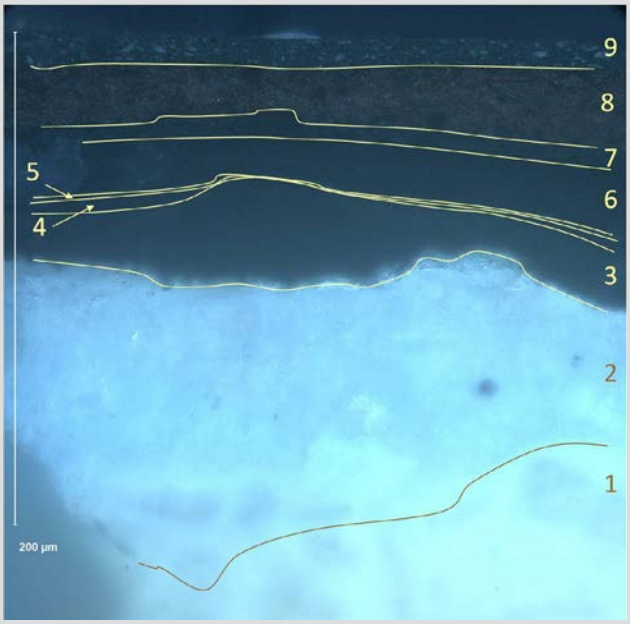


FIGURE 1.37C
Cross section Eames House_putty#1b-2; UV fluorescence. 50× objective.

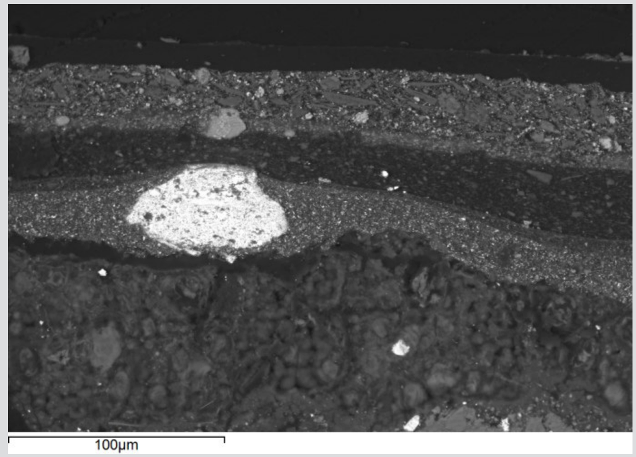


FIGURE 1.37D
Cross section Eames House_putty#1b-2. Backscattered electron image.

TABLE 1.31
Description and ESEM-EDS of cross section Eames House_putty#1b-2.

Layer	Description	Elements	Inferences
9	Fine-grained black or dark gray paint. Contains particles that fluoresce under UV.	**C,** *(Mg), Al, Si, (S), Cl Ca, (Ti), Fe, (Zn)*	Predominantly organic (carbon black)
8	Red primer	**Mg,** Al, **Si,** *(P), (S), Cl* Ca, *(Ti), (Cr),* Fe, *Zn,*	Iron oxide talc calcium carbonate
7	Dark brown paint (or mastic?).	*(Mg),* Al, Si, *(S),* **Cl** *Ca, (Ti),* Fe, *(Zn)*	Chlorine-rich
6	Dark gray or black paint. Includes large colorless particulates.	*(Mg),* **Al, Si,** *(S),* Cl *Ca, Ti, (Fe, Zn,*	**Aluminosilicates** (carbon black)
5	Unpigmented fluorescent organic medium	–	–
4	Thin, dark gray paint.	*(Mg),* **Al, Si,** *(S), Cl Ca, Ti, (Cr), Fe, Zn,*	Aluminosilicates Trace itanium dioxide Trace red iron oxide Zinc chromate or oxide??
3	Mixed gray paint with large aggregate of blue green pigment. Particulates: opaque white; transparent colorless; red; blue-green; possibly yellow.	**Al, Si,** *Cl Ca,* Ti, *Cr, Fe, Zn, Pb*	Aluminosilicates Titanium dioxide Red iron oxide Chrome green (lead chromate + Prussian blue)❖
2	Putty or primer	**Zn**, Ca (slight traces of *Mg, Al, Si, S, Cl, Ti, Cr and Fe)*	Deteriorated zinc primer?
1	Putty	Calcium-rich	Probably calcium carbonate

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table
❖ Indicated by coincident abundance, in large blue-green aggregate, of lead, chromium and iron.

1.8 Analysis of Painted Reference Plates

The Eames House archives include a series of painted plates that reportedly correspond with various painting interventions at the residence and/or studio. Samples from the painted plates were taken for analysis and for comparison with findings on samples from the residence itself. Although dated, it is not wholly clear when the various plates were prepared and from what paint stock. The paint layers on Plates #4 through 7 are extremely thin and difficult to prepare as cross sections for optical microscopy. Paint from Plate #6 was so thin as to prevent preparation altogether.

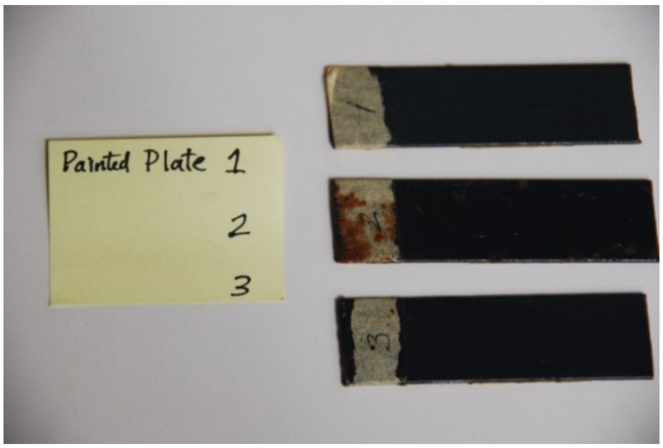


FIGURE 1.38A
Painted Plates #1–3, recto

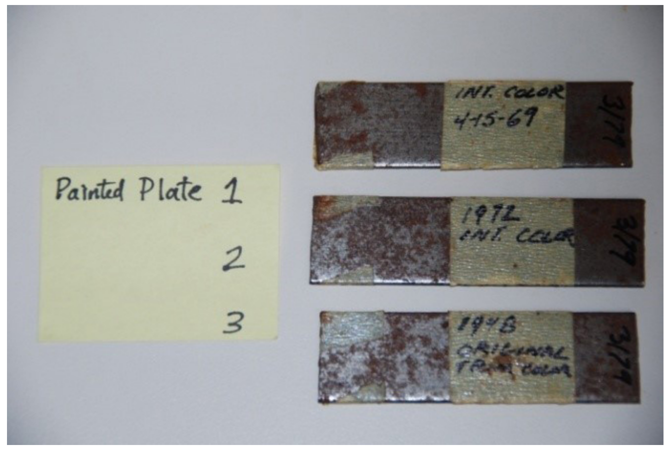


FIGURE 1.38B
Painted Plates #1–3, verso

1.8.1 Painted Plate #1.

Description on plate (see fig. 1.38b): Int. Color 4-15-69

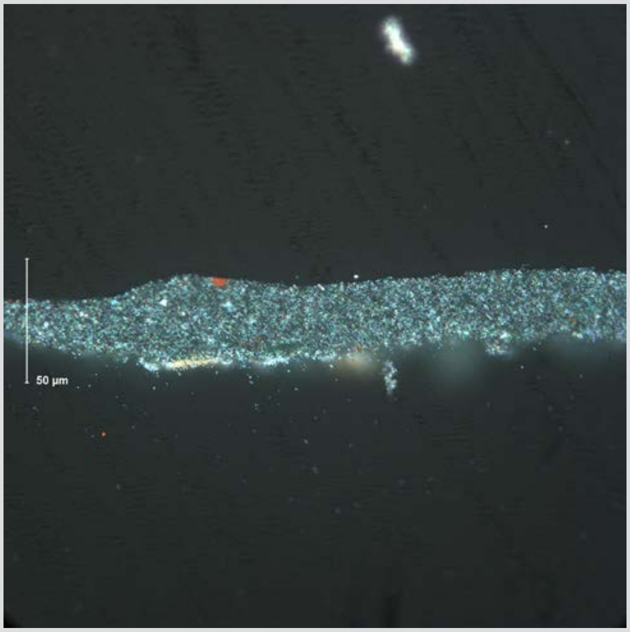


FIGURE 1.39A
Cross section Plate #1; Crossed polarizing filters. 50× objective + 2× magnifier (= 100×).

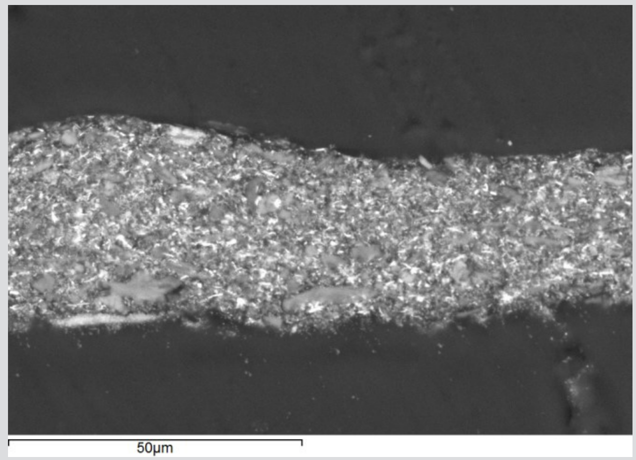


FIGURE 1.39B
Cross section Plate #1. Backscattered electron image.

The combination of optical and electron microscopy indicates that the pigment is composed of titanium dioxide, talc, aluminosilicates, red iron oxide, and lead chromate. The blue-green colorant is not clearly identified by the ESEM-EDS analyses, but it may be chrome green, that is, a preparation of yellow lead chromate and Prussian blue (ferric ferrocyanide), the latter pigment possibly contributing to the ESEM-EDS signal detected for iron. A notable occurrence in this paint is the presence of at least two colorless extender substances including talc (hydrated magnesium silicate) and an aluminosilicate mineral.

Summary: mixed gray with abundant talc.

TABLE 1.32
Eames House_ Plate #1 summary of composition.

Description	Elements	Inferences
Eames House_ Plate #1 is a mixed gray paint composed mostly of very fine particles: opaque white; orange-red; and blue-green; possibly also with some opaque yellow and very fine black. Some larger transparent colorless particles are also present.	*(Na),* Mg, Al, **Si,** *(P), Cl, (K), (Ca),* **Ti,** *Cr, Fe, Pb*	Titanium dioxide ❖ talc ✠ aluminosilicates ✦ Red iron oxide ✶ Lead chromate

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table:
❖ Indicated by coincidence of magnesium and silicon.
✠ Indicated by coincidence of aluminum and silicon.
✦ Indicated by localized abundance of Fe in red particles/aggregates.
✶ Indicated by coincidence of lead and chromium by mapping and in single particle analyses.

1.8.2 Painted Plate #2.

Description on plate (see fig. 1.38b): 1972 Int. Color

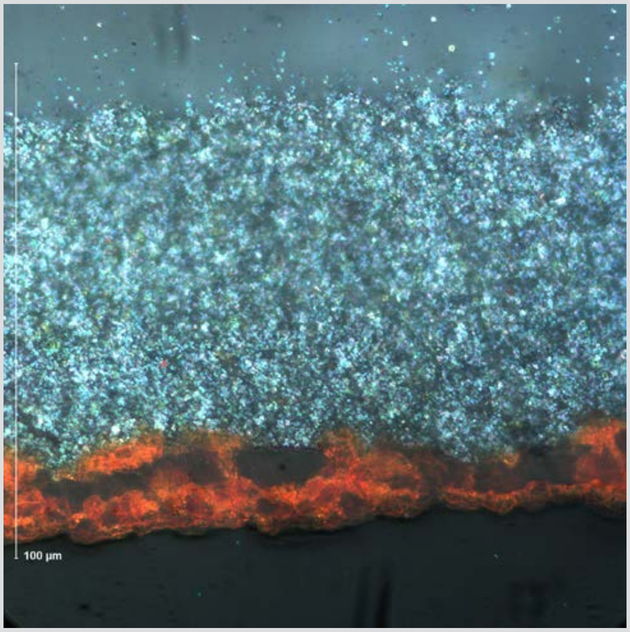


FIGURE 1.40A
Cross section Plate #2. Crossed polarizing filters. 50× objective + 2× magnifier (= 100×).

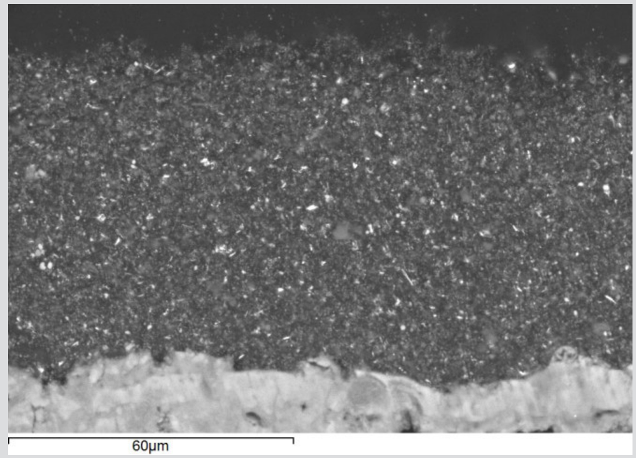


FIGURE 1.40B
Cross section Plate #2. Backscattered electron image.

The combination of optical and electron microscopy indicates that the pigment is composed of titanium dioxide, talc, aluminosilicates, red iron oxide, and lead chromate. The blue-green colorant is not clearly identified by the ESEM-EDS analyses, but it may be chrome green; that is, a preparation of yellow lead chromate and Prussian blue (ferric ferrocyanide), the latter pigment possibly contributing to the ESEM-EDS signal detected for iron. Single-particle ESEM-EDS analyses suggest the presence of some chromium oxide, either hydrated or anhydrous form. Particles are present in which chromium is highly abundant but with very low levels of lead, or other metals associated with chromate pigments, such as zinc, barium, or strontium.

The paint contains an abundant fraction of colorless extender that consists of aluminosilicate mineral. The low abundance of magnesium suggests talc is absent, save for a few isolated particles.

Summary: mixed gray, aluminosilicate abundant, and chromium oxide.

TABLE 1.33
Eames House_ Plate #2 summary of composition.

Description	Elements	Inferences
Eames House_ Plate #2 is a mixed gray paint composed mostly of very fine particles: opaque white; orange-red; and blue-green; and some opaque yellow. Some slightly larger transparent colorless particles are evident. Black particles may also be present, but are difficult to discern. A layer of iron corrosion products, ca. 20µm thick, occurs at the base of the paint layer.	*(Na), (Mg),* **Al, Si,** *(P), Cl, (K),* **Ti,** *Cr, Fe, (Pb)*	Titanium dioxide ✠ aluminosilicate extender ✦ Red iron oxide ✶ Lead chromate ⊙ chromium oxide

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table:
✠ Indicated by coincidence of aluminum and silicon.
✦ Indicated by localized abundance of Fe in red particles/aggregates.
✶ Indicated by coincidence of lead and chromium in single particle analyses.
⊙ Possibly indicated by localized abundance of chromium in the absence of lead (or zinc, barium or strontium).

1.8.3 Painted Plate #3.

Description on plate (see fig. 1.38b): 1948 Original Trim Color

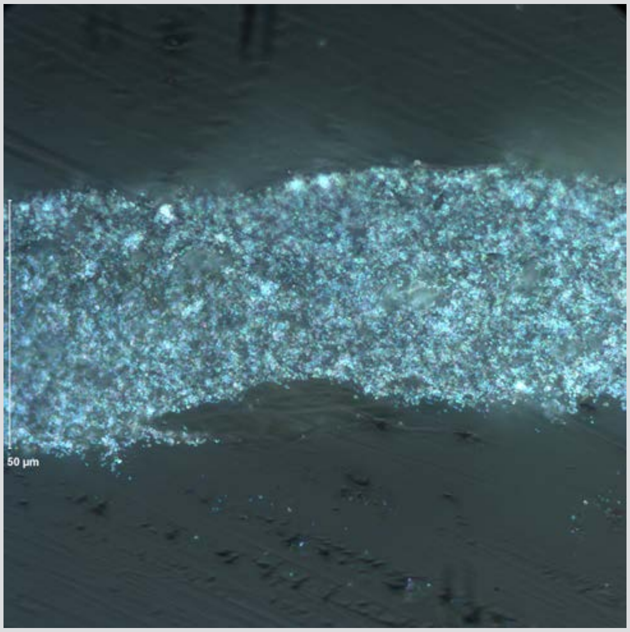


FIGURE 1.41A
Cross section Plate #3. Crossed polarizing filters. 50× objective + 2× magnifier (= 100×).

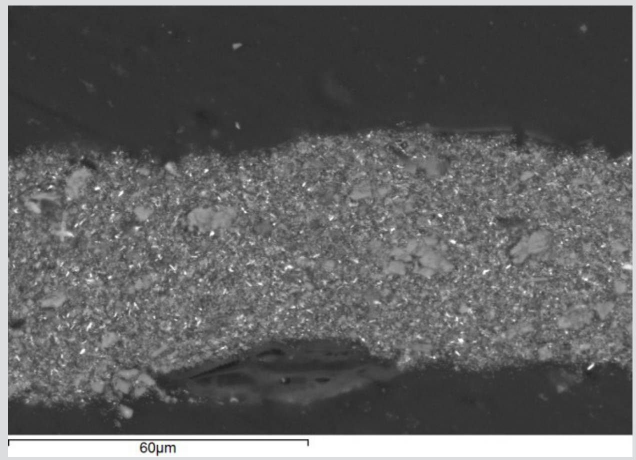


FIGURE 1.41B
Cross section Plate #3. Backscattered electron image.

The particulates made most clearly visible by optical microscopy are colorless and occur in two forms: one very fine and opaque white, the other coarser and transparent. If present, any colored particles—as observed in the preceding samples—are not clearly visible.

Summary: neutral gray, abundant TiO_2, abundant calcium carbonate, some talc, and very low iron (oxide).

TABLE 1.34
Eames House_ Plate #3 summary of composition.

Description	Elements	Inferences
Eames House_ Plate #3 is a cool neutral gray paint in which any colored particles, if present, are not clearly visible. The particles that are discernible are white/colorless: one very fine and opaque, the other coarser and transparent. Some very fine yellow and/or blue-green grains may be present; and the presence of very fine black particles cannot be excluded.	*(Na), Mg,* **Al**, **Si,** *(P), Cl, (K),* Ca, **Ti,** *Cr, (Fe), (Pb)*	Titanium dioxide ◆ Calcium carbonate ❖ talc ✠ aluminosilicate extender ✶ Lead chromate

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table:
❖ Indicated by coincidence of magnesium and silicon.
✠ Indicated by coincidence of aluminum and silicon.
✶ Weakly indicated by general coincidence of lead and chromium.
◆ Indicated by coincidence of calcium and oxygen.

1.8.4 Painted Plate #4.

Description on plate (see fig. 1.42a): Eames Interior Trim Gray (no date) 2nd mix; This sample painted 3/3/72 from qt. can [dap compound]

FIGURE 1.42A
Painted Plate #4

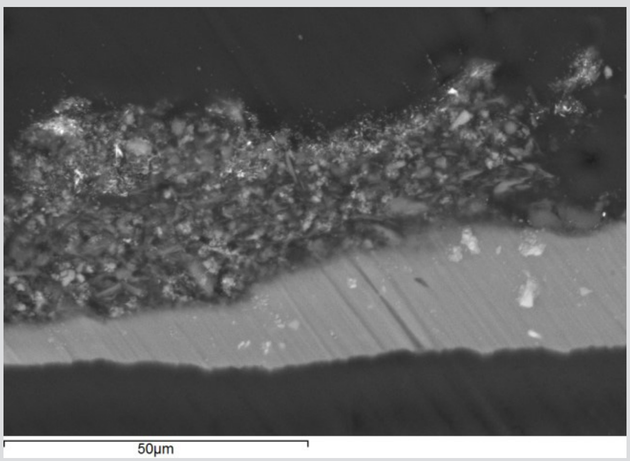


FIGURE 1.42C
Cross section Plate #4. Backscattered electron image.

Eames House_ Plate #4 appears to consist of separate applications of slightly different paints, which give the internal substructure that is evident both by optical and electron microscopy. Towards the upper surface, the paint is finer grained, with some red and yellow particles visible, possibly together with black. ESEM-EDS analysis of the upper substratum points to a composition that includes abundant aluminosilicate extender and titanium dioxide, possibly with traces of iron oxide and lead chromate. Some calcium carbonate may also be present; carbon black cannot be excluded.

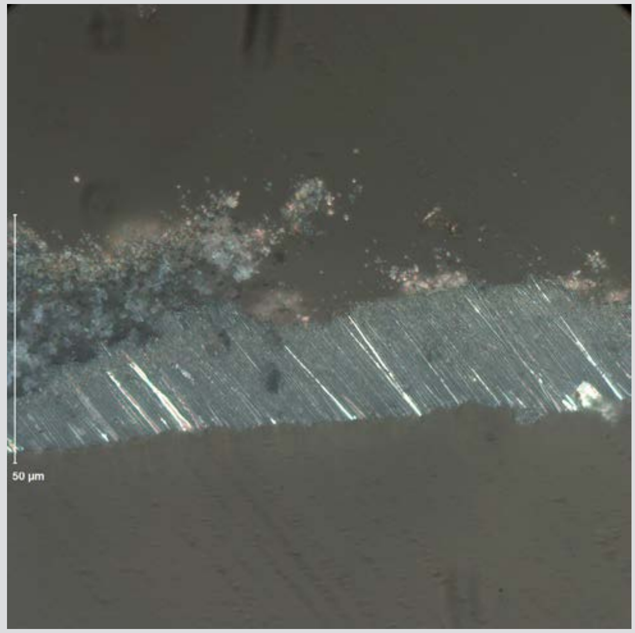


FIGURE 1.42B
Cross section Plate #4. Crossed polarizing filters. 50× objective + 2× magnifier (= 100×).

The coarser, more transparent lower substratum is seemingly composed mostly of aluminosilicate extender and titanium dioxide, with calcium carbonate also present in greater abundance than in the upper substratum. As in the upper sublayer, carbon black cannot be excluded.

Summary: neutral gray, with two substrata.

Upper substratum: abundant aluminosilicate, TiO_2, trace iron (oxide), lead chromate, trace calcium carbonate, and trace talc.

Lower substratum: abundant aluminosilicate; TiO_2; calcium carbonate, minor talc.

TABLE 1.35

Eames House_Plate #4 summary of composition.

Description	Elements	Inferences
Eames House_Plate #4 is a very thin application of cool neutral gray paint, with some internal substructure. Towards the upper surface, the paint is finer grained, with some colored particles (red and yellow) and possibly black. The lower substratum is coarser, more transparent and seemingly devoid of colored grains; it appears to consist mostly of white/colorless particles and very fine black grains. The sample includes a thin base layer of a metallic coating applied to the plate.	**Upper substratum** *Mg,* **Al, Si,** *(P), (Cl), Ca,* Ti, *(Cr), (Fe), (Pb)* _________ **Lower substratum** Mg, **Al, Si,** *(P),* S, *(Cl),* Ca, Ti, *(Fe),* **Metal: Al**	Aluminosilicate extender Titanium dioxide trace iron oxide trace lead chromate trace calcium carbonate talc _________ Aluminosilicate extender Titanium dioxide Calcium carbonate talc

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.8.5 Painted Plate #5.

Description on plate (see fig. 1.43a): Eames original interior, metal trim, color, no date; This sample painted 3/3/72 from gal. can * of [Dunn-Edwards 27 : 1 white] * newly mixed “Horn” paint 1972

Summary: neutral gray paint, black clearly visible, titanium oxide, aluminosilicates, and some talc. No chromium detected.

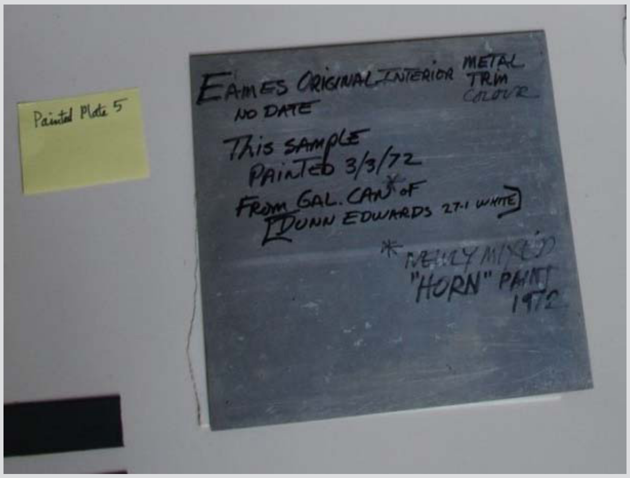


FIGURE 1.43A
Painted Plate #5

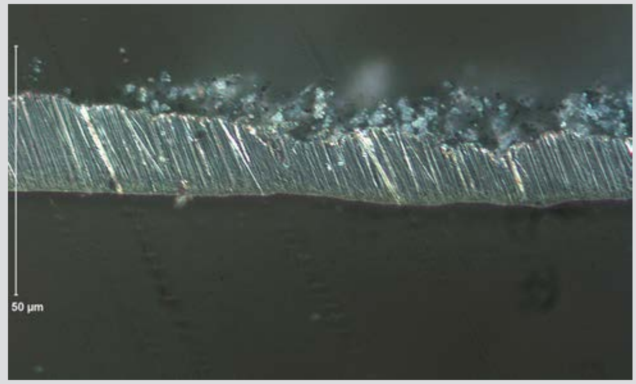


FIGURE 1.43B
Cross section Plate #5. Crossed polarizing filters. 50× objective + 2× magnifier (= 100×).

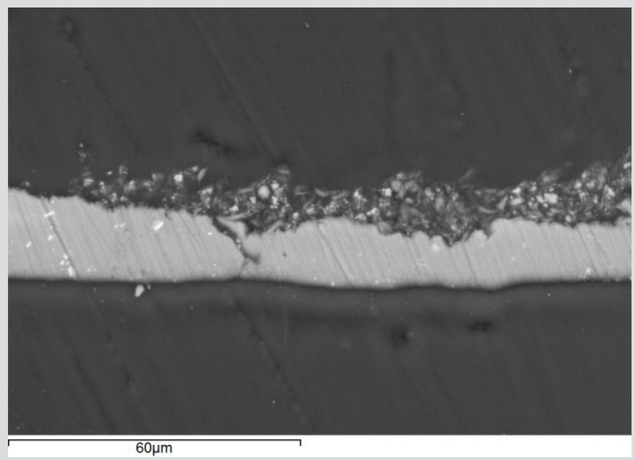


FIGURE 1.43C
Cross section Plate #5. Backscattered electron image.

TABLE 1.36
Eames House_Plate #5 summary of composition.

Description	Elements	Inferences
A very thin application of cool neutral gray paint seemingly composed of fine black, and two types of colorless/white particulate.	Mg, **Al, Si,** *(P),* S, Ca*,* Ti,	Titanium dioxide Aluminosilicates Minor talc Minor calcium-based substance possibly sulfate.
The sample includes a thin base layer of a metallic coating applied to the plate.	**Metal: Al**	

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

1.8.6 Painted Plate #6.

Description on plate: Interior metal paint, 4-15-69 2nd mix. This sample painted 3/3/72 from glass jar wet sample (see fig. 1.44a).

This sample was examined by electron microscopy only.

Summary: neutral gray paint, abundant titanium dioxide, talc and aluminosilicate extenders, some lead chromate and iron oxide.

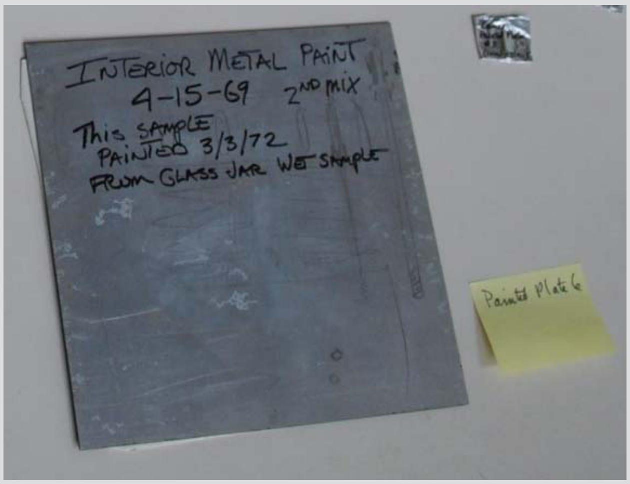


FIGURE 1.44A
Painted Plate #6

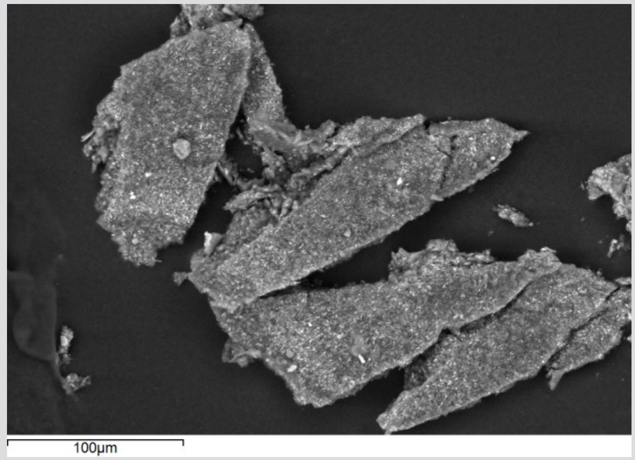


FIGURE 1.44B
Unmounted sample: Plate #6. Backscattered electron image.

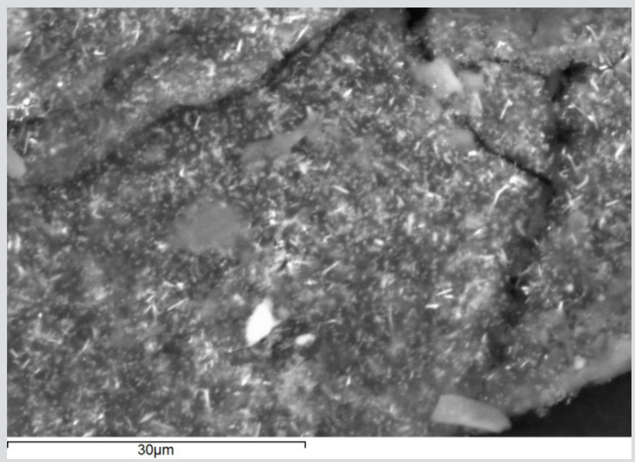


FIGURE 1.44C
Unmounted sample: Plate #6. Backscattered electron image.

TABLE 1.37
Eames House_Plate #6 summary of composition.

Description	Elements	Inferences
	Mg, Al, **Si,** *(P),* S?, *Cl, Ca,* **Ti,** *Cr, Fe, Pb*	**Titanium dioxide** Aluminosilicates ✶ Lead chromate ✦ Iron oxide ◆ Calcium sulfate?

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace.* These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table:
❖ Indicated by coincidence of magnesium and silicon.
✠ Indicated by coincidence of aluminum and silicon.
✶ Indicated by coincidence of lead and chromium.
✦ Indicated by localized concentration of Fe.
◆ Weakly Indicated by coincidence of calcium and sulfur.

1.8.7 Painted Plate #7.

Description on plate sample (see fig. 1.45a): second interior trim paint. 3-27-69. This is the color mixed by Paul Isley to match the original paint.

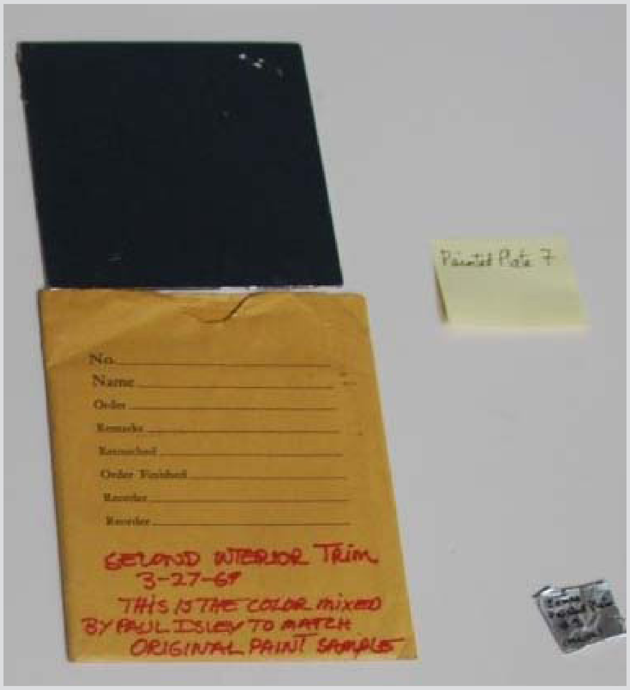


FIGURE 1.45A
Painted Plate #7

Summary: mixed gray paint, titanium dioxide abundant, talc and aluminosilicate extenders with silica and calcium carbonate, and some lead chromate. Iron (oxide, red) not detected.

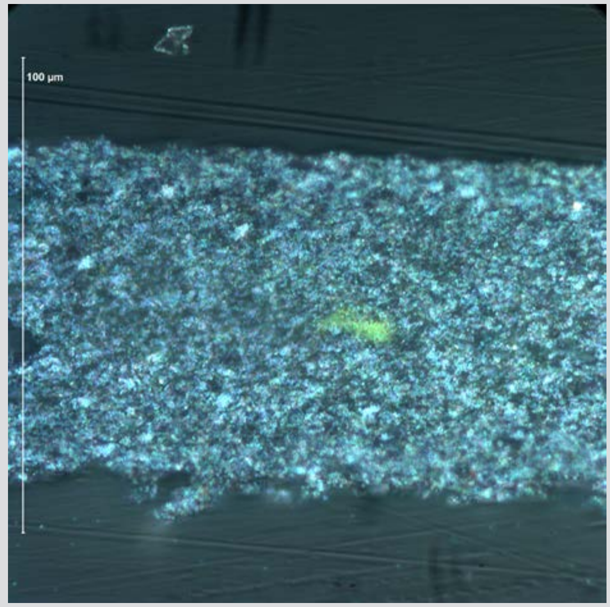


FIGURE 1.45B
Cross section Plate #7. Crossed polarizing filters. 50× objective + 2× magnifier (= 100×).

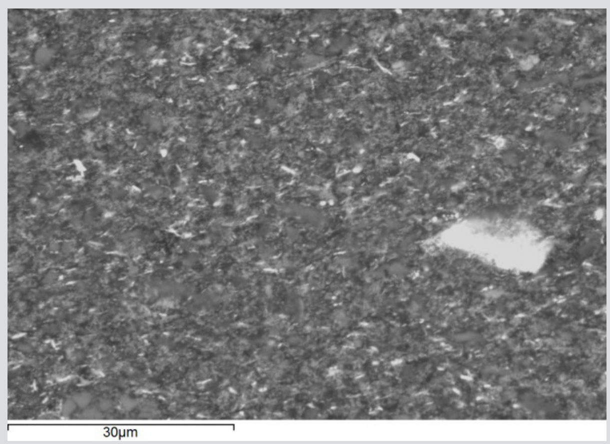


FIGURE 1.45C
Cross section Plate #7. Backscattered electron image.

TABLE 1.38
Eames House_Plate #7 summary of composition.

Description	Elements	Inferences
Eames House_Plate #7 is a mixed gray paint composed mostly of very fine particles: opaque white; blue-green; and opaque yellow. A few, very fine isolated orange-red grains occur. Some slightly larger transparent colorless particles are evident. Black particles may also be present, but are difficult to discern.	*Mg*, Al, **Si**, *(P)*, S?, *Ca*, **Ti**, *Cr*, *Pb*	Titanium dioxide ✠ Aluminosilicates ❖ talc ✶ Lead chromate Silica Calcium carbonate

Key to notation regarding elemental composition:
bold = major; normal text = minor; *italic = trace; (italic parentheses) = very slight trace*. These are relative amounts estimated based on peak intensities in the ESEM-EDS spectra and are qualitative rather than fully quantitative.

Notes to table:
❖ Indicated by coincidence of magnesium and silicon.
✠ Indicated by coincidence of aluminum and silicon.
✶ Indicated by coincidence of lead and chromium.

1.9 Analysis of Paint Cans

A number of paint cans that were used in interventions on the residence are archived at the Eames House (appendix 1.2). Samples were taken from the three that seemed relevant to the interpretation of the samples from the residence itself and were prepared as cross sections for analysis by ESEM-EDS. The results are summarized below.

1.9.1 Can #5: Ameritone Interior Black Satin

Summary of inferences:
Carbon black with trace amounts of inorganic (Mg, Al, Si, Ca) extenders.

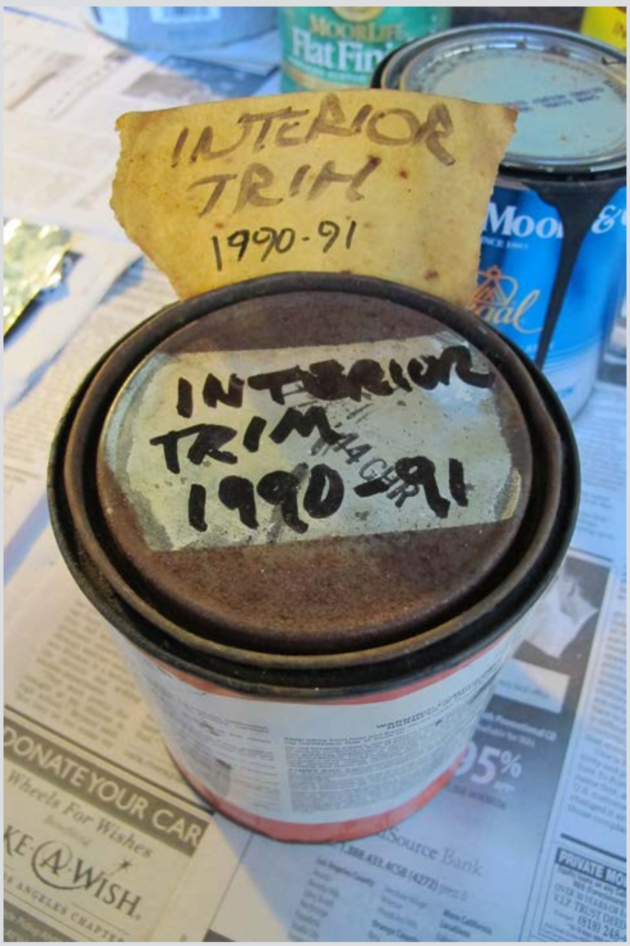


FIGURE 1.46A
Can #5. Ameritone Interior Black Satin 1990–91.

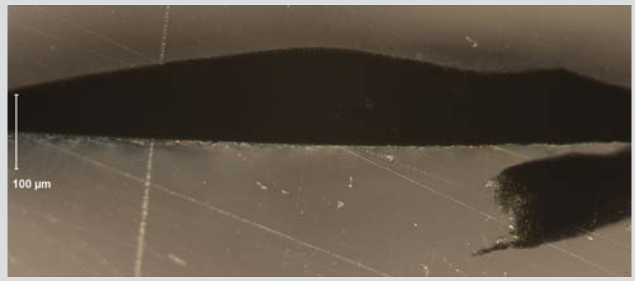


FIGURE 1.46B
Cross section Can #5. Crossed polarizing filters. 10× objective + 1.5× magnifier (= 15×).

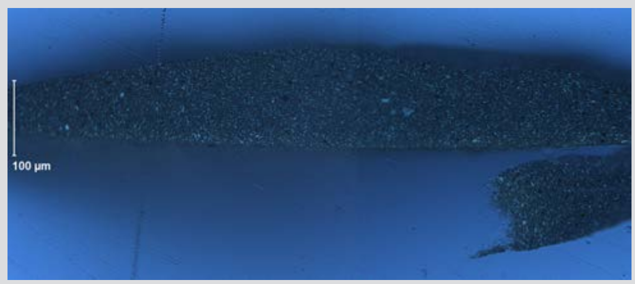


FIGURE 1.46C
Cross section Can #5. UV fluorescence. 10× objective + 1.5× magnifier (= 15×).

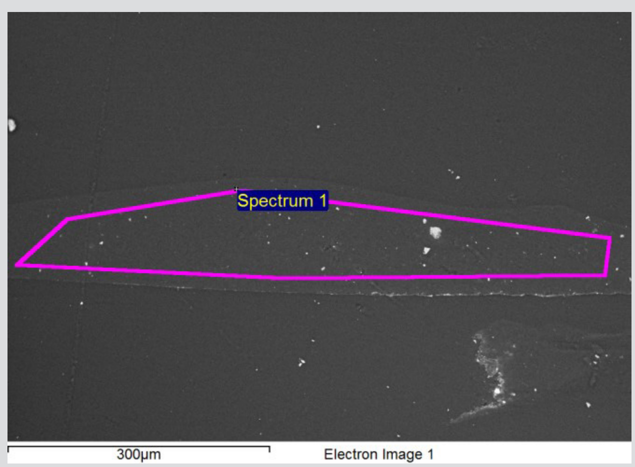


FIGURE 1.46D
Cross section Can #5. Backscattered electron image and spectrum target area.

(continued on next page)

1.9.1 Can #5: Ameritone Interior Black Satin
(continued)

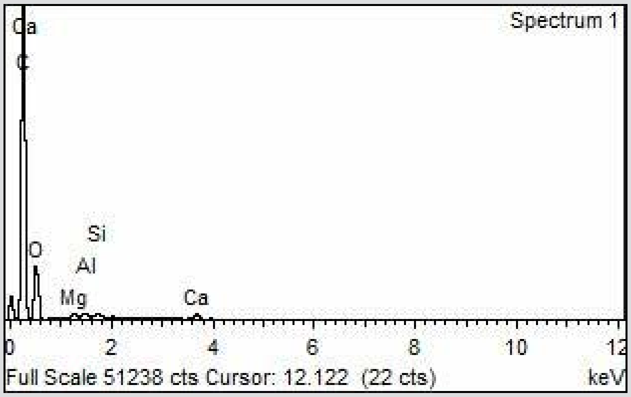


FIGURE 1.46E
Cross section Can #5. ESEM-EDS Spectrum.

1.9.2 Can #11: Cal Western Interior House Trim Black 2003

Summary of inferences:
Carbon black with substantial amounts of inorganic extenders, mainly talc, silica, and calcium.

FIGURE 1.47A
Can #11. Cal Western Interior House Trim Black 2003.

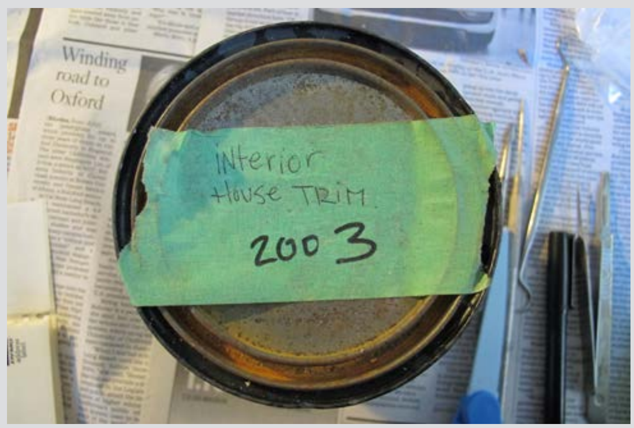


FIGURE 1.47B
Can #11. Cal Western Interior House Trim Black 2003.

(continued on next page)

1.9.2 Can #11: Cal Western Interior House Trim Black 2003 *(continued)*

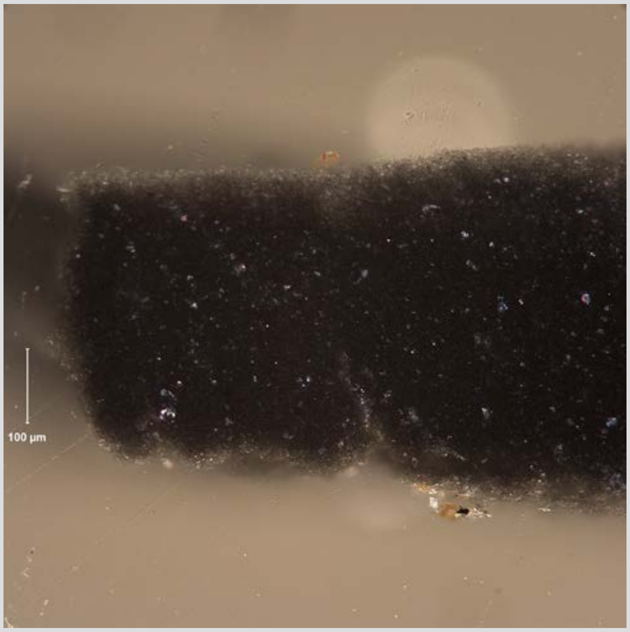


FIGURE 1.47C
Cross section Can #11. Crossed polarizing filters. 10× objective + 1.5× magnifier (= 15×).

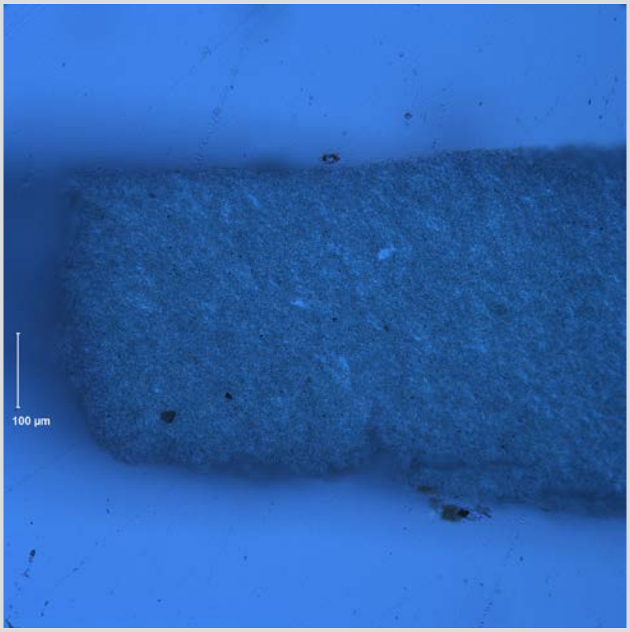


FIGURE 1.47D
Cross section Can #11. UV fluorescence. 10× objective + 1.5× magnifier (= 15×).

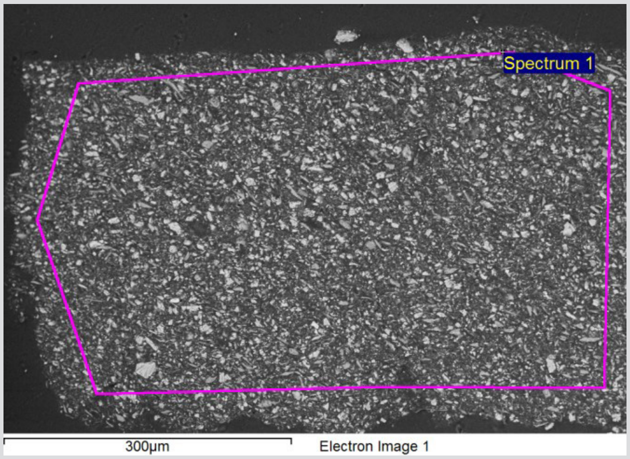


FIGURE 1.47E
Cross section Can #11. Backscattered electron image and spectrum target area.

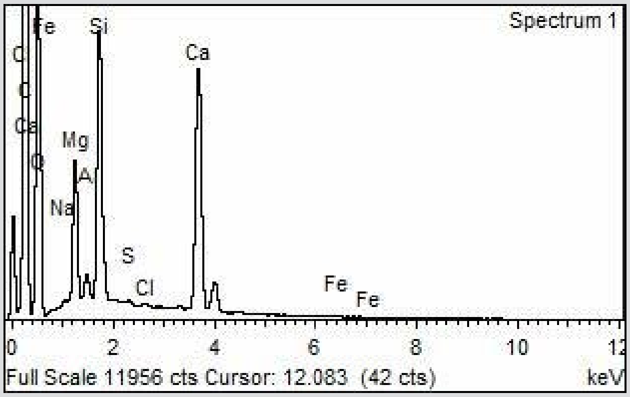


FIGURE 1.47F
Cross section Can #11. ESEM-EDS Spectrum.

1.9.3 Can #15: Shiny Black Ext Carbonate

Summary of inferences:
Carbon black with trace amounts of inorganic (Al, Si) extenders. Source of chlorine not known.

FIGURE 1.48A
Can #15. Shiny Black Ext.

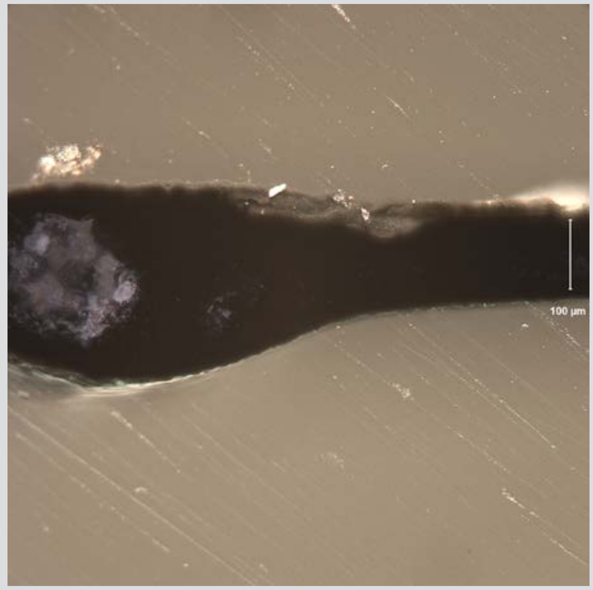


FIGURE 1.48B
Cross section Can #15. Crossed polarizing filters. 10× objective + 1.5× magnifier (= 15×).

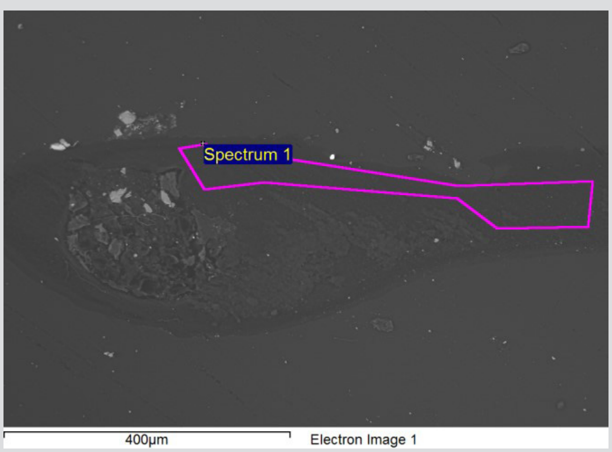


FIGURE 1.48C
Cross section Can #15. Backscattered electron image and spectrum target area.

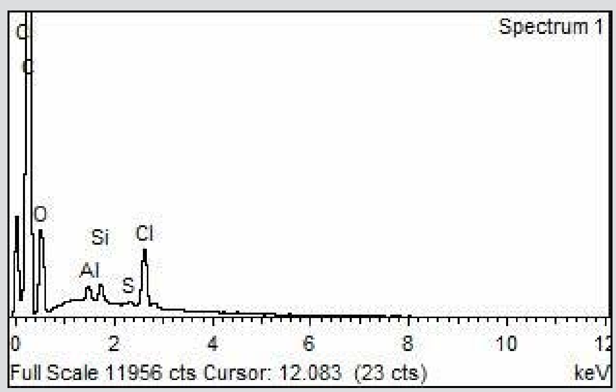


FIGURE 1.48D
Cross section Can #15. ESEM-EDS Spectrum.

1.10 Discussion of Results

1.10.1 Paints on Exterior Metal Framework/Windows

Samples were obtained from six sites on the exterior black metalwork, mostly from areas where the paintwork butted up to the window glass. Sample locations included all four elevations of the building and areas of both original and replacement glass. The set of cross section samples from the black metalwork are illustrated together in figure 1.50.

It can be seen immediately that both East Exterior_2b and North Exterior_10 have far more complex stratigraphies than the other samples, regardless of whether they come from areas of historic or replaced glass. The two samples appear to illustrate relatively complete histories of the painting interventions at those locations, while the other samples only offer evidence of recent repainting. "Old" paint layers are missing from all of the samples East Exterior_1, East Exterior_2a, East Exterior_3, South Exterior_11, and West Exterior_14.

The same pattern of two adjacent paint layers—dense black over dark gray—at the uppermost level appears in all of the samples from the exterior metalwork, and it seems probable that these layers derive from a recent repainting intervention, or, possibly, two separate interventions. According to information from the Eames Foundation, the most recent painting campaign was performed in 2003 by Dan Elliot. Comparison of sample North Exterior_10 with sample Eames House_putty#1b-2 (see fig. 1.50) shows good correspondence between the lower strata of the samples, up to a black paint, layer #9 in both samples, that is composed essentially just of carbon black, but the upper layers of gray paint (#12) and black paint (#13) that occur in North Exterior_10 are missing from the putty fragment, reportedly detached in 1994. This observation leads to the conclusion that gray paint (#12) and black paint (#13) in sample North Exterior_10, and the corresponding layers in the other samples from the exterior metalwork, were applied after 1994 (i.e., as part of Dan Elliot's painting campaign). The lower dark gray paint (#12), which is characterized by

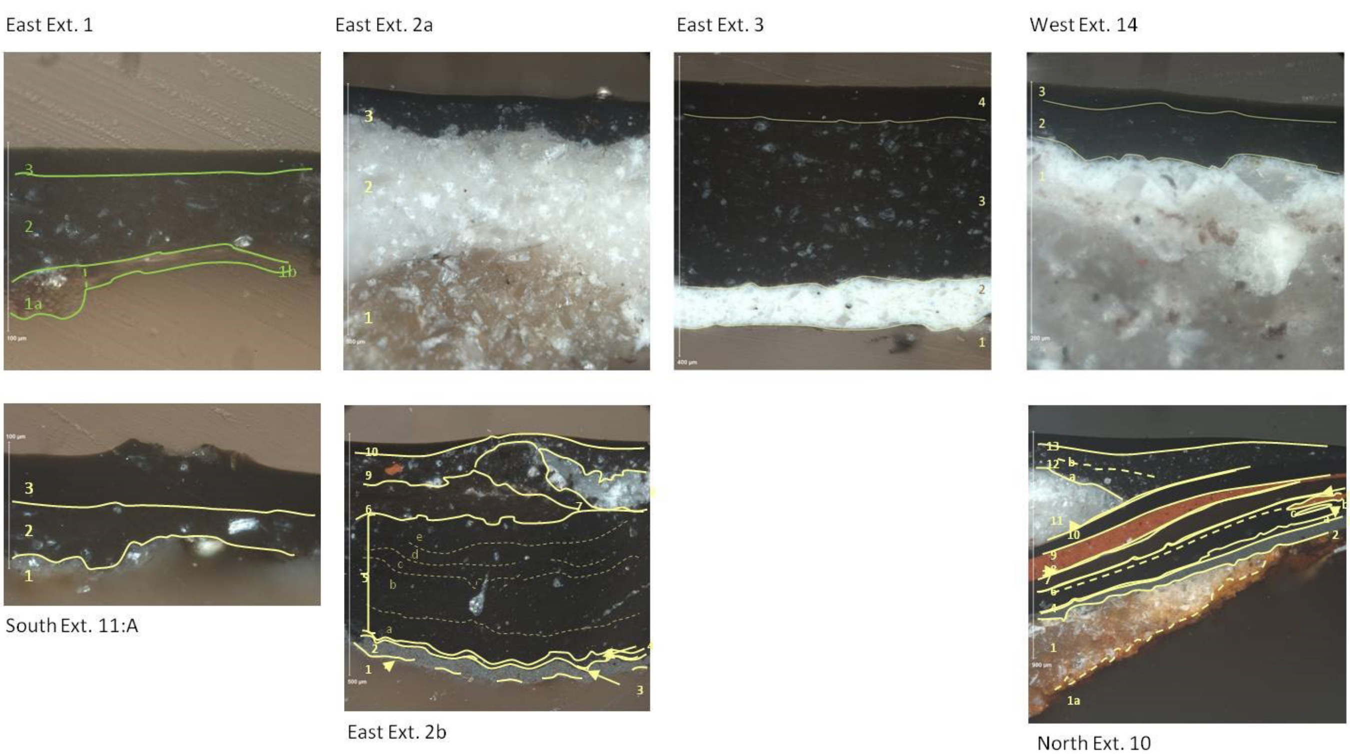


FIGURE 1.49
Set of cross section samples from the exterior black metalwork.

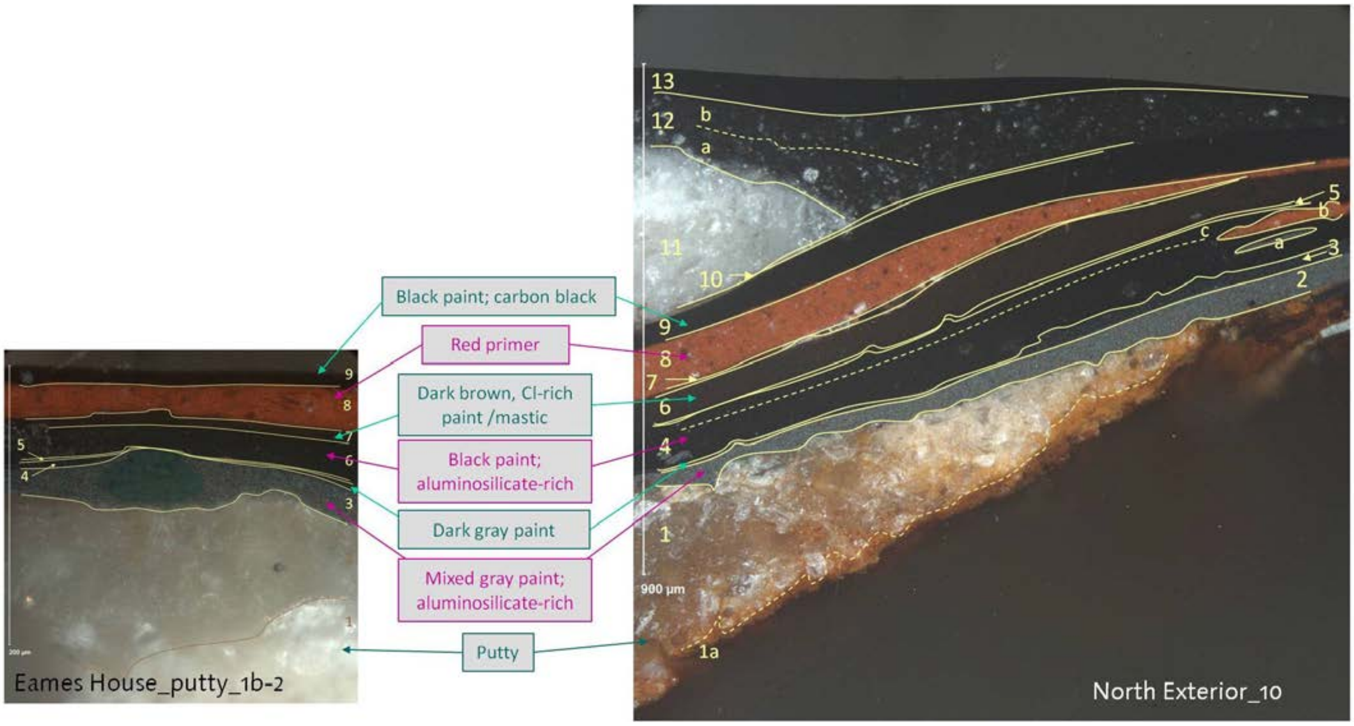


FIGURE 1.50
Correspondences of layers between sample North Exterior_10 and sample Eames House_putty#1b-2.

abundant Mg- and Si-rich material, probably talc, as extender pigment, may well be undercoat, though it could also represent a separate painting campaign, perhaps a response to the earthquake damage.

As already mentioned, only samples East Exterior_2b and North Exterior_10 present evidence of painting interventions earlier than 1994, perhaps going back to the first painting of the metalwork, and there are some correspondences in the stratigraphies of these two samples. It is not possible, however, to date any of the lower layers with any degree of certainty on the basis of these samples. Having said this, though, there are features within the samples that suggest interventions at different times, and these are perhaps best explained by sample North Exterior_10, which has the more complex layer structure.

The two uppermost paint layers #12 and #13 of sample North Exterior_10, as already noted, appear quite recent and are almost certainly connected with the most recent repainting of the residence metalwork in 2003. The same status probably also applies to bright white putty layer #11 which appears to be preparation for the most recent campaign of painting. Putty layer #11 marks a discontinuity with the underlying strata, which are almost certainly from earlier interventions.

The sequence of layers #8 (red primer), #9 (black paint), and #10 (thin layer of black paint) might also be tentatively suggested as representing a single repainting campaign that was commenced with application of the red primer. The presence of unpigmented organic layer #7 suggests a "break'" between the lower strata and the layers immediately above (#8, #9, and #10). It is tempting to associate layers #8, #9, and #10 with the repainting of 1989 that is documented by Eames House as having been carried out by Clayton Coatings. The work that was to be done included painting of the black trim on both buildings; the method to be used was stated as consisting of scraping and treating rust, local priming with Dunn-Edwards Bloc-Rust #43-4, local painting with finish coat, and full painting with finish coat of Ameritone Alkyd Enamel Satin black. Although it is informally labeled

"Interior Trim 1990-91," a can of Ameritone Alkyd Enamel 775 Ebony Satin is retained at the Eames House. Analysis of a sample of dried paint from that can indicates that it is pigmented with carbon black with only a very slight trace of inorganic extenders; analysis of black paint (#9) of sample North Exterior_10 produced essentially the same finding. If, as seems likely, black paint (#9) of sample North Exterior_10 is Ameritone Alkyd Enamel Satin black applied in the painting campaign of 1989, then underlying red primer layer #8 should represent Dunn-Edwards Bloc-Rust #43-4 applied as part of the same intervention.[1] Accordingly, layers beneath red primer might be understood as dating from earlier than 1989, but the evidence that would allow dates to be assigned to any of the strata is somewhat lacking. It seems unlikely that the dark brown, chlorine-rich paint or mastic layer that occurs in sample North Exterior_10 (as layer #6), as well as in other samples, is part of the original paint scheme. It is more likely that this is part of a repainting/restoration intervention that sought to add water-repellency by using a hydrophobic chlorinated binder.

The status of the lowest three paint layers (#2–#4) in sample North Exterior_10, and the corresponding layers in sample East Exterior_2b and Eames House_putty#1b-2, carries some degree of uncertainty. Gray layer #2, which lies directly on old putty, has a distinctive pigment composition that occurs elsewhere on the metalwork, especially in the interior of the residence. It is a gray created in part by subtractive color mixing of red iron oxide, chrome green (lead chromate yellow + Prussian blue), and possibly lead chrome yellow alone, as well as with titanium white and perhaps some carbon black. The similarity of this gray paint (#2) to other "subtractive color mixing" grays on the interior metalwork, combined with its position at the base of the paint stratigraphy, might tentatively suggest that gray paint layer #2 in sample North Exterior_10 corresponds to the original "dark warm gray" or "dark neutral gray" mentioned in early accounts of the residence (Eames and Entenza 1949a).

There are, however, a few objective indicators of the status of the dark gray (#3) and black (#4) paints in sample North Exterior_10, and their corresponding layers in samples East Exterior_2b and Eames House_putty#1b-2). It is conceivable that these two paint applications derive from the same campaign. They have some similarities in composition (carbon black and aluminosilicate extender), although the lower layer is slightly lighter due to the presence of titanium white. Putting aside the question of their originality, it can be noted that it is with the application of these paints that the color of the external metalwork is changed from warm gray to black, which occurred early on in the treatment history and has been retained through later painting campaigns. In sample East Exterior_2b, the presence of physical disruption and discontinuities associated with applied organic medium (#3) at the interface of the lowest warm gray paint (#2) and the overlying dark gray (#4) may be indicative of a temporal separation between the gray and the black states for the exterior metalwork.

Finally, in connection with the samples from the exterior metalwork, it should be noted that none of the samples taken from the building itself show evidence of gray primer comparable with the dark or light zinc-based primers observed in the samples from the interior metalwork. Both of the cross section samples of Eames House_putty#1b, however, show zinc-based light-gray primer layers, though in the case of sample Eames House_putty#1b-2 particles of metallic zinc are not evident, possibly due to chemical reaction to oxidation/hydrolysis products and/or zinc soap-type substances. Sample Eames House_putty#1b-1 contains a unique complexity in its stratigraphy, the interpretation of which remains uncertain. In this sample there occurs a light gray zinc metal-containing primer that is superficially comparable with the lighter zinc-based primer observed as the lowest paint layer in the interior samples. In sample Eames House_putty#1b-1, however, this primer is not the lowest paint stratum, but lies over a descending sequence of putty, red primer, and gray primer, the last of which is seemingly not zinc-based. In the absence of comparable strata in other samples from the exterior metalwork, the question of whether these lowest three layers in sample Eames House_putty#1b-1 represent the original priming and putty remains essentially open.

The absence of zinc-based gray primer in samples from the exterior metalwork, in combination with the very simple stratigraphies of most of the samples, may point to removal of old, degraded coatings ("back to sound surface") during the preparatory stages of the recent repainting campaigns, or—more likely—derive from the fact that the samples came from areas of putty applied over any metal primer.

1.10.2 Paints on Interior Metal Frameworks/Windows

Compared alongside each other (fig. 1.51), it can be seen that there is considerable variability in the stratigraphies of the cross section samples from the interior: no two samples have the same layer structure. Nonetheless, some similarities and correspondences do occur within the sample set.

Taking into account the fragmentation that occurred with some of the samples, specifically East Interior_6 and East Interior_8, which resulted in the lowest layers becoming detached from the main bulk of the sample, the most obvious commonality among the samples is the presence of two gray primer layers that contain metallic zinc particles, probably zinc dust. In all cases, the lower zinc-based primer is pale gray in color, with dark zinc particles dispersed throughout a white matrix, and the upper zinc metal primer is dark gray in color and seemingly in good condition. The lower pale gray zinc primer shows signs of deterioration: it is brittle and seemingly poorly adhered to the paint layers above. Although no special primer is mentioned in documentation specifically connected with the original painting of the interior metalwork of the structures, a product from A.C. Horn, called Galvanide, is mentioned in the 1949 *Arts and Architecture* article on the house as being used "…to prime the surface of these all steel houses" (Eames and Entenza 1949b). Insufficient evidence exists at present to indicate whether the pale gray primer observed in the interior samples is A.C. Horn's product Galvanide, or is another material associated with a later painting campaign, although it is quite possible. The upper dark gray zinc dust primer is clearly not original and must be associated with a later campaign of repainting, but there is no evidence for the likely date of that intervention.

The various cross section samples from the interior differ in the sequence of paint layers between the two zinc-based primers, and also differ in the paint stratigraphy above the later dark gray primer. As already noted, there is little consistency in stratigraphy across the sample set.

Assuming that the dark gray zinc-based primer in each sample was applied at the same time, which seems very likely, then the paint layers above must post-date that intervention and span the same general time period. The paint applications on top of the dark gray zinc primer vary across the sample set:

- East Interior_5: two layers, a thin black paint superposed on a mixed gray
- East Interior_6b: three layers of fine-grained gray paint that differ slightly in shade.
- East Interior_7, East Interior_8a, and North Interior_9: two layers of fine-grained gray paint, the lower one lighter and cooler, more blue-green, than the upper.

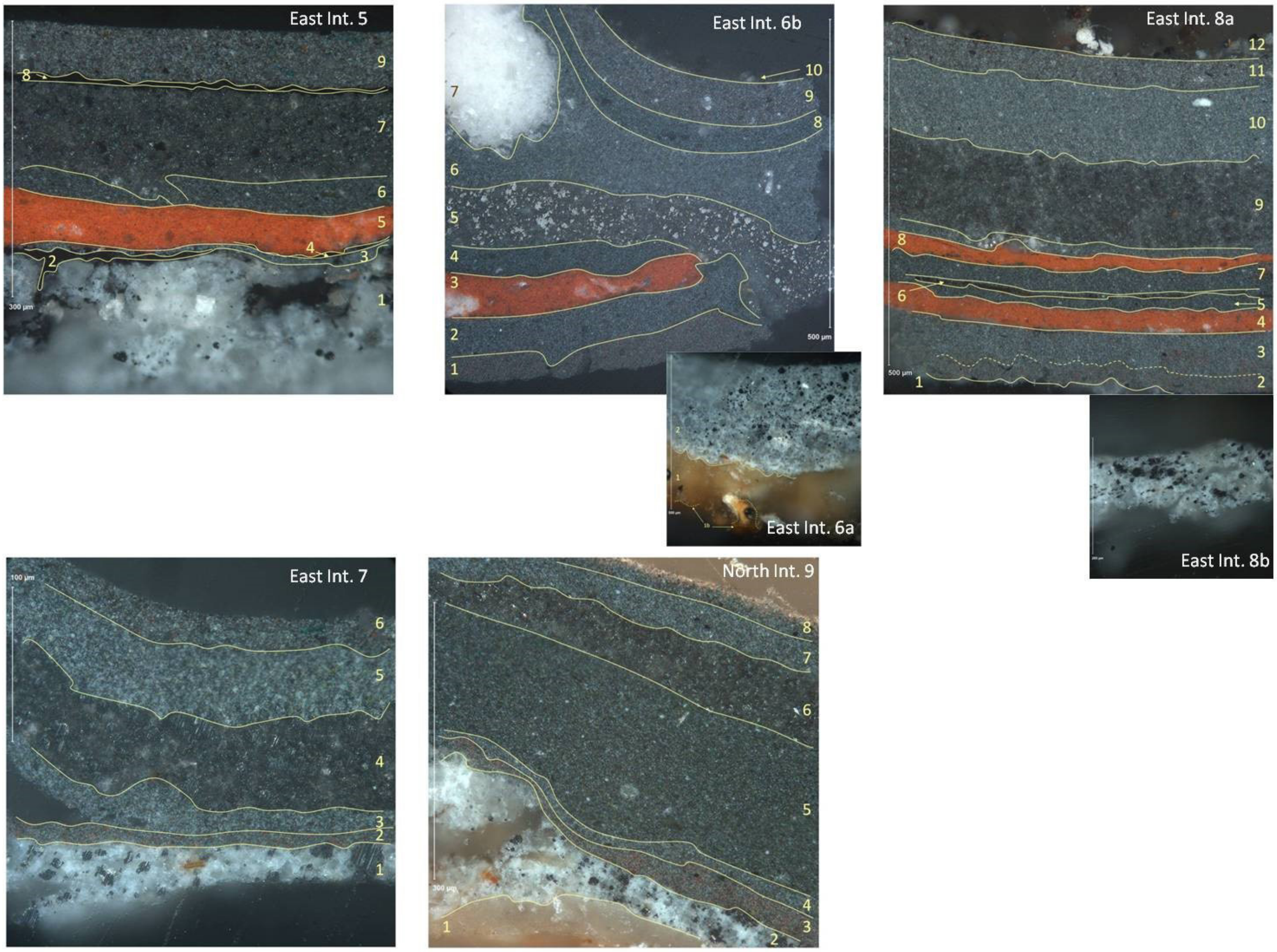


FIGURE 1.51
Cross section samples from the interior metalwork of the Eames House.

A common feature among the group of interior paint samples is the composition of the uppermost paint layer, which is a neutral gray formed by an admixture of opaque white (TiO_2), fine orange-red (iron oxide), yellow (possibly zinc chromate), and transparent blue-green particles (probably viridian[2]), with some black and larger transparent colorless grains (extender). In terms of elemental composition, all of the elements, Mg, Al, Si, S, Cl, Ca, Ti, Cr, Fe, and Zn,[3] are presented. Distinctive features include:

- Massive abundance of chlorine, possibly from the paint binder (perhaps as hydrophobe).
- Presence of barium sulfate as extender, which occurs in no other paint layers.
- Relatively high proportions of Mg Si, but low aluminum, suggestive of talc as extender.
- Relatively high proportion of iron, probably as red iron oxide.
- Moderate levels of calcium.

The similarity of these layers can be seen by comparing the ESEM-EDS spectra obtained from them (fig. 1.52). The distinctive chlorine-rich paint must derive from the most recent painting campaign on the interior metalwork.

Another clear correspondence among samples from the interior is a gray paint that occurs between the uppermost chlorine-rich layer and the underlying dark gray priming.

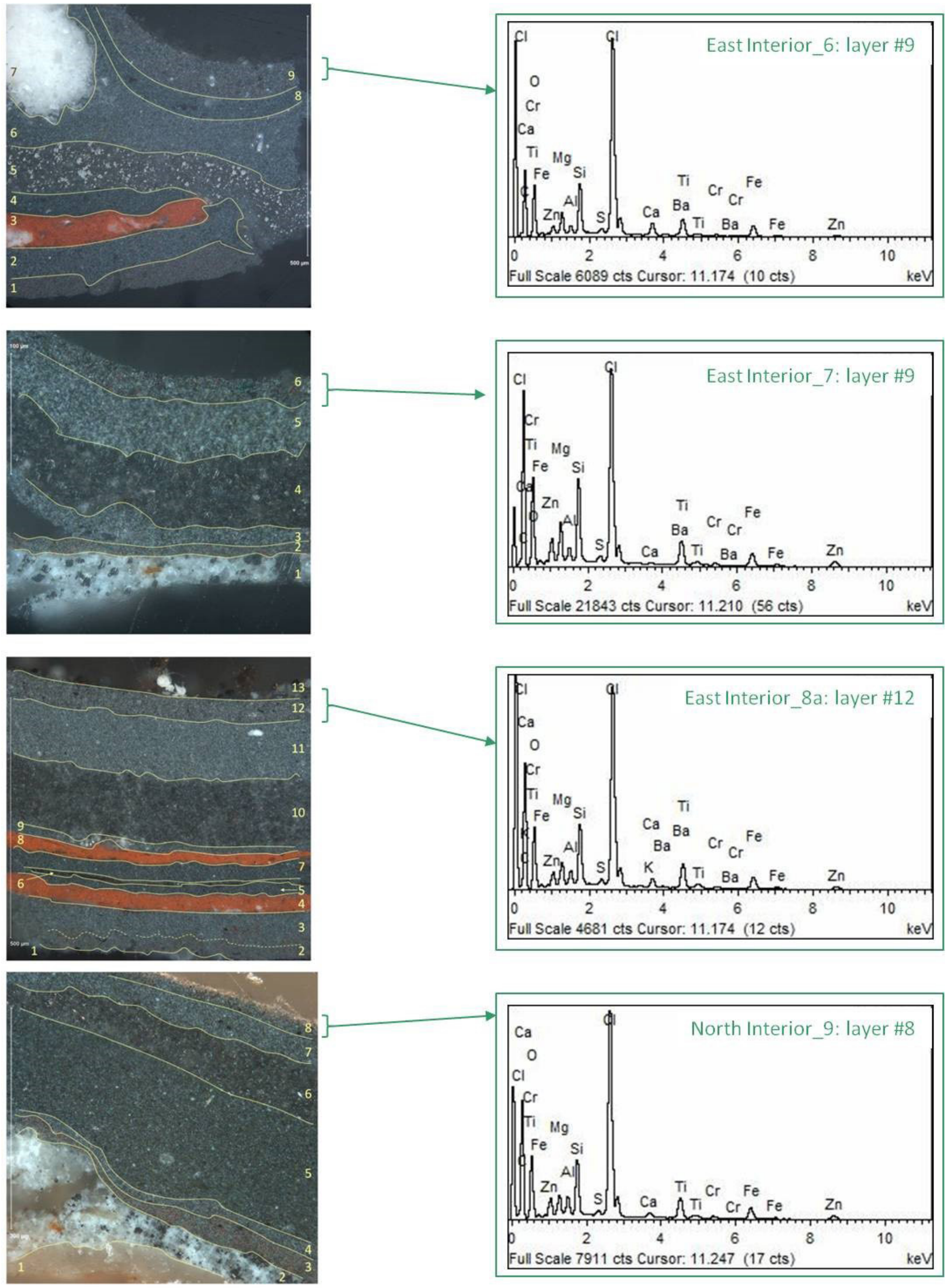


FIGURE 1.52
Comparison of topmost paint layers in samples from the interior metalwork. A similar elemental profile is observed also in sample East Interior_5.

This layer is missing from sample East Interior_5, but features in all other samples in this group. It is characterized by an elemental profile in which Si predominates, with abundant Al and Ti, and some chlorine, but at much lower levels than in the uppermost paints (fig. 1.53).

Samples East Interior_7, East Interior_8a, and North Interior_9, then, share the same sequence of upper paint and dark gray primer layers. Sample East Interior_6b is an anomaly in that it includes an additional gray paint layer (#8) above the dark gray priming. This extra paint layer has a similar elemental profile to the paint just below it, described above, but contains also a minor amount of lead.

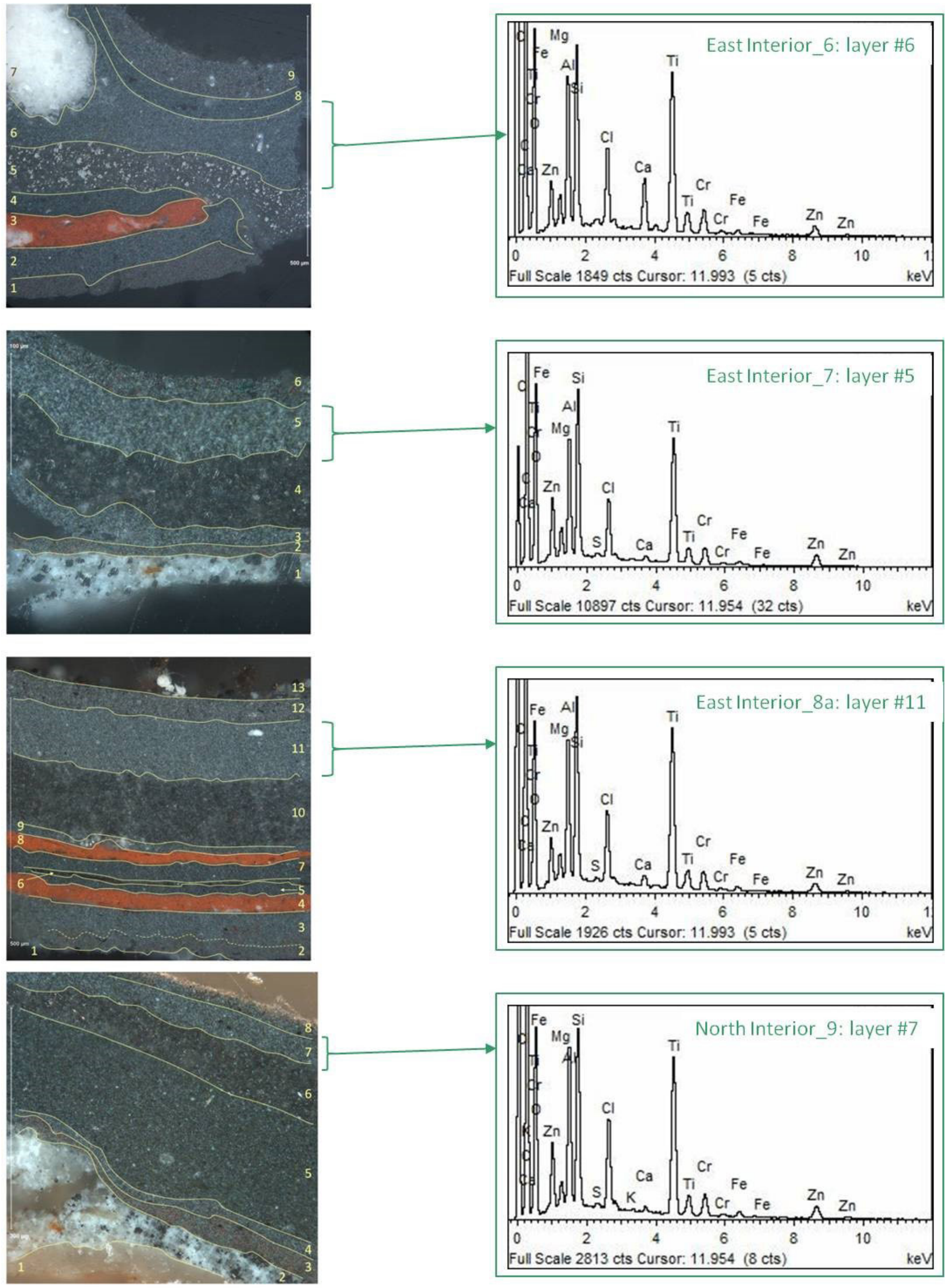


FIGURE 1.53
Comparison of next-to-topmost paint layers in samples from the interior metalwork. A corresponding layer is missing from sample East Interior_5.

It is reasonable to assume that layers of red primer, where they occur in East Exterior_5, East Exterior_6a, and East Exterior_8, are associated with a repainting intervention. Accordingly, gray paint layers directly above red primer might logically be associated as part of the same repainting campaign. This situation occurs in three of the samples: East Interior_5, East Interior_6b, and East Interior_8a. The last of these samples differs in that it contains two red primer layers that do not have the same composition. Correspondence between the primer layers in these three samples cannot be made conclusively, but East Exterior_5 layer 5, East Exterior_6a layer 3, and East Exterior_8a layer 6 share a high abundance of phosphorus, used possibly to inhibit corrosion.

Clear correspondences across the sample set of layers that lie between the lowest red primer and the dark gray zinc-based primer are difficult to discern, given the differences in stratigraphy and general similarity of elemental compositions of the gray paints. In the context of considerations of likely original paint color, comparisons of the lowest paint strata—those lying immediately above the pale gray primer and below the first red primer—are perhaps the most important. Sample East Interior_5 is excluded from this discussion because that part of the stratigraphy appears to be incompletely preserved. The lowest two mixed gray paint layers in each of samples East Interior_6b, East Interior_7, East Interior_8a, and North Interior_9 share very similar elemental profiles featuring Mg, Al, Si, S, Cl, Ca, Ti, Cr, Fe, Zn, and Pb. The presence of Pb suggests a use date prior to regulatory restriction of lead in paints. A general pattern is observed that the lower of these two paints

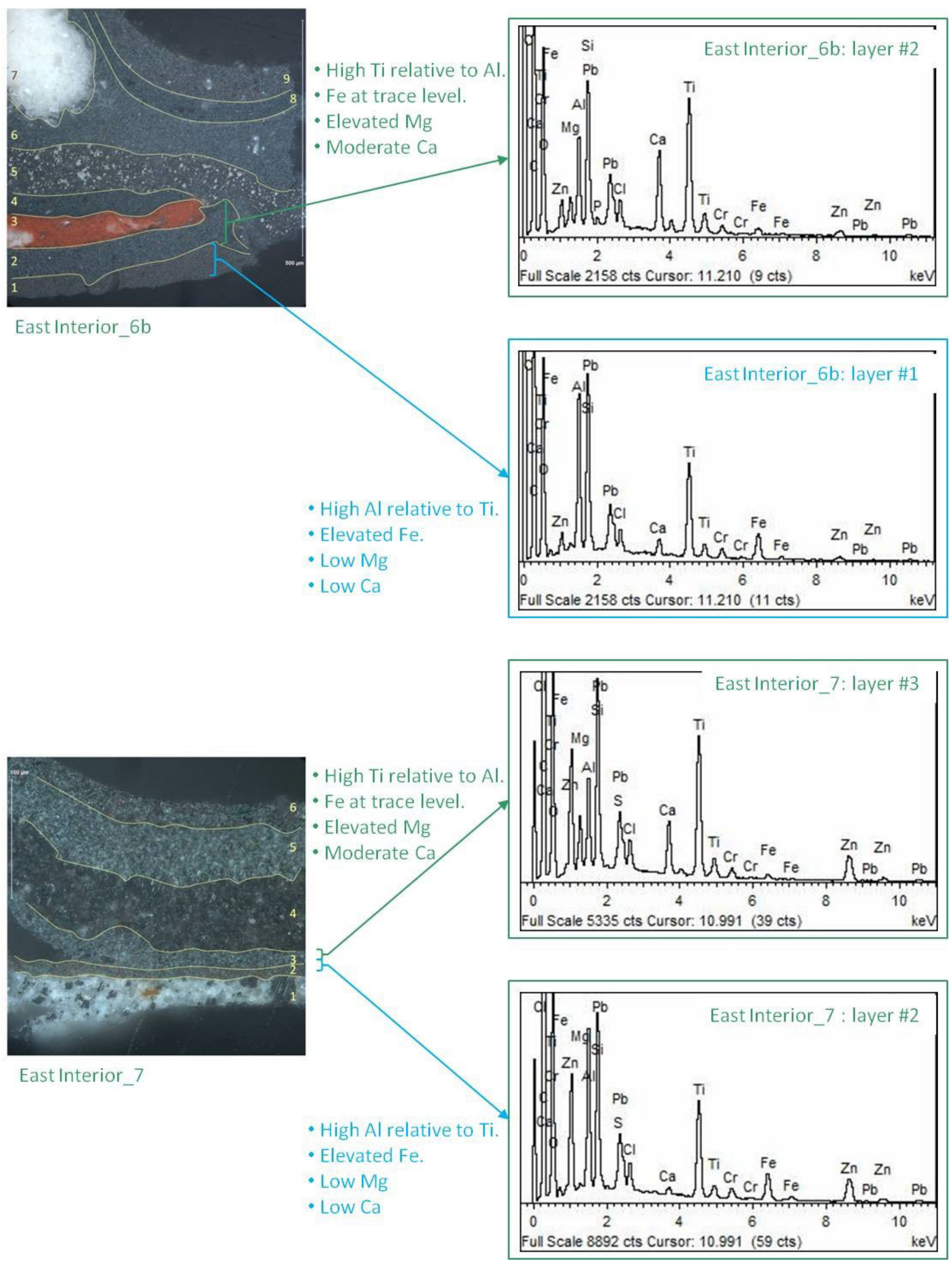


FIGURE 1.54
Comparison of lowest two paint layers in samples East Interior_6b and East Interior_7 from the interior metalwork.

is warmer, redder in color due to greater abundance of red particles (i.e., iron oxide). Despite the general similarity of elemental compositions of the first and second paint layers, there are subtle differences between them, the pattern of which is repeated across the group. This pattern is best illustrated by comparison of the corresponding layers in samples East Interior_6b and East Interior_7 (fig. 1.54). The same pattern is observed also in samples East Interior_8a and North Interior_9. It is not unreasonable to conclude that the first two paint layers in each of these samples correspond directly. If the pale gray priming corresponds with the original Galvanide primer, which is a reasonable hypothesis, although it cannot be proved from the available information, then the two paint layers just discussed appear to represent the first and second paint coatings applied to the interior metalwork. Whether these two paint applications are from the same painting campaign (i.e., multiple coats of slightly different color) or are separated temporally cannot be ascertained from the evidence provided by the samples. The elemental profile of the lowest paint layer in each of the samples under consideration here—East Interior_6b, East Interior_7, East Interior_8a, and North Interior_9—is very similar to that found for the first, warm gray paint layer in sample East Exterior_10. Curiously, the elemental profiles that are characteristic of the first two paint layers in this group of samples do not correspond perfectly with the paints on any of the reference plates associated with the interior metalwork/trim that are archived at the Eames House. Reference Plate #3 labeled “1948 Original Trim Color” shows some similarities with the second paint application: it has high proportion of Ti compared to Al, moderate Ca, and elevated Mg, with Cr and Pb present, but Fe is nearly completely absent. Reference Plate #1, labeled “Int. Color 4-15-69,” also has an elemental composition similar to that of the second paint application, but the abundance of Ca is lower, and the Fe is elevated relative to Cr. None of the paints on the reference plates have the moderately elevated levels of iron (as red oxide) that are seen in the first paint layer in the interior metalwork samples.

1.10.3 Colored Paints on Exterior Panels

Four samples were obtained from the painted exterior paneling: three from the west facade West Exterior_12: blue; West Exterior_13: blue; and West Exterior_15: silver metallic; and one from the east facade, East Exterior_4: orange-red. The limited number of samples and the constraint of having to take samples from the very edges of the painted panels limit the conclusions that can be drawn, particularly with regard to the repainting history. Nevertheless, there is sufficient evidence to suggest that some panels, on the west facade at least, have been repainted. Both blue samples include multiple blue paint layers separated by what appears to be white caulk, and two distinct layers of metal-flake paint can be discerned in the sample from the silver metallic panel. In each of these cases the composition of the earlier and later paints is very similar. The blue pigment, which is probably organic, has not been identified, but the identification could probably be achieved through FTIR or Raman spectroscopy, if that information were considered necessary. The metal-flake constituent of the silver paints is aluminum.

No complex stratigraphy is observed, however, in the sample from the orange-red panel (East Exterior_4), which comprised a single paint layer directly on the panel support. This paint probably contains two different orange-red colorants: lead chromate and an organic pigment the identity of which has not been determined. Again, the identity of this organic pigment could be determined by FTIR or Raman spectroscopy, if necessary.

A more comprehensive evaluation of the restoration history of the painted panels would require many more samples.

1.11 Summary and Overview

Fifteen samples were taken from the residence paintwork for microscopic examination and chemical analysis, with particular focus on matters of stratigraphy and pigment composition insofar as those things might inform an understanding of the history of painting of the building. The set of samples taken from the residence itself comprised six samples from the exterior metalwork (all facades), five samples from the interior metalwork (east and north faces), and four samples from the exterior painted panels. In some instances, multiple fragments from a single stock of sample were prepared as cross sections because of sample fragmentation or variability within the stock material.

Additionally, samples were obtained and analyzed from seven painted reference plates and a series of old paint cans retained at the Eames House. Two fragments of putty, original locations unknown, that reportedly detached in the 1994 Northridge earthquake, provided paint samples that could not include any layers after that specific date, thereby offering a specific chronological reference point.

Paint samples were prepared as polished cross sections; examined and photographed by optical microscopy; and analyzed by ESEM-EDS for spatially resolved elemental composition. Selected samples were analyzed for organic binder identification by Pyrolysis-GCMS. The findings are described in appendix 1.1 of this report.

The residence is a large structure that has had several painting interventions that added material or, possibly, took material away. The particular event history at any given location may be very specific. The limited number of samples may not give a complete picture of the global event history.

The samples from both the interior and exterior metalwork trim showed good evidence for repeated campaigns of puttying, priming, and painting. The interior and exterior metalwork have been treated quite differently in terms of the patterns of their repainting campaigns. In many instances, samples from the metalwork reveal complex stratigraphies consisting of many layers (putty, primer, paint), but stratigraphies are often inconsistent across a specific group, for example between interior metalwork and exterior metalwork.

The appearance (absolute color, tonality) of a paint layer in a cross section sample viewed microscopically cannot be directly translated to the likely perceived color of that paint surface when viewed macroscopically. In optical terms, the situations are different. It is nonetheless reasonable to make broad comparative evaluations of color differences between layers observed in a cross section sample.

Evidence for repainting of some the color panels (blue, aluminum metallic) on the west facade was also observed in paint cross sections from those areas.

1.11.1 Exterior Metalwork (see fig. 1.55)

The exterior metalwork is now a glossy, deep black. The paints giving this finish occur on all the samples from the exterior metalwork and consist of two layers: a lower coat, probably very dark gray rather than black, characterized by (carbon) black heavily extended with talc, overlaid with a dense black paint pigmented essentially with just carbon black. These paints do not occur in the samples of painted putty detached in the 1994 earthquake. It is likely that these two paints derive (perhaps as undercoat and topcoat) from the most recent painting campaign, which according to documentary evidence was conducted in 2003 by Dan Elliott.

The two paint layers just noted form the only paint coatings at several of the sample sites on the exterior metalwork, which suggests considerable loss of earlier material at

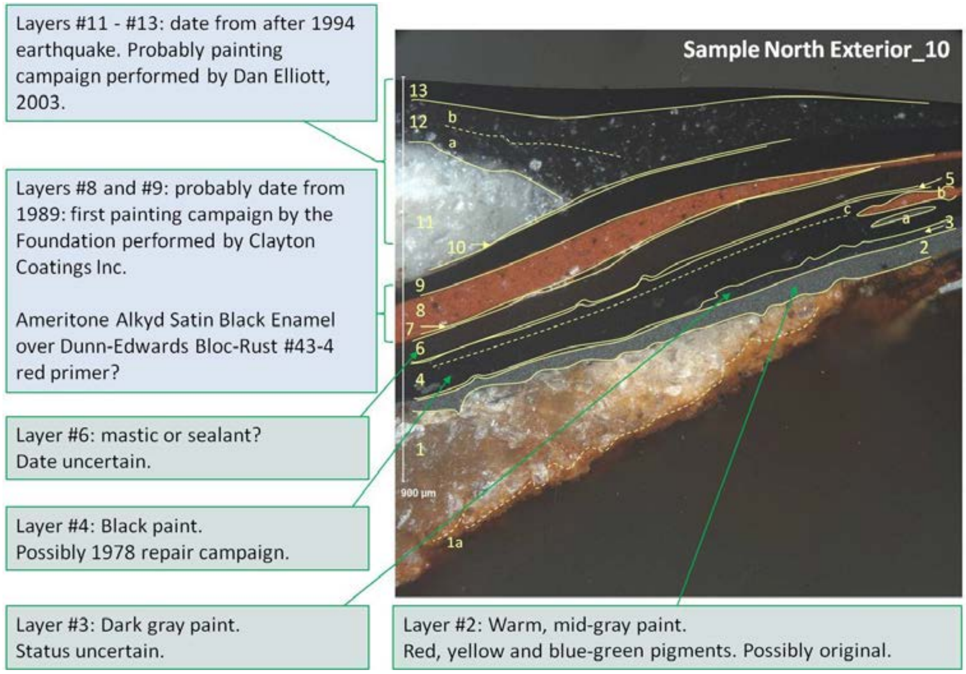


FIGURE 1.55
Sample North Exterior_10 with suggestions for status of the respective layers.

those locations, either by flaking/delamination, putty loss, or active removal (taking back to sound surface) during preparation for repainting.

Only two of the six samples taken from the exterior metalwork on the building, East Exterior_2b and North Exterior_10, show evidence of paint layers earlier than the most recent painting campaign. Older paint applications, however, are observed on the putty fragments. Within this small group of samples that contain older paint layers, some degree of correlation can be discerned within their stratigraphies. Putting aside the paint and putty applications associated with the 2003 Dan Elliott painting campaign just discussed, the evidence from the stratigraphies points to two other repainting campaigns during which the exterior metalwork was painted black. The more recent of these two campaigns involved application of red iron oxide primer followed by a black paint filled/pigmented almost exclusively with carbon black. These strata correspond well with the materials reported to have been used in the 1989 painting campaign conducted by Clayton Coatings: priming with Dunn-Edwards Bloc-Rust #43-4 and finish coat of Ameritone Alkyd Enamel Satin black. Beneath these strata circumstantially connected with the 1989 Clayton Coatings intervention occurs a very dark brown layer that is distinctively abundant in chlorine. Although the status of this layer remains unclear, it may be a layer of mastic/sealant rather than paint. Beneath the dark brown, chlorine-rich coating is a carbon black-based paint, which was possibly applied in multiple layers, that includes characteristically high abundance of aluminosilicate (clay-type) extender. Some red primer is associated, by inclusion, with the application of this material. This black paint layer, which is very thick in sample East Exterior_2b, is interpreted as the first major repainting of the exterior metalwork; significantly, it is the intervention in which the exterior metalwork changes from dark gray to black. However, little evidence exists to date this intervention with any degree of certainty.

In the few instances where older paint layers occur in samples from the exterior metalwork, such as East Exterior_2b; North Exterior_10; Eames House_putty#1b-2, consistently across the group the lowest (oldest) two paint strata are a very dark gray (thin, uneven in thickness, TiO_2 present) over a lighter warm gray that has a distinctive composition. The gray color is achieved, in addition to mixing of carbon black and titanium white, in part by subtractive color mixing of red, blue-green, and yellow pigments: iron oxide, chrome green (lead chromate yellow + Prussian blue), and (probably) lead chromate yellow. The lower gray paint is similar in conception to other subtractive-mixing gray paints on the interior metalwork. Its composition, combined with its situation at the base of the paint stratigraphy, might tentatively suggest a connection to the original "dark warm gray" or "dark neutral gray" color for the metalwork that is mentioned in early accounts of the site (Eames and Entenza 1949a). The status of the thin, uneven, dark gray paint that occurs immediately above the warm, subtractive-mixing gray remains uncertain. There is insufficient evidence to determine whether this dark gray is an original paint layer associated, perhaps as a modifying topcoat, with the lighter warm gray beneath, or whether it represents an early repainting. Nevertheless, it seems plausible that this layer predates 1978, the year of Charles Eames's death. This second-earliest paint layer is a very dark gray in color and might easily have been misinterpreted as black.

There is little evidence, in the samples taken from the building itself, of any original primer applied to the steel framework, though there are some indications of zinc-based primer in the samples from the two fragments of painted putty.

The findings reported here are essentially consistent with those of the small excavation of the paint layers on the exterior metal framework, east elevation, conducted by Emily MacDonald-Korth in Spring 2012, which are presented in Chapter 2.

1.11.2 Interior Metalwork (see fig. 1.56)

The samples of paint from the interior metalwork all have quite complex stratigraphies that illustrate repeated cycles of priming and painting. The stratigraphies are somewhat variable across the sample set. No two samples have exactly the same layer structure. Some correspondences and commonalities do occur, however, within the sample group. The differences in the stratigraphies across the group suggest a degree of specific local variation in the paint treatments at the different locations. There are few, if any, temporal reference points to allow reliable dating of any of the layers in the interior metalwork samples, except perhaps the uppermost, most recent, one in each.

Apart from occurrences of red primer and two isolated instances of black paint, all the paint and primer layers in the samples are gray. Two different gray primers occur that are based on metallic zinc: a lower pale gray primer that may be original, and an upper dark gray zinc primer that must derive from a later repainting intervention. Although it cannot be said definitively, the lower gray zinc-based primer may be the A.C. Horn product Galvanide that was reportedly used originally to prime the metalwork (Eames and Entenza 1949b).

The paint layers, as opposed to primer layers, in the samples are dark grays, not black, that vary somewhat in tonality and hue. There is a considerable degree of compositional overlap between the different layers. They generally share quite similar elemental profiles featuring most of the elements, Mg, Al, Si, S, Cl, Ca, Ti, Cr, Fe, Zn, and Pb, with occasional specific omissions, mainly Fe or Pb, or distinctive high abundances, such as Ba, Cl, and Fe. The general similarity of the composition of the various paint layers might point to a common formulation concept, with some variation over time with regard to specific ingredients. The basis for dark gray interior paints is essentially titanium white (TiO_2) and carbon black, which is presumed by observation, though not positively identified chemically, plus colorless extenders of different types, and minor, variable amounts of colored pigments: red (iron oxide), yellow (chromate), and possibly blue-green (chromium-containing).

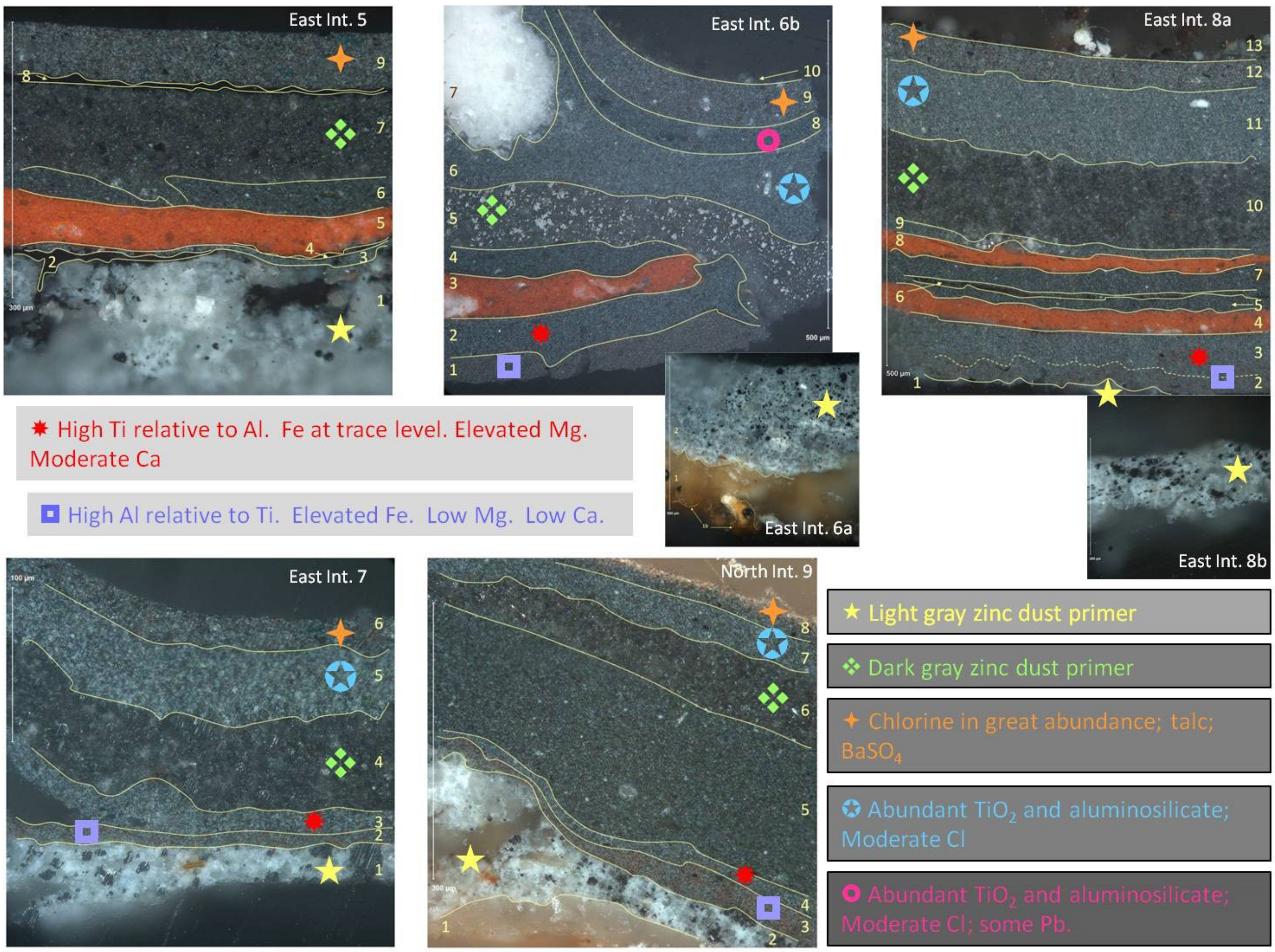


FIGURE 1.56
Samples from interior metalwork: commonalities across the sample set.

As with the samples from the exterior, all the interior samples share a common uppermost paint layer. Distinctive features of this layer include:

- Massive abundance of chlorine, probably from the organic paint binder (see appendix 1.1).
- Presence of barium sulfate as extender, which occurs in no other paint layers.
- Relatively high proportions of Mg Si, suggestive of talc as extender.
- Relatively high proportion of iron, probably as red iron oxide.
- Chromium-based transparent blue-green, possibly viridian.

Again, it is reasonable to attribute this paint layer to the 2003 painting campaign by Dan Elliott.

As already noted, the upper dark gray zinc-based primer can be confidently identified as non-original. There is insufficient evidence, however, to suggest a date for the application of the dark gray zinc-based primer. Its occurrence in all samples from the interior metalwork indicates it was applied as part of a large, site-wide repainting campaign. There are no mentions in the documentary evidence of specific products of this type.

The paints lying beneath the dark gray zinc-based primer are naturally more significant in terms of the early history of the interior paint scheme. There is, however, quite a degree of variability across the sample set in the stratigraphies of the lower levels, seemingly connected with different repainting (and priming) interventions at the different locations. Aside from sample East Interior_5, which is anomalous within the group, the interior metalwork samples have commonality in the lowest two paint layers that lie directly above the pale gray zinc-based primer. These paints are both mixed (subtractive) grays of the type described above; the upper one is cooler, less red than the lower, which can be seen to be more abundant in red (iron oxide) particles. The compositions of these two early paint layers are quite similar, but there are some distinctive differences that allow them to be positively correlated across the sample set. The lowest two mixed gray paint layers in each of samples East Interior_6b, East Interior_7, East Interior_8a, and North Interior_9 share very similar elemental profiles featuring Mg, Al, Si, S, Cl, Ca, Ti, Cr, Fe, Zn, and Pb. However, in all of these cases, the upper, cooler gray paint contains relatively high titanium (Ti, as dioxide) to aluminum (Al, probably as aluminosilicate), elevated magnesium (Mg, probably as talc, magnesium silicate), moderate levels of calcium (carbonate), and low iron (oxide, red). The lower, warmer gray paint is characterized by relatively high Al relative to Ti, elevated Fe, low Mg, and low Ca.

The lower, warm gray paint is understood as the earliest surviving paint on the interior metalwork. It is probably original and appears to coincide with the written references to "dark warm gray" (Eames and Entenza 1949a). It is a subtractive gray, made in part by mixing red, yellow, and blue-green colorants, and it is similar in concept and composition to the lowest paints on the exterior metalwork, also warm gray. The status and dating of the cooler gray of the two under consideration here (i.e., the second-lowest in the stratigraphy) are uncertain. There is insufficient evidence to say whether this is an original layer, or is from one of the later repainting campaigns, such as those of 1969 and 1972, mentioned in the records.

The elemental profiles that are characteristic of the first two paint layers in this group of samples do not correspond perfectly with the paints on any of the reference plates archived at the Eames House. Reference Plate #3 labeled "1948 Original Trim Color" is quite close to the second paint application: it has high proportion of Ti compared to Al, moderate Ca, and elevated Mg, with Cr and Pb present, but Fe is nearly completely absent.

Works Cited

Eames, Charles, and John Entenza. 1949a. Case Study House for 1949: Designed by Charles Eames. *Arts and Architecture* 66 (12): 26-39.

———. 1949b. Merit specified Case Study House 1949. *Arts and Architecture* 66 (12): 8-11.

Notes

1 Dunn-Edwards product information describes Bloc-Rust Red Oxide Primer 43-4 as "Alkyd-based, plus penetrating oil." Although the primary pigment is indicated as red iron oxide, an MSDS sheet for Bloc-Rust Primer 43-4 suggests also the presence of basic zinc chromate (see http://hazard.com/msds/f2/bkv/bkvgd.html). Zinc and chromium are detected in red primer layer #8 of cross section North Exterior_10, and this finding further supports the connection between red primer layer #8 and the Bloc-Rust product Red Oxide Primer 43-4.

2 The probable occurrence of viridian (hydrated chromium oxide) as the blue-green pigment in the uppermost paint layer on the interior metalwork is intriguing for several reasons. This pigment, which is more typically an artist's colorant, could be considered as quite an unusual

constituent of a relatively recent industrial paint. Viridian was also indicated by ESEM-EDS in the paint on reference Plate #2, but without the dominant presence of chlorine. A number of the early subtractive mixed gray paint layers on the interior and exterior metalwork include a different blue-green colorant composed of lead chromate (chrome yellow) and Prussian blue, the combination of which is commonly known as chrome green. It remains an open question whether the viridian (a chromium-based transparent blue-green) in the uppermost layer on the interior metalwork and on Plate #2 was an intentional substitution for the chrome green in the mixed gray formulation, or whether the instances of viridian are associated with a different interpretation of the term “chrome green” to its more traditional application to the combination of lead chromate (chrome yellow) and Prussian blue.

3 Since zinc is present in abundance in all samples through the two gray zinc metal based primers, it is possible that the ESEM-EDS weak signal observed for zinc is part of the general background signal.

APPENDIX 1.1

Organic Binder Analysis

Introduction

The goal of this part of the analytical study of paints from the residence Eames House was to determine the nature of the organic binder materials of paints forming particular layers observed in the cross section stratigraphy.

The samples analyzed for organic binder constituents included:

- The uppermost paint layer (or possibly two layers) removed selectively by scalpel from the main stock of sample North Interior_9.
- The uppermost paint layer removed selectively by scalpel from the main stock of sample East Exterior_1 (figure A1.6).
- A series of scrapings of selected paint layers observed on two of the fragments of putty (Eames House_putty#1a and Eames House_putty#1b-2) from the larger collection of material that was reportedly detached as a consequence of the 1994 Northridge earthquake.
- A set of three sample scrapings deriving from an in situ excavation of the paints on the exterior metalwork, east facade, done to uncover the layer structure (figure A1.6). Emily MacDonald-Korth provided these samples on March 26, 2012 (figure A1.1).

It should be noted that in the creation of sample material (i.e., scrapings) by more or less selective mechanical removal from either larger sample stocks or from the residence metalwork itself, perfect selectivity could not always be assured. Some of the material

FIGURE A1.1
Emily MacDonald-Korth carrying out paint investigations at the Eames House, 2011. Photo: Scott Warren

forming the subsamples analyzed for organic binder composition included matter from more than one paint layer, in which case the analytical findings could apply to a combination of layers and should be interpreted with some degree of caution.

The samples were analyzed by Fourier Transform Infrared Spectroscopy (FTIR) and Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GCMS). The experimental details are provided below:

- FTIR: For each sample, selected particles were placed on a diamond window and flattened using a metal roller. The samples were analyzed using a 15× Cassegrain objective attached to a Bruker Optics Hyperion 3000 FT-IR microscope housing a liquid nitrogen cooled mid-band MCT detector, and purged with dry air. The spectra are the sum of 64 scans at a resolution of 4 cm-1. Reference spectra from the infrared spectral database were utilized in the identification process.
- Py-GCMS: Py-GCMS analysis was carried out on a Frontier Lab PY-2020D double-shot pyrolyser system (550°C, 6 secs) attached to an Agilent Technologies 5975C inert MSD/7890A GCMS. Column: Frontier Ultra ALLOY-5 30m (0.25 mm × 0.25 μm); helium carrier gas: 1 ml/min flow; GC oven: 40°C for 2 mins, ramped 20°C /min to 320°C, then held at 320°C for 9 mins; MS ionization: 70eV.

In addition to providing information on organic binder constituents, FTIR Spectroscopy also offered data on some inorganic components (pigments and extenders) that are complementary to and supportive of the ESEM-EDS elemental analytical results in chapter 1 of this report.

Sample Descriptions and Summary of Results

Sample North Interior_9: uppermost paint layer #8

The stratigraphy of sample North Interior_9 is indicated in figure A1.2.

Py-GCMS analysis confirmed that the uppermost paint layer #8 is based on a chlorinated rubber binder, as had been suspected from the findings of elemental analysis by ESEM-EDS, which indicated abundant chlorine not associated with pigments/extenders.

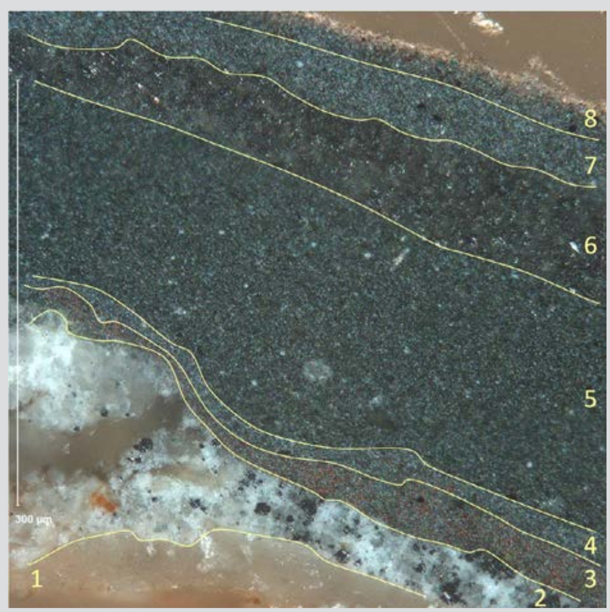


FIGURE A1.2
Cross section of sample North Interior_9; visible light. Annotated to show layer structure.

(continued on next page)

Sample North Interior_9: uppermost paint layer #8 *(continued)*

TABLE A1.1
Sample North Interior_9.

Sample	Description	Markers (polymer)	Markers (additives)	Fillers and Pigments	Comments
North Interior_9	uppermost paint layer #8	Chlorobutane	Dibutyl phthalate, diisooctyl phthalate	Kaolinite	Chlorinated rubber✠

Notes to table
✠ The top-most paint layer #8 was observed by ESEM-EDS analysis to be highly abundant in chlorine; and the chlorine was not embodied in pigments or extender.

Sample East Exterior_1: uppermost paint layer #3

The stratigraphy of sample East Exterior_1 is indicated in figure A1.3.

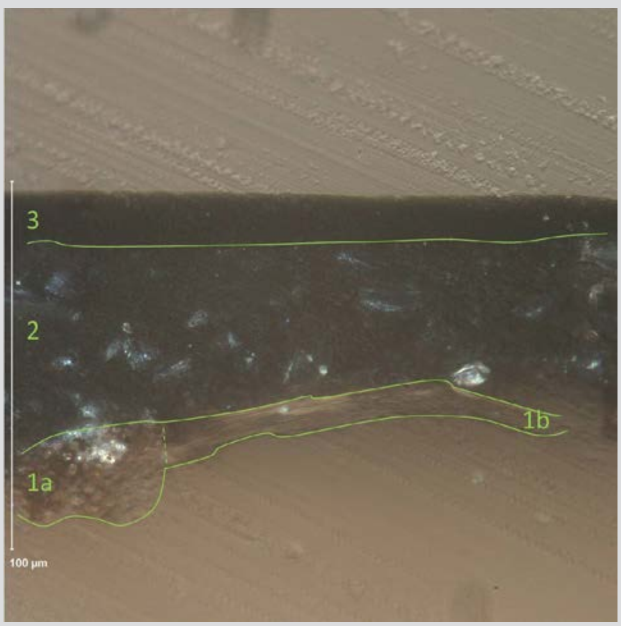


FIGURE A1.3
Cross section of sample East Exterior_1; visible light. Annotated to show layer structure.

Uppermost black paint layer #3, which has parallels to all other samples from the exterior metalwork, is understood as being associated with the most recent repainting campaign at the residence in 2003. The organic binder is identified as an alkyd resin.

TABLE A1.2
Sample East Exterior_1.

Sample	Description	Markers (polymer)	Markers (additives)	Fillers and Pigments	Comments
East Exterior_1	uppermost paint layer #3	phthalic acid; ions from ring-closure reactions of fatty acids during pyrolysis	Dibutyl phthalate, diisooctyl phthalate	Kaolinite, Calcium carbonate	Alkyd

Fragment Eames House_putty#1a

The stratigraphy of sample Eames House_putty#1a may be indicated in figure 1.A1.2a–b. It includes two sequences of dark gray to black paints separated by a thick layer of putty that derives from an early repainting campaign. Several samples of material removed by selective excavation were analyzed for organic binding medium.

The major findings of these analyses are that the lower strata of dark gray and near-black paints (layers 2, 3, and 6) are based on a (synthetic) styrene-butadiene rubber binder, a finding that is consistent with early documentary evidence reporting the use of a rubber-based paint produced by A.C. Horn. Uppermost black paint layer 9, by contrast, appears to be in an alkyd medium; it is likely that this layer corresponds to the Ameritone alkyd satin black paint that was reportedly used in the 1989 repainting of the house by Clayton Coatings.

FIGURE A1.4A
Cross section of sample Eames House_putty#1a; visible light.

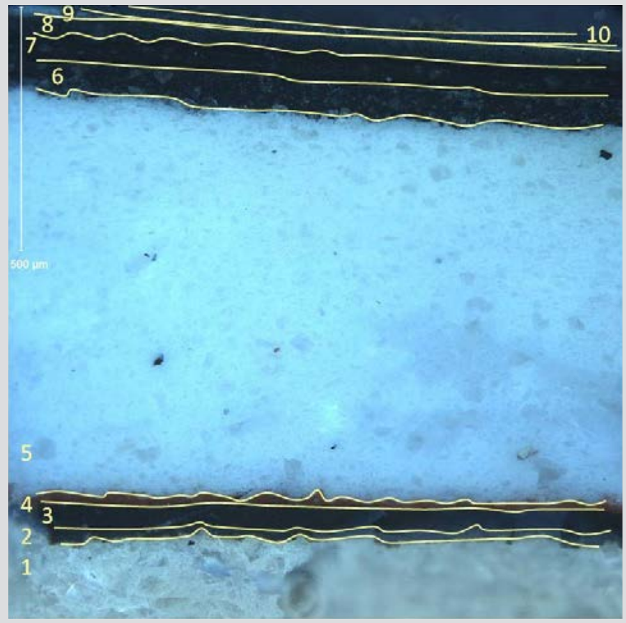


FIGURE A1.4B
Cross section of sample Eames House_putty#1a; UV fluorescence. Annotated to show layer structure.

(continued on next page)

Fragment Eames House_putty#1a *(continued)*

TABLE A1.3
Fragment Eames House_putty#1a.

Sample	Description	Markers (polymer)	Markers (additives)	Fillers and Pigments	Comments
1	Uppermost black paint (mostly layers 8 and 9?)	phthalic acid; ions from ring-closure reactions of fatty acids during pyrolysis	Dibutyl phthalate, diisooctyl phthalate	Calcite, Talc	Alkyd based paint
2	Black 2nd down (layer 8)			–	Insufficient sample for py-GCMS
3	Black 3rd down (layer 7)			Kaolinite	Insufficient sample for py-GCMS analyses, FTIR indicate that styrene-butadiene is possible.
4	Black 4th down (layer 6)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate	Kaolinite Calcium carbonate✠	Styrene-butadiene rubber
5	Red primer (layer 4)	–	–	–	Insufficient sample (py-GCMS)
7	Lowest 2 paint layers, (layers 2 and 3, but predominantly layer 3)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate	Kaolinite	Styrene-butadiene rubber
8	Lowest 2 paint layers, (layers 2 and 3, but predominantly layer 2)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate	Kaolinite, Prussian blue◆	Styrene-butadiene rubber

Notes to table
✠ Probably sample contamination from putty layer (5) above.
◆ The pigment Chrome green (i.e., mixture of Prussian blue + lead chromate yellow) was identified by ESEM-EDS in paint layers at the same point in the stratigraphy of other samples including Eames House_putty#1b-2.

Fragment Eames House_putty#1b-2

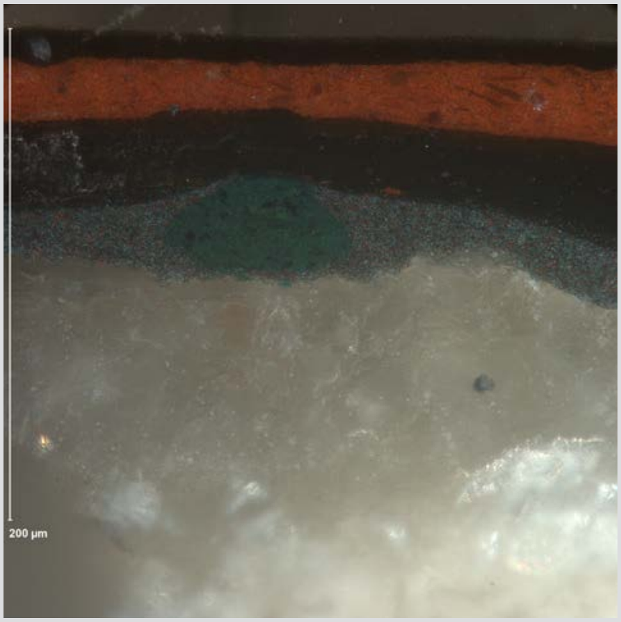


FIGURE A1.5
Cross section of sample Eames House_putty#1b-2; visible light. Annotated to show layer structure.

Summary of FTIR and Py-GCMS Analysis: Eames House_putty#1b-2.

The results of the organic binder analyses that were performed on material selectively removed from fragment Eames House_putty#1b-2 were essentially consistent with the results obtained for the corresponding layers in the previous sample: the lower strata of dark gray and near-black paints/coatings (layers 3–5 and 6–7) include material that is based on a (synthetic) styrene-butadiene rubber.

TABLE A1.4
Fragment Eames House_putty#1b-2.

Sample	Description	Markers (polymer)	Markers (additives)	Fillers and Pigments	Comments
1	Black paint below red primer (layers 6 and 7)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate	Kaolinite	Styrene-butadiene rubber
2	Lowest dark gray layers (layers 3-5)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate	Kaolinite, Prussian blue◆	Styrene-butadiene rubber

Notes to table
◆ Probably present as the pigment Chrome green (i.e., mixture of Prussian blue + lead chromate yellow)

Summary of FTIR and Py-GCMS analysis: in situ excavations on the East Exterior (window, steel frame).

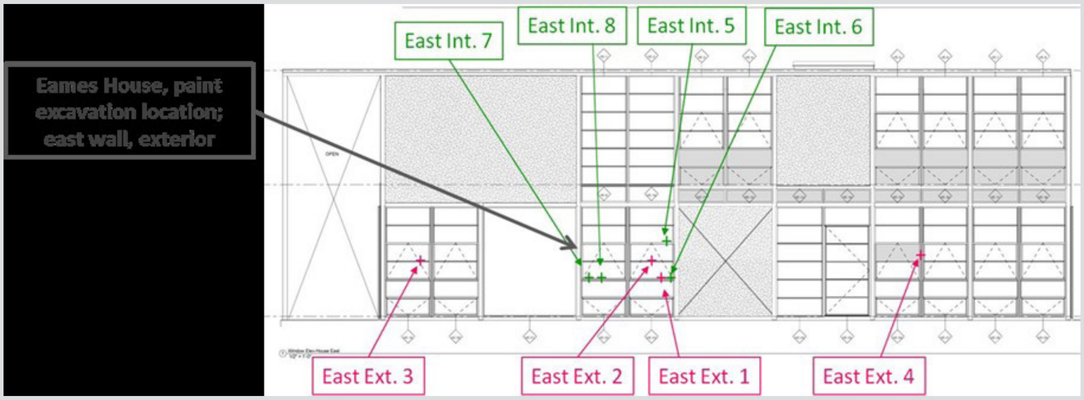


FIGURE A1.6
Eames House paint excavation location. Drawing: Adapted from drawing by Escher GuneWardena Architecture, © Eames Office.

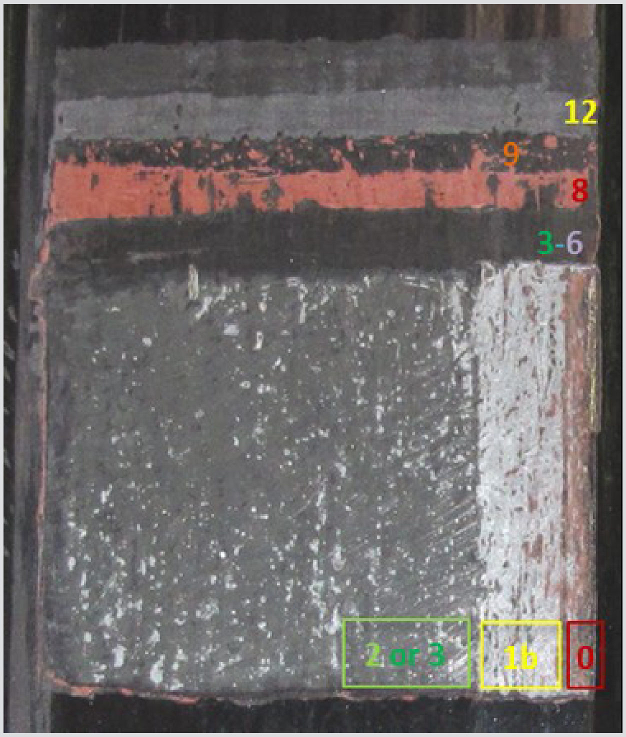


FIGURE A1.7
Paint excavation site on the exterior of the east wall.

TABLE A1.5
In situ excavations on the East Exterior (window frame).

Sample	Description	Markers (polymer)	Markers (additives)	Fillers and Pigments	Comments
1	Gray paint (layer 3)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate	Kaolinite, Prussian blue	Styrene-butadiene rubber
2	Gray and lighter gray paint (4–7)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate	Kaolinite, Prussian blue	Styrene-butadiene rubber
3	Black paint (layers 4–8)	styrene (monomer, dimer and trimer); 1,3-butadiene	Dibutyl phthalate, diisooctyl phthalate		Styrene-butadiene rubber; FTIR indicates primer layer may be an alkyd

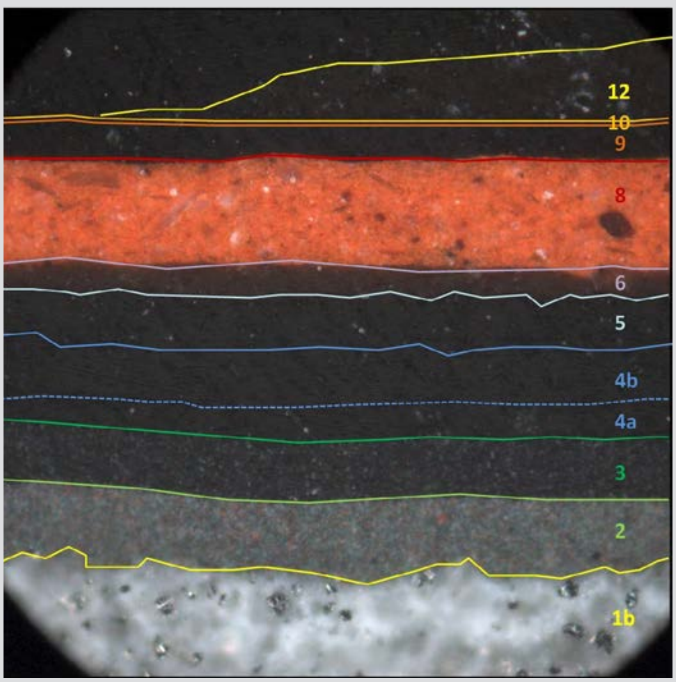


FIGURE A1.8
Stratigraphic diagram of a cross section paint sample from the exterior of the east wall, next to the excavation site (50× objective).

Commentary on Organic Binder Analysis Results

Eight samples were identified by Py-GCMS analyses as being made of a styrene-butadiene based synthetic rubber. These included three paint samples from Eames House_putty#1a (4, 7, and 8), the two paint samples from Eames House_putty#1b-2, and the three samples from the East exterior window excavation. The pyrogram of sample 4, Eames House_putty#1a, is presented in figure A1.9. The peaks for polystyrene and 1.3-butadiene (peaks 4 and 1 in figure A1.9) are evidence of the presence of a styrene-butadiene copolymer. In addition, dibutyl and diisooctyl phthalates were present in these samples, most likely acting as plasticizers. Other peaks in the spectrum include toluene, ethylbenzene, α-methylstyrene, and styrene dimers and trimers, all of which are typically observed in styrene-containing compounds.

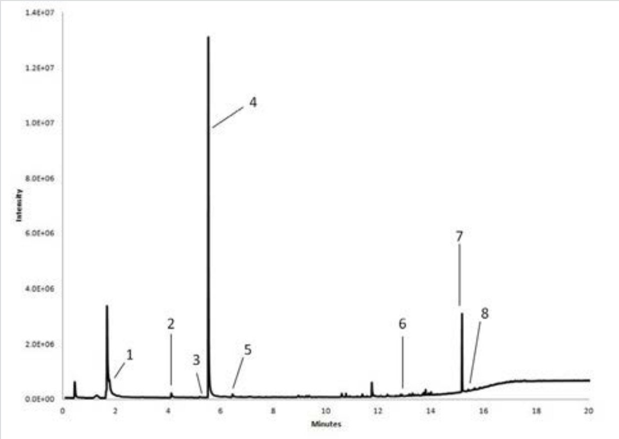


FIGURE A1.9
Pyrogram of Sample 4 from Eames House_putty#1a.

The similarity of the pyrograms for all eight samples indicates that the products used were composed of identical organic components, although significant differences in the inorganic content were observed with FTIR.

FTIR analyses also indicated the presence of a styrene-butadiene rubber in these eight samples. The spectrum of sample 7 from Eames House_putty#1a is presented in figure A1.9. The spectra are mostly dominated by the features of styrene, including typical aromatic C-H stretches between 3000 and 3100 cm-1 and peaks at 698 and 756 cm-1. The material available for sample 3 from Eames House_putty#1a was not sufficient for Py-GCMS analyses, but the FTIR spectrum, dominated by the features of styrene, suggests that a styrene-butadiene composition is possible.

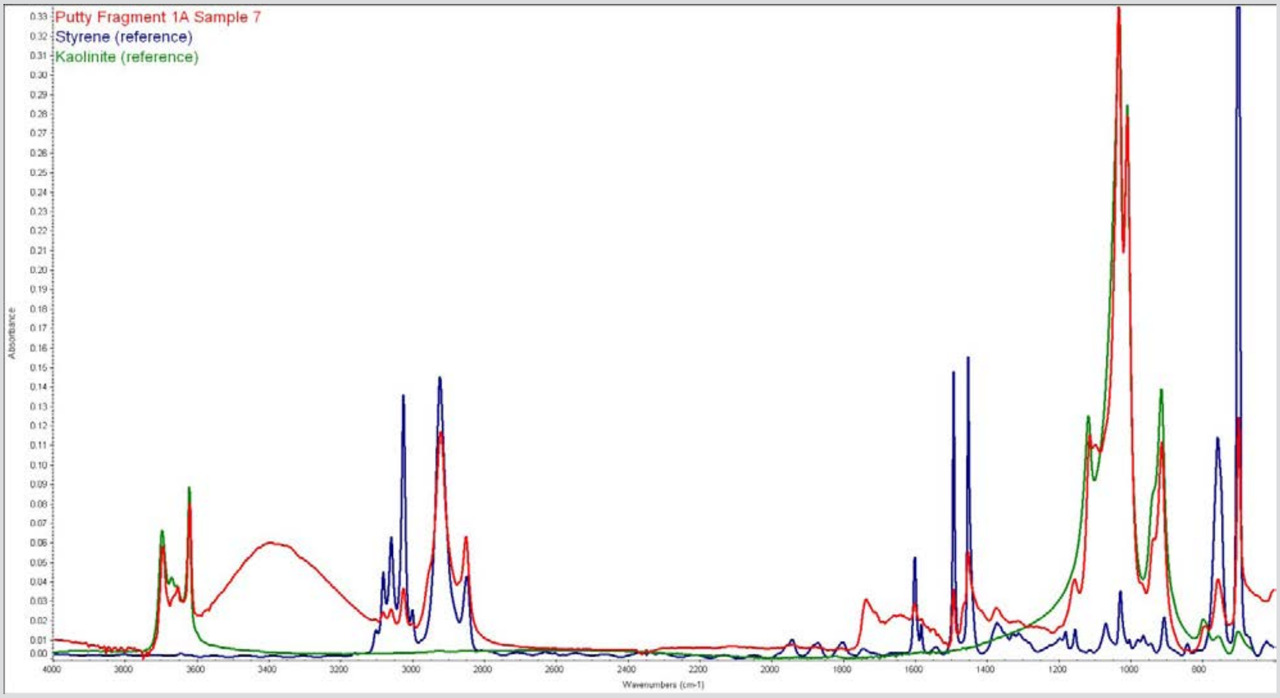


FIGURE A1.10
FTIR spectrum from Sample 3 from Eames House_putty#1a, along with reference spectra for kaolinite and styrene.

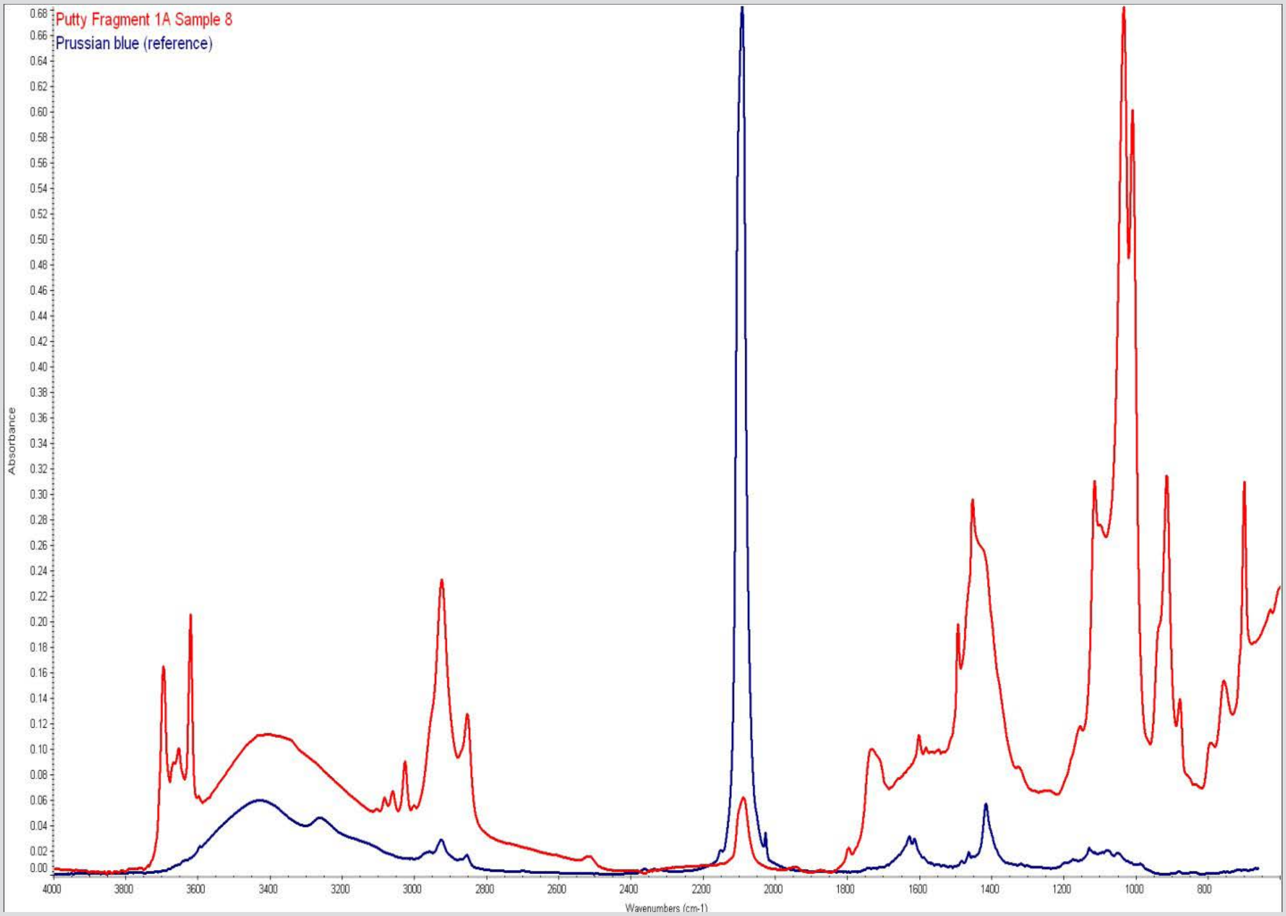


FIGURE A1.11
FTIR spectrum from Sample 8 from Eames House_putty#1a, along with reference spectrum of Prussian blue.

The spectra of all samples containing styrene-butadiene also displayed spectral features characteristic of kaolinite (aluminum silicate), a common filler/extender. The spectrum of sample 4, Eames House_putty#1a, also showed a strong absorbance band at 1450 cm-1 indicating the presence of calcium carbonate in the sample. In addition, Prussian blue was detected in a group of gray and dark gray samples. These were sample 8, Eames House_putty#1a, sample 2, Eames House_putty#1b-2, and samples 1 and 2 from the East exterior window excavation. In the case of sample 8, Eames House_putty#1a and sample 2, Eames House_putty#1b-2, ESEM-EDS analyses of these samples indicated that Prussian blue is actually present as a component of chrome green (i.e., yellow lead chromate with Prussian blue). This could be the case for all samples. The spectrum of Sample 8 from Eames House_putty#1a is presented in figure A.11.

The sample 9 from the North Interior was identified as a chlorinated rubber based on the presence of chlorobutane. The chromatogram from this sample is presented in figure A1.12. Additional peaks include phthalates and styrene (peaks 2, 6 and 8 in figure A1.12).

The FTIR analysis of this sample confirmed the presence of styrene. In addition, the spectrum displayed peaks characteristic of kaolinite. The spectrum was also significantly different from the spectra of samples identified as styrene-butadiene rubbers. The spectrum of sample 9 from North Interior is presented in figure A1.13.

Other samples, (sample 1 from Eames House_putty#1a and East Exterior 1) are likely to contain an alkyd binder. The pyrogram from sample 1 of Eames House_putty#1a is presented in figure A1.14. The markers exhibited by these samples include phthalic acid (peak 4 in figure A1.14) and ions possibly stemming from pyrolysis-induced ring closure reactions of fatty acids (peaks 1-3 in figure A1.14).

(continued on next page)

Commentary on Organic Binder Analysis Results *(continued)*

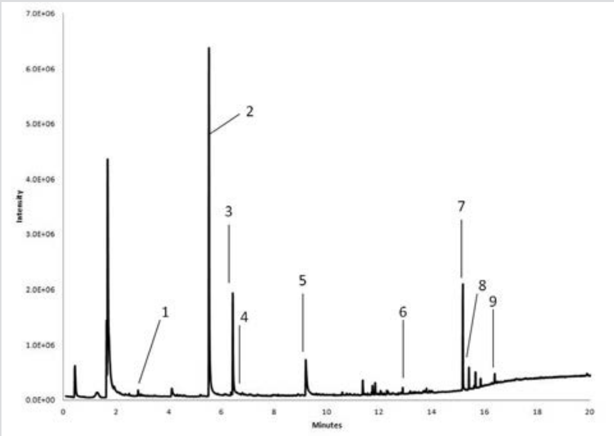


FIGURE A1.12
Pyrogram of sample from North Interior 9.

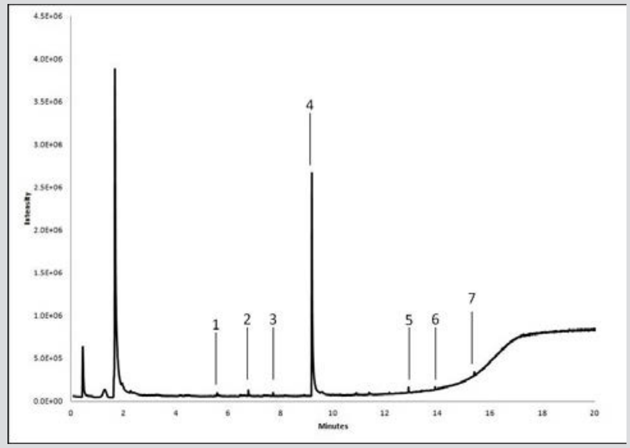


FIGURE A1.14
Pyrogram of Sample 1 from Eames House_putty#1a.

Phthalate plasticizers (dibutyl and diisooctyl phthalates noted as peaks 6 and 8 in figure A1.14), were also identified. It is worth noting that no polyol, one of the building blocks of alkyd resins, was detected in these samples.

The FTIR analysis of these samples confirmed the presence of an alkyd resin. Characteristic alkyd stretches observed in their spectra include strong absorbance bands

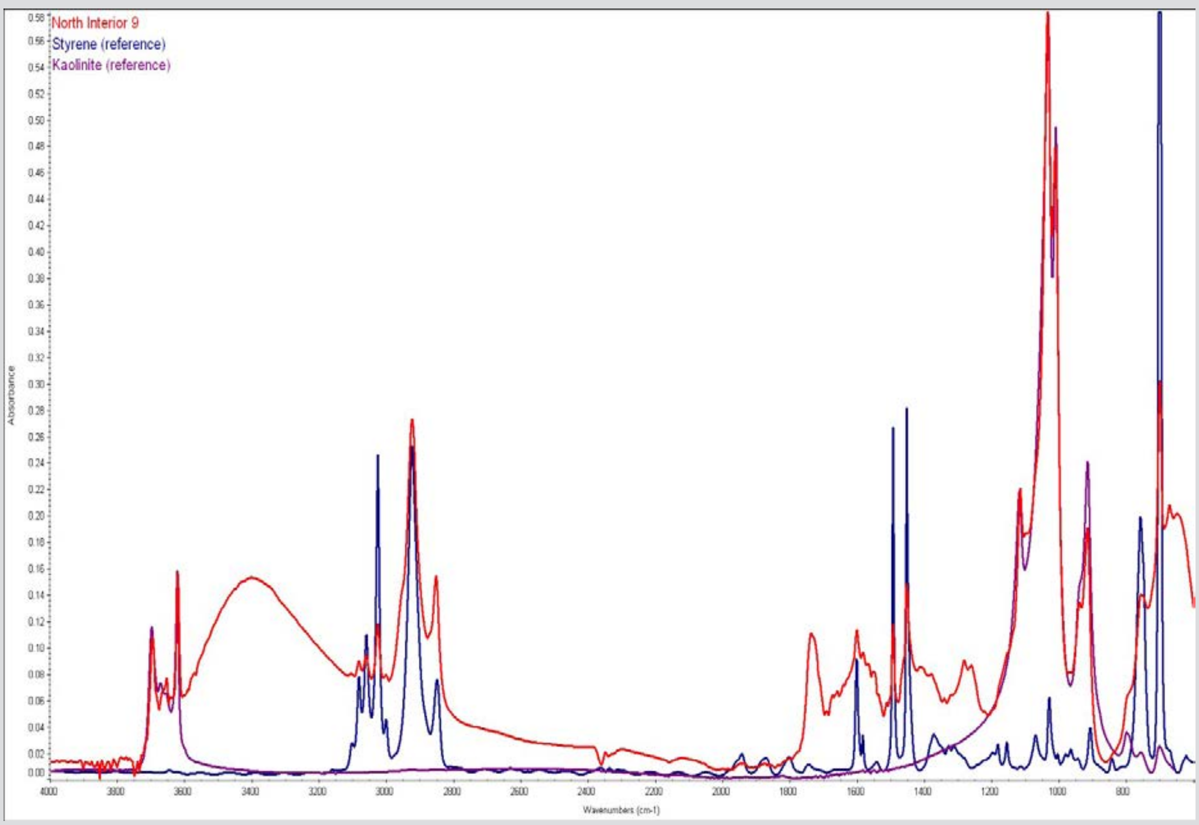


FIGURE A1.13
FTIR spectrum from sample from North Interior 9, along with reference spectra for kaolinite and styrene.

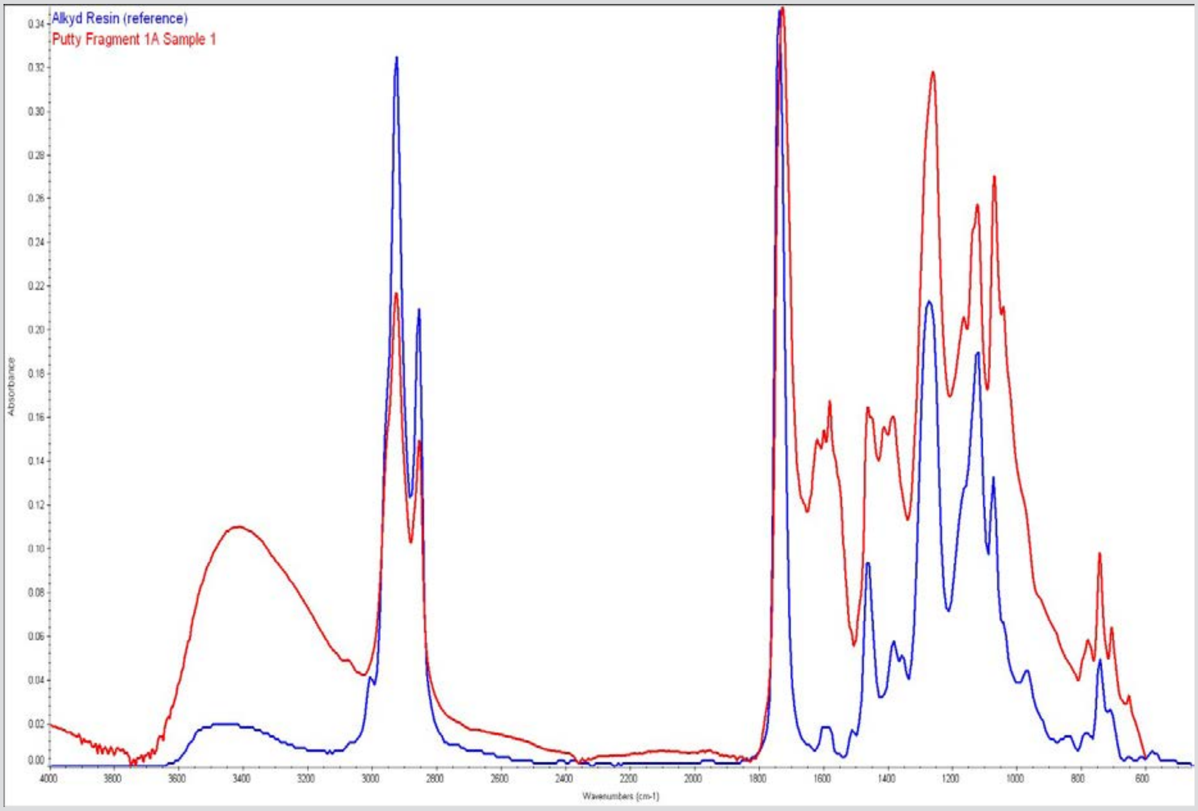


FIGURE A1.15
FTIR spectrum from Sample 1 from Eames House_putty#1a, along with reference alkyd resin spectrum.

at 1730 and 1260 cm^{-1}, as well as smaller peaks at 750, 1100, and 1490 cm^{-1}. Various fillers were also detected. Sample 1 from Eames House_putty#1a included peaks indicative of the presence of talc (magnesium silicate) and calcium carbonate, while East Exterior 1 showed peaks characteristic of kaolinite and calcium carbonate. The spectrum of Sample 1 from Eames House_putty#1a is presented in figure A1.15.

APPENDIX 1.2

List of Samples from Paint Cans and Painted Putty Fragments

TABLE A1.6

Sample List: 12/13/2011, Eames House (prepared by EMK, 1/2/12).

Samples from cans that were previously located and photographed		
Sample No.	**Sample label/description**	**Notes**
Can #1	Royal Blue Unknown	White and blue paint inside the can, white under blue, looks like blue was poured into the can over dried white paint, sampled a drip from interior and flakes from exterior
Can #2	Benjamin Moore Flat Finish Acrylic Studio Exterior Orange	Sample taken from can lip, some coating (gray) and possibly metal may be included in the sample
Can #3	Benjamin Moore Interior White 2009	Sampled from paint can lid
Can #4	Exterior Wall Flat Black 2003	Sampled from a drip down the side of the can, from over the label; can says "¼ Oil Satin"
Can #5	Ameritone Interior Black Satin 1990-91	Sampled two drips from the label, includes some paper
Can #6	Ultra Latex Flat Red, Kitchen 1996	Sample taken from can lip
Can #7	Dunn-Edwards exterior metal white 1990-91	Sample taken from can lip
Can #8	Dunn-Edwards exterior wall Royal Blue 1990	Sample taken from can lip
Can #9	Dunn-Edwards Studio Wall Light-blue 1990	Sample taken from can lip
Can #10	Dunn-Edwards Studio Walls White	Sampled from can lip, can photographed
Can #11	Cal Western Interior House Trim Black 2003	Sampled from can lip, photo of can and lid label, the can lip has grey and black paint layers; the black shiny surface appears grey when cut into, the can coating is also grey
Can #12	Benjamin Moore Flat Finish Black 215 80	Sampled from can lip, photographed can
Can #13	Zinsser Primer White	Scraping/sample from can lip and from a drip over the label just below the lip (white painted label)
Can #14	Dunn-Edwards Vin-L-Tex Exterior White Walls 1990	Sampled from can lip, photographed can
Can #15	Shiny Black Ext	Samples from can lip, photographed can, no label on can and label on lid is illegible (image processing may help with legibility)
Putty #1	Painted window putty from after 1994 earthquake	Large samples taken from a container filled with putty fragments, the samples have a slightly different appearance – lighter and darker putty colors, perhaps two different putty campaigns

CHAPTER 2

In Situ Paint Investigation of the Exterior Steelwork of the Eames House Residence and Studio

Emily MacDonald-Korth

2.1. Introduction

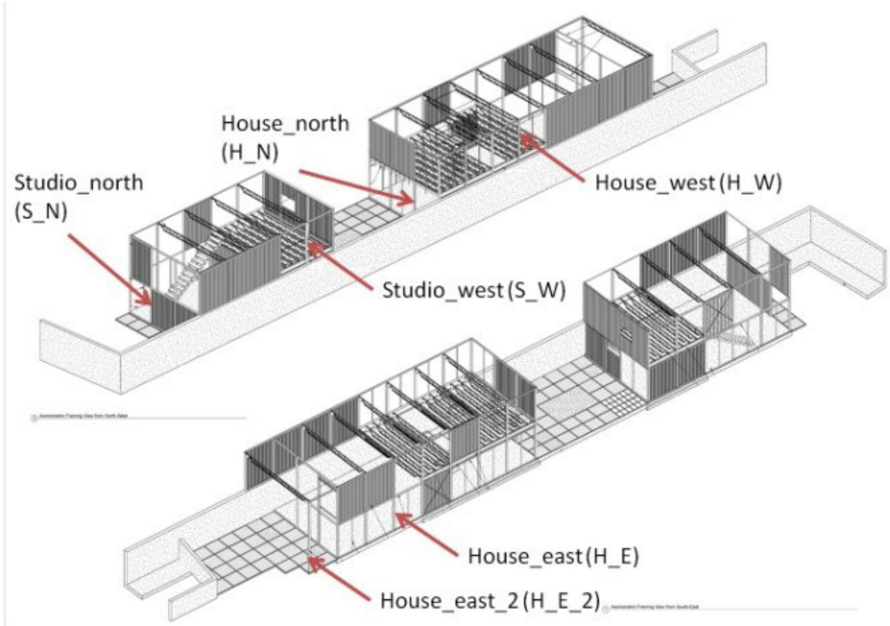
From March 2012 to February 2013, an in situ paint investigation was carried out on the exterior of the Eames House by Emily MacDonald-Korth, Associate Project Specialist, the Getty Conservation Institute (GCI) (fig. 2.1). The investigation aimed to reveal the stratigraphy of the exterior paint color at the residence and studio of the Eames House, and specifically at three significant dates: 1949, when the house was completed; 1978 when Charles Eames died; and 1988 when Ray Eames died. Color information was also obtained during the investigation and may be used to develop paint color recommendations for future painting campaigns. This investigation builds upon the results of the historic research, as well as the scientific analysis of paint stratigraphy, pigments, and organic binders (see chapter 1).

2.2. Methodology

This section outlines the methodologies and techniques that were used to determine the stratigraphy and approximate dates of paint campaigns at the Eames House residence and studio.

FIGURE 2.1
The Eames House during the in situ paint excavations, 2013.

FIGURE 2.2
Locations of in situ paint excavation sites.
Drawing: Adapted from drawing by Escher GuneWardena Architecture, © Eames Office.



2.2.1 Excavation Exposure Windows

The in situ paint investigation is focused solely on the paint on the exterior steel framework of the Eames House. Six in situ paint excavation exposure windows, and complementary cross-sectional optical microscopy, were carried out on the exterior steel beams on the north, east, and west elevations of the residence and on north and west elevations of the studio (fig. 2.2). The paint excavation sites (sample sites) were selected based on proximity to sampling sites undertaken in 2011, and on the need to study different elevations.

The paint excavation names and dates of excavations are as follows:

- House_north (H_N) – June 20 2012
- House_east (H_E) – July 3 2012
- House_west (H_W) – July 20 2012
- Studio_north (S_N) – July 20 2012
- Studio_west (S_W) – July 20 2012
- House_east_2 (H_E_2) – October 10 2012

The in situ paint excavations sought to reveal all layers of paint from the uppermost paint layer to the steel beam substrate on a sufficient scale to gauge the hue with the naked eye and take color measurements where required. The results of the in situ paint investigation were compared with the results of the GCI's 2011 investigations and historic research on the paint campaigns at the Eames House (see chapter 1).

Using a small stainless steel scalpel blade and other mechanical techniques, each paint layer was carefully scraped and cleaved away to reveal the layer beneath, from the steel substrate to the uppermost paint layer (figs. 2.3–2.4). The sizes of the exposure windows varied; they were approximately 1 × 1–2.5 in. (2.5 × 2.5–6.4 cm). Observations made during in situ examination were written and recorded with digital photo documentation before and after excavation. A digital microscope was also used to photograph select sample sites. Sample sites are not visually distracting from a distance, but are large enough to reveal the color of each layer when viewed up close.

FIGURE 2.3
Emily MacDonald-Korth excavating exterior paint layers at the Eames House (sample location House_ east), 2013.
Photo: Scott Warren

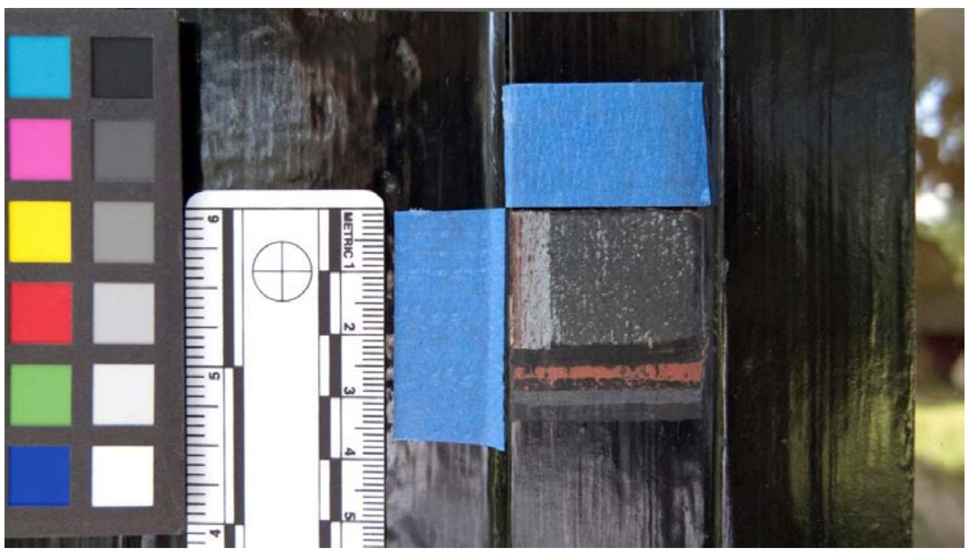


FIGURE 2.4
Detail of in situ paint excavation exposure window (H_E) after completion.
Photo: Scott Warren

2.2.2 Sampling

Cross section samples were taken from the edge of each sample site, and samples were collected using a wearable magnification visor and a stainless steel microscalpel (blade #15). Sampling aimed to include as many layers as possible and to be certain all layers revealed in the exposure window were collected. The samples were taken on a very small scale and sampling was kept to a minimum to preserve the work in its most intact form and to limit the need for later intervention.

2.2.3 Cross-Sectional Optical Microscopy Procedures

Cross-sectional optical microscopy provides information about paint layer stratigraphy and allows for some characterization of binders and coatings, based on the morphology of layers and particles, and autofluorescence of the layers under varying wavelengths. The samples were cast in acrylic resin, sanded, and polished to expose the cross section surface. In the laboratory, cross section samples were examined using a stereomicroscope, and the fragments selected for examination as cross sections were mounted in Technovit 2000 LC resin, a UV-curing acrylic. After curing, the mounted samples were fine-sanded and dry-polished by hand. The prepared cross section samples were examined under visible light with a polarizing filter and ultraviolet (UV) light, to view autofluorescence, using a Leica DM4000 microscope. Digital images were captured through the microscope using a Diagnostic Instruments Flex camera. Using fluorescence microscopy and imaging techniques, the stratigraphy was identified. The stratigraphy of the excavation exposure window and the stratigraphy of the cross section samples were compared.

2.2.4 Color Measurement and Matching Procedures

Color measurements of the stratigraphic layers were taken in situ at the sample sites with a tristimulus handheld spectrophotometer, manufactured by Konica Minolta (CM-2600d), to measure color revealed as the earliest paint layer on excavation site House_East (appendix 2.1). The color data is communicated in the CIELAB color space, which is very accurate, but is not widely used by paint manufacturers. Munsell color systems are more widely used and the data can be translated to the Munsell system, if necessary. The Tnemec paint system was preselected for the project. The color of the earliest extant (estimated to be the original) paint layer was matched by eye and by color data correlated to the selected swatches. The change in color in the CIELAB system is measured as total color difference or ΔE^*; the perceptible difference between two colors is accepted to be 2–5 ΔE, although well-trained eyes may see as little as 1 ΔE.

Color measurements of the residence and studio were taken, and the earliest extant layer estimated to be the original paint layer of the steelwork was measured. Colors were measured on site; the exposure window was compared to color swatches of commercial paint over different times of day and at different elevations (Tnemec Industrial Coatings). The swatches that most closely matched the earliest extant paint layer were then measured with a handheld spectrophotometer, and the closest commercial paint color match was selected as a guide for future paint campaigns.

2.2.5 Complementary Techniques of the GCI Paint Investigations

In 2011, the GCI scientists performed an extensive paint analysis investigation on samples taken from the interior and exterior steel beams and window frames of the Eames House (see chapter 1). The investigation included optical microscopy and organic and inorganic analysis to characterize the materials and identify the components in an attempt to determine the age of the paints based on their chemistry, products on the market at certain dates, and known dates of painting campaigns at the site. Chapter 1 discusses the results of the broad study of the paint layering history and describes the characteristics of each paint layer in great detail.

The cross-sectional optical microscopy in the 2011 investigation and in situ paint excavation exposure windows undertaken in 2012–13 are valuable complementary techniques for multiple reasons. Cross-sectional optical microscopy is necessary when performing paint excavations to compare the layers revealed in the exposure window to the layers visible in the cross-sectional sample; more layers are often visible in cross section. There is a value in viewing historic colors at the macro scale: cross-sectional representations of colors often cannot represent hues accurately, though relative color differences can be compared between strata; and an exposure window made through paint excavation techniques can be extremely valuable for communication among the project partners. Furthermore, accurate color measurements cannot usually be made using standard colorimeters, but require a larger area from which to measure the color. Under the microscope, it is possible to see very subtle structural variations; to identify differences between layers using ultraviolet light; and to see temporal changes, such as dirt. Excavation exposure windows reveal paint layers on a scale visible with the unaided eye, and yields textural material property data not possible to get with microscopy; observations about layers such as brittle, tough, soft, or well-adhered are regularly made during paint excavation. There are advantages to each method, but using both together is the most valuable approach. Comparisons of the results of these techniques are discussed in Section 2.4.

2.2.6 Limitations

In many paint excavations, it can be nearly impossible to separate all of the layers because of the thickness, hardness, texture, bonding, or cleaving at layer interfaces, or the degree of deterioration. For example, a very thin and brittle paint layer is often more difficult to reveal than a thick and tough paint layer because the brittle layer will likely fracture during removal of the layer above it. Similarly, two semisoft layers can interact in such a way that their border becomes joined and impossible to separate at the interface with standard excavation methods.

In most cases the sheen cannot be accurately evaluated in an exposure window because of abrasion to the surface, interactions between layers over time, possible sanding before repainting, and the scraping and damage to the paint layer caused during excavation with a scalpel. In some cases, paint layers cleave completely and cleanly because of poor adhesion, potentially making it possible to accurately evaluate the sheen.

A number of excavations were carried out on warm days and in direct sun causing the paint layers to soften. In some areas the softened layers would not separate without nicks. Cooler weather allowed these layers to cleave more readily.

2.3. Analysis of the Exterior Paint Stratigraphy of the Steelwork at the Eames House

The six excavation sites had very similar stratigraphy, with few and slight variations in layering structure. The results of the in situ paint investigation were as expected: the stratigraphy correlated closely to the stratigraphy identified in the 2011 investigation. For example, the initial excavation on the east wall aligns with the previous paint analysis. The residence was originally a warm gray and was painted a series of grays and blacks before being painted the current black paint color. In the 2011 study, a warm gray paint comprised of fine black, white, red, blue-green, and yellow particles was identified in all exterior samples and is accepted as the original exterior paint color. A representative sample from each study was compared, and the photomicrographs were diagrammed and annotated. It was observed that select elevations appeared to deviate slightly from the general stratigraphy, which is described below, though the first several coating layers are alike in all samples. The stratigraphic variations between excavation sites may be a result of localized repairs and maintenance.

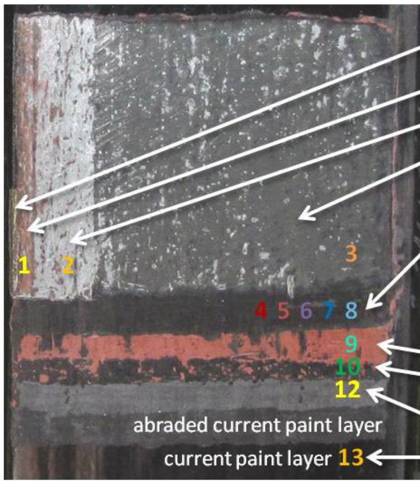


FIGURE 2.5
In situ paint excavation exposure window after completion (H_E), with layers numbered chronologically from lowest (earliest, number 0) to uppermost (most recent, number 13), and annotations where necessary.

FIGURE 2.6
Paint layering structure diagram (not to scale), with arrows referring to the adjacent exposure window diagram.

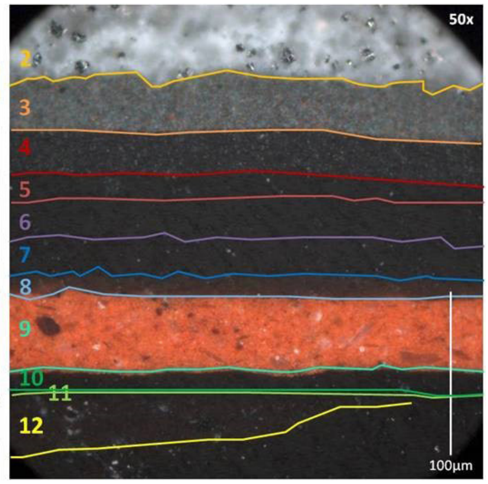


FIGURE 2.7
Photomicrograph of cross-sectional sample taken from the exposure window in figure 2.5 (H_E). Layers are delineated and numbered.

2.3.1 Details of the Paint Stratigraphy Analysis

From the results of the in situ investigation, a general paint stratigraphy for the exterior steelwork of the residence and studio can be summarized as follows. The steel substrate shows one to three layers of primer and a corrosion inhibitor, followed by a warm gray paint. A dark gray paint was applied at some time, followed by a series of one to three black paints. The black paint was then coated with a shiny brown material, followed by a black paint and then a gray paint, before the current black paint was applied (figs. 2.5–2.7).

The colors of the first and second paint layers were made using a painterly method—they were mixed as a fine artist might—and suggest a great care in achieving very specific grays. These two earliest gray paints differ in color, but have compositional similarities. They were made via subtractive color mixing with red, blue-green, and yellow particles in addition to white and black. The lower warm gray is estimated to be the original surface coating for the house and it was a unique gray. Early accounts of the house mention a "dark warm gray" or "dark neutral gray" color for the metalwork (Eames and Entenza 1949, 29–30). Ray Eames was an artist and colorist, and the earliest paint layers at the Eames House may demonstrate her influence on the selection of paint colors

Detailed observations from each sample site and associated cross section sample can be found in figures 2.8–2.13. Diagrammed photomicrographs of each sample cross section with annotations (under reflected visible and ultraviolet lights) can be found in figures 2.14–2.18.

House_north

FIGURE 2.8A
Eames House paint excavation location: House_north.

FIGURE 2.8B
House_north, in situ paint excavation exposure window.

FIGURE 2.8C
House_north, in situ paint excavation exposure window.

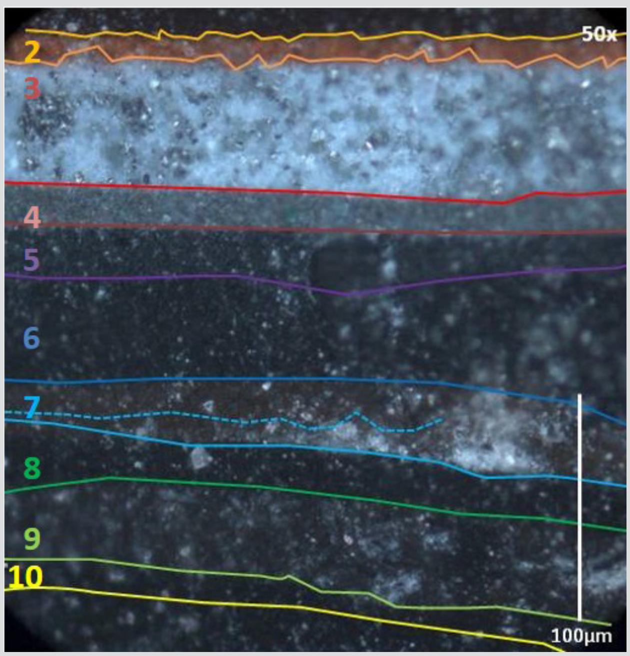


FIGURE 2.8D
House_north cross section microphotograph, with stratigraphic layers numbered (reflected visible light, 50×).

KEY:

0. Steel, (not included in cross section)
1. Primer, yellow-green (not included in cross section)
2. Primer, orange
3. Corrosion inhibitor
4. Warm gray paint (white, black, red, yellow, blue-green particles), the first exterior paint layer
5. Dark gray paint (black, white, and red particles)
6. Black paint (uniform black particle content)
7. Brown layer, possibly a coating
8. Black paint (uniform black particle content)
9. Dark gray paint (black and white particles)
10. Current paint layer, black paint

House_north

FIGURE 2.9A
Eames House paint excavation location: House_east. Pictured: Tom Learner and Ana Paula Arato Gonçalves from the GCI.

FIGURE 2.9B
House_east, in situ paint excavation exposure window.

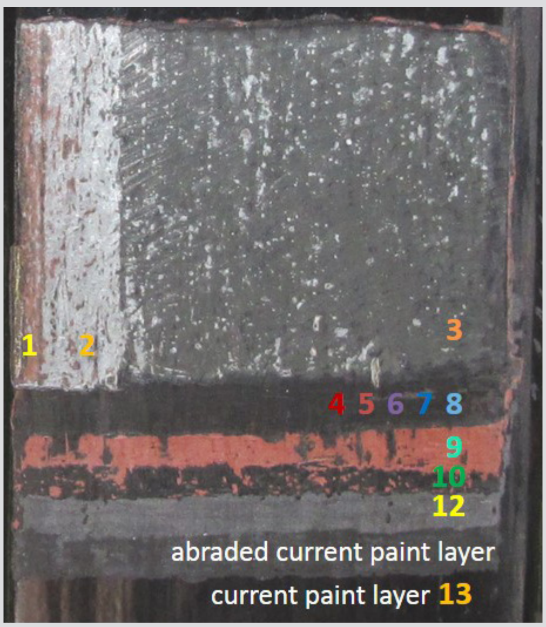


FIGURE 2.9C
House_east, in situ paint excavation exposure window with numbered layers.

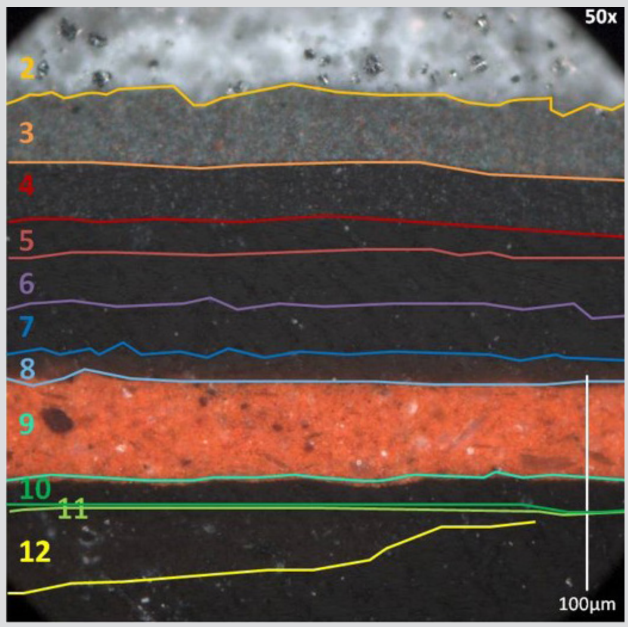


FIGURE 2.9D
House_east cross section microphotograph with stratigraphic layers numbered (reflected visible light, 50×).

KEY

0. Steel, not pictured
1. Primer (not included in cross section image)
2. Corrosion inhibitor
3. Warm gray paint (white, black, red, yellow, blue-green particles), the first exterior paint layer
4. Dark gray paint (black, white, and red particles)
5. Black paint (uniform black particle content)
6. Black paint (uniform black particle content)
7. Black paint (uniform black particle content)
8. Brown layer, possibly a coating
9. Orange primer
10. Black paint (uniform black particle content)
11. Dirt/grime layer
12. Dark gray paint (black and white particles)
13. Current paint layer, black paint (not included in cross section image)

House_east_2

FIGURE 2.10A
Eames House paint excavation location: House_east_2

FIGURE 2.10B
An additional excavation was performed on beam 4D. A cross section sample was taken but was not imaged in 2013, at the time this report was prepared.

KEY

1. Primer, yellow-green
2. Primer, orange
3. Corrosion inhibitor
4. Warm gray paint; the first exterior layer
5. Dark gray paint
6. Black paint
7. Brown layer, possibly a coating
8. Current paint layer, black paint

FIGURE 2.10C
House_east_2, in situ paint excavation exposure window with numbered layers.

House_west

FIGURE 2.11A
Eames House paint excavation location: House_west.

FIGURE 2.11B
House_north, in situ paint excavation exposure window.

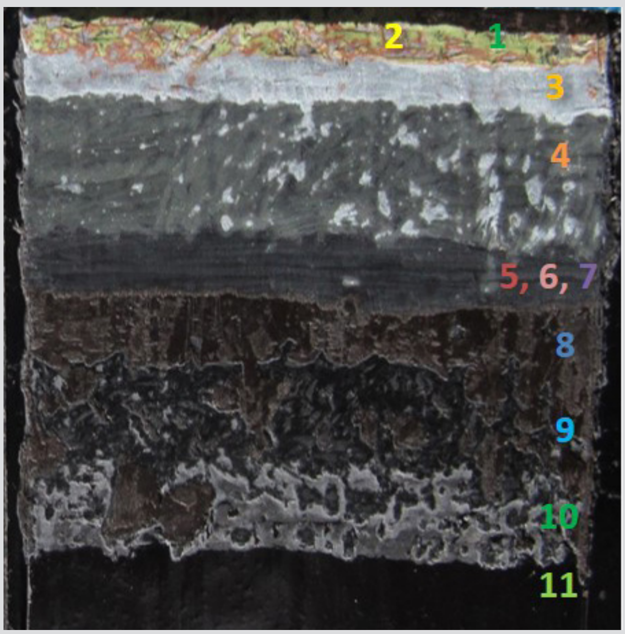


FIGURE 2.11C
House_west, in situ paint excavation exposure window.

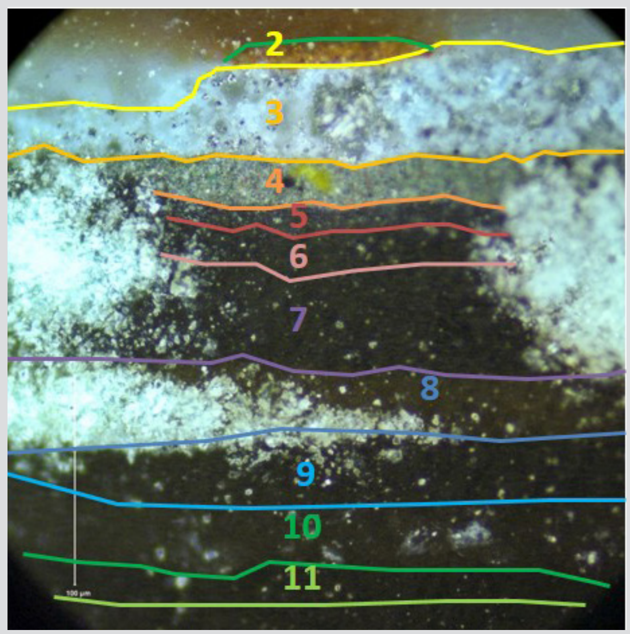


FIGURE 2.11D
House_west, cross section microphotograph, with stratigraphic layers numbered (reflected visible light, 50×).

KEY

0. Steel, (not included in cross section)
1. Primer, yellow-green (not included in cross section)
2. Primer, orange
3. Corrosion inhibitor
4. Warm gray paint (white, black, red, yellow, blue-green particles), the first exterior paint layer
5. Dark gray paint (black, white, and red particles)
6. Black paint (uniform black particle content)
7. Black paint (uniform black particle content)
8. Brown layer, possibly a waterproofing layer
9. Black paint (uniform black particle content)
10. Dark gray paint (black and white particles)
11. Current paint layer, black paint

Studio_north

FIGURE 2.12A
Eames House paint excavation location: Studio_north.

FIGURE 2.12B
Studio_north, in situ paint excavation exposure window.

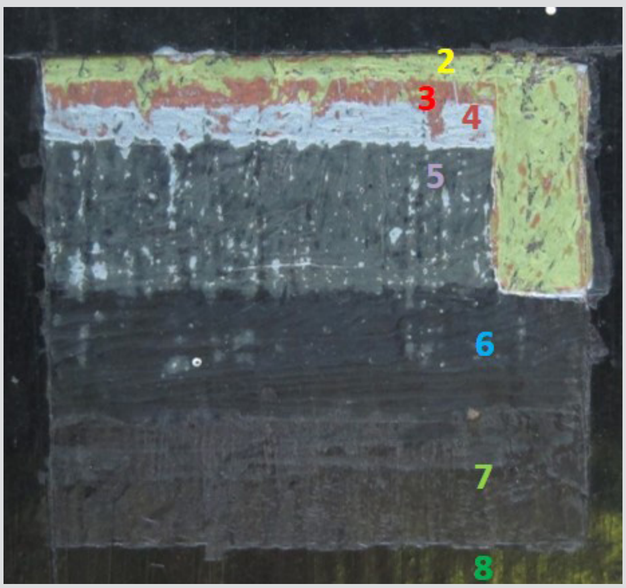


FIGURE 2.12C
Studio_north, in situ paint excavation exposure window.

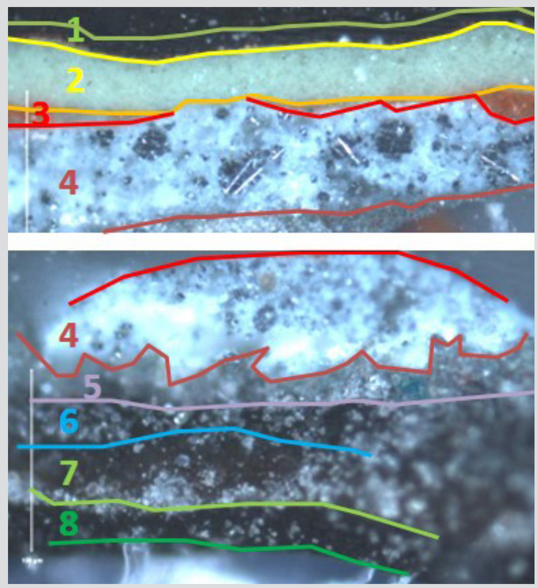


FIGURE 2.12D
Studio_north, cross section photomicrographs of one sample in two fragments with stratigraphic layers numbered (reflected visible light, 50×), the sample fractured during mounting.

KEY

0. Steel, (not included in cross section)
1. Black primer
2. Yellow-green primer
3. Orange primer
4. Light gray corrosion inhibitor (contains Zn particles)
5. Warm gray paint (white, black, red, yellow, blue-green particles), the first exterior paint layer
6. Dark gray paint (black, white, and red particles)

Studio_west

FIGURE 2.13A
Eames House paint excavation location: Studio_west.

FIGURE 2.13B
Studio_west, in situ paint excavation exposure window.

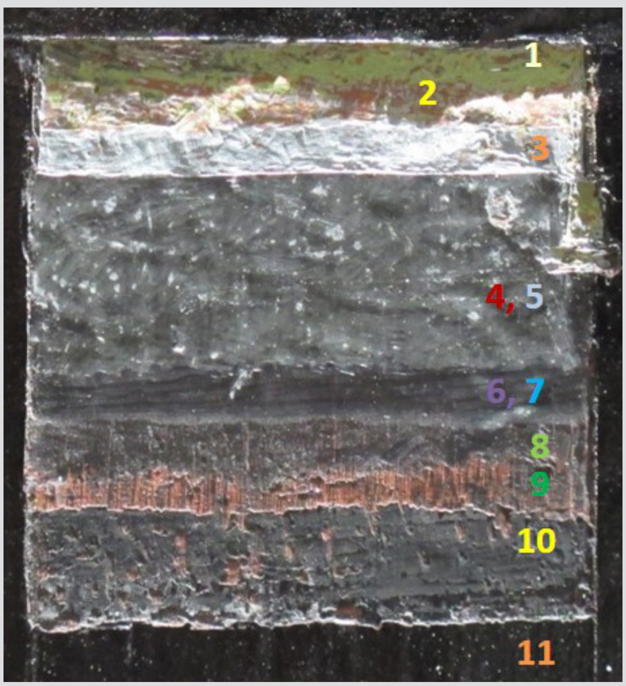


FIGURE 2.13C
Studio_west, in situ paint excavation exposure window.

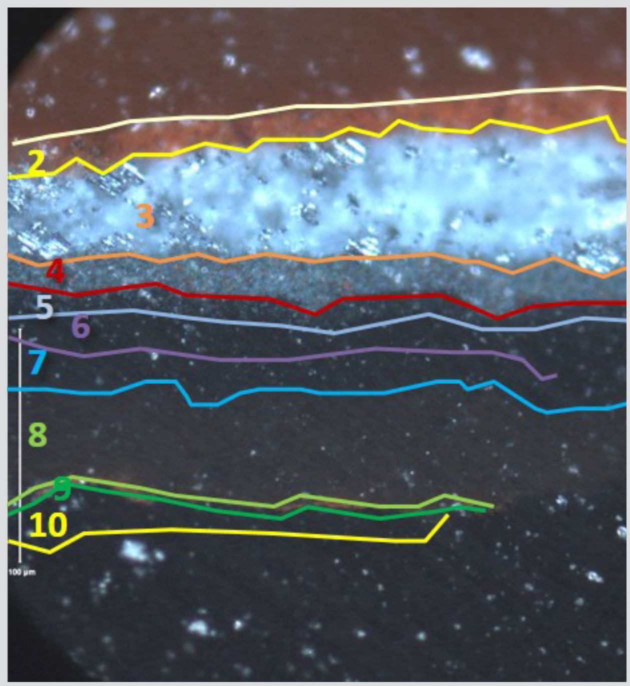


FIGURE 2.13D
Studio_west, cross section photomicrograph, with numbered layers (reflected visible light, 50×).

KEY

0. Steel, (not included in cross section)
1. Primer, yellow-green (not included in cross section)
2. Primer, orange
3. Corrosion inhibitor
4. Warm gray paint (white, black, red, yellow, blue-green particles), the first exterior paint layer
5. Dark gray paint (black, white, and red particles)
6. Black paint (uniform black particle content)
7. Black paint (uniform black particle content)
8. Brown layer, possibly a waterproofing layer
9. Primer, orange
10. Dark gray paint (black and white particles)
11. Current paint layer, black paint (not included in cross section)

House_north

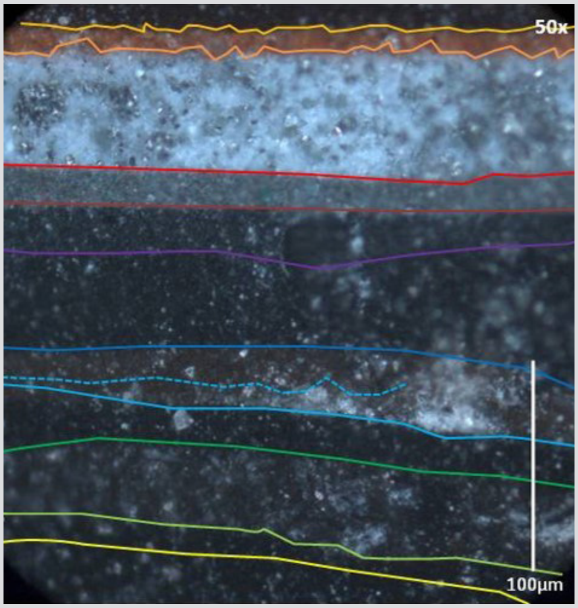


FIGURE 2.14A
House_north, cross section photomicrograph, with stratigraphic layers numbered (reflected visible light, 50×).

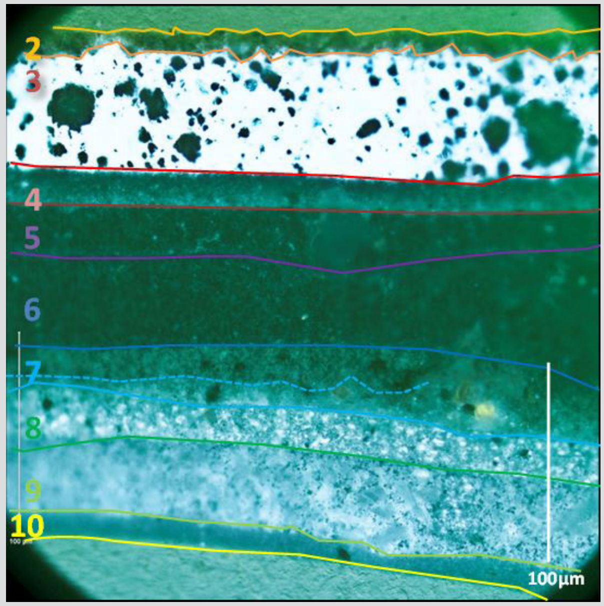


FIGURE 2.14B
House_north, cross section photomicrograph, with stratigraphic layers numbered (reflected ultraviolet light, 50×).

House_east

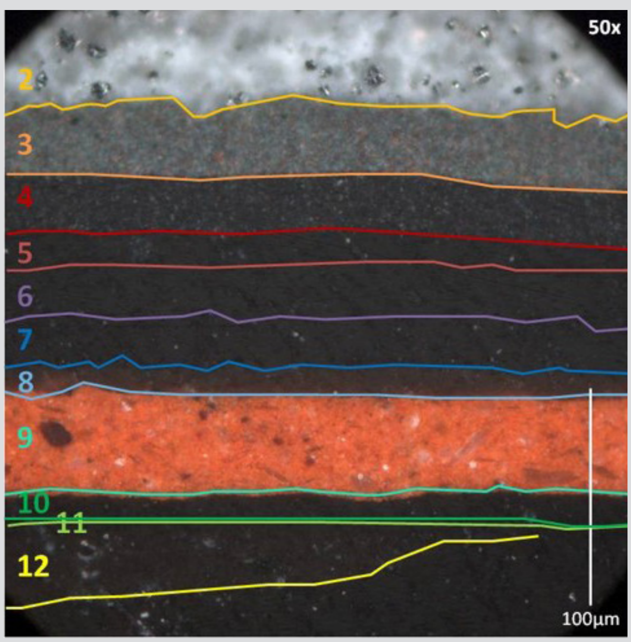


FIGURE 2.15A
House_east, cross section photomicrograph, with stratigraphic layers numbered (reflected visible light, 50×).

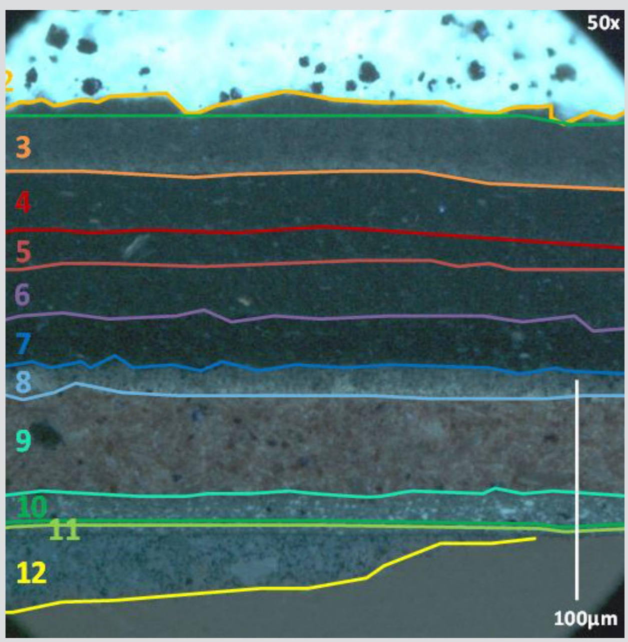


FIGURE 2.15B
House_east, cross section photomicrograph, with stratigraphic layers numbered (reflected ultraviolet light, 50×).

House_west

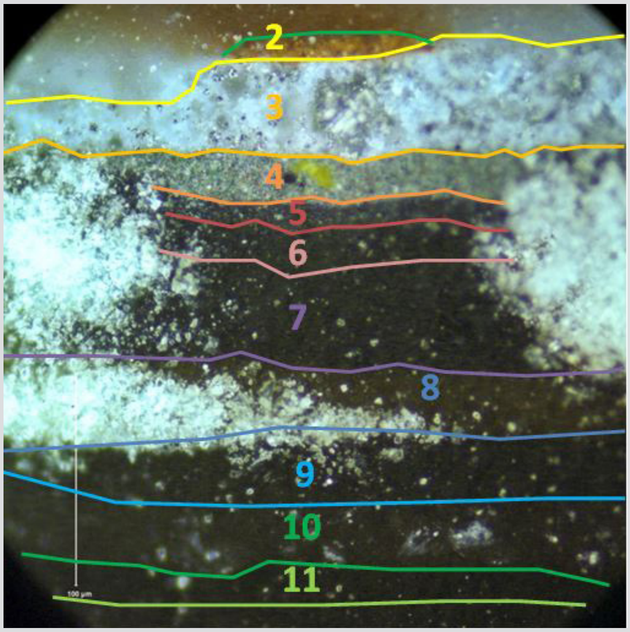


FIGURE 2.16A
House_west, cross section photomicrograph, with stratigraphic layers numbered (reflected visible light, 50×).

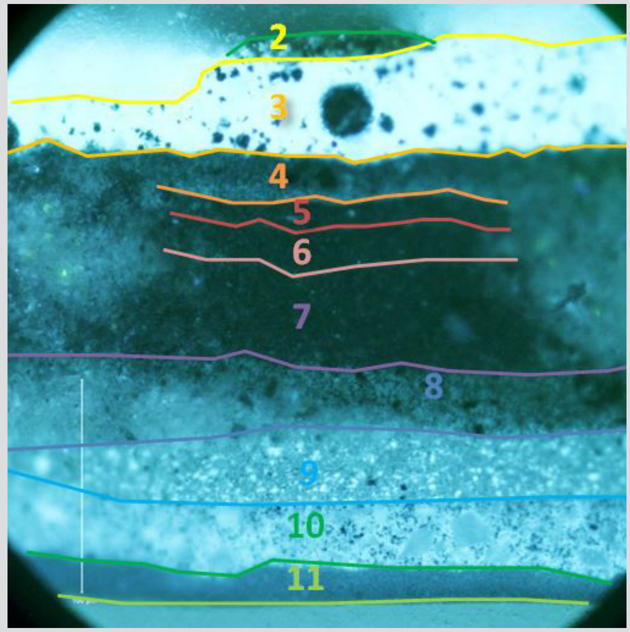


FIGURE 2.16B
House_west cross section photomicrograph, with stratigraphic layers numbered (reflected ultraviolet light, 50×).

Studio_north

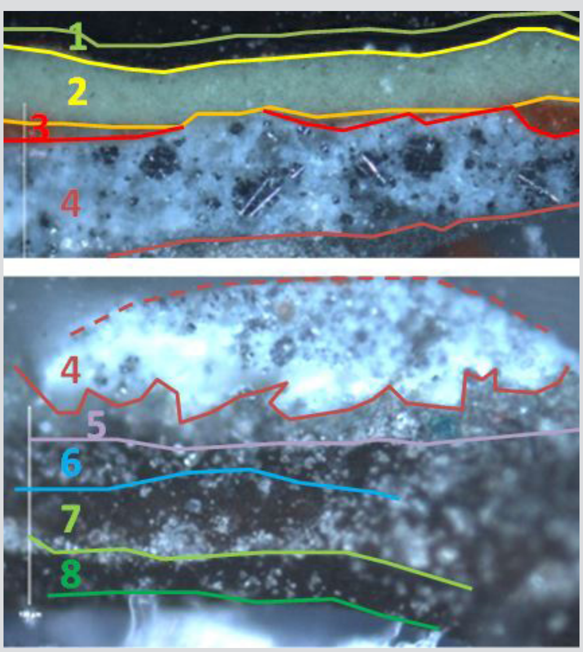


FIGURE 2.17A
Studio_north, cross section photomicrograph, with stratigraphic layers numbered (reflected visible light, 50×).

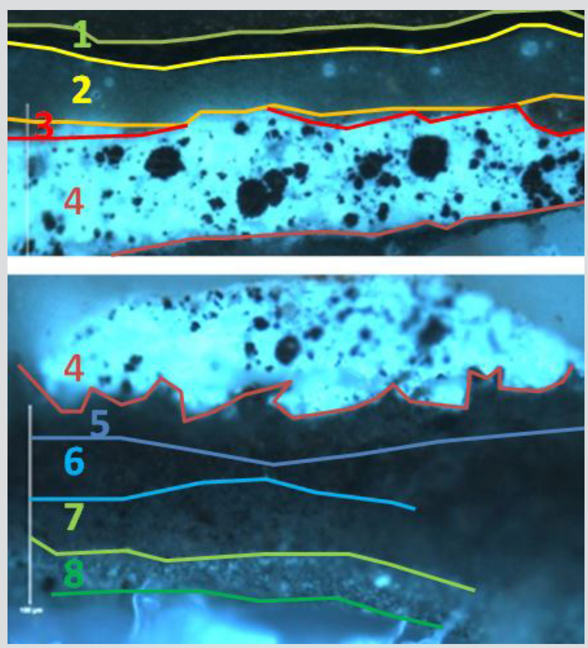


FIGURE 2.17B
Studio_north cross section photomicrograph, with stratigraphic layers numbered (reflected ultraviolet light, 50×).

Studio_west

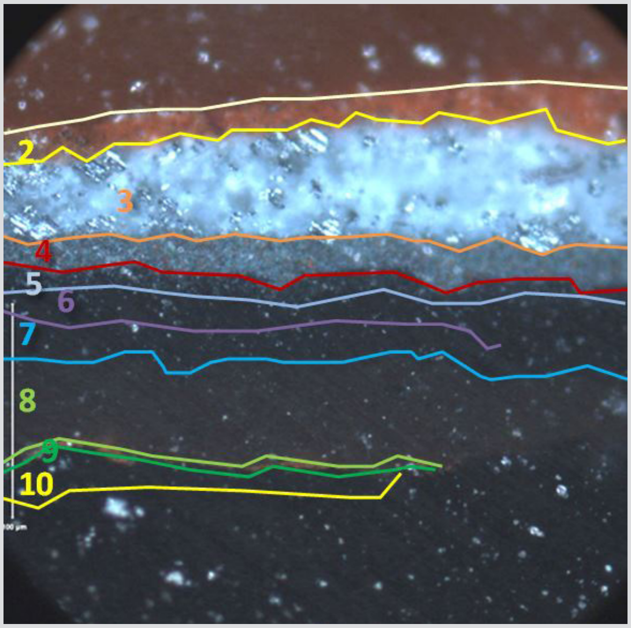


FIGURE 2.18A
Studio_west, cross section photomicrograph, with stratigraphic layers numbered (reflected visible light, 50×).

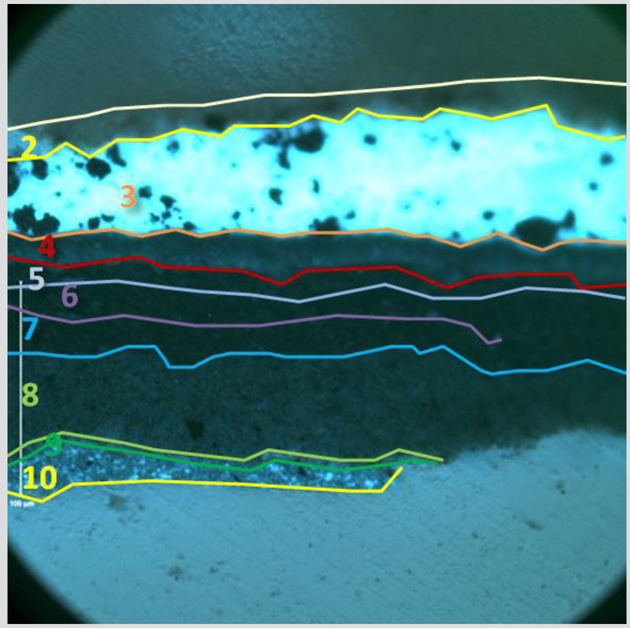


FIGURE 2.18B
Studio_west cross section photomicrograph, with stratigraphic layers numbered (reflected ultraviolet light, 50×).

2.3.2 Deduction of Estimated Painting Campaign Dates and Related Observations

In 2011, the GCI attempted to date each coating layer using historical records and methods of chemical analysis (see chapter 1). The study yielded a great deal of information about the coatings, but the date of each painting campaign could not be identified. Reasonable approximations were made, however, based on available resources and are illustrated in an estimated timeline. Known and approximate dates of painting campaigns were based on physical evidence found in the in situ investigation and compared to the results of the 2011 investigation and to documentation from the Eames Foundation.

The results of the paint investigations at the Eames House residence and studio show between eight and thirteen layers, organized in six to eight painting campaigns between 1949 and 2013 (fig. 2.19). The samples from the exterior metalwork give evidence for repeated campaigns of priming and painting, and the residence and studio show nearly the same painting history.

Documentation of painting campaigns is held by the Eames Foundation and serves as temporal reference points for comparing revealed strata. These dates are taken from chapter 1:

- 1949 The residence and studio were painted at the completion of construction Source: Entenza and Eames 1949a: 29–30.
- 1958 The Eames House was painted. Source: Note by Dan Osloff, no other supporting documentation.
- 1966 The Eames House studio and residence were painted by Paul Isley in October 1966. Source: Notes from Paul Isley.

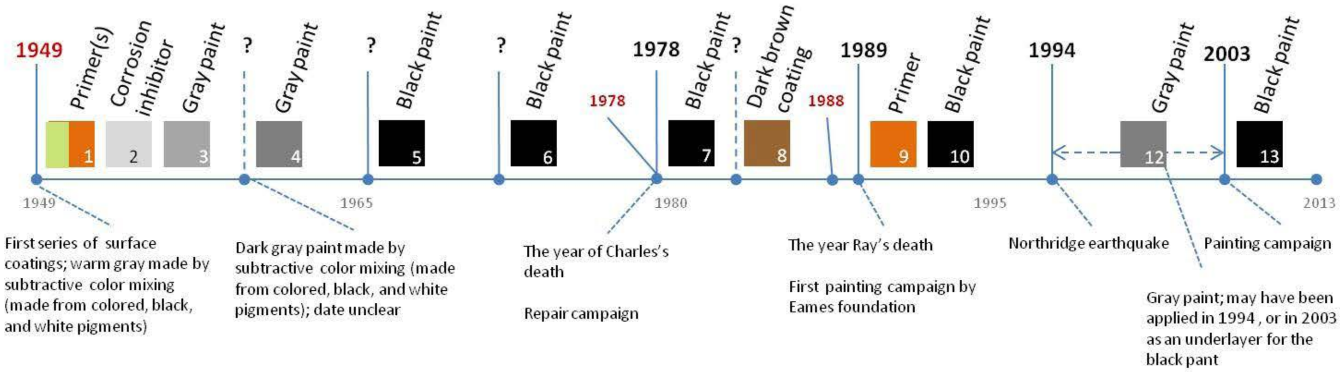


FIGURE 2.19
Estimated timeline of the Eames House exterior paint history. The timeline shows estimated dates for each painting campaign and notes regarding each date or approximate date. Each layer is numbered and each generation is separated with a vertical line that signifies a specific date. The three significant dates are indicated in red. Known dates for paint generations are identified wherever possible and approximate dates are noted with a question mark (e.g. 1978?). Dotted vertical lines and horizontal arrows represent unknown temporal differences between the paint layers on both sides.

- 1968–1973 Several partial painting campaigns of the residence and studio, touch ups. Source: Paul Isley invoices and notes, 1968; 1972; 1973.
- 1974 The Eames House studio and residence were painted on the exterior and interior in July and August 1974. Source: Dan's Painting Company invoice dated October 9, 1974.
- 1977–1978 Several partial painting campaigns of the residence and studio, touch ups. Source: Eames House maintenance log.
- 1989 Eames House painted by Clayton Coatings Inc. Source: Quotations, notes, and recollections of Foundation staff.
- 2003 Eames House exterior painted by Dan Elliott. Source: Invoice by Dan Elliott dated November 2003.

According to the Eames Foundation, no painting campaigns have been undertaken since 2003.

These historical records do not make it clear exactly when the paint color shifted from gray to black.

The same pattern of two adjacent paint layers, dense black over dark gray, at the uppermost level appears in all exposure windows and samples from the exterior metalwork of the building and suggests that these two uppermost layers derive from a recent repainting intervention (or possibly two separate interventions), most likely 2003. The uppermost (black) paint layer can be connected with the known painting campaign in 2003, but whether the dark gray layer immediately beneath derives from that campaign, as undercoat to the black, or from an earlier repair campaign, perhaps immediately after the Northridge earthquake in 1994, cannot be ascertained from the evidence within the samples.

Samples of paint from fragments of putty that were detached in the Northridge earthquake were examined during the GCI's 2011 investigation (see chapter 1). The putty samples show distinct correspondences with the paint samples taken from the residence and studio, and serve as a time-marker. By comparing the layers of the putty fragments (which can be dated pre-1994 with certainty) to exposure windows and samples taken from the structure, a definite dating of the post-1994 layers can be made. The uppermost two layers in the putty fragment samples, black paint over red primer, correspond to layers found in exposure windows and samples from the exterior metalwork of the building. These strata represent the most recent coatings prior to the 1994 earthquake.

Accordingly, based on both their position in the stratigraphy and their composition, these layers can be securely linked to the first repainting campaign commissioned after Ray Eames's death in 1989. The metal framework of the house was black in color in 1989. Immediately beneath the paint and primer layers applied in 1989 lies a dark brown, tough coating, the status and dating of which are relatively uncertain, but surely pre-1989. This layer may be a water-repellent sealant.

In each of these samples, lying directly beneath the dark brown potential sealant is a sequence of black paint layers that appear to represent multiple painting campaigns. The dates of these black painting campaigns cannot be determined with any certainty from the evidence. The materials applied in 1989 are known, however, and the uppermost black paint lies beneath the 1989 coatings and also under the dark brown layer, so it is logical to conclude that the exterior metalwork was black in color at the time of Ray Eames's death in 1988. If the uppermost layer of this early black sequence is tentatively linked to the 1978 repair campaign, then the lower black paint layers must be earlier and could predate Charles Eames's death, suggesting that the exterior metalwork was painted black during Charles's lifetime. Each black paint layer has a distinct interface which indicates complete drying before subsequent paint application. There is no dirt layer present, which could indicate a temporal change, but the surfaces were most likely cleaned before painting. Different numbers of black paint layers among investigation sites suggest some areas may have undergone localized maintenance, touch-ups, for example.

Beneath the series of black paints are two grays: a very dark gray over a lighter warm gray. It is extremely likely that the lower pair of paint layers, dark gray over a lighter warm gray, represent the first two applications of paint to the exterior metalwork.

Both gray paints are made by subtractive color mixing (see chapter 1). The dark gray paint is comprised of black, white, and red particles; similarly, the warm gray is comprised of white, black, green, red, and yellow particles, but is more abundant in red particles (figs. 2.20–2.21). The subsequent paint layers, several blacks and another gray, do not exhibit subtractive color mixing, but are instead made of exclusively black or black and white pigments. Because the two lowest gray paints are made by a painterly method of subtractive color mixing, and are mixed from similar materials in different quantities, it suggests both the dark gray and warm gray paints were made and applied when Charles and Ray Eames were living at the Eames House.

The investigations indicate that the warm gray was completely dry before the dark gray was applied which indicates some time passed, though it is impossible to estimate how long that was. There is no dirt layer between the first and second gray which would indicate a gap in time between painting (and a generational difference), however, the surface could have been prepared or cleaned before the new paint was applied. Historic documentation includes a note that the Eames House was painted in 1958; it is possible that the dark gray paint was applied during this painting campaign. The lower, warm gray paint is estimated to be the original surface coating, applied in 1949. Beneath the warm gray paint are one to three layers of primers (black, yellow-green, and/or orange) followed by a pale gray corrosion inhibitor that features metallic particles (Zn particles).

As the lowest warm gray paint layer is considered to be the original exterior paint color, its color was measured from an exposure window with a Konica Minolta (CM-2600d) handheld spectrophotometer. The color was matched to a commercial paint color that may be considered in future painting campaigns. The color data can be found in appendix 2.1.

2.3.3 Some Qualifications of Results

The residence and studio exterior steelwork have undergone a number of painting campaigns since 1949. The painting history in one location may differ from another, and the small scale of the paint excavation windows leaves additional room for misinterpretation because of the limited surface area that is revealed. For this reason, exposure windows

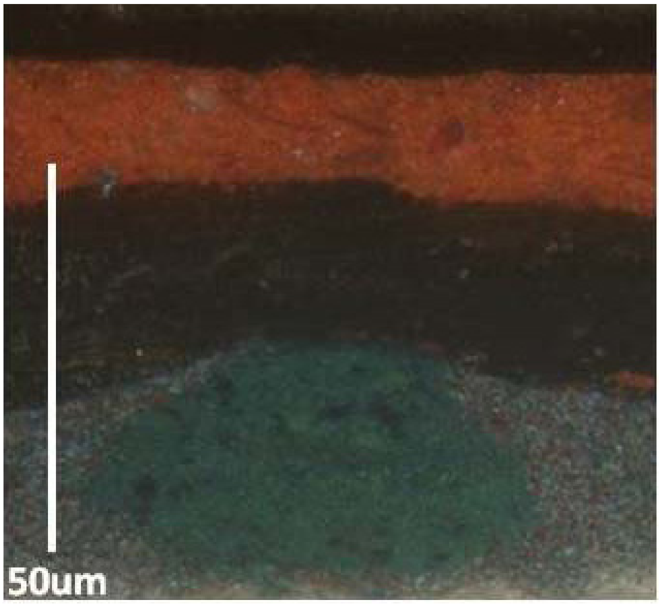


FIGURE 2.20
Cross-sectional photomicrograph of sample taken from putty fragment, showing a large blue-green pigment aggregate and very fine red particles in the gray layer.

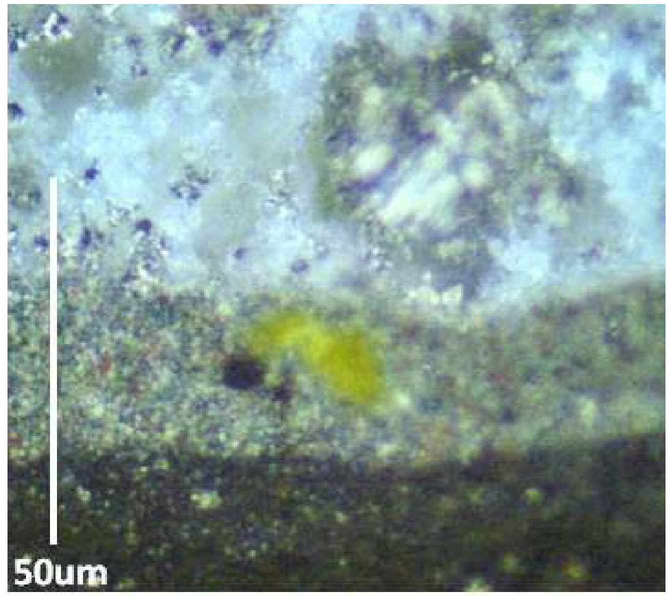


FIGURE 2.21
Cross-sectional photomicrograph of sample taken from exterior paint, showing a large yellow pigment aggregate and very fine red particles in the gray layer. Note the metallic zinc particles in the adjacent layer.

were carried out on multiple elevations, aimed at gathering as much information as possible without compromising the aesthetics of the building.

Paint excavations were undertaken on steel beams with a flat face and away from window frames, which often have more frequent maintenance coatings. The excavations were still relatively close to window frames in many cases and may have been repainted more frequently than other locations. Though there were repair and maintenance campaigns on the window frames, which resulted in varying strata, there is little variation between the layering structure of the steel beams of the residence and studio. There is no evidence of any underlayer having been stripped or heavily sanded, however, this does not rule out this possibility.

2.4 Conclusions

The in situ paint investigation, coupled with the GCI's 2011 paint analysis, reveals the complex painting history of the residence and studio of the Eames House and gives an estimate of the exterior paint colors at significant historical dates. A first-generation paint layer, a warm gray distinctively mixed with colored pigments, was identified, which tends to confirm the original warm gray color of the metalwork described in early accounts of the Eames House.

As expected, the stratigraphy correlates to that identified in the 2011 investigation (see chapter 1). The six excavations sites were found to have a very similar stratigraphy; the house was originally a warm gray and went through a series of grays and blacks before the current black paint color. Based on the results of two paint investigation projects, the color of the residence and studio at the three significant dates is estimated to be gray in 1949, black in 1978, and black in 1988.

The investigations reveal between eight and thirteen layers, organized in six to eight painting campaigns between 1949 and 2003. Although the date of each painting campaign could not be identified, well-informed approximations can be made, and a stratigraphy is summarized as follows:

- 1949 The steel substrate was coated in 1 to 3 layers of primer and a corrosion inhibitor, followed by a warm gray paint.
- 1958 A dark gray paint was applied at some time.
- 1978 A series of 1 to 3 black paints were applied, the final black layer of this series estimated to c. 1978. The black paint was then coated with a brown material.
- 1989 A black paint was applied.
- 2003 A gray paint, potentially a primer for the final and current black paint.

It is extremely likely that the lower pair of paint layers, dark gray over a lighter warm gray, represent the first two applications of paint to the exterior metalwork. The lower warm gray is most likely the first coat of paint applied to the exterior metalwork in 1949. The dark gray paint may have been applied in 1958, although the temporal relationship of the two gray layers is uncertain. The two earliest paint layers were mixed as a fine artist might, using a painterly method of subtractive color mixing. This suggests great care in achieving very specific grays, and may contribute to the historical value of the original exterior paint color. The warm gray paint layer was measured from an exposure window with handheld spectrophotometer. The color was matched to a commercial paint color made by a manufacturer that may be recommended in future painting campaigns.

Works Cited

Eames, Charles, and John Entenza. 1949a. Case Study House for 1949: Designed by Charles Eames. *Arts and Architecture* 66 (12): 26-39.

APPENDIX 2.1

Color Measurement Data

TABLE A2.1

Color measurement and color matching data and results of the earliest paint layer compared to current exterior paint

Sample description	L* (D65, SCI)	a* (D65, SCI)	b* (D65, SCI)
Eames paint, exterior, current, black	.92	.93	.81
Eames paint, exterior, original gray (from excavation window)	24.38	–0.68	1.35

TABLE A2.2

Color measurement and color matching data and results of the earliest paint layer compared to Tnemec Industrial Coatings

Sample description	L* (D65, SCI)	a* (D65, SCI)	b* (D65, SCI)
Eames paint, exterior, original gray (from excavation window)	24.38	–0.68	1.35
Tnemec Industrial Coatings, color Briquet 49GR paint swatch	21.48	–2.58	–1.43
Color difference between Eames original gray and Tnemec Briquet 49GR: dE* (D65, SCI) = 3.74 Note: (Acceptable dE*value = 2 – 5)			

TABLE A2.3

Data Name	**SCI**/ SCE	L* D65)	a* (D65)	b* D65)	dL* (D65)	da* (D65)	db* (D65)	dE*ab (D65)	Lightness(D65)
Eames_exterior historic gray_Target1 (6/28/2012 4:30:03 PM)	**SCI**	21.12	–1.39	2.08	—	—	—	—	—
Eames_exterior historic gray_Target1 (6/28/2012 4:30:03 PM)	SCE	19.86	–1.64	1.83	—	—	—	—	—
Eames_exterior historic gray (6/28/2012 4:31:01 PM)	**SCI**	21.27	–1.39	2.27	0.15	0	0.18	0.24	lighter
Eames_exterior historic gray (6/28/2012 4:31:01 PM)	SCE	20	–1.62	2.01	0.14	0.02	0.17	0.22	lighter
Eames_exterior historic gray 2 (6/28/2012 4:31:36 PM)	**SCI**	21.26	–1.39	2.26	0.14	0	0.17	0.22	lighter
Eames_exterior historic gray 2 (6/28/2012 4:31:36 PM)	SCE	19.99	–1.57	2.04	0.13	0.07	0.2	0.25	lighter
Eames_exterior historic gray 3 (6/28/2012 4:31:43 PM)	**SCI**	21.28	–1.4	2.23	0.16	–0.01	0.15	0.22	lighter
Eames_exterior historic gray 3 (6/28/2012 4:31:43 PM)	SCE	20.03	–1.64	2	0.17	0	0.16	0.23	lighter
Eames_exterior historic gray 4 (6/28/2012 4:31:50 PM)	**SCI**	21.29	–1.38	2.26	0.17	0.01	0.17	0.24	lighter
Eames_exterior historic gray 4 (6/28/2012 4:31:50 PM)	SCE	20.01	–1.66	2.01	0.15	–0.02	0.17	0.23	lighter
Eames_exterior historic gray 5 (6/28/2012 4:31:56 PM)	SCI	21.28	–1.39	2.24	0.16	–0.01	0.15	0.22	lighter
Eames_exterior historic gray 5 (6/28/2012 4:31:56 PM)	SCE	19.99	–1.6	1.99	0.13	0.04	0.15	0.21	lighter

TABLE A2.3 (CONTINUED)

Data Name	SCI/ SCE	L* D65)	a* (D65)	b* D65)	dL* (D65)	da* (D65)	db* (D65)	dE*ab (D65)	Lightness(D65)
Eames_exterior historic gray 6 (6/28/2012 4:32:18 PM)	**SCI**	21.65	–1.46	2.22	0.53	–0.08	0.14	0.55	lighter
Eames_exterior historic gray 6 (6/28/2012 4:32:18 PM)	SCE	20.29	–1.69	2.03	0.43	–0.05	0.2	0.47	lighter
Eames_exterior historic gray 7 (6/28/2012 4:32:25 PM)	**SCI**	21.63	–1.44	2.23	0.5	–0.05	0.14	0.52	lighter
Eames_exterior historic gray 7 (6/28/2012 4:32:25 PM)	SCE	20.26	–1.69	1.97	0.41	–0.05	0.14	0.43	lighter
Eames_exterior historic gray 8 (6/28/2012 4:32:32 PM)	**SCI**	21.62	–1.43	2.23	0.49	–0.04	0.15	0.52	lighter
Eames_exterior historic gray 8 (6/28/2012 4:32:32 PM)	SCE	20.22	–1.65	1.97	0.36	–0.01	0.14	0.38	lighter
Tnemec Briquet (2/1/2013 10:50:15 AM)	**SCI**	21.47	–2.57	–1.44	0.35	–1.18	–3.52	3.73	lighter
Tnemec Briquet (2/1/2013 10:50:15 AM)	SCE	14.64	–4.14	–1.92	–5.22	–2.5	–3.76	6.9	darker
Tnemec Briquet 2 (2/1/2013 10:50:47 AM)	**SCI**	21.49	–2.59	–1.42	0.37	–1.2	–3.51	3.73	lighter
Tnemec Briquet 2 (2/1/2013 10:50:47 AM)	SCE	14.7	–4.18	–1.91	–5.16	–2.54	–3.74	6.86	darker
Tnemec Briquet 3 (2/1/2013 10:51:04 AM)	**SCI**	21.48	–2.58	–1.44	0.36	–1.2	–3.53	3.74	lighter
Tnemec Briquet 3 (2/1/2013 10:51:04 AM)	SCE	14.72	–4.02	–1.96	–5.14	–2.38	–3.79	6.82	darker
Tnemec Briquet 4 (2/1/2013 10:51:18 AM)	**SCI**	21.48	–2.59	–1.41	0.35	–1.21	–3.49	3.71	lighter
Tnemec Briquet 4 (2/1/2013 10:51:18 AM)	SCE	14.71	–4.13	–1.91	–5.14	–2.49	–3.75	6.83	darker
Tnemec Briquet 5 (2/1/2013 10:51:33 AM)	**SCI**	21.47	–2.59	–1.43	0.35	–1.21	–3.52	3.73	lighter
Tnemec Briquet 5 (2/1/2013 10:51:33 AM)	SCE	14.7	–4.15	–1.9	–5.16	–2.51	–3.73	6.84	darker
Tnemec Briquet 6 (2/1/2013 10:51:47 AM)	**SCI**	21.48	–2.6	–1.42	0.36	–1.21	–3.51	3.73	lighter
Tnemec Briquet 6 (2/1/2013 10:51:47 AM)	SCE	14.71	–4.16	–1.92	–5.14	–2.52	–3.75	6.85	darker
Tnemec Briquet 7 (2/1/2013 10:52:00 AM)	**SCI**	21.48	–2.57	–1.43	0.35	–1.18	–3.51	3.72	lighter
Tnemec Briquet 7 (2/1/2013 10:52:00 AM)	SCE	14.72	–4.11	–1.97	–5.14	–2.47	–3.81	6.85	darker
Tnemec Briquet 8 (2/1/2013 10:52:13 AM)	**SCI**	21.48	–2.58	–1.42	0.36	–1.19	–3.51	3.72	lighter
Tnemec Briquet 8 (2/1/2013 10:52:13 AM)	SCE	14.72	–4.12	–1.92	–5.14	–2.49	–3.75	6.83	darker

CHAPTER 3

Wood Panel Investigation and Conservation Treatment

Arlen Heginbotham

3.1 Introduction

3.1.1 Background

This chapter documents the technical study and conservation treatment of the wood paneling in the living room and south courtyard of the Eames House residence. The wood paneling was the subject of one of the earliest investigations initiated by the GCI and Eames Foundation. From September 2011 to June 2012, the contents of the Eames House living room were on loan to the Los Angeles County Museum of Art for exhibit, creating an opportunity for the Eames Foundation to address various issues relating to the maintenance of the living room interior. In addition to replacing the deteriorating floor tiles in the residence living room and part of the hallway, there was an opportunity to do maintenance on both the interior wood panel wall that covers the west elevation of the living room, and part of the exterior retaining wall in the south courtyard. Technical investigations and the development of a treatment proposal were undertaken from October 2011 to April 2012 by the GCI and J. Paul Getty Museum staff. Brian Miller Wood Finishing performed the conservation treatment from July to October 2012, under the supervision of Getty staff.

3.1.2 Description and Condition

The wood paneling is located along the west wall of the Eames House residence (fig. 3.1). In the living room, the double-height west wall is clad entirely in vertical wood boards. This wood paneling extends along the covered section of the external west wall of the south courtyard, giving continuity to the length of the living room wall (fig. 3.2). A gold-painted

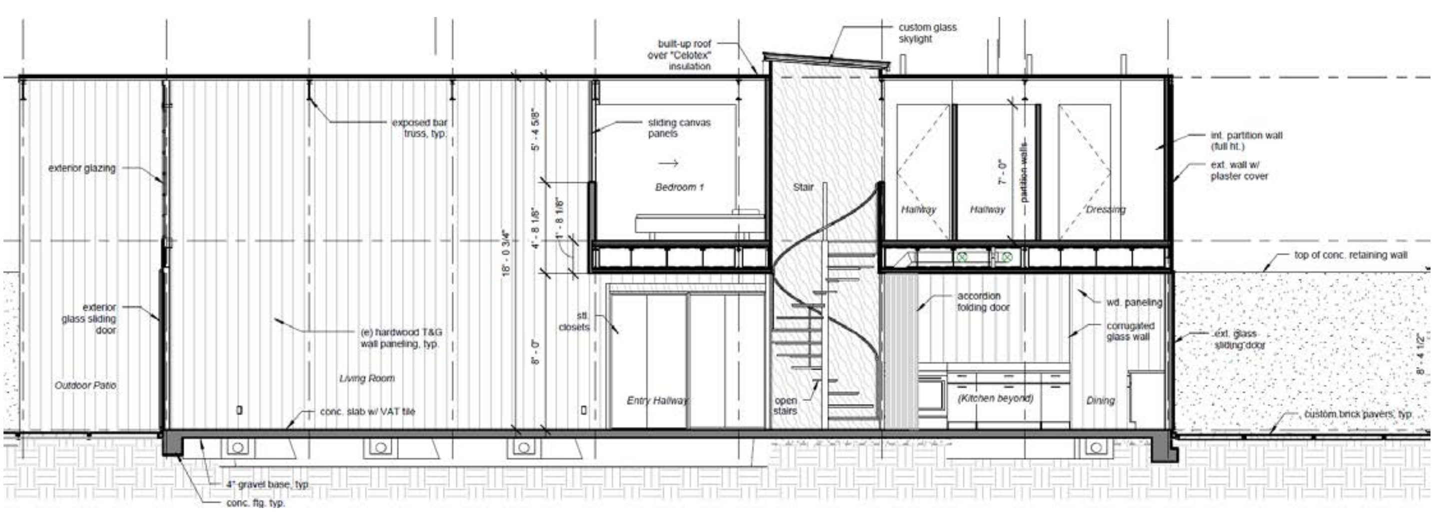


FIGURE 3.1
Detail of an architectural drawing of a longitudinal section through Eames House residence.
Drawing: Adapted from drawing by Escher GuneWardena Architecture,

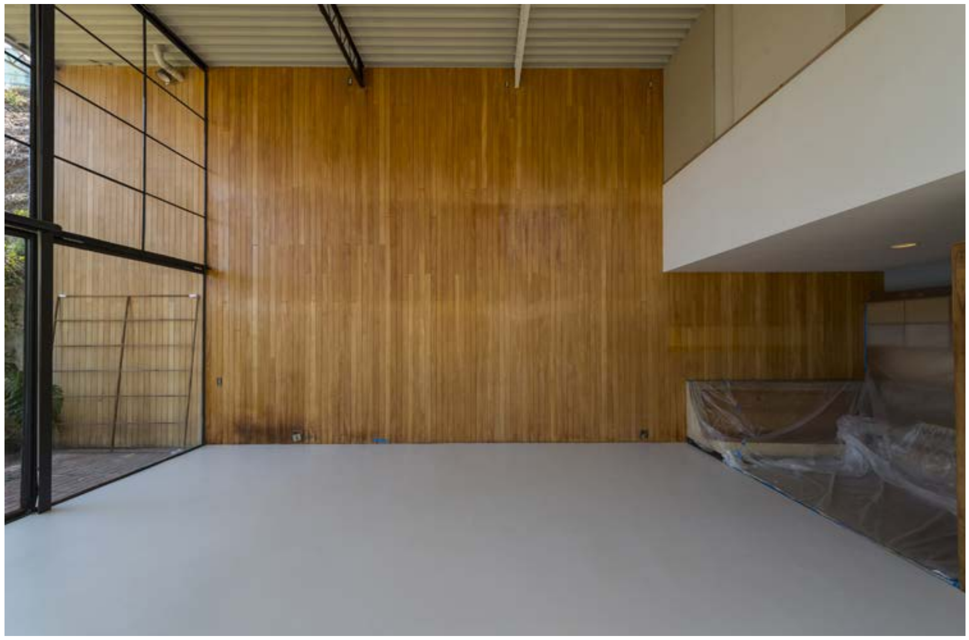


FIGURE 3.2
The wood paneling extends along the covered section of the external west wall of the south courtyard, giving a continuity to the length of the living room wall, 2011.
Photo: Joshua White, © Eames Office

FIGURE 3.3
Detail of wood paneling in alcove, 2011.
Photo: Joshua White, © Eames Office

wooden trellis hangs on the upper portion of the paneled wall, and the exterior edge of the paneling is also painted gold. From the living room, the wood paneling on the west wall continues toward the north through the alcove and into the utility area (fig. 3.3–3.4).

Though described as wood paneling, investigation revealed that the wood paneling is actually tongue and groove flooring that was installed with ¼-in. (6 mm) gaps to achieve the grooves characteristic of wall paneling.

Once all artworks and other objects had been removed from the wall, the paneling's patchy and uneven appearance was evident. Dirt, dust, and soiling were unevenly distributed on the wall revealing ghost impressions of objects that had hung on the wall at different times in the past. Irregular, light-induced discoloration of the wood and varnish also became evident, along with several types of patchy dark staining. Staining at the

FIGURE 3.4
The wood paneling extends into the utility room behind the kitchen of the residence, 2016.
Photo: Joshua White, © Eames Office

west end of the wall near floor level where a planter had been kept for many years was particularly notable, and dark stains that appeared irregularly at the short horizontal joints between different lengths of board. Some splattered dark brown staining was also present, centered on an area of the east end of the interior wall at a height of about 10 ft. above the floor.

3.1.3 Objectives

The objectives of the technical investigation phase of the project included identifying the wood species used for the paneling, characterizing the coatings or varnishes found on the wood, and developing a conservation treatment plan for both the interior and exterior paneling. Following the investigations, the conservation treatment phase aimed to restore an even tonality and gloss to the paneling, in keeping with the estimated original appearance. In developing the treatment plan, the team sought to preserve as much as possible of the remaining original varnish and to intervene as lightly as possible, while still achieving an aesthetically pleasing result.

3.2 Technical Investigation: Methods and Results

3.2.1 Wood Species Identification

A sample of wood was taken from the wood panel in the living room to determine the species. The sample was examined in 2012 by Arlen Heginbotham, Associate Conservator at the J. Paul Getty Museum (appendix 3.1). The wood species was identified as *Eucalyptus microcorys*. Common names for this species include Australian tallowwood, tallowwood, or microcorys gum. The wood is native to Australia, in particular, New South Wales extending into the coastal districts of Queensland and to Fraser Island. David Kribs, in his highly regarded *Commercial Foreign Woods on the American Market*, originally published in 1959, states that *E. microcorys* is “considered ‘par excellence’ for dancing floors and skating rinks” (Kribs 1968).

3.2.2 Wood Paneling Coating Investigation

Heginbotham took six samples from the wood paneling to determine the composition of coatings that had been applied. Samples were taken from the wood panels located in the south courtyard, living room, alcove, and utility room in 2011 (appendix 3.2).

Cross sections were prepared from the samples and these were examined using visible and UV fluorescence microscopy, as well as scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX). The visible and UV microscopy of the interior samples reveal only one thin layer of varnish or lacquer on the wood. This coating appeared to include a semitransparent pigment. There were no traces of other coating materials in the pores of the wood, suggesting that the varnish could be original. SEM-EDX showed that the particulate matter in the coating contains zinc and silicon (appendix 3.3). Minute scrapings of the varnish material were analyzed with Fourier transform infrared spectroscopy (FTIR) microscopy by Herant Khanjian (scientist, GCI). The samples from the living room and kitchen areas yielded spectra suggesting a cellulose nitrate lacquer, metal (likely zinc) stearates, and phthalate plasticizers. The FTIR analysis also suggested the presence of an ester containing wax, probably beeswax.

These analytical results reveal components that are typical for a lacquer sealer or primer. In this type of lacquer preparation, zinc stearate is often used as a transparent bulking agent, allowing the lacquer to build thickness more quickly. It is possible that some fumed silica was also incorporated into the formula, as a bulking or matting agent. The presence of beeswax suggests that the paneling was waxed after application of the lacquer sealer. It is not known when the beeswax was applied or whether it was applied more than once.

Cross sections from the exterior show one highly degraded layer of coating on the surface with residues of a different coating in the pores of the wood cells below. FTIR analysis of scraping samples of the upper layer show spectra consistent with alkyd varnish and calcium oxalate (appendix 3.4). It seems likely then, that the exterior paneling has been stripped and revarnished at least once.

3.2.3 Staining Investigation

Small scraping samples were also taken from the thick and disfiguring staining on the lower section of the west end of the living room wall, near where a planter had been kept for years. FTIR analysis did not provide any clues as to the nature of this staining.

3.3 Conservation Treatment Testing and Recommendations

On March 7 and 28, 2012, several cleaning and revarnishing methods were tested on small sections of the wood panel wall in the living room. Cleaning treatments were designed to remove dirt and grime build up on the wood paneling while protecting and conserving the original varnish. Cotton swabs were used to apply all of the cleaning products. Revarnishing treatments were tested with the goal of restoring transparency and optical saturation to hazy and degraded areas of original varnish so that the final appearance would have the look of the original sealed and waxed finish. Treatment should not make the surface coatings appear thicker or glossier than the original application. For this reason, very dilute mixtures of varnish were used, commonly referred to as resaturating varnishes. The only varnish types tested were those that could be removed in the future without damaging or dissolving the original varnish.

Contractor Brian Miller Wood Finishing tested cleaning and revarnishing methods on the exterior sections of the wood paneling. In this area, the goal of cleaning was to remove dirt and grime along with old, degraded varnish. The exterior needed a new varnish coating that would match the color, apparent thickness, and gloss of the interior paneling, but only *after* conservation treatment. Varnish should protect the wood from further light damage, if possible, by incorporating ultraviolet (UV) absorbing compounds.

3.3.1 Interior Cleaning

Shell Chemical's VM&P Naphtha HT, a moderately fast-drying aliphatic hydrocarbon solvent, was found to be very effective at removing wax and associated grayish brown soiling from the surface of the paneling without dissolving or disrupting the original lacquer. It was recommended that the entire interior wall be cleaned using brushed cotton wetted with naphtha.

A number of cleaning agents were tested on the staining associated with the planter at the west end of the living room. These included deionized water, saliva, a 2% aqueous solution of citric acid monohydrate buffered to pH 6.5 with ammonium hydroxide (commonly called tri-ammonium citrate or TAC), a 0.5% aqueous solution of Triton XL-80N (anionic detergent) adjusted to pH 8.5-9 with ammonium hydroxide, Shell VM&P Naphtha HT, Shell Chemical's ShellSol A100 (primarily tri-methyl benzene), denatured ethanol, and acetone. None of these tests were successful at significantly diminishing the staining in this area. It was recommended that the staining be mechanically reduced by wet-sanding the area using very fine sandpaper (400 grit) wetted with VM&P Naphtha.

A similar range of cleaning agents was tested on the brown staining on the east side of the living room wood panel wall at approximately 10 ft. above the floor, and also on the dark staining at the horizontal joints between boards. Both saliva and citric acid solutions gave good results, particularly on the splattered staining, entirely removing or greatly reducing the staining. It appeared, though, that the splattered material had caused deterioration of the original varnish. After cleaning, UV illumination showed that much of the varnish had been removed in this area, although the cleaning solutions had no adverse effects on unstained lacquer. It was recommended that brown staining (not associated with the planter) could be reduced using a 2% aqueous solution of citric acid monohydrate buffered to pH 7.0 with ammonium hydroxide, applied with cotton swabs, and rinsed with deionized water.

3.3.2 Interior Revarnishing

In March 2012, initial trials of resaturating varnishes were conducted on small test areas (approximately 3 × 1 in., or 7.5 × 2.5 cm) at about 10 ft. (3 m) above ground level, at the east end of the living room wall, in an area that was considered to be in average condition. After cleaning the test area with naphtha, several resaturating varnishes were tested for appearance, including Paraloid B-72 (copolymer of ethyl methacrylate and methyl acrylate), Laropal A-81 (a urea-aldehyde resin), Windsor and Newton's Winton Varnish (based on polycyclohexanone), and Soluvar (a mixture of n-butyl and isobutyl methacrylates). After the test areas were thoroughly dry, color measurements were taken with a Minolta colorimeter. These readings were compared to readings that were made of an area of paneling in the light-protected kitchen that had been cleaned with naphtha and waxed with Butcher's Boston Polish paste wax, and was considered to be in very good condition. Among the test areas, the best color match was the area that had been varnished with B-72 at 5% (w/v) dissolved in Shell A-100 solvent.

Based on this testing, and the fact that B-72 is considered to have the best aging characteristics of the resins tested, it was recommended that the entire living room wall be treated with a saturating varnish of 5% (w/v) dissolved in Shell A-100 solvent. The interior walls in the kitchen and utility area were in a much better state of preservation and no resaturating varnish application was recommended for these areas. In early July 2012, larger-scale test areas at the west end of the wall near ground level were varnished, focusing on areas that were more severely light damaged. It became clear that the 5% B-72 solution that had been recommended was not sufficiently saturating to restore transparency to the original varnish where it was badly degraded. Further testing found that adding Laropal A-81 resin to the mixture improved saturation and appearance, a mixture that has been successful in the past (Arslanoglu and Learner 2001). A revised treatment recommendation was made to use a saturating varnish composed of Laropal A-81 at 15% (w/v) and Acryloid B-72 at 4% (w/v) dissolved in Shellsol A100.

Although Heginbotham did not test treatments on the exterior sections of the paneling, recommendations were provided to Brian Miller, who performed the treatment as outlined in sections 3.3.3 and 3.3.4.

3.3.3 Exterior Cleaning

- The exterior wood should be stripped of existing coatings and revarnished.
- Any structural repairs to the exterior paneling should be made before treatment of the finish.
- Since cross section analysis suggests that the exterior varnish is not original, the existing varnish could be stripped with any number of commercial paint strippers, although it is important not to scrape or gouge the wood.
- If after stripping some areas of the wood appear gray from weathering, slow and careful local sanding of the wood may be necessary. This should be done with ~320 grit paper or a fine abrasive pad, wet with Naphtha. Continuous color monitoring should be done as the sanding/abrading is done, washing away any residue with naphtha, until an even appearance is achieved. This work should proceed slowly and sensitively, without over sanding.

3.3.4 Exterior Revarnishing

- The exterior woodwork should be revarnished, preferably with a very high quality exterior alkyd varnish such as Epifanes. The varnish should contain light stabilizers and UV absorbers. Tests should be undertaken blending gloss and matte varnishes to achieve a surface luster that matches the interior.
- If test areas on the exterior wood do not match the color of the interior, some color matching interventions should be considered. These could include subtle

staining of the wood using light-stable dyes, or delicate overall sanding/abrasion of the wood surface.

After further research, Heginbotham recommended a different exterior wood treatment product based on the recommendation of Pamela Kirschner who has tested and used it on several Frank Lloyd Wright structures. The product, manufactured by Gemini Industries of El Reno, Oklahoma, is a very high quality exterior alkyd wood preservative designated TWP 1530 (Natural). It contains UV protection, and is designed to weather and be re-treatable without chemical stripping.

3.4 Implementation of Conservation Treatment

In July 2012, contractor Brian Miller Wood Finishing performed all of the conservation treatments on the wood paneling in the living room and south courtyard at the Eames House. Heginbotham was present for the treatment of the interior surfaces and documented the process. The outdoor surfaces were done without Getty supervision. This section documents the actions undertaken by the contractor.

3.4.1 Living Room Tallowwood Paneling (interior): Figure 3.5

CLEANING

1. The wall was cleaned overall by wiping with a moderately fast-evaporating aliphatic solvent on soft cotton rags or on loose cotton. Commercially available Naphtha was used for this purpose and performed well.
2. Blotchy staining was significantly reduced with aqueous cleaning, using a solution of about 2% citric acid, buffered to pH 7 with ammonia. This included the splattered staining to the right of the painting halo, the dripping stains originating at the ceiling toward the west side of the wall, and the dark staining at the horizontal joints between boards. Complete removal, particularly of the latter, was not possible, but a significant improvement was made.
3. The soiling on the lower left section of the wall, associated with the planter was reduced using fine Scotch-Brite abrasive pads wetted with naphtha to gently abrade away the bulk of the crusty soiling.

RESATURATING

1. The wall was cleaned of all previously applied test varnishes using Shellsol A-100 on soft cotton cloths. The walls were then allowed to dry thoroughly.
2. The interior paneling surfaces were brush coated with a mix of two resins in Shellsol A-100 solvent (primarily tri-methyl benzene) solution using wide varnishing brushes (~ 5 or 6 × ¼ in.). The resin mix was composed of Laropal A-81 at 15% (w/v) and Acryloid B-72 at 4% (w/v). All personnel carrying out the treatment wore air purifying respirators, and a large industrial fan was used to ensure good air flow out of the room.
3. After resaturating, some localized discoloration of the wood remained due primarily to uneven light exposure and deterioration of the surface, especially where artworks or other items were hung. In order to minimize the visual disruption caused by this unevenness, the contractor applied thin glazes of color in the same, but diluted resin

FIGURE 3.5
Contractors undertaking conservation treatment on the wood paneling in the living room, 2012.
Photo: Arlen Heginbotham

solution, using a spray gun. He tinted the resin solution with TransTint dyes produced by J. B. Jewitt Co of Cleveland, Ohio, which are very light stable colorants reportedly based on Orasol dyes made by Ciba-Geigy.

4. Some small areas of particularly heavy staining that were not entirely removed by cleaning were in-painted using powdered pigments mixed into the resaturating varnish.

3.4.2 Tallowwood Paneling, South Courtyard (exterior): Figure 3.6

STRIPPING

1. The exterior wood was cleaned and residues of existing coatings removed using trisodium phosphate (TSP) in distilled water at a concentration of approximately ½ cup in 2 gallons of water, applied with cellulose sponges. The surfaces were then rinsed thoroughly with distilled water in cellulose sponges. Some mildew was evident on the wall and so the paneling was disinfected using a one-to-one household bleach/distilled water mixture, rapidly applied and rinsed with cellulose sponges. After drying the exterior surfaces were de-whiskered with a light sanding using 400-grit sandpaper. The wall was then vacuumed prior to recoating.

FIGURE 3.6
Contractors undertaking conservation treatment on the wood paneling in the south courtyard, 2012.
Photo: Eames Foundation staff,
© Eames Office

REVARNISHING

1. The exterior woodwork was then revarnished with a single coat of a very high quality exterior alkyd wood preservative manufactured by Gemini Industries of El Reno, Oklahoma, designated TWP 1530 (Natural). It contains UV protection and is designed to weather and be re-treatable without chemical stripping. It was recommended by Pamela Kirschner who had tested and used it on several Frank Lloyd Wright structures.

Works Cited

Arslanoglu, Julie, and Tom Learner. 2001. The evaluation of Laropal A81: Paraloid B-72 polymer blend varnishes for painted and decorative surfaces: Appearance and practical considerations. The Conservator 25 (1):62–72. https://doi.org/10.1080/01410096.2001.9995165.

Kribs, David A. 1968. *Commercial Foreign Woods on the American Market,* rev. ed. New York: Dover Publications

APPENDIX 3.1

Wood Identification Report

The J. Paul Getty Museum
Decorative Arts and Sculpture Conservation Department

Wood Identification Report

Title/Object: Eames House

Accession number: N/A

Artist/Maker: Charles and Ray Eames

Execution date: ca. 1949

Analyst: Arlen Heginbotham

Submitted to: Susan MacDonald

Date of Report: February 9, 2012

Sample Number: PNL-3

Wood identified as: *Eucalyptus microcorys* F. Muell; common name: Tallowwood, Australian Tallowwood, or Microcorys Gum

Date and location of examination: JPGM Decorative Arts and Sculpture Conservation Labs.

Examination Conditions: Thin sections of the sample (transverse, radial, and tangential) were prepared and mounted on glass slides. The sections were examined by transmitted light at magnifications from 100-400X using an Olympus BH-2 microscope. The sections were examined in water, then dried, mounted in Meltmount[i], and re-examined. The prepared slides are stored in the department's slide storage cabinet, and the remaining bulk sample was returned to GCI field projects.

Sample size and location: The sample was taken from the wood paneling of the living room; behind the cover plate for the electrical outlet near the built-in sofa. The sample was about 5x5x5mm.

Macroscopic features:

- Pale yellow-brown color
- Growth ring boundries indistinct.
- No ripple marks or storied structure apparent.
- Wood of commercial importance.

Microscopic features:

- Diffuse porous.
- One distinct radial cluster of vessels observed, but vessels primarily solitary.
- Intervessel pits alternate and very large (12-15μm).
- Vessel lumina average about 175μm tangential diameter.
- Vessels sparse, 5-10 per mm^2.
- Tyloses abundant
- Axial parenchyma abundant, diffuse and some vasicentric.
- No parenchyma bands or clusters observed.
- Parenchyma predominantly 4 cells per strand.
- Rays exclusively uniseriate with no examples of even partially biseriate rays observed.
- All ray cells procumbent (homocellular).

P 1 of 2

- Rays average about 280μm in height. All of similar size.
- Rays 4-12 per tangential mm.
- No storied structures apparent.
- Prismatic crystals abundant in unchambered axial parenchyma.

Other features or notes:
The wood was identified by entering the criteria outlined above into the Inside Wood online database of nearly 6000 hardwood species, according to the International Associaton of Wood Anatomists (IAWA) list of standard features. The features entered were:: 1a 5r 11e 22r 26p 27p 36a 42r 47p 56p 75e 76r 80a 81a 82a 84a 85e 89a 92p 96r 102a 104p 136r 138a 141r 189r 192p 199p with 2 allowable mismatches. This resulted in six possible identifications, all of which were in the family Myrtaceae, and five of which were species of Eucalyptus. E. mycrocorys (with only one, insignificant, mismatch) was clearly the best fit and all others were excluded based on evaluation of the specific mismatches noted (primarily color of heartwood and presence of occasional biseriate rays). This should thus be considered a reasonably unambiguous identification as *E. microcorys* or Tallowwood.

The wood is native to Austtralia; in particular, New South Wales extending into the coastal districts of Queensland and to Fraser Island.

David Kribs, in his highly regarded *Commercial Foreign Woods on the American Market*, originally published in 1959, states that *E. microcorys* is "considered "par excellence" for dancing floors and skating rinks".

References:

InsideWood. 2004-onwards. Published on the Internet. http://insidewood/ lib.ncsu.edu/search [2012].

Kribs, David,A. 1968. *Commercial Foreign Woods on the American Market.* New York: Dover.

Miles, Anne 1978. *Photomicrographs of World Woods.* London: Her Majesty's Stationary Office.

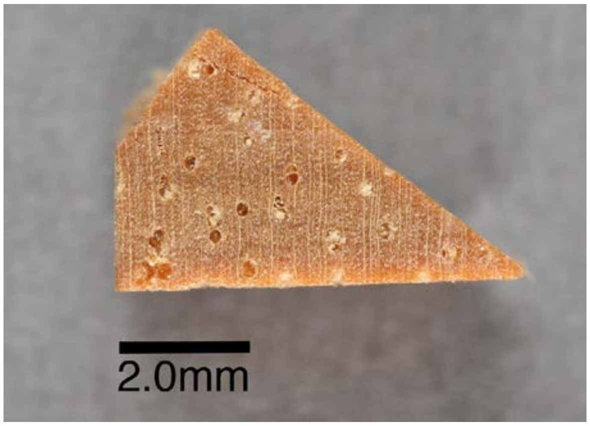
E.A.Wheeler, P. Baas & P.E. Gasson eds. 1989. *IAWA List of Microscopic Features for Hardwood Identification.* in IAWA Bulletin n.s. 10(3):219-332. Leiden.

Analyst: ______________________
Arlen Heginbotham

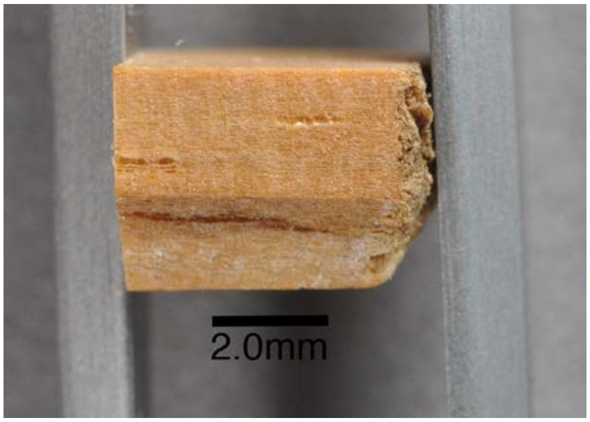
[i] **Meltmount** (Refractive Index 1.662). Electron Microscopy Sciences, 321 Morris Road, Box 251, Fort Washington, PA 19034, 800-523-5874.

P 2 of 2

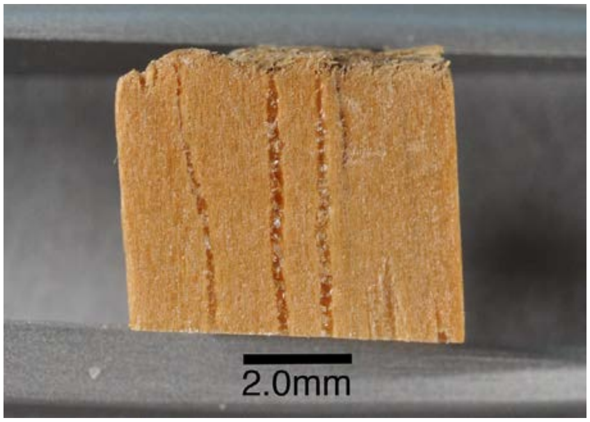
Eames House PNL-3 Wood ID



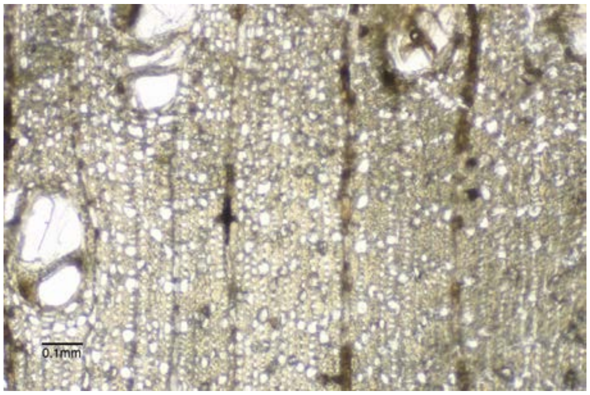
EAMES-PNL-3-D.psd



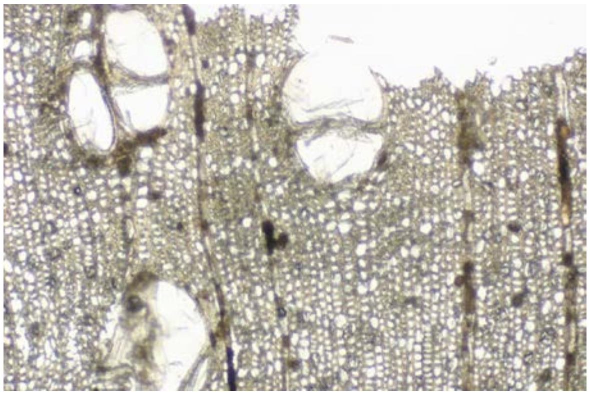
EAMES-PNL-3-F.JPG



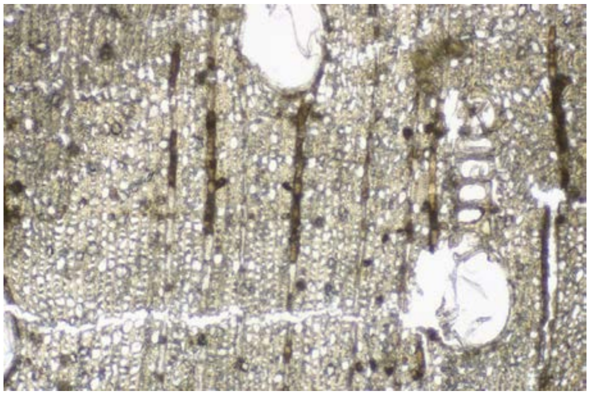
EAMES-PNL-3-G.JPG



EAMES-PNL-3-_01.JPG

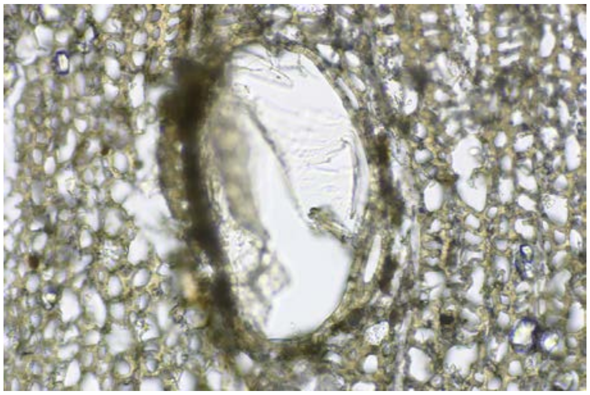


EAMES-PNL-3-_02.JPG

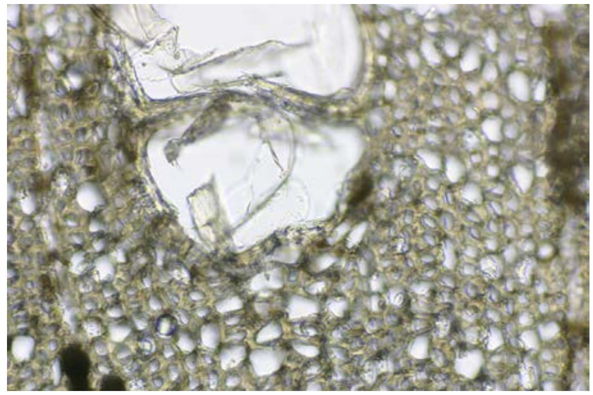


EAMES-PNL-3-_03.JPG

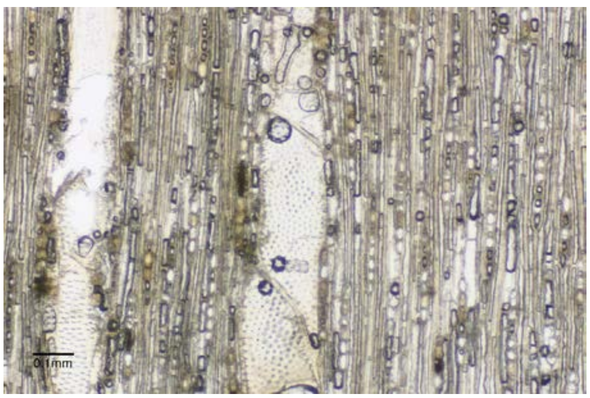
Eames House PNL-3 Wood ID



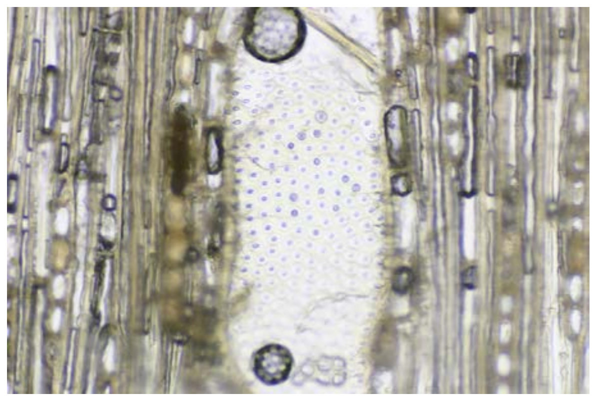
EAMES-PNL-3-_05.JPG



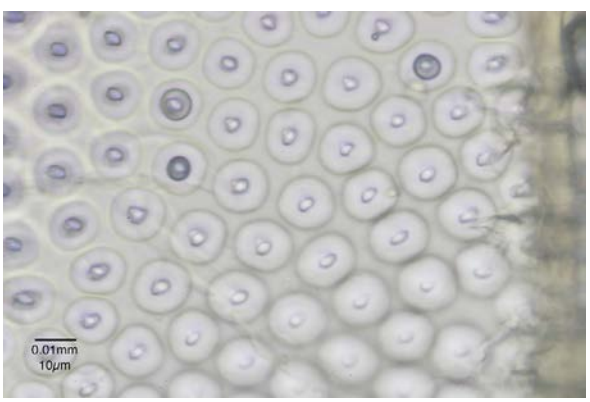
EAMES-PNL-3-_06.JPG



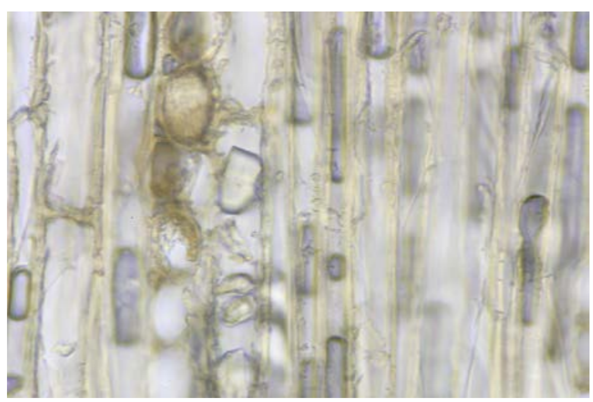
EAMES-PNL-3-_07.JPG



EAMES-PNL-3-_08.JPG

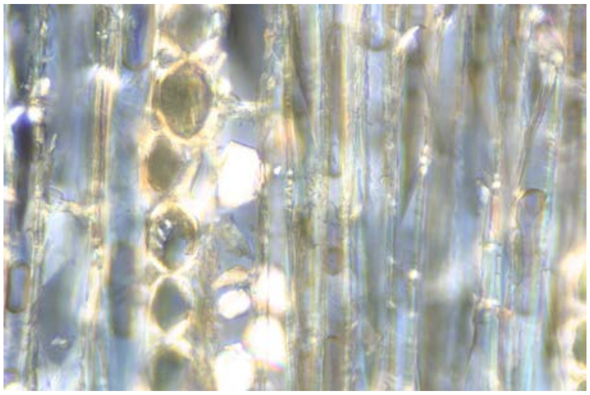


EAMES-PNL-3-_09.JPG

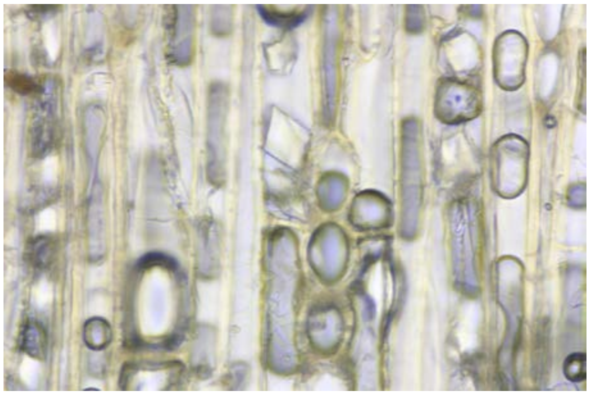


EAMES-PNL-3-_10.JPG

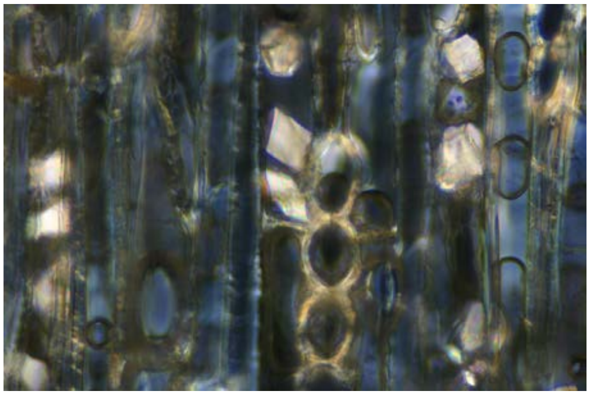
Eames House PNL-3 Wood ID



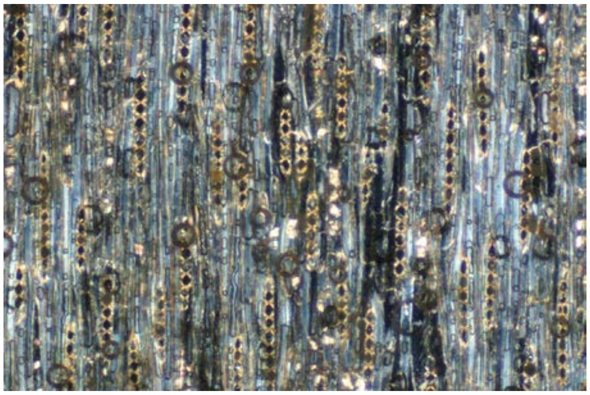
EAMES-PNL-3-_11.JPG



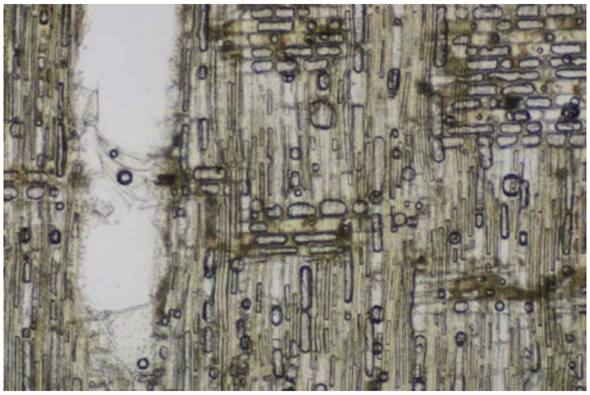
EAMES-PNL-3-_12.JPG



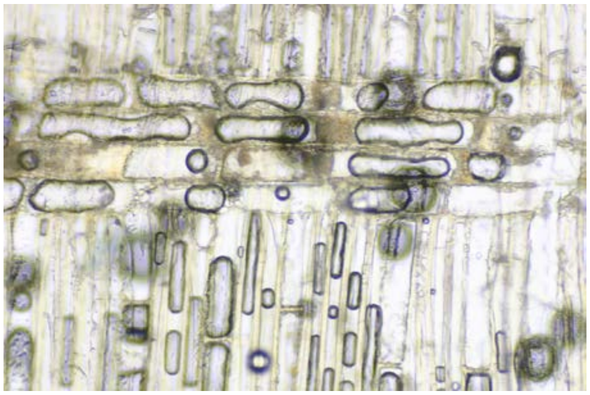
EAMES-PNL-3-_13.JPG



EAMES-PNL-3-_15.JPG

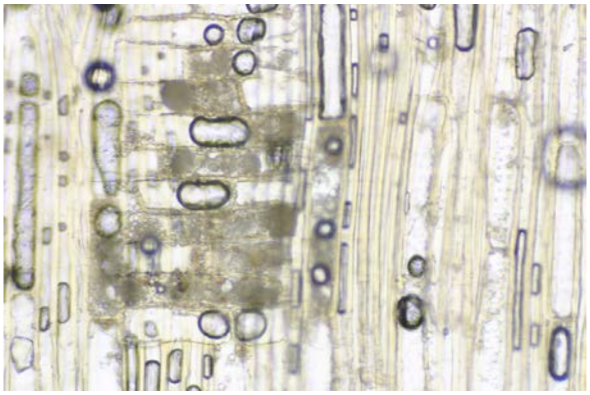


EAMES-PNL-3-_16.JPG

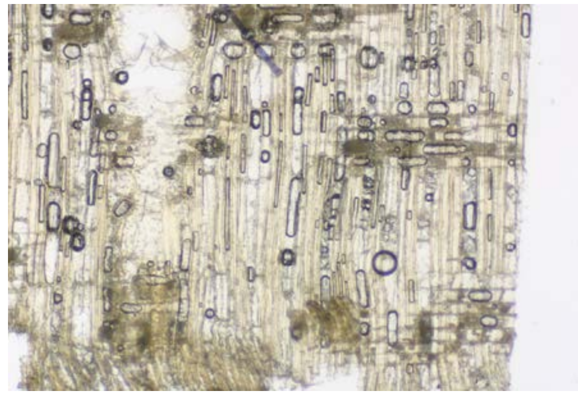


EAMES-PNL-3-_18.JPG

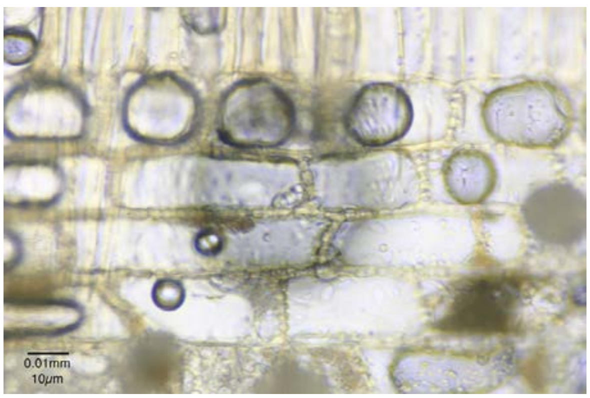
Eames House PNL-3 Wood ID



EAMES-PNL-3-_19.JPG



EAMES-PNL-3-_20.JPG



EAMES-PNL-3-_21.psd

APPENDIX 3.2

Wooden Wall Paneling Organic Coatings and Wood Identification Sampling Locations and Context

THE J. PAUL GETTY MUSEUM
DECORATIVE ARTS AND SCULPTURE CONSERVATION DEPARTMENT
1200 GETTY CENTER DRIVE - LOS ANGELES, CALIFORNIA 90049-1687

THE J. PAUL GETTY MUSEUM

SAMPLING REPORT

Title/Object:	Eames House 203 Chautauqua Boulevard Pacific Palisades, CA 90272
Material of interest:	Wooden Wall Paneling: Organic Coatings and Wood Identification
Conservator:	Arlen Heginbotham
Date of Sample Collection:	December 13, 2011

Context for sampling:

These samples were removed to aid in the preparation of a treatment plan for the wooden panelling in the Eames house living room, kitchen area, and exterior. Currently, the appearance of the wood in these three areas is significantly different. It appears that the kitchen area represents the most untouched and original appearance (samples PNL-4, PNL-4a, and PNL-4b). In general the wood in the kitchen has a warm, rich tone and the pores of the wood appear dark. It feels as if there may be a thin waxy coating over the varnish in this area. My guess is that the original treatment of the wood involved one or two coats of a single varnish, directly on the wood, with a thin wax coating above. It would be worth checking, however to see if a distinct 'sealer' coat was applied before the varnish, and also whether any grain filler was used (mineral pigment, possibly with the addition of dyes, that would be found in the wood vessels).

In the living area (samples PNL-1, PNL-1b, and PNL-2), the wood has a paler, cooler tone and the pores of the wood are very light, approximately the color of the surrounding wood fibers. It is not clear if this is the result of greater exposure to light in the living area, or if they may have been some previous interventions on the wall that changed its appearance. It would be useful to compare the composition of the varnish from these areas to help illuminate the situation. In addition, the change in the pore color might be the result of a grain filler applied to the wood (before varnishing) in one area or the other, or different grain fillers used in different areas. Examination and comparison of the cross section samples from each area might help resolve this.

On the exterior wood (samples PNL-5, PNL-5a), my assumption is that the wood has been previously revarnished, perhaps several times. This area is clearly in need of revarnishing now. The primary purpose of the sampling is to determine the nature of the current coating(s) to see if it is different from both interior coatings, and also to help us select several stripping methods for testing that have a reasonable likelihood of succeeding.

One sample (PNL-6) was also taken of the deteriorating coating on the wood paneling at the top of the stairwell. This sample is a fragment of flaking varnish (removes with tweezers) that represents the full thickness of the coating.

Additionally, one sample (PNL-3) was taken for wood ID. I will do this by examination of microscopic wood anatomy.

Conservator: [signature]
Arlen Heginbotham
12/13/11

P. 1

THE J. PAUL GETTY MUSEUM
DECORATIVE ARTS AND SCULPTURE CONSERVATION DEPARTMENT
1200 GETTY CENTER DRIVE - LOS ANGELES, CALIFORNIA 90049-1687

Sample PNL-1 - Living Room

Sample PNL-1
Gentle surface scrapings from superficial waxy layer. Well preserved and light-protected area.

P. 2

THE J. PAUL GETTY MUSEUM
DECORATIVE ARTS AND SCULPTURE CONSERVATION DEPARTMENT
1200 GETTY CENTER DRIVE - LOS ANGELES, CALIFORNIA 90049-1687

THE J. PAUL GETTY MUSEUM

Sample PNL-1b - Living Room

Sample PNL-1b
Deep scrapings of all varnish layers from beneath switchplate. Well preserved and light-protected area.

P. 3

THE J. PAUL GETTY MUSEUM
DECORATIVE ARTS AND SCULPTURE CONSERVATION DEPARTMENT
1200 GETTY CENTER DRIVE - LOS ANGELES, CALIFORNIA 90049-1687

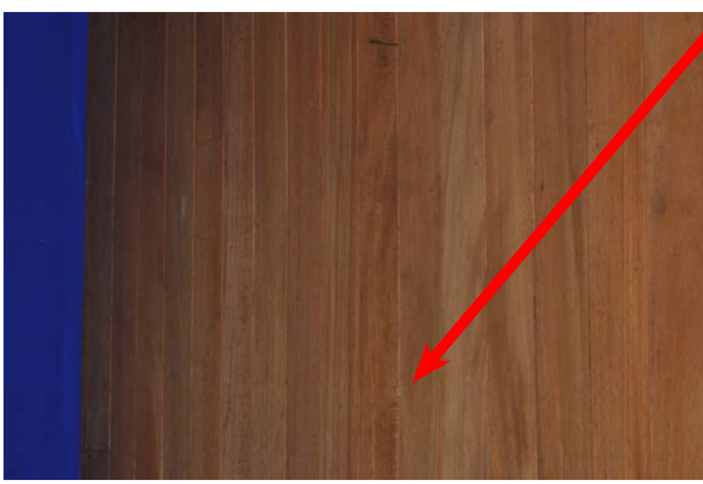
Samples PNL-2 and PNL-3 - Living Room

Sample PNL-2
Cuttings of wood surface and all existing varnish and wax layers, suitable for cross sections and/or scraping for GC-MS. Taken from behind the cover plate in a well protected area.

Sample PNL-3
Sample of wood substrate for wood identification. Approximately 5x5x5mm.

THE J. PAUL GETTY MUSEUM
DECORATIVE ARTS AND SCULPTURE CONSERVATION DEPARTMENT
1200 GETTY CENTER DRIVE - LOS ANGELES, CALIFORNIA 90049-1687

Sample PNL-4, PNL-4a, PNL-4b - Kitchen



Sample PNL-4 Full thickness cuttings with all layers. Suitable for cross section analysis and/or layer by layer unpacking.

PNL-4a Wood only, removed from below PNL-4. This could be useful for Py-GC/MS to serve as a reference in case any wood fibers are accidentally introduced into the pyrolyzer.

PNL-4b Scrapings of varnish adjacent to PNL-4. I tried to scrape all layers down to the wood.

THE J. PAUL GETTY MUSEUM
DECORATIVE ARTS AND SCULPTURE CONSERVATION DEPARTMENT
1200 GETTY CENTER DRIVE - LOS ANGELES, CALIFORNIA 90049-1687

Sample PNL-5, PNL-5a - Exterior

Sample PNL-5 Full thickness cuttings with all layers. Suitable for cross section analysis and/or layer by layer unpacking. Relatively well preserved area of varnish.

PNL-5a Scrapings of varnish adjacent to PNL-5. I tried to scrape all layers down to the wood. I did not detect any kind of waxy surface coating here.

THE J. PAUL GETTY MUSEUM
DECORATIVE ARTS AND SCULPTURE CONSERVATION DEPARTMENT
1200 GETTY CENTER DRIVE - LOS ANGELES, CALIFORNIA 90049-1687

Sample PNL-6 - Interior, top of stairwell.

Sample PNL-6 Full thickness flake of deteriorated varnish.

P. 7

APPENDIX 3.3

Electron Microscopy Report on Coating Samples

The J. Paul Getty Museum
Decorative Arts and Sculpture Conservation Department

1200 Getty Center Drive
Los Angeles, CA 90049-1687 USA
Tel 310 440 7330 or 310 440 + extension
Fax 310 440 7751
www.getty.edu/musem

Electron Microscopy Report

Date: June 3, 2012

Site: Eames House

Address: Pacific Pallisades, CA

Project: Eames House Conservation Project

Prepared for: Modern Architecture Project

Prepared by: Arlen Heginbotham

Summary

Sample PNL-2 was examined by electron microscopy and energy dispersive spectroscopy to characterize inorganic components in the presumed original lacquer layer. This followed FTIR analysis by Herant Kanjian suggesting the presence of metal stearate compounds in the lacquer. Results of the analysis strongly suggest that zinc stearates are present, possibly along with some fumed silica. These additives are common in nitrocellulose lacquers as fillers and flattening agents. Zinc stearate in particular tends to render lacquer somewhat cloudy and is a common filler in so-called 'sanding sealers' which are normally intended to be overcoated with transparent lacquer.

Experimental

Sample PNL-2 was embedded in Technovit LC2000 resin and polished for electron microscopy. Data were acquired using a Phillips FEI XL-30 Environmental Scanning Electron Microscope (ESEM) with a field emission gun. Samples were examined uncoated. Operating conditions were 0.8 torr H_2O vapor, 20 kV, and spot size 3. Images were acquired with a backscatter detector. X-ray spectra were collected and processed using an Oxford INCA energy dispersive x-ray spectroscopy (EDX) system with an X-Max 80^2mm silicon drift detector (SDD). Collection time was 30 seconds (live time) with a process time of 5.

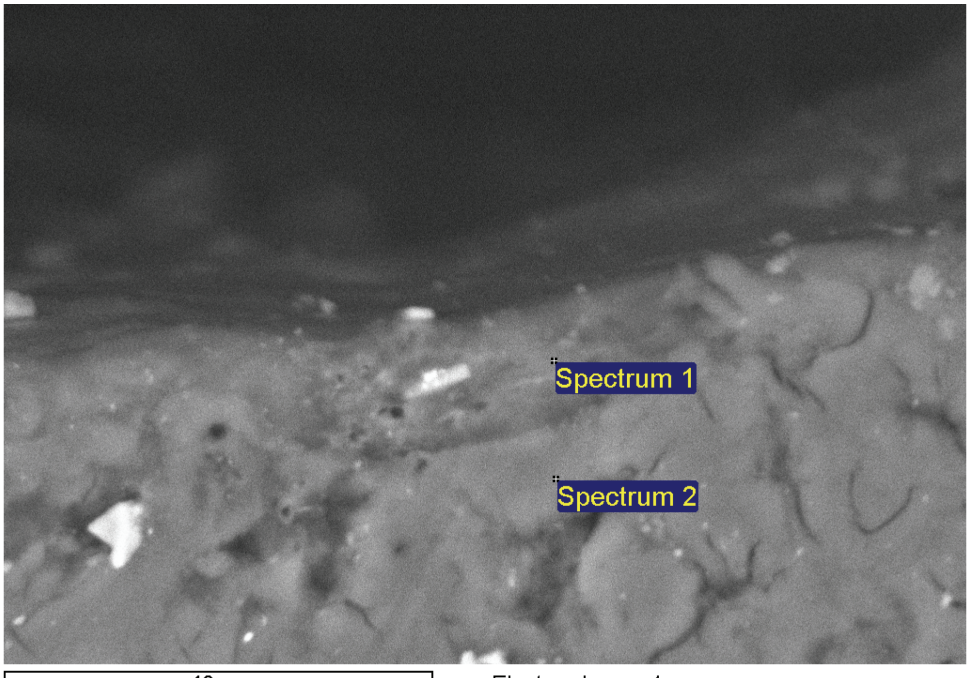
Results and Discussion

The sample was imaged as below and two spectra were acquired. The first, Spectrum 1, was directed at the lacquer layer. The second, Spectrum 2, was directed at the underlying wood for comparison. The spectra show elevated zinc and silicon present in the lacquer layer.

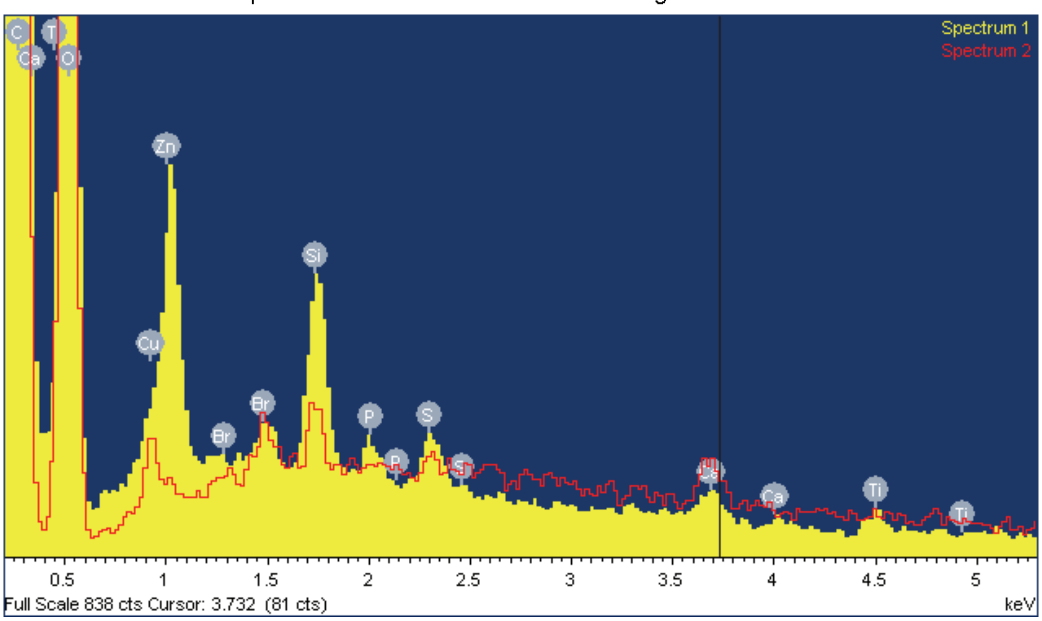
The J. Paul Getty Museum
Decorative Arts and Sculpture Conservation Department

Sampling Report

CMAI - Eames House Conservation Project

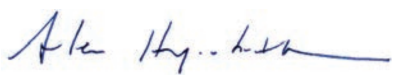


Electron Image 1



2

These results, in conjunction with the FTIR results and knowledge of common practice in the nitrocellulose lacquer industry, suggest the lacquer contains zinc stearate as filler and/or matting agent, and possibly some fumed silica as an additional matting agent.

Conservator: 

Arlen Heginbotham, Associate Conservator of Decorative Arts and Sculpture

APPENDIX 3.4

Organic Analysis Report on Coating Samples

The Getty Conservation Institute
Science Department

1200 Getty Center Drive, Suite 700
Los Angeles, CA 90049-1684 USA
Tel 310 440 7325 or 310 440 + extension
Fax 310 440 7702
www.getty.edu/conservation

Analysis Report

Organic Analysis Laboratory

Date: April 19, 2012

Site: Eames House

Address: Pacific Pallisades, CA

Project: Eames House Conservation Project

Prepared for: Modern Architecture Project

Prepared by: Herant Khanjian, Assistant Scientist

Summary

A group of seven coating samples collected on December 13, 2011 by Arlen Heginbotham from the Eames House were investigated, to assist in the understanding of their composition and preparation of a treatment plan for the wooden paneling. Using Fourier-transform infrared spectroscopy (FTIR), the samples were analyzed in February and March, 2012 to determine their chemical make-up and ascertain the factors that may contribute to the discolored appearance. The analysis results indicated the presence, to varying degrees, of cellulose nitrate, waxes, metal salts and phthalate plasticizers. In addition to the organic coatings found in the living room and kitchen areas, oxalate salts were found in the exterior coating sample.

Experimental

Optical microscopy was first used to examine sample composition and strategraphy. Representative particles were placed on a one-millimeter thick diamond window and flattened using a metal roller. Analysis was performed on the resultant translucent sample using a 15X Schwarzschild objective, attached to a Bruker Hyperion 3000 FT-IR microscope and purged with dry air. The samples were analyzed individually using a transmitted infrared beam apertured to 200 x 200 micrometers. Polarizing filters were used to enhance sample contrast and assist in targeted analysis of the various components. The spectra are the sum of 64 scans at a resolution of 4 $cm^{-1.}$ The identification of the infrared spectral data was performed with the help of in-house generated reference libraries.

1

The Getty Conservation Institute
Science Department

Analysis Report
Organic Analysis Laboratory
CMAI - Eames House Conservation Project

Results and Discussion

The samples from the living room and kitchen areas, and exterior showed the presence of cellulose nitrate, ester containing wax, metal salts, phthalate plasticizers, calcium oxalate and alkyd (see table 1). The surface scraped sample PNL-1 showed the presence of cellulose nitrate based on the presence of peaks at 1655, 1280, 1073 and 842 cm^{-1}, ester containing wax peaks at 2918, 2849 and 1737 cm^{-1}, metal salts due to the presence of asymmetric CO_2 stretch at 1539 cm^{-1}, and phthalate plasticizers peaks at 1730, 1600, 1579 and 744 cm^{-1} (see spectrum 1). When examined under light polarizing filters, the deeper scraped PNL-1b sample showed some optical differences indicating the presence of multiple components. The analysis results from the transparent part appeared somewhat similar to sample PNL-1, showing less prominent C-H stretching peaks from wax around 3000 cm^{-1}. In comparison, the white area showed the presence of cellulose nitrate, metal carboxylates and higher concentration of ester containing wax (see spectra 2 & 3). Sample PNL-1c, a deep scraping removed from a reddish stained area, showed a higher concentration of metal salts based on the presence of the peak at 1539 cm^{-1} (see spectrum 4).

Sample PNL- 4b, a deep scraping of varnish originating from a darker appearing wood panel in the kitchen, indicated the presence of cellulose nitrate, metal salts and phthalate plasticizers (see spectrum 5). Extraction of the sample with benzene solvent indicated the presence of ester containing wax (see spectrum 6). When compared to the living room analysis results, the noticeably higher metal salt as well as a slight lower cellulose nitrate concentrations, may account for the color difference (see spectrum 7). Other factors such the cooking oil and miscellaneous vapors may have also contributed to the discoloration phenomenon.

Sample PNL-5a collected from an exterior wood panel showed the presence of calcium oxalate in the white area observed under the polarizing filters (see spectrum 8). The analysis result from the slight beige area showed the presence of wood fibers, oil and possible calcium oxalate (see spectrum 9). The presence of oil may indicate additional applications of coatings to the exterior panels.

Sample PNL-6 flakes collected from top of stairwell showed the presence of alkyd, an indication of the type of paint applied to the wood substrate (see spectrum 10).

The Getty Conservation Institute
Science Department

Analysis Report
Organic Analysis Laboratory
CMAI - Eames House Conservation Project

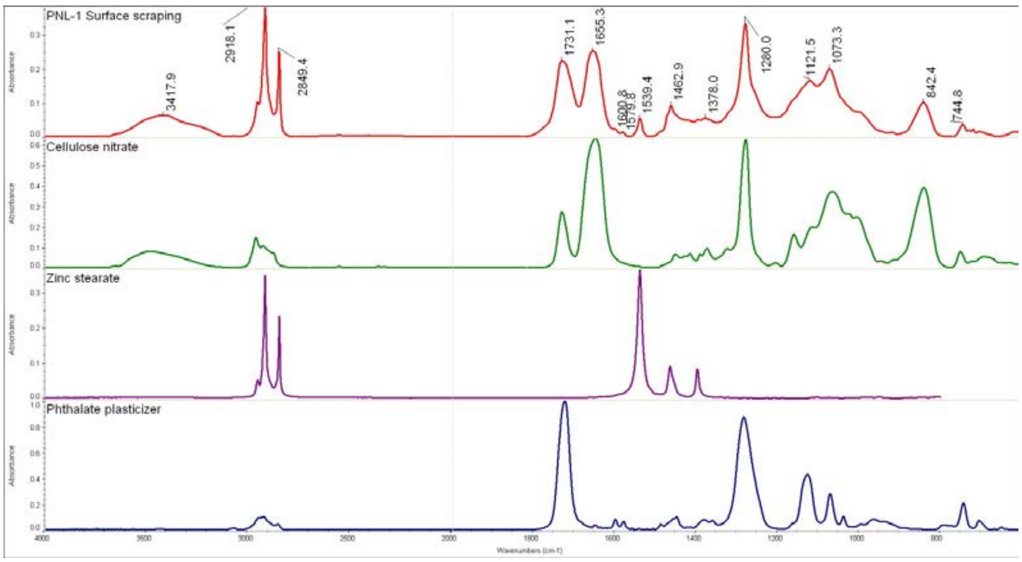
Table 1: Summary of analytical results

Sample	Description/Color Layer	FTIR analysis
PNL-1: Surface scraping from the living room	White flakes	Cellulose nitrate, Metal soap, Phthalate plasticizer
PNL-1b: Deep scraping from beneath switch plate from living room	Brown flakes from wood and brown particles	Cellulose nitrate, metal soaps, phthalate plasticizer and ester containing wax
PNL-1c: Deep scraping from a reddish stained area above floor switch plate in the living room	Red and brown flakes	Cellulose nitrate, metal soaps, ester containing wax and phthalate plasticizer
PNL-4b: Scraping of varnish adjacent to cutting board in the kitchen	Wood flakes with white and beige particles	Cellulose nitrate, metal soaps, phthalate plasticizer and ester containing wax
PNL-5a: Deep scrapings of varnish from exterior panel	Flakes of wood and coating	Calcium oxalate and oil
PNL-6: Flake from top of stairwell	Translucent white paint and coating	alkyd

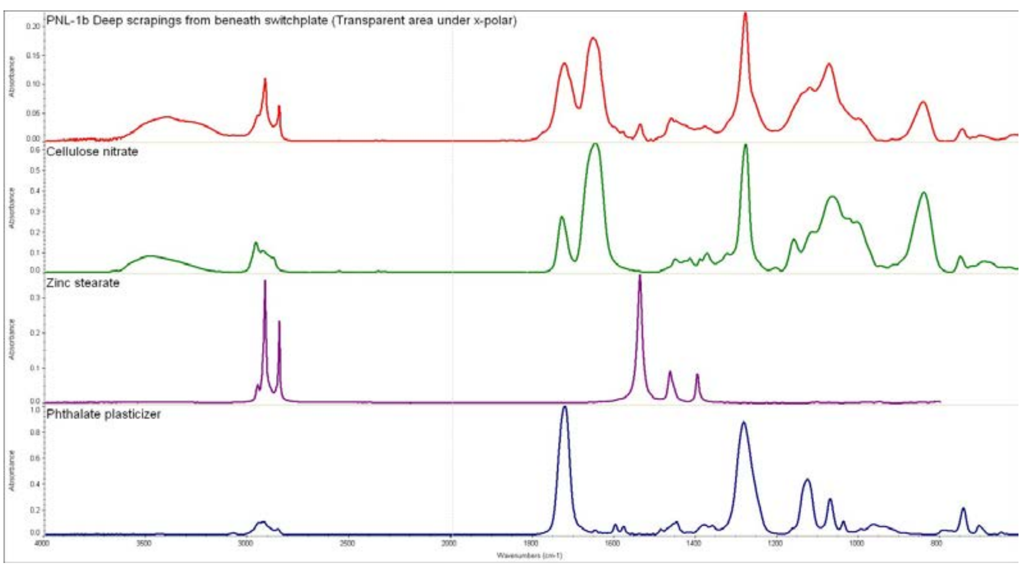
Report submitted by:
Herant Khanjian
Assistant Scientist
Organic Materials Research Group

The Getty Conservation Institute
Science Department

Analysis Report
Organic Analysis Laboratory
CMAI - Eames House Conservation Project



Spectrum 1 (PNL-1)

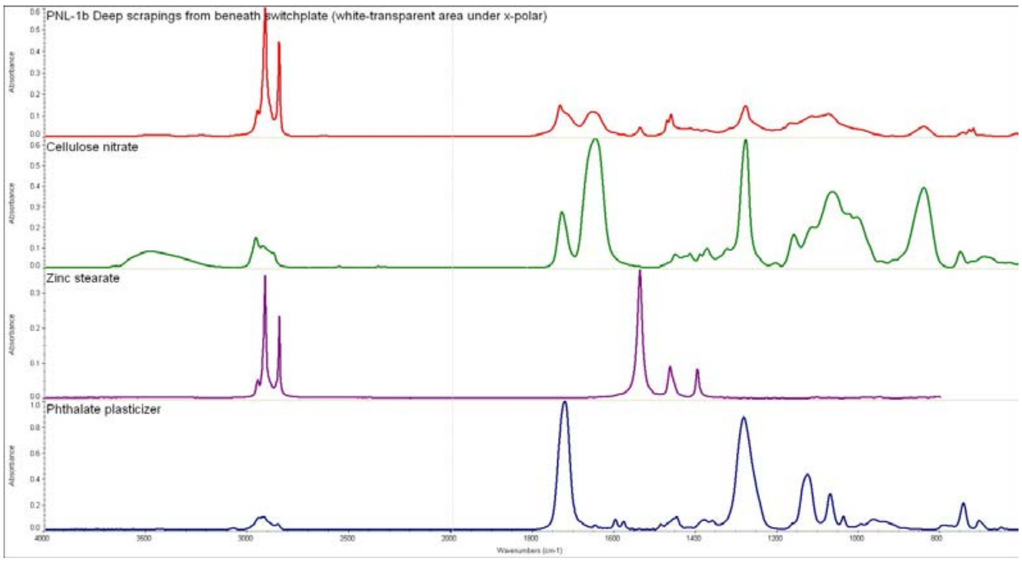


Spectrum 2 (PNL-1b)

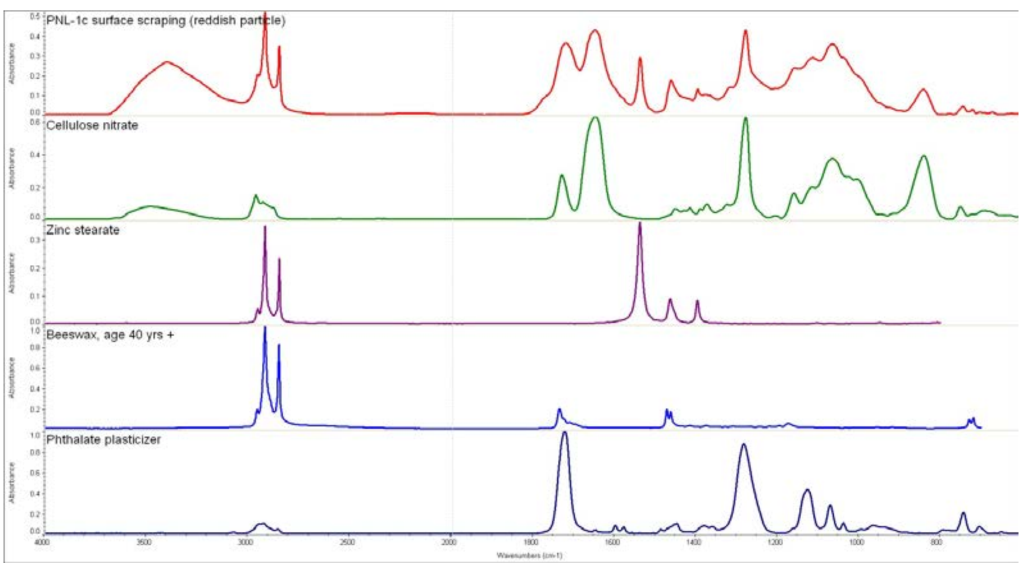
4

The Getty Conservation Institute
Science Department

Analysis Report
Organic Analysis Laboratory
CMAI - Eames House Conservation Project



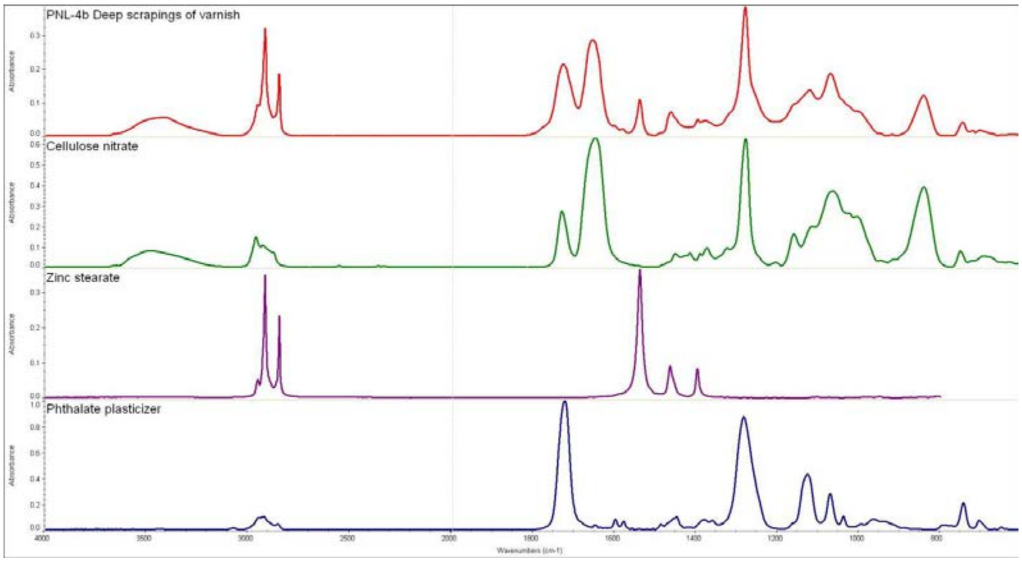
Spectrum 3 (PNL-1b)



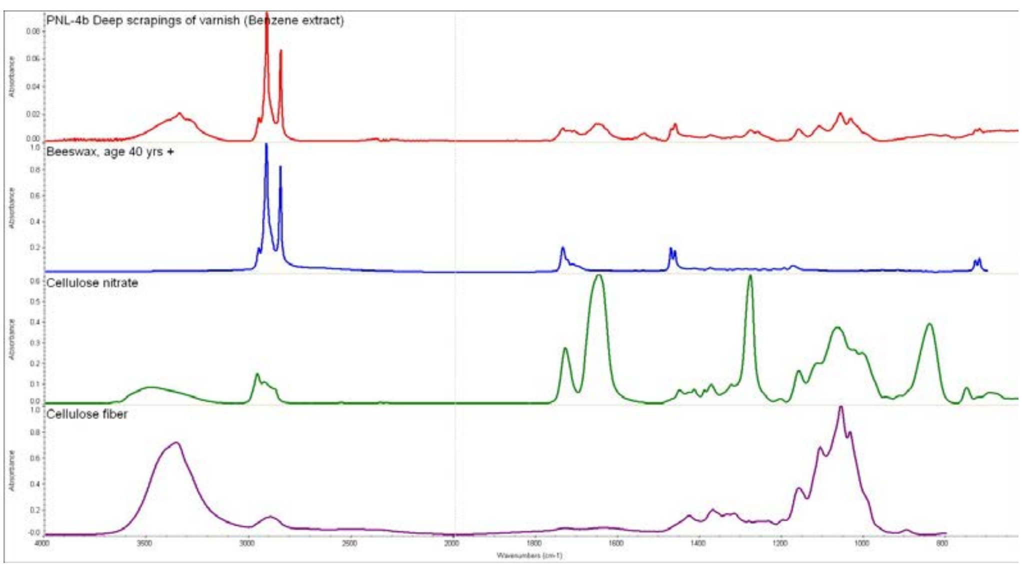
Spectrum 4 (PNL-1c)

The Getty Conservation Institute
Science Department

Analysis Report
Organic Analysis Laboratory
CMAI - Eames House Conservation Project



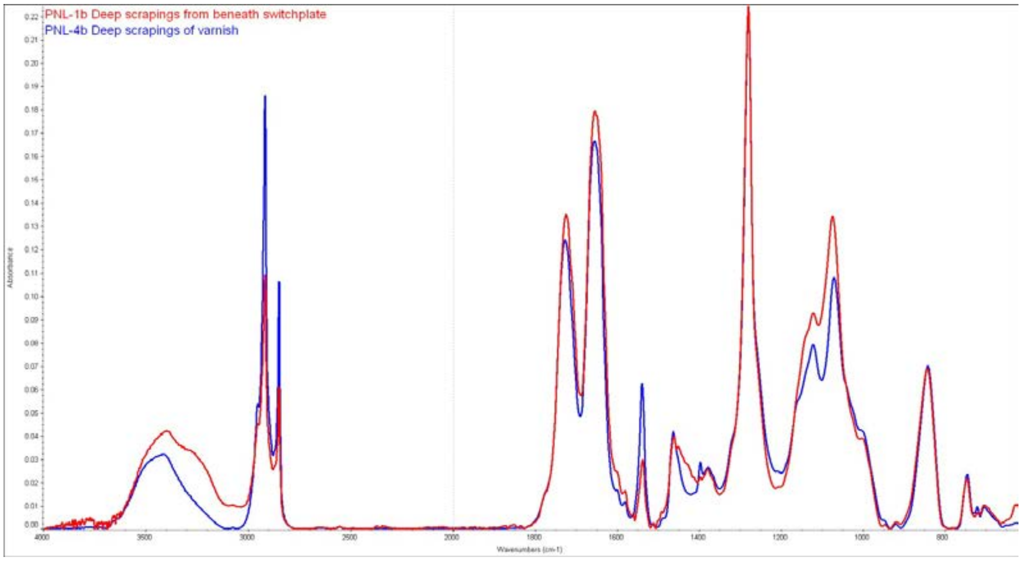
Spectrum 5 (PNL-4b)



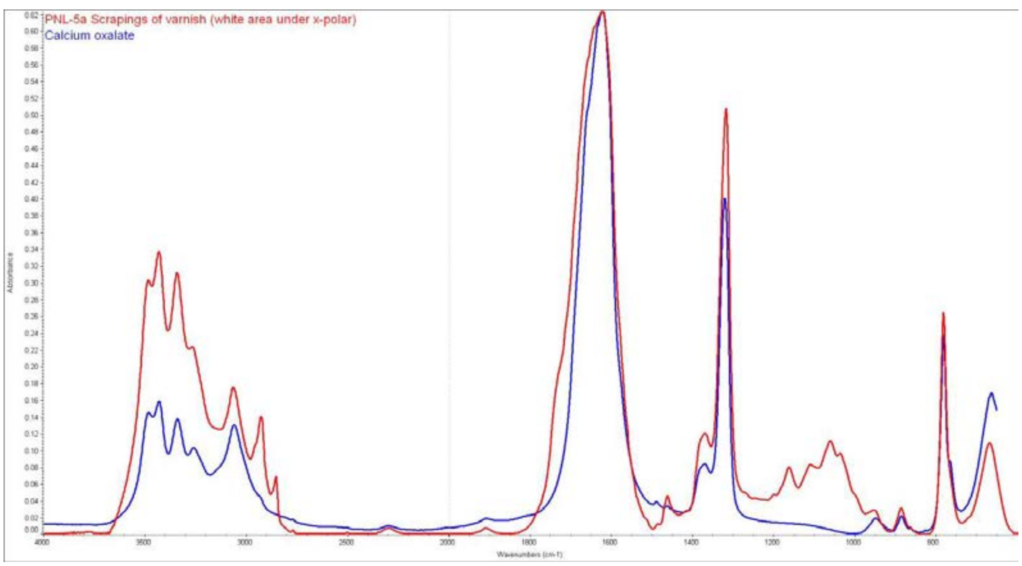
Spectrum 6 (PNL-4b)

The Getty Conservation Institute
Science Department

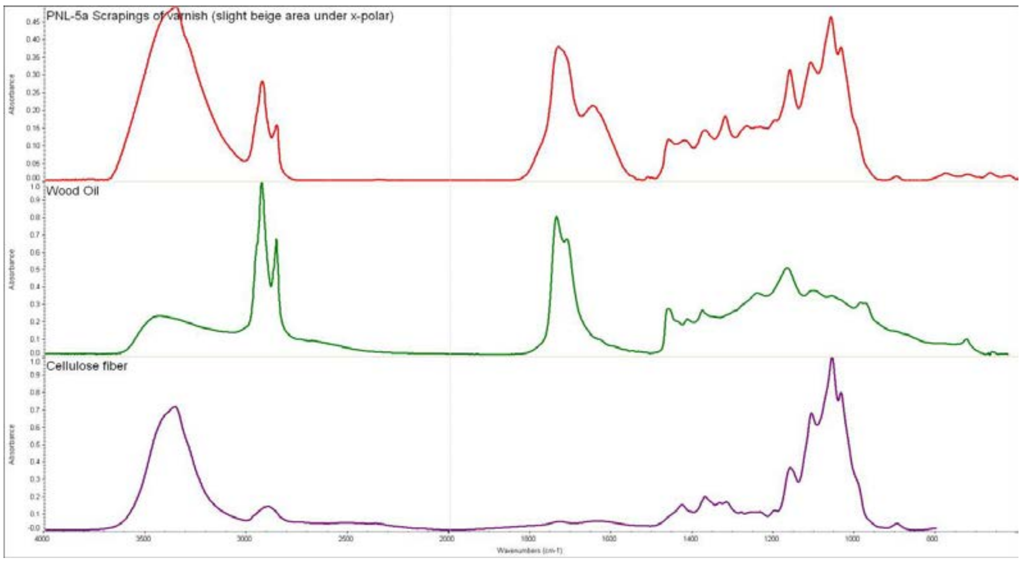
Analysis Report
Organic Analysis Laboratory
CMAI - Eames House Conservation Project



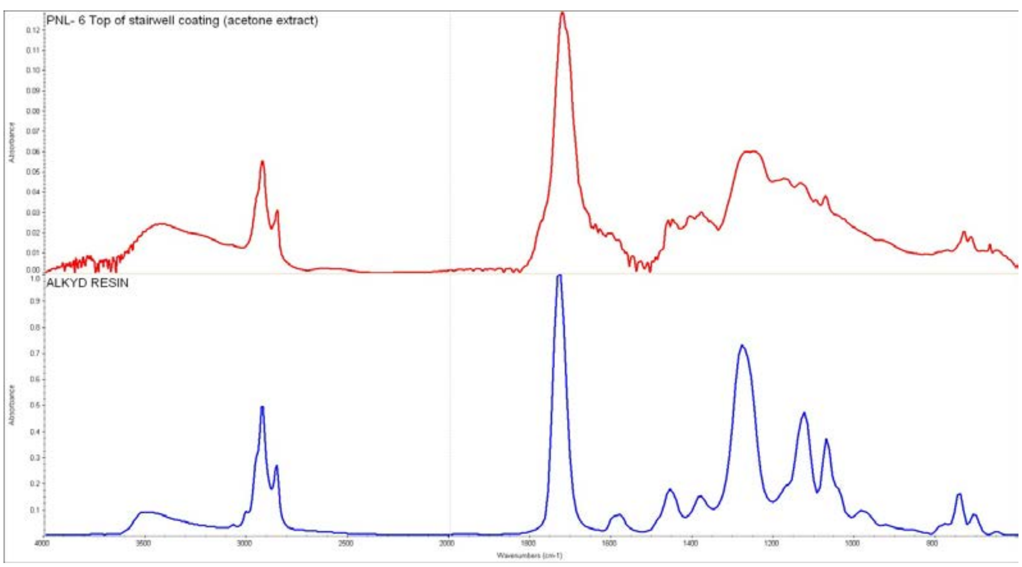
Spectrum 7 (PNL 1b 7 4b)



Spectrum 8 (PNL-5a)



Spectrum 9 (PNL-5a)



Spectrum 10 (PNL-6)

CHAPTER 4

Environmental Assessment of the Eames House Residence

Shin Maekawa

4.1 Introduction

4.1.1 Purpose of the Environmental Assessment

The purpose of undertaking an environmental assessment was to gain an understanding of the environment in and around the residence and to gather information about how agents of deterioration were affecting the house and its contents. The environmental assessment applied a number of monitoring and assessment techniques to gather information on a wide array of factors, which taken together could yield a full picture of the building's environment. Information was gathered on the following:

- Temperature and humidity
- Moisture in the soil behind the retaining wall
- Moisture in the floor slab of the living room
- UV and visible light
- Airborne particulates

The monitoring program lasted for four years; at its conclusion, recommendations for environmental improvements were developed to address the conservation of both the building and the collection, while also accommodating the Eames Foundation's needs as they continued to operate the Eames House as a house museum.

4.12 Agents of Deterioration

Adverse environmental conditions can produce three types of deterioration in historic buildings and their collections—biological, mechanical, and chemical. Between 2011 and 2015, data were gathered in order to identify if any agents of deterioration were present at the Eames House and how they could be eliminated or reduced to prevent further decay.

Biological deterioration (biodeterioration) results from the actions of animals, insects, fungi, or bacteria. It can be both catastrophic and fast. Animal and insect damage can be eliminated by eradicating the population in the building and removing points of entry. Various types of pest management techniques are available. Fungal damage can be avoided by maintaining humidity of the environment to less than 75% relative humidity (RH), which is a threshold humidity level for most fungal spores. Damage caused by bacteria can be avoided by keeping the environment at less than 90% RH, or by avoiding condensation.

Mechanical deterioration can occur when organic materials absorb and desorb moisture due to changes in the temperature and humidity of the surrounding environment. The moisture change in these materials will result in dimensional changes. Uneven changes of the moisture content within a material may result in warping and cracking. Large dimensional changes or gradients in dimensional changes may be irreversible. The effect of temperature on hygroscopic materials is normally less than that of humidity, since dimensional changes caused by temperature are an order of magnitude less than those caused by humidity. Extreme conditions are responsible for cracks and warps. Cyclic conditions over a long period produce material fatigue, such as adhesion failures. Mechanical deterioration can be reduced by keeping humidity and temperature stable. Typically, the appropriate humidity and temperature ranges are those within which the collection materials have already been exposed and therefore have been tested or proofed by the climate, threshold humidity.

Both temperature and humidity trigger chemical deterioration, with lower temperatures and humidity slowing chemical reactions. Reducing humidity to a material's threshold humidity, which varies depending on the metals and their corrosion products, can arrest corrosion. Films and plastics require lower temperatures to slow chemical reaction rates. Rates of hydrolysis of organic materials, such as cellulose and fibers, are affected by both temperature and humidity. Photochemical reactions are activated by the energy of light and ultraviolet (UV) radiation and reactions are accelerated by the intensity of light and UV radiation.

4.2 The Components of the Eames House

4.2.1 The Site

The Eames House site (the site) is located at 203 Chautauqua Boulevard in the Pacific Palisades neighborhood of the City of Los Angeles, California, overlooking Santa Monica Bay (34°01'48" N, 118°31'07"W, Elevation: 109½ ft. or 33.4 m). The site comprises the building complex, the landscape, and collections (fig. 4.1).

THE LOCAL CLIMATE

A continuously operating weather station at the Santa Monica Airport (34°00'57"N 118°27'05"W, Elevation: 176⅘ ft. or 53.9 m), approximately 4.1 mi. (6.6 km) southeast of

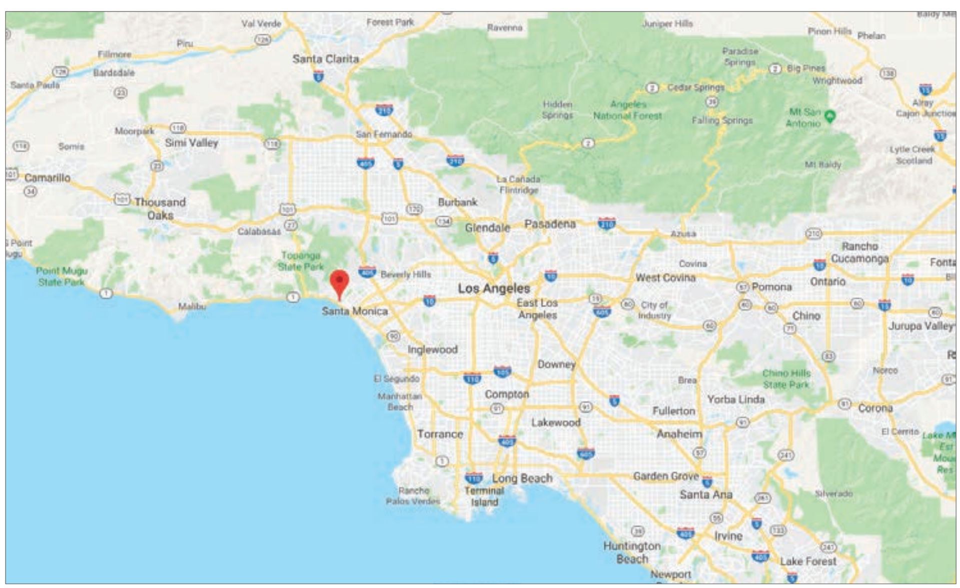


FIGURE 4.1
Site map of Los Angeles showing location of the Eames House.
Map: Adapted from Google Maps, map data © 2018 Google

TABLE 4.1
Summary of monthly weather averages in Santa Monica, CA (Source: http://www.weatherbase.com).

	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	16.8	13.7	13.8	14.6	14.9	16.8	18.5	20.4	20.7	20.1	18.4	15.7	13.3
Humidity (% RH)	69.5	62.3	66.1	67.9	67	72.2	74.6	76.8	75.9	75.8	71.3	62.5	61.6
Precipitation (mm)	373.4	86.4	83.8	66	17.8	5.1	2.5	7.6	2.5	5.1	20.3	30.5	50.8
Wind Speed (km/h)	9.4	9.1	10.1	9.9	10.7	10.4	10.3	10.1	9.3	8.5	8.2	8.5	8.9

the Eames House, provided historic climate data and context for the climate of the site and the environmental condition of the residence.

The thirty-year averages of climate parameters for this station are listed in table 4.1. Based on the data, the climate of Santa Monica is characterized by mild, wet winters and warm, dry summers, which is classified as the Mediterranean climate (Csa), by the Köppen-Geiger climate classification system (Arnfield 2017).

The Santa Monica climate can also be classified using ANSI/ASHRAE/IES Standard 90.1-2013, which considers separate criteria for thermal and moisture conditions. Thermal classification (Very Hot, Hot, Warm, Mixed, Cold, or Very Cold) is based on the cooling-degree days and heating-degree days and indicates the need for heating and cooling. For Santa Monica, there are 2260 cooling-degree days (CDD10°C), and 866 heating-degree days (HDD18°C), placing the region in the Warm zone. Moisture classification (Dry, Humid, and Marine) is based on a number of factors, and indicates the need for humidification or dehumidification. Santa Monica is typical of the Marine type climate. Combining the thermal zone and the moisture criteria, Santa Monica, with a wet mild winter and a warm and dry summer, is in Climate Zone 3C (Warm-Marine) defined by ANSI/ASHRAE/IES Standard 90.1-2013.

4.2.2 The Building Complex

The building complex includes the residence, studio, and three courtyards—the central court between the residence and studio; south court, south of the residence; and north court, north of the studio—as well as the integrated retaining wall, carport, driveway, and parking area. The building complex is surrounded by a well-established garden and many potted plants; it faces a meadow with views to the Pacific Ocean beyond. A row of mature eucalyptus trees is located along the east elevation of the building complex, in addition to numerous other mature eucalyptus around the site (fig. 4.2). The environment of the residence was studied, but the studio was not part of the scope.

THE RESIDENCE

The Eames House residence is two stories connected by a spiral staircase located at its center (fig. 4.3). The ground floor is an open floorplan, consisting of the living room, alcove, closet with clothing, entry hallway, dining area, kitchen, and utility area. The living room has a double-height ceiling. Other spaces have 8-foot (2.43 m) ceilings. The second floor contains an ensemble of private spaces including two bedrooms, two bathrooms, and several small closets with sliding doors. The two bedrooms are separated by a large sliding door, which is normally left open. A pair of half-height sliding panels separates the bedrooms and the upper portion of the living room space. The panel on the east side is left

FIGURE 4.2

Detail of plan showing the building complex and surrounding trees at the Eames House.

Drawing: Ph.D, A Design Office

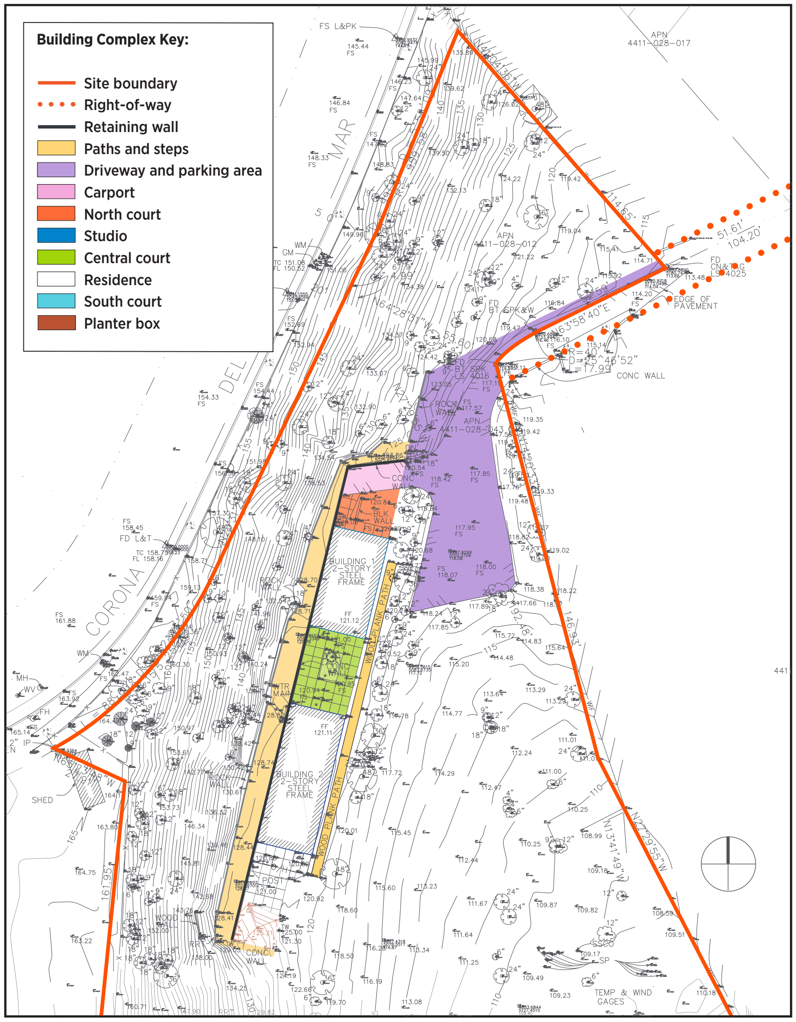


FIGURE 4.3

Ground and second floor plans of the Eames House residence.

Drawing: Ph.D, A Design Office

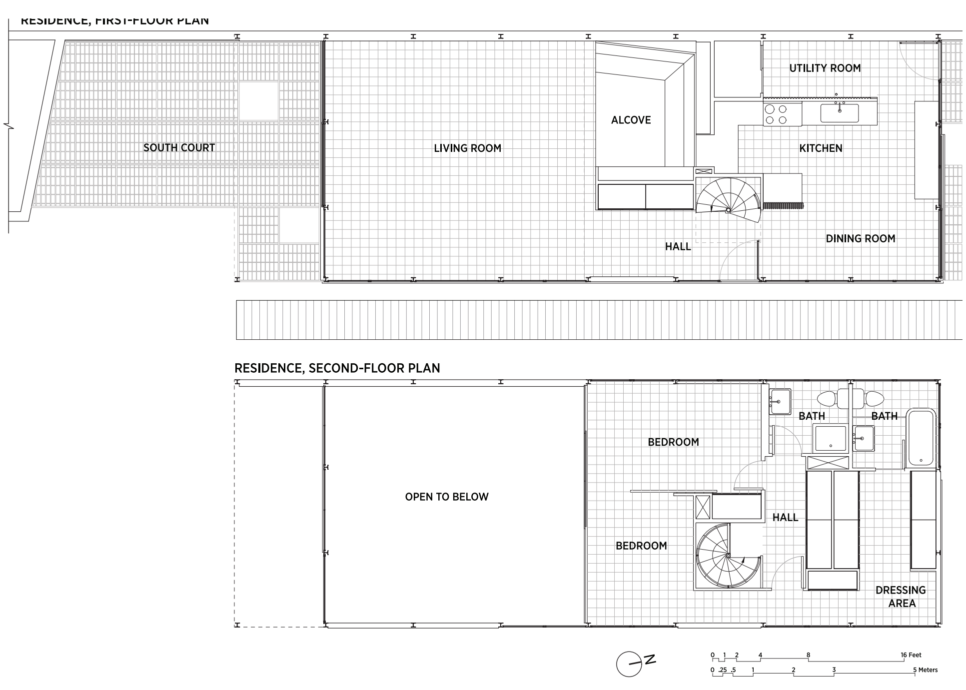


FIGURE 4.4
The interior of the residence, such as the upstairs bedroom, has a number of finishes including various types of wood veneer and wall fabrics, 2017. Photo: Joshua White, © Eames Office

open. The bathrooms are situated along the west elevation above the grade of the rear pathway, and their hinged doors are normally left open. Closets full of clothing and other materials are located on both floors, and the kitchen cupboards contain utensils, crockery, and cutlery.

The residence is constructed of Truscon steel frame. The steel frame is infilled with Truscon operable sash, which is infilled with a variety of materials including transparent and translucent glass; Ferrobord profiled steel decking or framing with a stucco finish; and Cemesto panels, an insulated cement-asbestos fiberboard. The interior of the residence has a number of finishes including vinyl composite tiles, wood paneling, various types of wood veneer, and wall fabrics (fig. 4.4).

The residence originally had a minimally insulated flat roof with a gravel stop around the edges. The current roof assembly, installed in the winter of 2014–2015, comprises a layer of rigid insulation topped with a membrane and gravel.

CONCRETE RETAINING WALL AND FLOOR SLABS

An 8-foot tall, reinforced concrete retaining wall that is nearly 200 feet in length forms the continuous west wall of the building complex (residence, studio, and courtyards) at the first-floor level (fig. 4.5). An original architectural drawing dated October 14, 1948, indicates

FIGURE 4.5
The concrete retaining wall during construction, ca. 1949.
Photo: © Eames Office

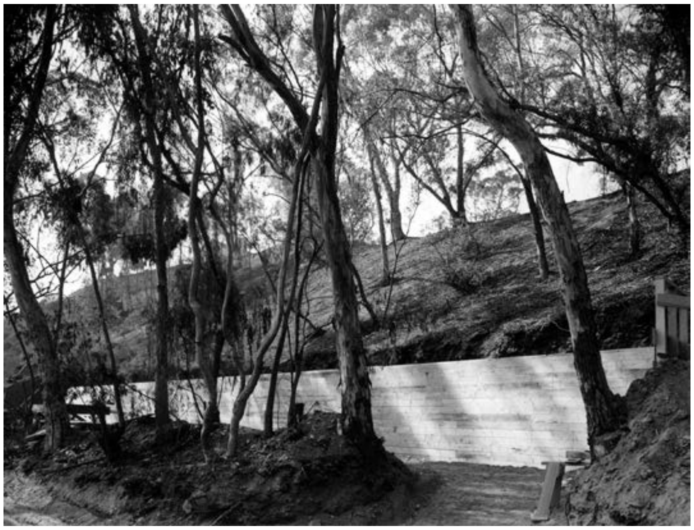


FIGURE 4.6
Detail of the living room and alcove showing a range of materials in the collection including textiles, paper, shells, stone, wood, plants, and ceramics, 2016.
Photo: Joshua White, © Eames Office

that the retaining wall has a water membrane on its west face and that water was designed to discharge to openings, known as weep holes, that are visible near the base of the sections of the retaining wall on the external courtyards (Eames Office 1948). The weep holes provide drainage for ground water seeping from the hillside soil as well as for the surface runoff from soil on the west side of the complex.

The residence and studio sit on a poured-in-place, reinforced concrete slab. The slabs rest on concrete footings that run under the length of both buildings. An original architectural drawing dated October 14, 1948, describes the slab as having a "waterproof membrane and 3-inch gravel under" (Eames Office 1948). The floor slab consists of two layers of cast-in-place concrete, the bottom with coarse aggregate and the top with fine aggregate. The building complex was built between a hillside and a row of tall eucalyptus trees; construction required grading a level bench into the toe of the hillside. As a result, the concrete slab foundation varies from being at-grade on the south side and approximately 8 ft. (2.43 m) below grade on the north side.

4.2.3 Collection

The collection in the residence comprises an array of furnishings and objects that Ray and Charles Eames collected throughout their lives (fig. 4.6). It includes artwork, craft, and found objects, such as paintings, toys, models, dolls, ceramics, books, shells and stones, plants, folk artifacts, clothing, utilitarian items (such as kitchen items), and Eames-designed furnishings. Clothing and other objects are stored in cupboards and closets on the ground and second floors.

4.3 Existing Environmental Conditions of the Residence

The residence is a historic house museum operated by the Eames Foundation; the studio is used as the Foundation office. The environment of the residence is managed by Foundation staff, mainly by manually operating windows on both the ground and second floors of the east elevation and sliding glass doors on the ground floor at the south and north elevations.

FIGURE 4.7
Curtains being drawn open at the living room's south elevation, 2016.
Photo: Joshua White, © Eames Office

The kitchen and the bathroom windows are fitted with curtains. The kitchen curtains are located on the north elevation above the kitchen counter and across the sliding door, and are typically opened during operating hours. The curtains in the bathrooms are kept closed at all times.

The living room is also fitted with curtains of a loose-weave, beige linen fabric on the entire south elevation and part of the east elevation of the residence (upper and lower windows) (fig. 4.7). There are curtains on the east elevation of the dining room over sections of clear glazing. From approximately October 2011 until late 2014, the living room curtains were temporarily removed. The living room curtains are opened during operating hours between 10:00 a.m. and 4:00 p.m., but remain closed overnight and on Wednesday and Sunday, when the site is closed to the public. During operating hours, sunlight penetrates the residence and is all but unobstructed; during the morning, direct sunlight penetrates far into the living room. A row of large eucalyptus trees along the east elevation of the building complex partially shades the residence. These trees, as well as large trees in the meadow, provide some protection from the morning sun. The upper slope and landscape on the south of the building effectively block the sun after 2:00 p.m. to 3:00 p.m., depending on the season.

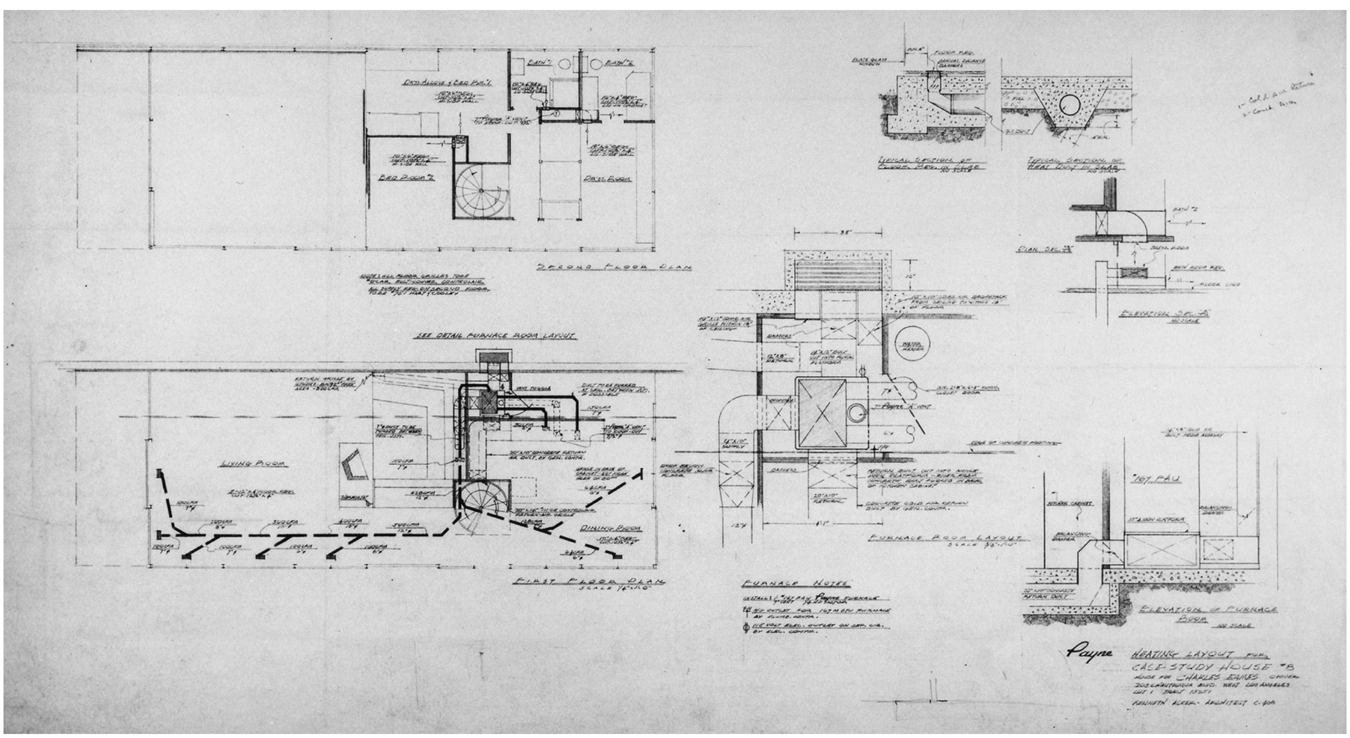
Two thermostatically controlled, natural gas-fired forced-air heating units (FAU) are located in the studio and residence of the Eames House. The FAU in the residence is located in a small mechanical closet between the alcove and the kitchen along the west retaining wall on the ground floor. The FAU distributes heated air throughout the residence via a network of metal ductwork and grilles. An analog thermostat, utilizing a bi-metal coil and liquid metal (mercury) switch, is mounted on the east wall of the alcove (fig. 4.8). In 2013 and 2014, the FAU was set to turn on at 60°F (15.6°C). Since early 2015, it has been set to 50°F (10°C), the minimum setting, so that the FAU is rarely used, only when the residence is exceptionally cold.

The FAU is a single-speed fan unit, probably manufactured in the 1960s or earlier; it might be the residence's original unit. The return-air plenum, located at the bottom of the FAU, draws return air from a floor opening below the stair and outside air from an opening above the retaining wall in the west elevation.

FIGURE 4.8
Location of thermostat in the alcove, 2011.
Photo: Joshua White, © Eames Office

The heated supply air exits the FAU at its top and is divided into two main supply ducts, one serving the ground floor and the other serving the second floor (fig. 4.9). The former is distributed through a system of uninsulated metal ducts located below the concrete floor slab. Supply air grilles are located in the floor slab along the east and south walls. Another set of uninsulated metal ducts extends from the FAU to bedrooms and north hallway on the second floor. The bedroom supply air grilles are located at approximately 6 ft. 3 in. (190 cm) from the floor on internal walls. The supply air grille near the north bathroom is located several inches above the floor facing the hallway.

FIGURE 4.9
Historic plan of the heating ducts dated October 14, 1948.
Drawing: Eames House Detail Drawing Sheet 3, © Eames Office



4.4 Environmental Assessment Objectives and Methods

This section describes the objectives of the environmental monitoring and investigations that were undertaken between 2011 and 2015.

4.4.1 Climate and Environmental[1] Monitoring Stations at the Eames House

OBJECTIVES

From 2012 to 2014, both the indoor environment and outdoor climate of the Eames House residence were monitored because outdoor climate conditions affect changes of environments in buildings. A climate, or weather monitoring station, and a residence environment monitoring station were established to simultaneously document indoor and outdoor conditions. The stations measured temperature, humidity, and other factors that can cause mechanical, biological, and chemical deterioration of materials.

METHODS

On December 1, 2011, a solar-powered autonomous climate monitoring station was installed in the meadow along the southeast edge of the site. The station was equipped with typical climate sensors to measure temperature, humidity, rainfall, solar radiation, and wind speed and direction. The data-logging and data-communications equipment (a multi-spectrum radio) and the climate sensors were mounted on a 10-ft. (3.05 m) tower structure (fig. 4.10). The station was accessed remotely from the Getty Conservation Institute via the residence environmental monitoring station's Internet Protocol (IP) connection and a pair of multi-spectrum radios.

FIGURE 4.10
Weather station installed at the south edge of the site overlooking Santa Monica Beach, 2016.
Photo: Leslie Schwartz, © Eames Office

On April 17, 2012, a station in the residence was established in the centrally located bathroom on the second floor, and was equipped with a data-logger, rechargeable battery, data-communications devices, and environmental sensors. The station recorded the temperature and humidity via sensors placed throughout the residence. Continuous power was provided to the station through the electrical outlet in the bathroom. Temperature and humidity sensors were located in the living room and kitchen on the ground floor, as well as in the west bedroom, the stairway landing, and north closet on the second floor (figs. 4.11a–4.11e).

FIGURES 4.11A-4.11E
Locations of photometric sensors indicated by white circles.

FIGURE 4.11A
Bookcase sensor location, 2016. Photo: Leslie Schwartz, © Eames Office

FIGURE 4.11B
Kitchen sensor location, 2016. Photo: Leslie Schwartz, © Eames Office

FIGURE 4.11C
Upstairs bedroom sensor location, 2016. Photo: Leslie Schwartz, © Eames Office

FIGURE 4.11D
Top of stairs sensor location, 2012. Photo: Shin Maekawa

FIGURE 4.11E
North closet on the second floor location, 2012. Photo: Shin Maekawa

On January 15, 2013, six photometric sensors for measuring the intensity of visible light were added to the installation in the living room and the alcove. (figs. 4.12a–4.12b).

FIGURES 4.12 A-4.12B
Locations of six photometric sensors (indicated by white circles) in the living room and the alcove installed on January 15, 2013.

FIGURE 4.12A
Living room sensor locations, 2013. Photo: Scott S. Warren

FIGURE 4.12B
Alcove sensor locations, 2012. Photo: Shin Maekawa

FIGURES 4.13 A-4.13C
Air change rates in the residence were measured on September 25 and 26, 2012 and January 30 and 31, 2013 with the tracer gas dilution method: (a) SF5 gas was transferred to 60 cc syringes; (b) SF5 gas was released and dispersed in the house; and (c) gas concentration was monitored and data were processed in situ. Photos: 2013, Scott S. Warren

FIGURE 4.13A (LEFT)

FIGURE 4.13B (RIGHT)

FIGURE 4.13C

4.4.2 Building Envelope Air Infiltration and Air Change Rates

OBJECTIVES

The efficacy of the building envelope relative to the degree of air infiltration was assessed by measuring air change rate. Air change rates are measured by the rates of infiltration, exfiltration, and ventilation of a building. Infiltration, one form of air leakage, is the flow of outside air into a building through cracks and other unintentional openings, as well as through the normal use of openings in the building envelope. Exfiltration, another form of the air leakage, is the flow of inside air of a building to the outside. Ventilation is the intentional introduction of the outside air into a building interior, or removal of the indoor air to the outside. There are two types of ventilation, natural ventilation and mechanical ventilation. Natural ventilation is driven by the natural pressure difference between indoor and outdoor, often augmented by intentionally opening windows and doors to increase the rate of flow. Mechanical ventilation uses fans to force the airflow or produce the pressure difference. Rates of infiltration, exfiltration, and ventilation of a building are measured as the number of air changes, which are volume flow rates that are equivalent numbers of interior air volume, in a unit time period, typically one hour. Common residential buildings have rates between one and two air change per hour.

Air change rates for a particular building depend on the airtightness of the building envelope, whether the doors and windows are opened or closed, the temperature difference between exterior and interior, outside wind, and the architectural configuration of the building. Not surprisingly, a building with closed doors and windows has air change rates that are significantly smaller than when the doors and windows are open.

In general, good indoor air quality (IAQ) can be maintained and easily managed if sources of heat, moisture, and pollution are not present in the building and the infiltration is controlled and kept to a minimum. Ventilation is normally used to improve poor IAQ when heat, moisture, and/or indoor-generated pollutants are present. Pollutants accumulated in a building can be purged or diluted by ventilation if the outside air is cooler, drier, and/or cleaner than the inside air. Otherwise, the outside air has to be filtered and conditioned before the air is supplied to the indoor space if it is to improve the building environment.

In summer 2012 and winter 2013, the GCI measured infiltration and exfiltration rates of the Eames House residence to determine the potential air and moisture infiltration—through the building envelope, walls, windows, doors, and the roof—that may be contributing to the deterioration of the building fabric and collection.[2] By identifying the rates of infiltration and exfiltration in the residence, the air volume that needs to be controlled by a mechanical system can be determined.

METHODS

Air change rates in the residence were measured on September 25 and 26, 2012, and January 30 and 31, 2013, by using the tracer gas dilution method (Sherman 1990). A 100% concentration of sulfur hexafluoride (SF6) gas was used as the trace gas, and Innova 1412 Gas Analyzer with SF6 and H2O filters was used to measure the gas concentration. The air sample was continuously collected at the stairway, approximately 2 m from the ground floor, the approximate center of the building.

The measurement procedure is described as follows and shown in figures 4.13a–4.13c.

1. Closed all doors and windows and turned on the FAU.

2. Placed three floor fans in the residence, one at the southeast corner of living room, one in front of the entrance door, and one in the corridor between the bedroom and stairway on the second floor.
3. Started recording the concentration of sulfur hexafluoride gas and water vapor in the air to determine the background values.
4. Released 240 cc of 100% sulfur hexafluoride gas throughout the house in four 60 cc syringes.
5. Operated fans continuously for about thirty minutes to fully disperse the gas throughout the residence while monitoring the gas concentration.
6. Stopped the fans and FAU once the gas concentration (approximately 200–250 ppb) had stabilized.
7. Started recording the gas concentrations and elapsed time every two minutes until either the concentration dissipated below the analyzer's detection level (less than 50 ppb), or a new run started.
8. Repeated steps three through seven.

4.4.3 Light Monitoring

OBJECTIVES

The Eames Foundation exhibits the collection of Charles and Ray Eames in the residence, which is operated as a house museum. The collection includes paper, textile, and wood objects; wood, metal, and fiberglass furniture; and other materials throughout the residence. A large portion of the building's envelope is composed of clear glazing with some internal curtains providing some shade. Large eucalyptus trees along the residence's east elevation also provide limited external shading against eastern sunlight. A roof overhang, above the courtyard on the south end of the building, provides limited external shading during summer.

Displaying the contents of the residence in natural daylight is central to the Eames Foundation's interpretation of the site. Chemical and mechanical deterioration resulting from exposure to high levels of visible light and UV radiation, however, threatens the conservation of both the interiors and the collection.

The GCI carried out two studies to determine the extent and intensity of visible light and UV radiation in the living room. The information was used to develop a management strategy for reducing light damage to the collection.

METHODS

The first method documented the extent to which visible light enters the residence. Time-lapse photography was used throughout the year to record the sun-shade coverage in the living room. A digital camera was installed in the east bedroom on the second floor to capture images at intervals every two to four minutes throughout the day. No photographs were taken during the night. The camera recorded the extent of sun exposure in the living room at regular intervals for the following periods:

- January–December 2013 (one year)
- January–May 2014 (five months)
- April–December 2015 (nine months)
- January–June 2016 (six months)

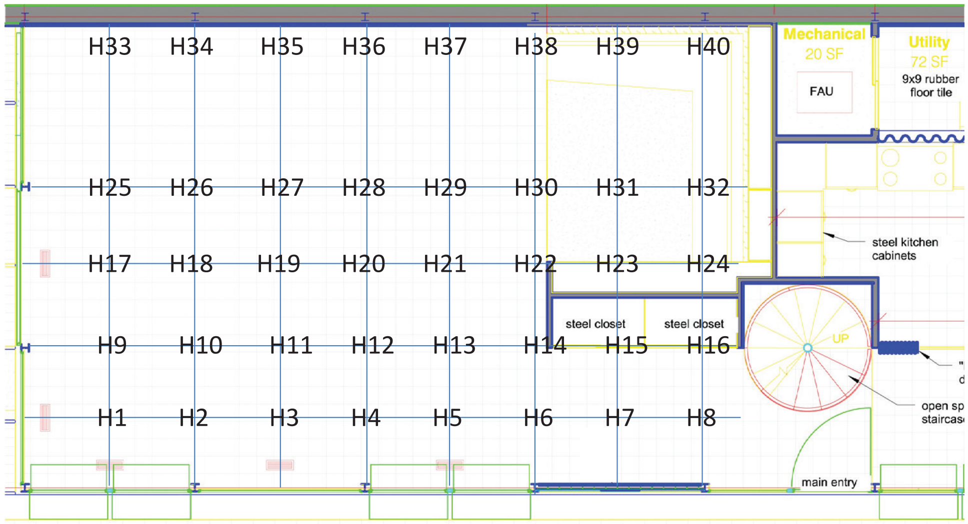


FIGURE 4.14
Residence ground floor visible light and UV radiation measurements—horizontal surface locations H1–H40

In the second study, on September 25 and 26, 2012, the extent and intensities of visible light and UV radiation in daylight were measured at forty horizontal and eighteen vertical locations throughout the living room. Horizontal values were taken on the living room floor (fig. 4.14) and vertical values on the bookcase and on the wood panel (figs. 4.15 and 4.16). Measurements were taken several times throughout each day using a Solar Light Company Model PMA2100 with PMA2130 Photopic Detector and PMA2107 UVA+B Detector (fig. 4.17). Both detectors were factory calibrated prior to the measurement.

During the measurements, the windows and sliding doors were closed, and no curtains were present. The Photopic (visible light) and UVA+B (UV radiation) detectors/sensors were placed at designated locations, and outputs of the visible light and UV radiation sensors were manually recorded. Three sets of measurements, which took approximately forty minutes each, were taken during the two-day period. The first two measurements were taken under a well-defined sun/shadow condition, and the last measurement was made under a diffused light condition. The sky was clear during the 12:00 p.m. and 4:00 p.m.

FIGURE 4.15
Residence ground floor visible light and UV radiation measurements, October 2012—vertical surface locations V1–V9. Photo: Shin Maekawa

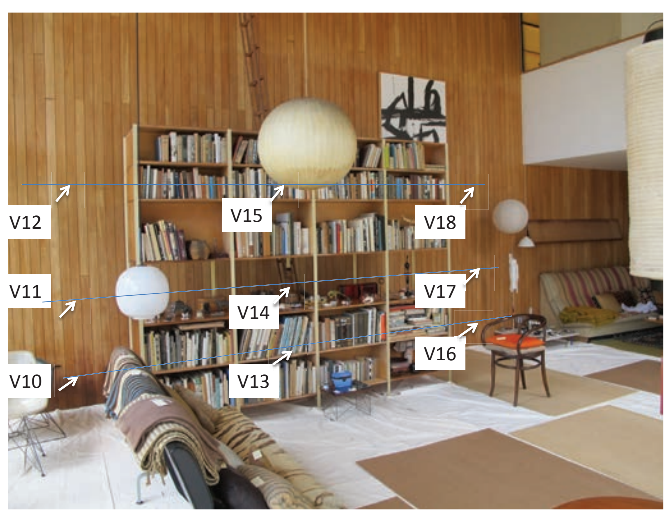


FIGURE 4.16
Residence ground floor visible light and UV measurements, October 2012—vertical surface locations V10–18. Photo: Shin Maekawa

FIGURE 4.17
Kyle Normandin (former GCI Senior Project Specialist) conducts UV and visible light measurements using a light meter in 2013.
Photo: Scott Warren

measurements on September 25, but on September 26 the sky was fully covered by a thick marine layer and only diffused light was present during the 9:00 a.m. measurement.

4.4.4 Retaining Wall and Soil Moisture Levels

OBJECTIVES

The retaining wall on the west elevation of the ground floor of the residence may impact the temperature and humidity in the residence because the temperature and moisture content in the soil behind the retaining wall fluctuate with the weather and the soil condition. This may affect the environment in the residence, depending on temperature and moisture differences between the two locations. The GCI investigated the west side, or exterior surface, of the reinforced concrete retaining wall for moisture intrusion from the soil. The investigation of the exterior of the retaining wall served these objectives:

- To document physical conditions of the retaining wall and its moisture barrier coating.
- To document characteristics of the soil behind the retaining wall including soil types, moisture content, and humidity levels.
- To confirm the presence of a drainage system at the base of retaining wall.
- To install sensors to measure the temperature and moisture content of the soil over time.

Microbial activities stimulated by high humidity can also contribute to a rapid loss of the wood panel or its supporting structure. Therefore, an investigation of the east side, or the interior surface, of the retaining wall and cavity between the retaining wall and wooden wall paneling of the living room, was undertaken to assess any evidence of moisture intrusion into the residence.

METHODS

On January 12 and 13, 2012, an excavation was undertaken adjacent to the retaining wall (figs. 4.18–4.20). A 4 × 4 × 5 ft. (1.22 × 1.22 × 1.52 m) pit was excavated at approximately

FIGURE 4.18
Location of pit at the rear of the Eames House residence, 2012.
Photo: Shin Maekawa

FIGURE 4.19
Pit during excavations, 2012.
Photo: Shin Maekawa

FIGURE 4.20
Backfilling the pit and installing sensors, 2012. Photo: Shin Maekawa

20 ft. (6.10 m) from the southwest corner of the residence. On the first day, the pit was carefully excavated manually using hand picks and shovels to avoid water or gas pipes in the area. The highly compacted soil also slowed the work. On the second day, excavation of the pit continued using an electrical jackhammer.

The excavation ceased at the depth of approximately 5 ft. (1.52 m) due to soil compaction. In order to characterize the soil and analyze its water content, 50–80 mL of soil samples were collected in sealed containers starting at the 18 in. (45.72 cm) depth at approximately 1-foot intervals. The analysis was carried out by the GCI Science Department and included grain size, soil type, water content, and humidity. Two methods were used to determine water content in the soil samples. First, several 10-gram samples of the soil samples were analyzed using the gravimetric method, which determines the soil moisture by weighing the difference of the soil before and after oven drying (at 212°F for forty-eight hours). Second, the volumetric water content (VWC) was measured by placing sensors in the excavated pit. The VWC differs from the gravimetric water content (moisture content by weight); it is the product of the gravimetric water content and the bulk density of soil. The bulk density normally ranges from 0.5 for an aggregated clayey soil to 1.2 for a sandy soil. However, the bulk density changes with the compaction for the same soil. Volumetric water contents of the soil behind the retaining wall were monitored at depths of ¼ in. (8 cm), ½ in. (15 cm), 1 in. (30 cm), 2 in. (61 cm), 3 in. (91 cm), and 4 in. (122 cm).

During the excavation, the surface of the retaining wall was inspected for cracks and to verify the presence of the waterproofing membrane that was noted in the original architectural drawings. Due to the depth of the excavation, the presence of a French drain could not be confirmed, nor the extent or condition of the waterproofing membrane to the base of the retaining wall.

The VWC sensors were connected to the station and their data were accessed remotely by the GCI via an IP connection.

Although large rocks and pebbles were removed from the soil, the same excavated soil was used for back filling. The soil was compacted using a hand tamper at approximately 6-inch (15 cm) intervals, and a small amount of water was sprayed approximately every foot (61 cm) to improve the compaction.

The condition of the interior surface of the retaining wall was assessed through observation using a borescope (endoscope with light source). On March 26, 2012, one of the vertical wooden planks was removed from the wall panel of the living room and a borescope was used to search for evidence of humidity within the wall cavity (fig. 4.21).

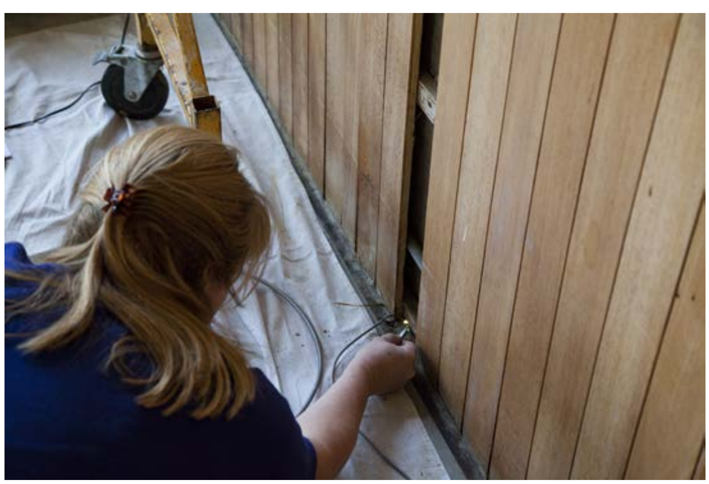


FIGURE 4.21
Joy Mazurek (GCI scientist) examines the structure of wooden panel and furring strips using a borescope, 2012. Photo: Holly Brobst

4.4.5 Floor Slab Investigations

OBJECTIVES

In 2011, while the collections of the living room were temporarily on display at the Los Angeles County Museum of Art, the original asbestos-containing vinyl composite floor tiles of the living room and part of the hallway (fig. 4.22) were removed due to their poor condition and hazardous composition, exposing the concrete floor slab and allowing access to the slab for scientific investigations.

A 2011 consultant's report identified high permeation of water vapor through the floor slab of the residence as the main cause of the deterioration of living room and kitchen floor tiles. The report also suggested that the water vapor permeating the floor slab could be contributing to increased moisture in the residence (D7 Consulting 2011). To further investigate these findings, the GCI conducted temperature and humidity investigations of the floor slab in the living room to determine if these factors contribute to the humidity in the residence and to confirm the need for a moisture vapor barrier as part of the replacement flooring system.

Additionally, there was a concern that the replacement flooring system could introduce volatile compounds harmful to the collection. Therefore, the new materials were tested for acceptable museum application.

FIGURE 4.22
Picture of the living room in 2011, with original floor tiles before removal.
Photo: Joshua White, © Eames Office

METHODS

The concrete slab's temperature and humidity were monitored to confirm results by D7 Consulting, who had performed a calcium chloride test (ASTM 1869-04 Standard Test Method) to measure water vapor emission from the slab. On October 27, 2011, three temperature and humidity data loggers were placed in the concrete slab floor of the living room for a week (fig. 4.23). Two were placed directly on different areas of the floor surface and covered with a moisture barrier film with edges taped to the floor with duct tape to isolate the measurement environment from the room; one data logger was placed 5 ft. (152 cm) away from the wood-paneled wall and the other at the center of the living room. The third data logger was placed over the barrier film to measure the ambient temperature and humidity. On November 3, 2011, another two-sensor unit was placed on the floor of the living room—one sensor measured the room environment and the other was located in an existing 8 in. (20 cm) deep hole in the slab floor near the alcove/retaining wall (fig. 4.24). These data loggers continuously recorded temperature and humidity data until November 23, 2011, when the data were downloaded.

FIGURE 4.23
Location of temperature and humidity sensors on floor slab, 2011. Photo: Ana Paula Arato Gonçalves

FIGURE 4.24
Data logger with temperature and humidity sensor in the concrete floor slab, 2011. Photo: Shin Maekawa

In order to evaluate the potential effect of materials on the collections, GCI Science performed Oddy testing of possible replacement vinyl composite tiles, of flooring systems (tiles, adhesives, primers and water vapor barriers), and of a heating duct liner. The Oddy test identifies materials that produce volatile compounds harmful to objects in enclosed spaces. All samples tested were run in triplicate in order to decrease the chance of anomalous results.

4.4.6 Investigation of Metal Ducts Below Floor Slab

OBJECTIVES

The GCI conducted an investigation to assess the condition of the subgrade metal heating ducts within the concrete floor slab, and to determine whether the ducts could be reused for a new environmental conditioning system in the residence, and whether the existing heating system is an effective environmental conditioning system.

METHODS

The examination of the floor heating ducts started with a UXR Model FF4010 borescope, but due to equipment limitations, it was unsuitable for viewing the ducts. Instead, a duct camera with video recording capacity was necessary (fig. 4.25). This investigation was conducted before and after the ducts had been cleaned by a contractor, to inspect the condition of the metal heating ducts as well as the condition of the concrete surrounding the ducts.

Eight segments of ductwork were inspected (fig. 4.26). Each length of duct started at a grille vent, which provided an entry point for the camera, and stretched in the direction of the furnace until it encountered an obstacle or reached the main line. Each length of duct was given a number according to the location of the entry point, or grille vent, starting in the living room and moving counterclockwise toward the kitchen and upper floor:

Numbers (1), (3), (4), and (5) identify lengths of duct that started at a grille vent and ended at the junction with the main line. Video recording went further into the main line when possible. Numbers (2) and (6) started at a grille vent and went as far as possible into the main line. Number (7) identifies the inspection of the return duct. Numbers (8) and (9) were located on the second floor and were built into the walls, as opposed to the other

FIGURE 4.25
Shin Maekawa inspecting the heating ducts, 2011. Photo: Ana Paula Arato Gonçalves

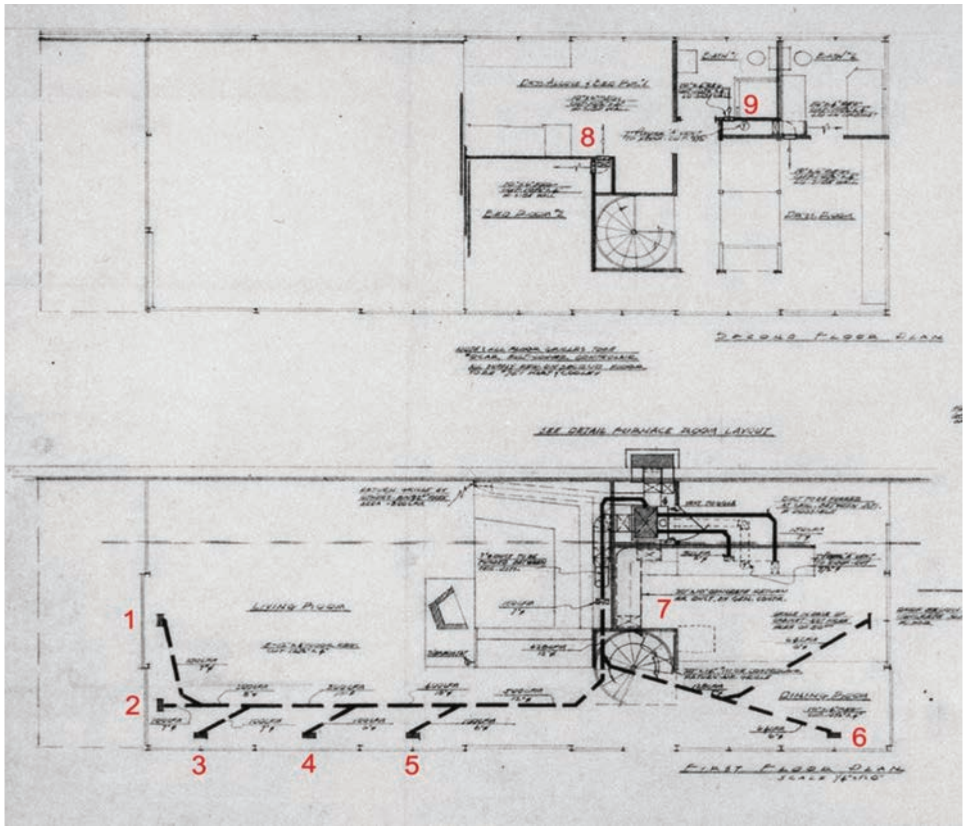


FIGURE 4.26
Location and number of inspected duct paths. Drawing: Adapted from Eames House Detail Drawing Sheet 3, dated October 14, 1948, © Eames Office

ducts that were built into the floor slab. These were not inspected with the video camera, but photographs of the entrance were taken with a regular digital camera.

The zero markers for each measurement were the point where the duct meets the grille vent. These length measurements were taken by the camera's cable measurement system (accuracy of +/- 1 to 2 ft., or 30 to 61 cm). The only length of duct that was not inspected was a kitchen duct that ends close to the north elevation of the residence. It is assumed that the vent for this duct is located under the kitchen cabinet, but it could not be accessed for inspection. Another duct camera was employed in a second inspection after the ducts had been cleaned by a contractor.

4.5 Environmental Monitoring Data

4.5.1 Climate at the Eames House (Exterior)

Monthly and annual averages of temperature, humidity, dew point temperature, rainfall (total), solar radiation, and wind speed measured at the site during 2012, 2013, and 2014 are listed in table 4.2.

TEMPERATURE

Annual average temperatures were 61°F (16.1°C), 61°F (16.1°C), and 63.7 °F (17.6°C) in 2012, 2013, and 2014, respectively. The maximum temperatures recorded were 90.1°F (32.3°C), 90.0°F (32.2°C), and 85.3°F (29.6°C), and the minimum temperatures recorded were 38.8°F (3.8°C), 38.3°F (3.5°C), and 42.3°F (5.7°C), in 2012, 2013, and 2014, respectively. Freezing temperatures were not recorded during this period. Monthly average tem-

TABLE 4.2
Monthly and annual averages of temperature, humidity, dew point temperature, rainfall (totals), solar radiation, and wind speed in 2012–2014 at the Eames House.

Parameter	Year	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	2012	16.1	13.8	13.0	12.8	14.2	16.3	17.6	17.9	20.5	20.4	18.9	15.3	12.5
	2013	16.1	12.6	12.4	13.6	15.3	17.6	18.4	18.9	18.6	19.0	16.9	15.9	13.9
	2014	17.6	14.9	13.8	15.4	15.5	18.8	18.6	20.8	20.5	21.3	19.5	17.7	14.2
Humidity (% RH)	2012	73	60	65	70	75	79	79	81	79	76	68	72	75
	2013	69	50	61	79	72	79	74	82	81	75	66	62	48
	2014	69	56	71	73	70	62	77	79	76	73	68	52	69
Rainfall (mm)	2012	206.8	27.7	1.3	47.0	32.0	0.0	0.0	0.3	0.0	1.0	0.0	35.8	61.7
	2013	77.0	29.0	2.5	21.9	0.0	0.0	6.6	0.0	0.0	0.0	4.6	8.6	3.8
	2014	84.3	0.3	77.2	2.5	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Solar Radiation (kW/m2)	2012	0.13	0.11	0.11	0.13	0.17	0.17	0.15	0.14	0.18	0.16	0.12	0.09	0.09
	2013	0.13	0.11	0.12	0.15	0.15	0.17	0.14	0.13	0.15	0.14	0.11	0.08	0.11
	2014	0.14	0.10	0.10	0.17	0.17	0.16	0.16	0.16	0.18	0.16	0.12	0.10	0.10
Wind Speed (km/h)	2012	2.3	2.0	2.3	2.7	3.0	3.1	2.9	2.3	1.5	1.5	1.9	2.0	2.6
	2013	2.4	2.6	3.0	2.7	2.8	3.1	2.7	1.7	2.2	2.0	2.1	1.9	2.2
	2014	2.7	2.5	3.2	3.2	3.3	2.6	2.7	2.4	2.2	2.4	2.3	2.6	2.9

peratures had a flat sinusoidal shape with highest temperatures July through October and lowest December through March. Day-to-day temperatures varied more in winter months than at other times of the year. Daily temperature variations averaged about 46.2°F (7.9°C) and ranged from a low of 34.3°F (1.3°C) on a rainy winter day to a high of 58.6°F (14.8°C) on a sunny winter day. Daily temperatures were lowest from 6:00 a.m. to 7:00 a.m. and the highest from 12:00 p.m. to 2:00 p.m.

HUMIDITY

Annual averages of relative humidity were 73%, 69%, and 69% RH in 2012, 2013, and 2014, respectively. Humidity values higher than 95% RH were recorded daily between September and April. The lowest humidity values, less than 10% RH, were recorded between January and April. The monthly average remained between high 50s and low 80s % RH for the remainder of the year.

Humidity remained stable, between 60% and 90% RH, from May through September. Between November and April, however, it varied wildly, between 30% and 95% RH. The highest monthly average was 75% RH in November, and the lowest was 58% RH in August. The average daily variation was about 20% RH, with the highest, 57% RH, on a hot and dry summer day in June, and the lowest, 5% RH, on a cool and rainy day in December. Typically, daily humidity fell to less than 70% RH between 10:00 a.m. and 4:00 p.m.

DEW POINT TEMPERATURE AND HUMIDITY RATIO

Dew point temperature is an indication of the amount of moisture vapor in the air. Vapor in moist air condenses at or below its dew point temperature—the higher the dew point temperature, the higher the moisture content of the air. Annual average dew point temperatures were 52.3°F (11.3°C), 50.9°F (10.5°C), and 53.4°F (11.9°C) in 2012, 2013, and 2014, respectively. The humidity ratio was above 12 g of water per one kilogram of dry air (g/kg) during summer, but was below 8 g/kg the rest of the year. The highest humidity ratio, 15 g/kg was recorded in September 2012, and the lowest, 1.0 g/kg, was recorded in January 2013.

PRECIPITATION

Annual totals of rainfall, as measured at the site, were 8.1 in. (206.8 mm), 3.0 in. (77.0 mm), and 3.3 in. (84.3 mm) in 2012, 2013, and 2014, respectively, which were considered to be drought years. Although there were a few rainfall events during summer months, most rainfall events were recorded between October and April.

The highest monthly rainfall totals of 2.4 in. (62 mm), 1.1 in. (29 mm), and 3 in. (77 mm) were recorded in December 2012, January 2013, and February 2014. No measurable rainfall was recorded in May, June, August, and October 2012; April and June through September 2013; and May through November 2014. Maximum daily rain fall totals were 0.3 in. (7.1 mm) in March 2012, 0.4 in. (10.6 mm) in March 2013, and 0.3 in. (7.6 mm) in February 2014.

SOLAR RADIATION

At the Eames House site, annual totals of the solar radiation were 1161 kWh/m2, 1133 kWh/m2, and 1212 kWh/m2 in 2012, 2013, and 2014, respectively. The maximum daily average was 0.17 kW/m2 in summer months and minimum values, 0.08–0.09 kW/m2, were recorded on rainy days in winter months.

WIND DIRECTION AND SPEED

Annual averages of wind speed were 1.77 ft./s (2.3 km/h or 0.54 m/s), 1.83 ft./s (2.4 km/h or 0.56 m/s), and 1.93 ft./s (2.7 km/h or 0.59 m/s) in 2012, 2013, and 2014, respectively. Wind vectors of fifteen-minute data are plotted for 2012, 2013, and 2014. As seen in figure 4.27, wind patterns for those three years were very similar (note that wind speeds are

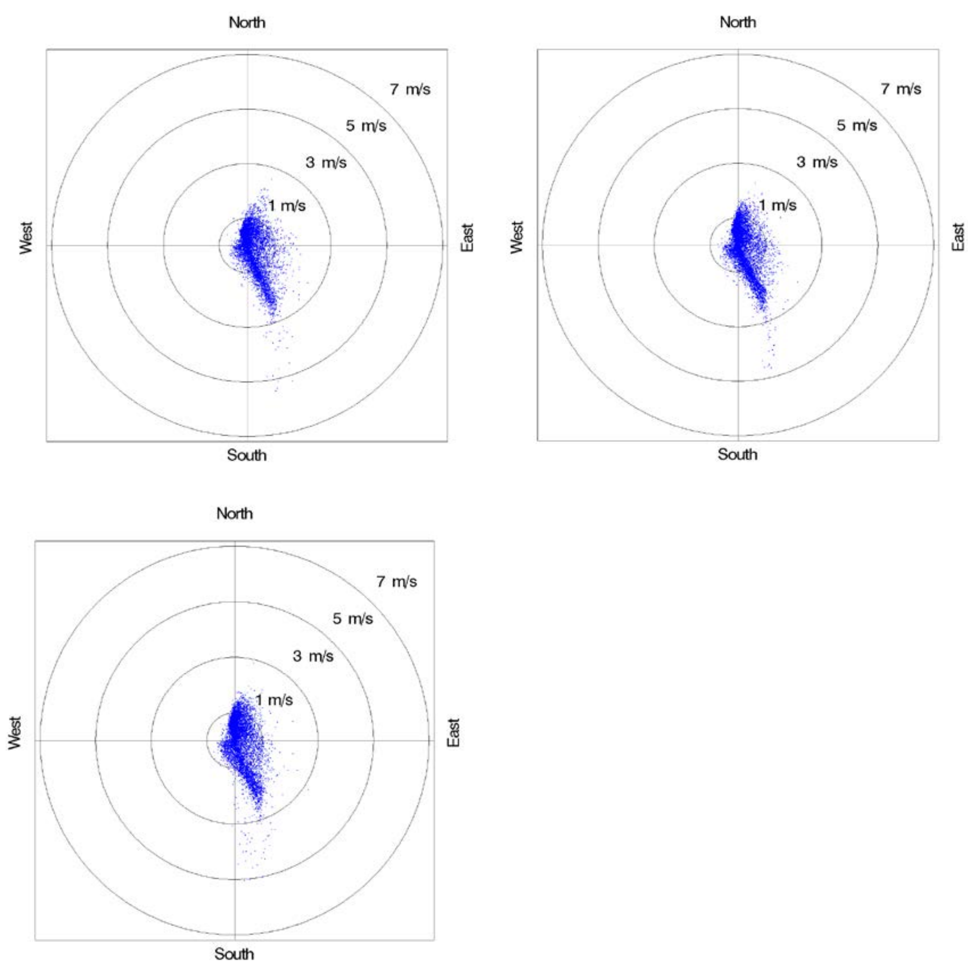


FIGURE 4.27
Annual winds for 2012 (top left), 2013 (top right), and 2014 (bottom) plotted in wind vectors (direction and speed). Each blue dot represents a set of the 15-minute average wind speed and direction.

scaled in m/s in the plots). The hill west of the site protects the building from winds from the north, west, and south.

The predominant wind was from the south-southwest with a speed less than 9.8 ft./s (3 m/s). Occasionally, wind speeds exceeding 3m/s were recorded from that direction. The maximum speed recorded was 17.7 ft./s (5.4 m/s), 15.4 ft./s (4.7 m/s), and 16.4 ft./s (5.0 m/s) for 2012, 2013, and 2014, respectively. High wind speeds, higher than 9.8 ft./s (3 m/s), were generally registered in spring, between March and May; 95% of wind speeds were less than 5.9 ft./s (1.8 m/s).

COMPARISON TO THE SANTA MONICA AIRPORT CLIMATE

Monthly averages of temperature, humidity, precipitation, and wind speed at both the Eames House site and the Santa Monica Airport are plotted for comparison in figure 4.28. Three-year averages, between January 2012 and December 2014, of temperature and humidity at the site were 61.9°F (16.6°C) and 70% RH, which were similar to historic averages, 62.2°F (16.8°C) and 70% RH, recorded at the Santa Monica Municipal Airport. Monthly average temperatures and monthly average humidity at the site also closely followed those of the Santa Monica Municipal airport.

Although rainfall varied year to year, all three years monitored were drought years. The rainfall in 2013 was less than 60% of the historic average of 15 in. (373 mm), and 2013 and 2014 had each less than 30% of the historic average. However, seasonal rainfall patterns were similar to historic patterns and the majority of rainfalls were recorded in winter months.

Wind speeds at the site were less than 30% of those recorded at the airport. Unlike the airport, which is located in a flat and unobstructed area, the Eames House site is protected from southeast-southwest winds by tall and dense trees in the meadow. An upper slope with trees behind the residence also protects the site from northeast-northwest winds.

4.5.2 Eames House Environment (Interior of Residence)

Interior environmental conditions are described in the following sections as they relate to conservation of both the collection materials and interior building fabric.

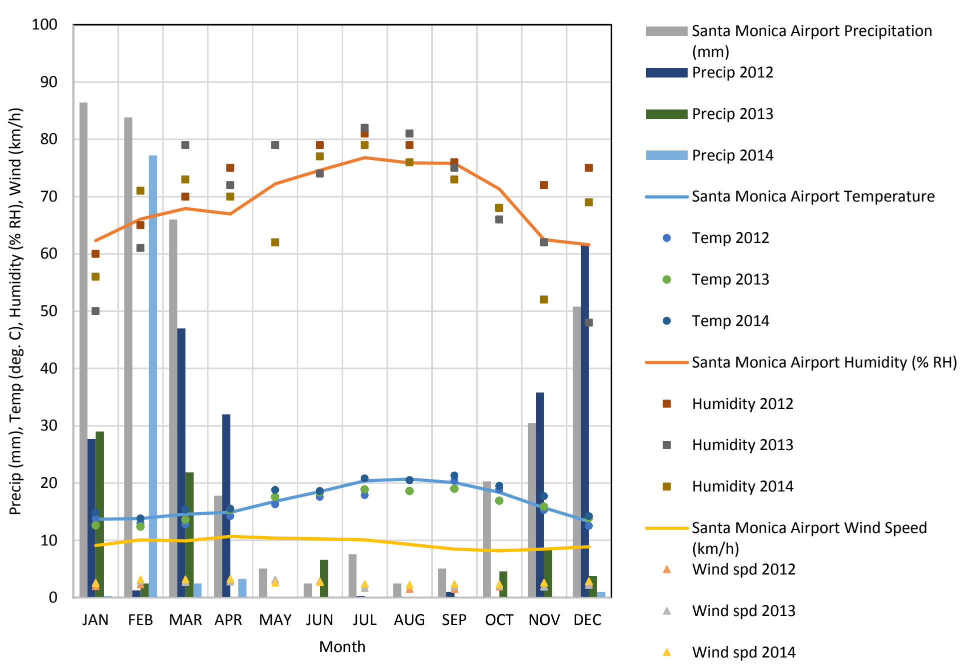


FIGURE 4.28
Graphic comparison of historical averages at Santa Monica Airport and monthly values recorded at the Eames House.

TEMPERATURES

Table 4.3 lists annual average temperatures at monitored locations throughout the residence. The results indicate that temperatures varied somewhat throughout the residence. Annual average temperatures, which fluctuated between 2°F and 3.6°F (1.5°C and 2°C) throughout the residence, were approximately 7.2°F to 11.7°F (4°C to 6.5°C) higher than outdoor temperatures measured at the weather station on site, indicating that the residence remained significantly warmer than the outdoors on average. The lowest annual average temperature was recorded in the second-floor closet for each of the monitored three years, which may be because the closet is located in the north side of the residence, which is both shaded from the sun and poorly ventilated. The next lowest annual average temperature was recorded in the living room, which may be because the living room is well ventilated during the day. The highest annual average temperature was recorded in 2013 at the entrance/kitchen area. A detailed review of the data, however, determined that these high readings were the result of the sensor being exposed to direct sunlight, which was corrected in late 2013. Temperatures in bedrooms on the second floor and the top of stair were the highest as the buoyant warm air accumulated in the area.

TABLE 4.3

Annual average temperatures at various locations inside and outside the house.

	Living Room	2FL Bedroom	2FL Stairway	2FL Closet	Entrance/ Kitchen	Outside
2012	20.2°C	21.5°C	22.0°C	20.0°C	22.6°C*	16.1°C
2013	19.4°C	20.4°C	20.5°C	19.1°C	20.4°C	16.1°C
2014	19.8°C	21.0°C	20.6°C	19.5°C	20.1°C	17.6°C

*Reading was affected by the exposure of the sensor to direct sunlight.

Figure 4.29 shows monthly averages of temperature at various locations inside and outside the residence between January 2012 and December 2014. Temperatures inside the residence followed the temperature trend of the outside: the maximum and minimum monthly average values changed depending on the outside averages. Temperatures were higher May through October, and lower November through April. Daily maximum tempera-

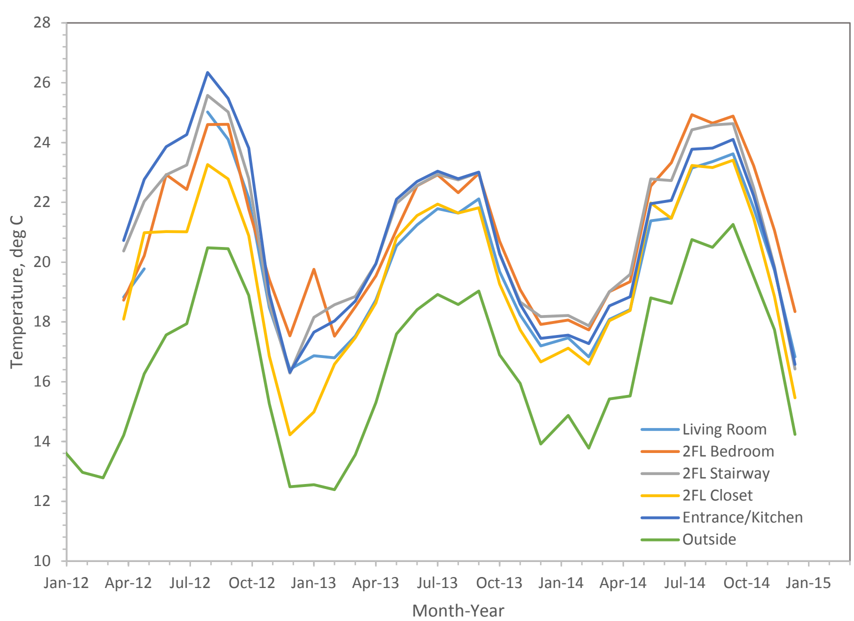


FIGURE 4.29

Monthly averages of temperature inside and outside the residence.

.31

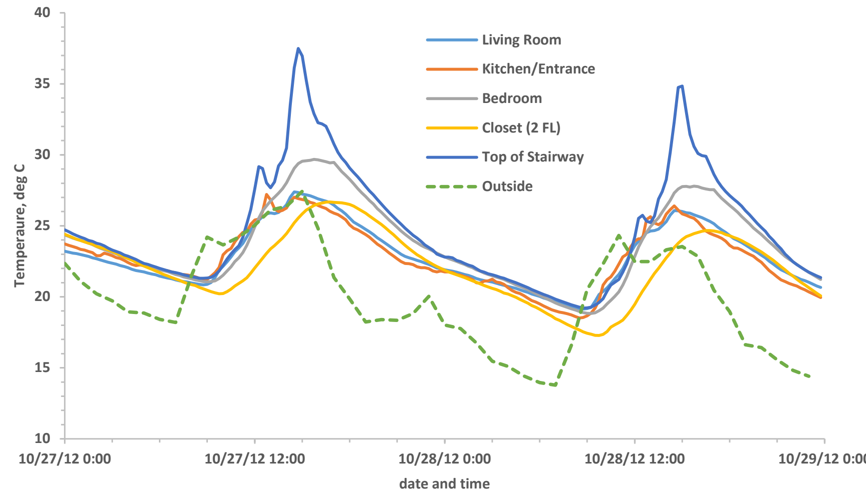


FIGURE 4.30
Temperatures inside and outside the house between October 27 and 28, 2012.

tures in the residence were reached at about 3:00 p.m. on the ground floor and 4:00 p.m. to 5:00 p.m. on the second floor. These daily trends were consistent throughout the year. The smallest daily variations of the temperature were recorded in the living room. Larger variations were observed in spaces on the second floor starting at around 9:00 a.m. until 6:00 p.m. to 7:00 p.m.

Inside temperature changes lagged one to two hours behind outside temperature changes in the morning. By midafternoon, however, the lag was less than a half hour. Inside temperatures were 1.8°F–3.6°F (1°–2°C) less than the outside temperatures, with the exception of the area at the top of the stairway. The temperature at the top of the stairway was nearly 9.0°F (5C°) higher than outside due to solar heat gain from a skylight directly above the stair. Temperatures on October 27 and 28, 2012, at various locations inside and outside the residence are plotted in figure 4.30.

The close tracking between inside and outside temperatures indicates that the envelope has very low thermal mass. Daily opening of doors and windows also contributed to the close tracking of the indoor and outdoor temperature changes during the day. This is consistent with the actual construction of the envelope, which is composed of glazing, composite panels, steel window sash and frames, lightweight steel structural elements, and a minimally insulated roof.

It is noted that roof insulation was improved with the installation of a new roof assembly in December 2014.

HUMIDITY

Relative Humidity

The annual average of relative humidity (% RH) inside the residence was lower than the outside relative humidity by 4%–15% RH (table 4.4), but nonetheless followed outside humidity trends, high in summer and low in winter. Considering that inside the residence was 7.2°F–11.7°F (4°C–6.5°C) warmer than the outside, the interior humidity was expected to be approximately 20% RH lower than that of the outside because a 1.8°F (1°C) increase corresponds to 5% RH reduction of typical room air. The smaller than expected difference between outside and inside humidity may be attributable to moisture buffering by the collections of the residence as well as moisture vapor permeation through the concrete retaining wall and the concrete floor slab (see below). Most of the time, the outside humidity was 5%–20% RH higher than the inside.

TABLE 4.4
Annual average humidity at various locations inside and outside the house.

	Living Room	2FL Bedroom	2FL Stairway	2FL Closet	Entrance/ Kitchen	Outside
2012	63% RH	58% RH	59% RH	67% RH	57% RH*	73% RH
2013	59% RH	53% RH	55% RH	62% RH	56% RH	69% RH
2014	60% RH	54% RH	58% RH	65% RH	59% RH	69% RH

*Reading was affected by the exposure of the sensor to direct sunlight.

The annual average humidity varied significantly, between 9% and 11% RH, throughout the residence. The highest humidity values, 62% to 67% RH, were recorded in the north closet on the second floor. The humidity in the closet on the second floor exceeded the outside humidity during winter months, October and November 2013, and October through December 2014. Humidity values above 75% RH, the threshold humidity for germination of most fungi, occurred between thirty and forty days over the course of a year. Monthly averages of humidity exceeded 70% RH in the second-floor closet for a total of eight months over the three-year monitoring period, indicating that the highest risk of fungal damage to materials is in the second-floor closets.

Although temperatures June through August were as cool in the second-floor closets as in the living room, humidity was 5%–10% RH higher in the closets. A cool and humid microenvironment was maintained in the closet over the eight months, when humidity exceeded 70% RH.

The lowest humidity values, 53%–58% RH, were recorded in the bedroom on the second floor, which was also the warmest area in the residence. The living room was cooler and more humid than the second floor bedrooms, but warmer and less humid than the second-floor closet. The presence of these microenvironments indicates uneven air circulation.

Lower humidity was observed at all locations in the residence during winter months due to lower humidity outside (fig. 4.31). Sharp drops of humidity were recorded when the temperature quickly rose, such when the dry Santa Ana winds blew through the region. Rapidly rising temperatures frequently occurred during the monitored period.

FIGURE 4.31
Monthly averages of humidity inside and outside the residence.

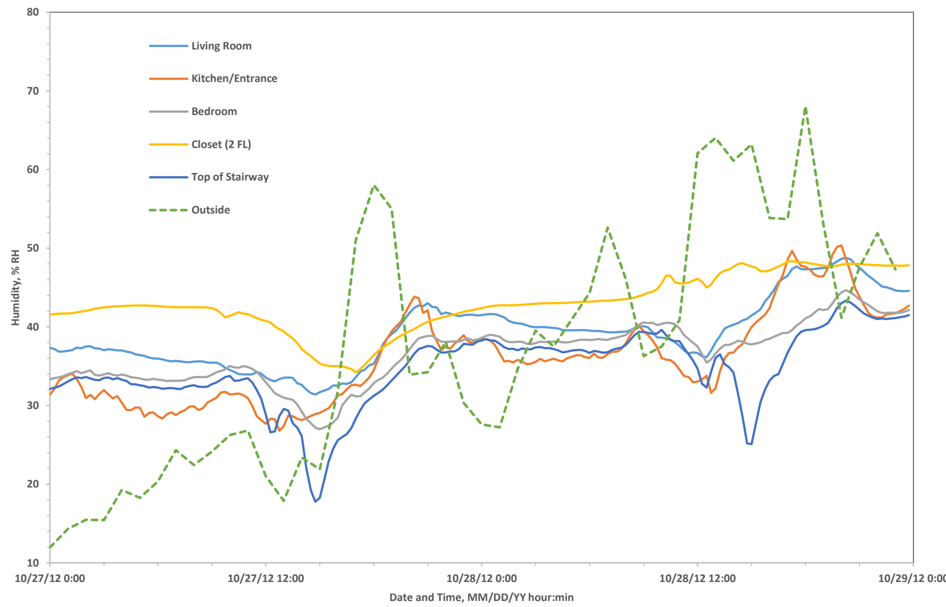


FIGURE 4.32
Humidity values inside and outside the house between October 27 and 28, 2012.

Variations in the living room humidity were typically less than 10% RH; greater fluctuations of humidity, 10%–20% RH, were observed with changes in the weather. On the second floor, the humidity fluctuated only during the daytime, as warm air from insolation (solar gain) depressed humidity. The humidity returned to morning values by late evenings, as the second floor cooled. In the bedrooms, the daily fluctuations were 10% RH or less in winter, but increased to 10%–15% RH in summer. In the closet, variations were less than 5% RH throughout the year.

Humidity values at various locations inside and outside the residence recorded on October 27 and 28, 2012, which were typical fall days, are plotted in figure 4.32. Outside humidity changes did not produce a noticeable impact on inside humidity during closed hours, between 4:00 p.m. and 10:00 a.m. Inside humidity values tracked changes of the outside during the daytime, when doors and windows were open. However, a 60% RH change outside produced less than a 30% RH change inside, indicating that the building envelope has a low infiltration rate when doors and windows are closed and the interior and collections have a medium hygroscopic mass to buffer the inside humidity.

Humidity Ratio

Annual averages of humidity ratio at the different locations in the residence and the outdoors are listed in table 4.5. On the whole, values throughout the residence were similar and consistent with the outside, with the exception of the values in the closet on the second floor, which were consistently higher than those recorded in other parts of the residence as well as outside.

TABLE 4.5
Annual averages of humidity ratio at various locations inside and outside the house.

	Living Room	2FL Bedroom	2FL Stairway	2FL Closet	Entrance/ Kitchen	Outside
2012	9.29 g/kg	9.45 g/kg	9.81 g/kg	10.03 g/kg	9.82 g/kg	9.55 g/kg *
2013	8.52 g/kg	8.17 g/kg	8.45 g/kg	8.93 g/kg	8.52 g/kg	8.10 g/kg
2014	8.86 g/kg	8.57 g/kg	8.88 g/kg	9.50 g/kg	8.91 g/kg	8.75 g/kg

*Average over April-December period for comparison.

FIGURE 4.33
Monthly averages of humidity ratio inside and outside the house.

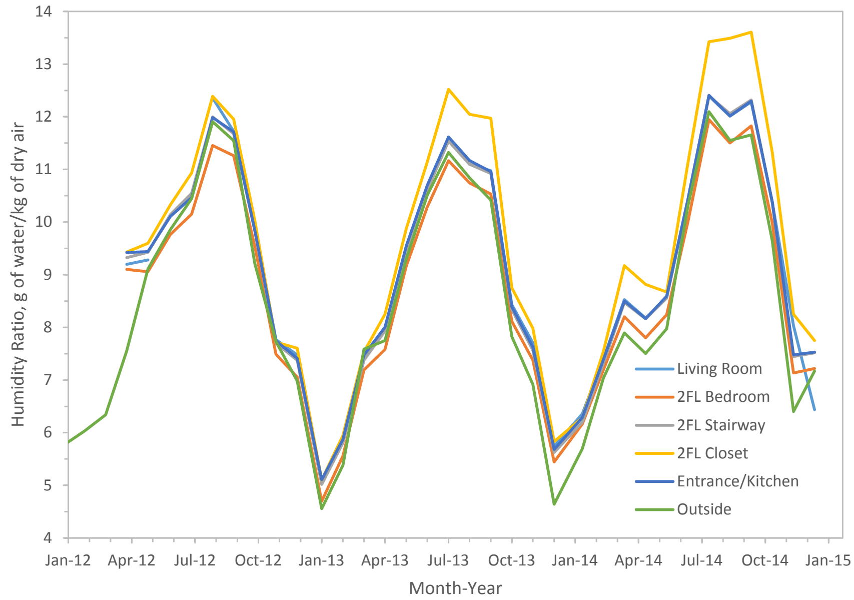


Figure 4.33 shows plots of monthly averages of humidity ratio at various locations in the residence as well as those of the outside. High values, above 10 g/kg, of the humidity ratios were seen in summer months, June through September. Although large amounts of moisture were found in the air during the period, humidity remained less than 70% RH in the residence due to elevated temperatures, mostly above 35.6°F (2°C). Throughout the year, humidity ratios in the residence, except those in the closet on the second floor, remained similar to those of the outside air. During the summer, humidity ratios were approximately 10% (or 1 g/kg) higher in the closet than in other areas, indicating that a source or accumulation of moisture was present in or around the closet. There were no likely moisture sources, such as roof failure or broken plumbing, reported in the area. The closets are full of clothing, fabrics, and shoes in cardboard boxes, however, so the moisture source must be in the objects and building fabric, which had been conditioned to high humidity, absorbing water vapor from the moist air over time.

Hygroscopic materials, such as paper, textile, fabric, and wood, hold fixed amounts of moisture when the humidity is stable. The amount of moisture is referred to as the equivalent moisture content (EMC). These materials absorb moisture, resulting in a higher EMC value, in a more humid environment and desorb moisture, resulting in a lower EMC value, in a less humid environment. EMC values are different depending on the direction of humidity changes, adsorption, or desorption. Higher EMC values are typically maintained in the desorption process as opposed to the absorption process. Rates of adsorption and desorption also vary significantly depending on the materials and differences in humidity. Normally rates of absorption are significantly higher than those of desorption.

In poorly ventilated or enclosed spaces, such as in the closets on the second floor, contents will retain a high EMC value even if the humidity drops. Once hygroscopic materials absorb sufficient moisture, the high EMC values stabilize and become constant, and the materials condition the environment. The outside dry (low humidity) air cannot replace the humid air in the poorly ventilated space fast enough to reduce the high humidity. This seems to be the case in the closets.

Similarly, high EMC conditions are maintained in hygrometric materials when the humidity cycles between low and high values. Since desorption of moisture from the materi-

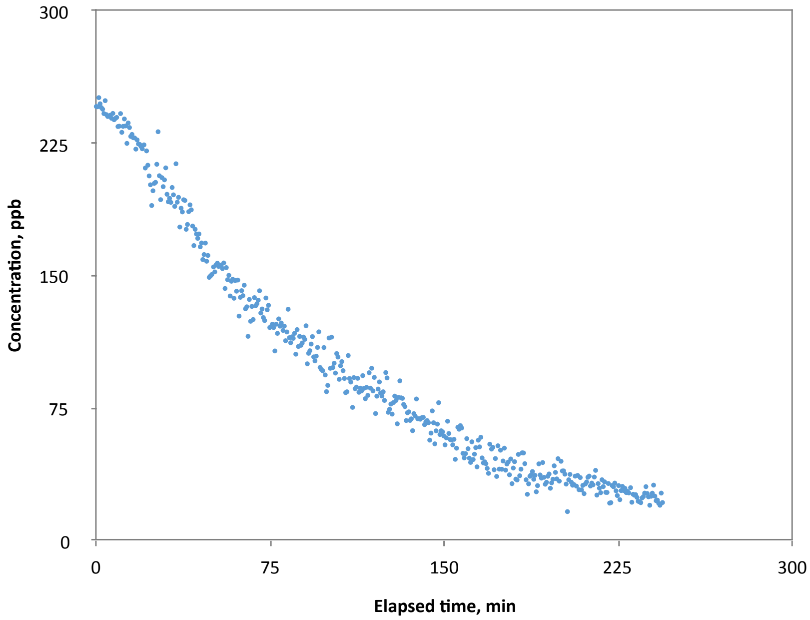


FIGURE 4.34
Typical data (gas concentration in ppb at given elapsed time in min.) from air change rate measurements. The concentration of sulfur hexafluoride was measured at the two-minute interval and recorded vs. elapsed time. Each blue dot represents one measurement (ppb vs. min.). The exponential line represents the first-order decay equation which was fitted to the data using the least square method.

als is slower and requires more energy (such as heat or air flow) than adsorption, the EMC values tend to remain higher even when the humidity is reduced in short cycles. This condition creates an environment conducive to biological deterioration, such as fungi.

AIR INFILTRATION AND AIR CHANGES

To determine the air change rates in the residence, measurements were taken over two days in summer and two days in winter. The measurements include values for both day and night, with and without the FAU running.

Measured gas concentrations were plotted against elapsed time. Then, a first-order decay equation was fitted to the data set using the least squares curve fitting method (fig. 4.34). Decay constants of the equations were used to calculate their half-times. The calculated half-time values were verified through graphically approximated half-time of the data.

Once the decay of the gas concentration is expressed by the first order decay equation as the following:

$$\text{Concentration (ppb)} = C_{0\ e}{}^{-\tau\ t,}$$

where C_0 is the concentration at t = t0, and τ is the decay constant. The half-time can be obtained as (– ln (0.5) / τ).

Table 4.6 summarizes air change rates for all measured periods with relevant climate information. During the day, air change rates ranged from 0.48 to 0.59 hour-1 with the average value of 0.53 hour-1 when the FAU was turned off. During the night, air change rates were 0.77 and 0.83 hour-1 (average value of 0.80 hour-1). However, the value increased to 1.1 hour-1 when the FAU was turned on.

The following results were observed:

- Air change rates in typical residential buildings are between 1 and 2 hour-1. The Eames residence had rates that ranged from 0.5 to 1.1 hour-1, indicating a relatively airtight envelope.
- No seasonal variation was recorded in either the day or night values.

TABLE 4.6
Summary of air change rate measurements.

Date of measurement	Period of measurement	Air change rate (hour-1)	Temperature (°C)		Wind		Forced Air Unit (FAU)
			Inside	Outside	Speed (m/s)	Direction (deg. from N)	
9-25-2013	10:00 AM–03:20 PM	0.53	20–26	21–23	0–1.5	130–150	OFF
9-25-2013	06:25 PM–10:15 PM	0.77	24–21	22–20	0–1.5	130–150	OFF
9-26-2013	10:15 AM–12:45 PM	0.48	22–24	20–22	0–1.5	130–150	OFF
1-30-2014	10:30 AM–01:30 PM	0.53	16–18	15–17	0–1.4	120–160	OFF
1-30-2014	01:30 PM–03:50 PM	0.59	17–18	14–17	0–0.8	120–180	OFF
1-30-2014	04:00 PM–04:45 PM	1.1	17–18	15	0–0.8	120–140	ON
1-30-2014	06:00 PM–10:00 PM	0.83	14–15	13–14	0–2.8	40–100	OFF
1-31-2014	10:20 AM–01:30 PM	0.59	15–18	14–18	0–1.8	140–160	OFF

- Significant differences in air change rates were observed: day values were 30% lower than night values.
- The highest air change rate, 1.1 hour-1, was recorded when the FAU was running. The operation of FAU produced the airflow and turbulence in the house that had contributed to the higher change rate.

UV RADIATION AND VISIBLE LIGHT

A time-lapse camera recorded the extent to which the living room was exposed to sunlight, with and without curtains. Excerpts of the recording are shown in figures 4.35–4.39. Time-lapse videos show how daylight infiltrates the living room to the alcove (along the horizontal surface), and to the bookcase and wood panel wall (along the vertical surface). The videos demonstrate that the collections are subjected to daylight throughout the year. Reinstallation of the curtains in late 2014 provided some shading in the living room, with the exception of the second to last bay window (adjacent to the Eames Lounge Chair), which had no curtain.

FIGURE 4.35
Photograph from time-lapse camera showing morning light in the living room with no curtains. January 19, 2013, 9:15 a.m.

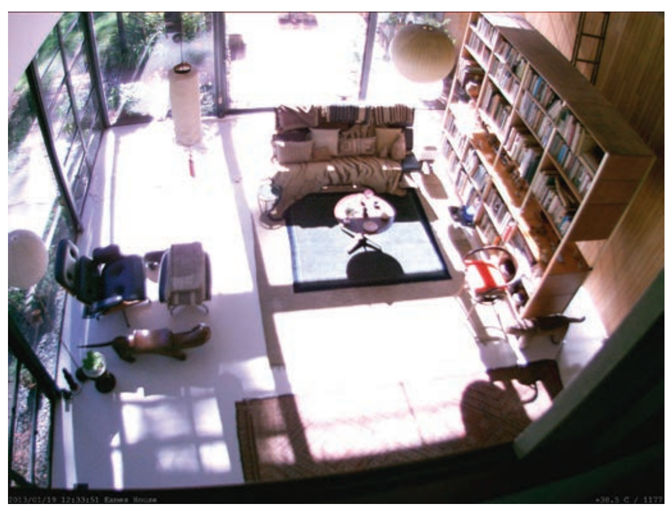


FIGURE 4.36
Photograph from time-lapse camera showing midday light in the living room with no curtains. January 19, 2013, 12:33 p.m.

FIGURE 4.37
Photograph from time-lapse camera showing diffused afternoon light in the living room with no curtains. January 2, 2014, 4:41 p.m.

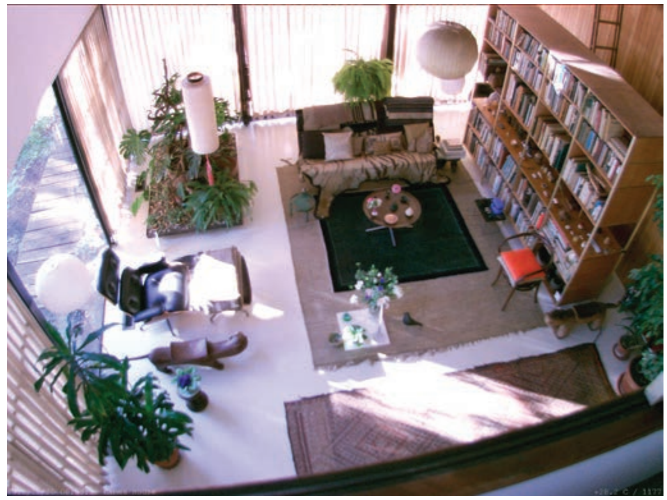


FIGURE 4.38
Photograph from time-lapse camera showing morning light in the living room with curtains. December 20, 2015, 8:53 a.m.

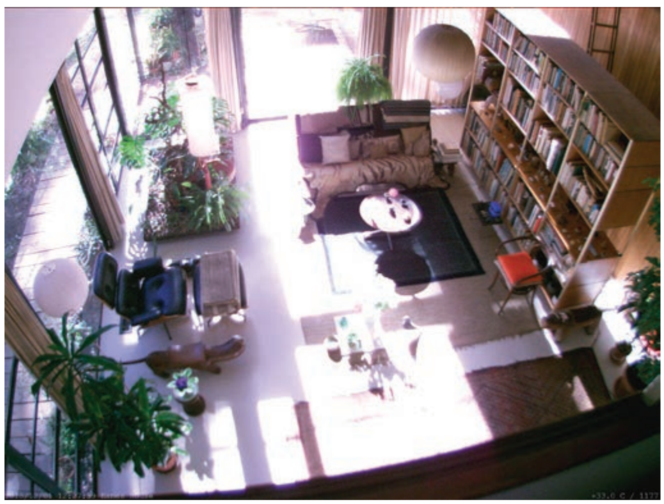


FIGURE 4.39
Photograph from time-lapse camera showing day light in the living room with curtains. December 1, 2015, 12:27 p.m.

Curtains are open during operating hours allowing direct light into the living room. While the curtains provide some shade, it is noted that they are linen curtains and have no protective film to prevent light damage to the interiors and collections.

The extent and intensity of visible light and UV radiation were measured on horizontal and vertical surfaces in the living room. On horizontal surfaces, intensities of visible light less than 10,000 lux were plotted for measured location numbers (fig. 4.40). Higher lux values were recorded towards the south elevation, H1, 9, 17, 25, and 33. High values, as high as 65,500 lux (not presented in figure 4.40), were recorded at the locations that receive direct sunlight at noon. Shaded areas still receive some visible light, with values ranging from 800 to 3,800 lux. The intensity decreases with the distance from both the east and south elevations. The alcove has the lowest intensity, 385 to 76 lux.

For vertical surfaces, visible light measurements recorded near the south elevation—V1, 2, 3, 10, 11, and 12—were above 3,000 lux, and are similar to horizontal surface

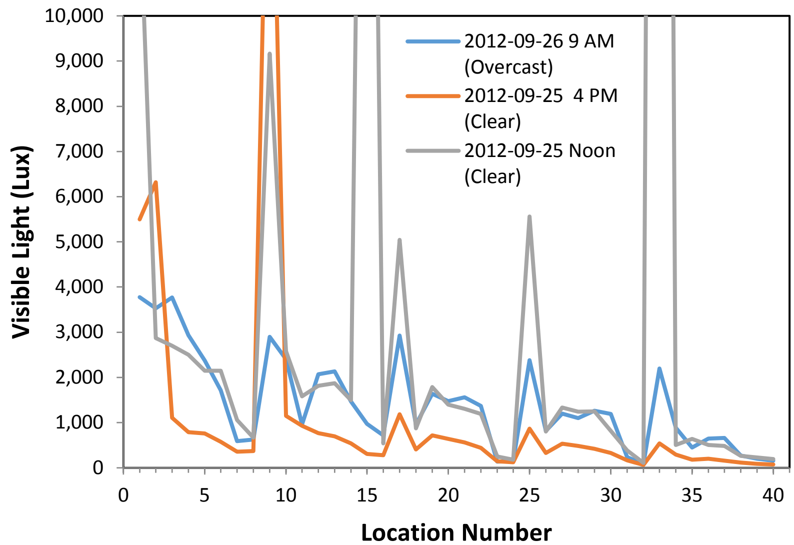


FIGURE 4.40
Visible light intensities on horizontal surfaces in living room for three sets of measurements.

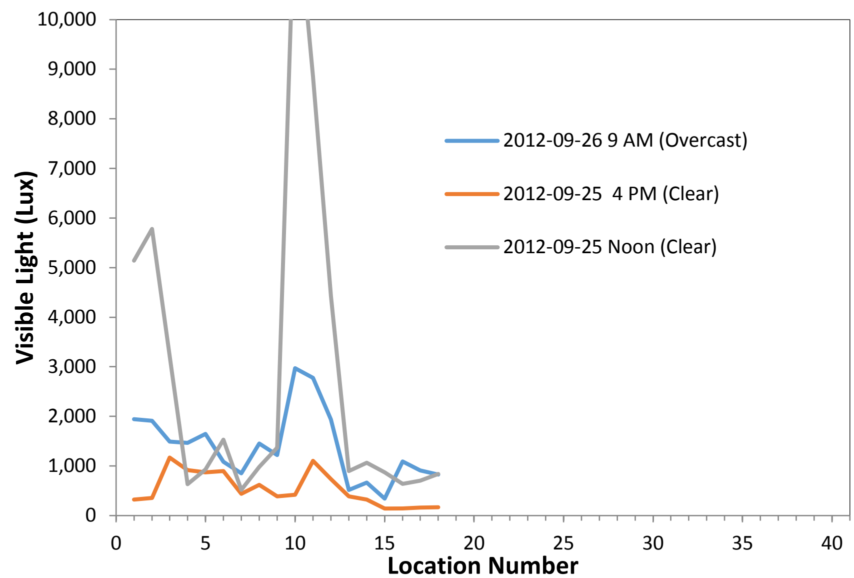


FIGURE 4.41
Visible light intensities on vertical surfaces in living room for three sets of measurements.

measurements (fig. 4.41). Values of less than 2,000 lux were recorded at other locations. The intensity decreases with distance from the southern elevation, similar to those of the horizontal measurements. Intensities on vertical surfaces on the bookcase are two to three times higher than their horizontal values at the same distance from the east and south elevations.

Ratios of UV radiation and visible light are plotted for measurement locations on horizontal surfaces of the living room (fig. 4.42). With the exception of peaks and valleys, most of the ratios were clustered between 0.2 and 0.4 mW/lumen. Ratios recorded in the cloudy morning were the lowest, and those recorded in the clear afternoon were the highest. Distance from the east and south elevations has no effect.

The ratio of UV radiation to visible light at vertical surfaces varied from near zero to 0.6 mW/lumen, with the exclusion of spikes and valleys possibly caused by reflection near the south wall (fig. 4.43). No correlation could be found from the data to produce a trend. This may indicate measurement errors or unsteady outputs due to constant movements of shadows as well as reflection on the floor. The 9:00 p.m. and 4:00 p.m. measurements are

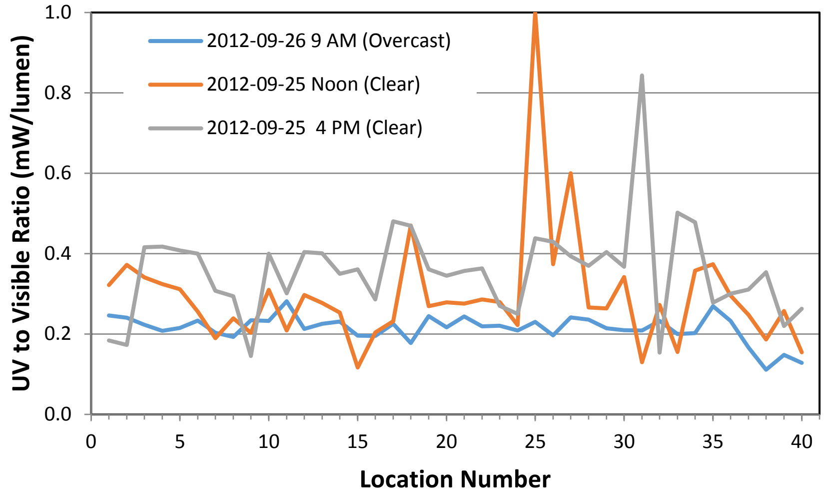


FIGURE 4.42
Ratios of UV radiations and visible light intensities on horizontal surfaces in living room for three sets of measurements.

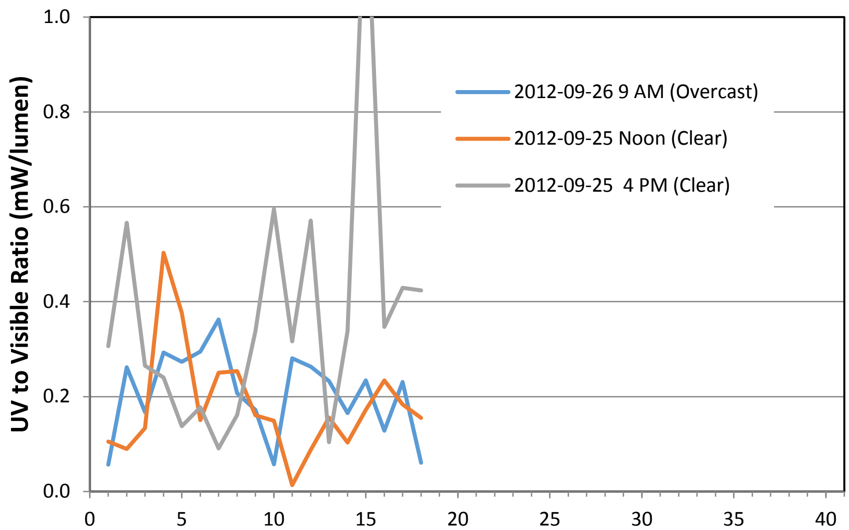


FIGURE 4.43
Ratios of UV radiations and visible light intensities on horizontal surfaces in living room for three sets of measurements.

similar to each other and more consistent, while the 12:00 p.m. measurements show greater variation.

4.5.3 Concrete Retaining Wall

MOISTURE IN SOIL BEHIND RETAINING WALL

During the excavation of the pit adjacent to the retaining wall, the soil appeared to be dry throughout. Soil samples collected from the excavation were characterized at the GCI laboratory (appendix 4.1). The grain size distribution was measured and the Atterberg limits (liquid limit, plastic limit, and plasticity index) were evaluated.

The liquid limit is the water content of soil and is defined as the moment between plastic and liquid states at which the soil starts to flow. At or beyond the limit, the soil will begin to flow when it is jarred slightly. Plastic limit is the water content of a soil at the boundary between the plastic and semisolid states. Plasticity index is the difference between the liquid limit and plastic limit, and it is the range of water content at which the soil remains plastic. The Atterberg limits of the soil samples are recorded in table 4.7. As these limits show, it is essential to keep absorption of water to a minimum in order to maintain the stability of the soil. Based on these values, the soil is classified as SC-SM group (silty, clayey sand with gravel) in the USCS- ASTM D 2487 Soil Classification.

TABLE 4.7
Atterberg limit of soil sample collected from the excavation.

Atterberg Limits	% moisture by weight
Liquid Limit	22
Plastic Limit	16
Plasticity Index	6

The results show the highest moisture contents of soil was 8.5% by weight at 1 in. to 6 in. (45.7 cm), the shallowest depth. It was almost a half of the plastic limit indicating that the sampled soil was well within the semirigid range.

Soil samples were also analyzed for humidity. All samples showed 100% RH (vapor saturation condition) as shown in table 4.8. Although no liquid moisture was observed in the soil during the excavation, the water vapor saturated condition was maintained in the soil at all depths. Even with the moisture barrier on the soil side of the retaining wall, moisture may have permeated the wall into the cavity between the concrete wall and the wooden wall panel.

TABLE 4.8
Results of the head space humidity measurement and gravimetric analysis of soil moisture.

Depth ft-in (cm)	Equilibrium Humidity at 23°C (% RH)	Soil moisture content (% by weight)
1-6 (46)	100	8.46
2-6 (76)	100	7.69
2-10 (86)	100	6.90
3-2 (97)	100	6.26
3-6 (107)	100	6.05
4-10 (147)	100	5.81
5-1 (155)	100	5.84
5-2 (160)	100	5.62

The water content of the soil samples was tested using the gravimetric testing method. The highest water content, 8.46%, was found at the shallowest depth, that is, 1 in. to 6 in. (45.7 cm). It reduced linearly to 6.05% at the 3 ft. 6 in. depth, and then it remained almost constant, 5.6% to 5.8%, as shown in figure 4.44.

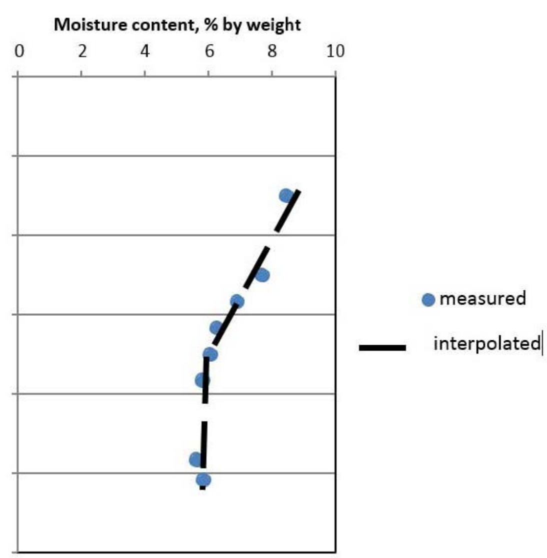


FIGURE 4.44
Results of the gravimetric moisture content analysis plotted against the depth.

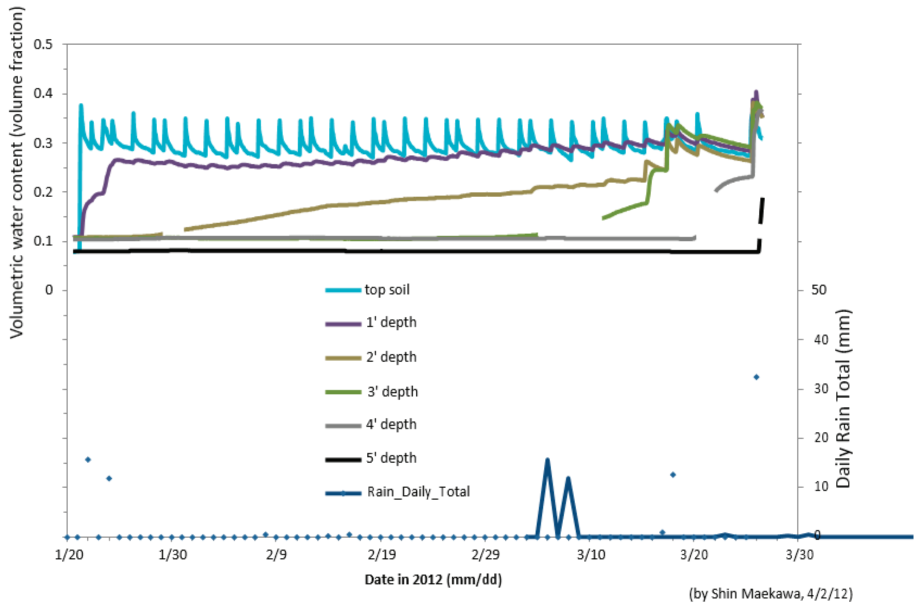


FIGURE 4.45
Changes of volumetric water contents (soil moisture) at various depths behind retaining wall and daily rainfall amount between January 21, 2012, and March 26, 2012.

VOLUMETRIC WATER CONTENT (VWC) SENSORS

The results of the first two months of the VWC monitoring, from January 21 to March 26, 2012, are plotted in figure 4.45. Readings of the topsoil (zero to 6 in., or zero to 15 cm) were affected by the runoff from sprinklers that watered every other day. The results show no cumulative effect on the soil's water content from the sprinkler, however.

Over the course of the two-month monitoring period, the high water content originally found only in the top 6 in. of soil seeped progressively deeper into the ground. Moisture contents at 1 ft. (30 cm), 2 ft. (61 cm), and 3 ft. (91 cm) reached that of the top soil, 25%–30%, by late January, mid-February, and mid-March, respectively. Sudden moisture increases at these depths after two rain events in late March indicated that deep fissures might have been developing.

Soil compaction as well as the clay-rich soil may limit the penetration of surface water (from rainfall and irrigation) to depths deeper than 3 ft. Water, between the hillside and the retaining wall, appears to drain off to the sides of the residence and studio rather than collect behind the concrete retaining wall. There is no evidence that water is ever released through the weep holes that exist at the bottom of the retaining wall in the courtyards.

EXTERIOR RETAINING WALL INVESTIGATIONS

Several images of the exposed retaining wall were taken to document its surface condition (fig. 4.46). No water or wetted area was found on the wall. Most of the original waterproof coating, a thin tar-like substance, is intact to the depth excavated and is adhering to the retaining wall. There are, however, some areas where tree and plant roots have penetrated between the coating and wall. The condition of the original waterproof membrane to the base of the retaining wall is unknown.

INTERIOR RETAINING WALL INVESTIGATIONS

The wooden wall paneling on the living room is attached to the retaining wall by a series of horizontal nailing strips; the 2 in. (5 cm) wooden nailing strips were embedded into the retaining wall during construction. Additional 1 × 2 in. (2.5 × 5.1 cm) wooden furring strips were nailed on to the embedded strips for mounting the tongue and groove wood planks.

FIGURE 4.46
Composite image of the soil side of retaining wall. The attachment of tree roots was seen at various depths.

In the visual inspection performed on March 26, 2012, both the nailing and furring strips were found to be in good condition and are providing adequate support for the wall panel. Only the nailing and furring strips closest to the floor (fig. 4.47) show advanced deterioration. Nails used in the furring strips are lightly rusted and show tidemarks of rust on the wood around them indicating past condensation. Dark stains found on the bottom surface of the wood panel were tested at the GCI laboratories and were found not to contain fungi

FIGURE 4.47
Deteriorated condition of the nailing and furring strips closest to the floor, 2012. Photo: Ana Paula Arato Gonçalves

(appendix 4.2). No other potential fungal growth was found on the surfaces observed during the inspection.

The lack of evidence of microbial activity in the wall cavity suggests that humidity in the cavity remains below 75% RH throughout the year. One of the reasons for this might be that the residence is typically 7.2°F–11.0°F (4°C–5°C) warmer than the outside, which reduces the humidity by 20%–25% RH, or to less than 75% RH. In addition, the wall cavity is open to the living room environment at both the floor and ceiling, allowing the buoyancy-driven natural convection of the air (ventilation) to continuously dilute the water vapor in the cavity.

At the base of the retaining wall, the water vapor may have migrated from both the wall, as the condition of the waterproof membrane in this location is not known, and the slab floor (see next section), and remained cooler than exposed areas. Exposure allows heat transfer with the air, warming the surface. There is no natural convection in such a small and limited space, however, resulting in a cool and humid environment and causing the bottom wooden strips to rot.

4.5.4 Concrete Slab Floor

MOISTURE IN FLOOR SLAB

In October and November of 2011, GCI conducted environmental monitoring of the slab floor in the living room, placing temperature and humidity sensors in pre-existing holes in the slab. Temperature and humidity in the slab were stable at 63.5°F–65.3°F (17.5°C–18.5°C) and 100% RH in the base throughout the year. The surface humidity, however, was 15%–20% RH less. The temperatures from the base to the surface of the slab were similar in each location. These measurements indicate that vapor permeation to the floor surface has been restricted or reduced by a finer grain top layer (approximately 5 in., or 12.7 cm, thick). No condensation was observed either in the holes where sensors were placed or on the floor under the carpet.

The results of concrete floor slab investigations indicate that water vapor permeates the floor slab into the interior of the building and may contribute to the humidity in the residence. This is likely a cause of the deterioration of the living room and kitchen floor tiles and the nail strips at the base of the cavity between the wood wall panel and retaining wall. The investigation confirmed the need for a moisture vapor barrier to be installed as part of the new flooring system. It is likely that the “water membrane” described in the historic records either was not installed or has deteriorated.

Oddy testing was performed on individual materials as well as on the flooring systems being considered by the Eames Foundation as a replacement. The analysis of test results, performance and aesthetic parameters resulted in the specification of Mapei Planiseal EMB as an epoxy-based moisture barrier, followed by Mapei Primer T, two layers of patching/skim-coating compound with feather finish (Mapei Planiprep FF), Mapei Ultrabond adhesive for vinyl composite tile, Azrock custom solid color vinyl composite tile, and an acrylic floor sealer.

METAL DUCTS UNDER SLAB

The inspection identified that more than half of the ducts have various levels of corrosion and disintegration (figs. 4.48–4.49). A summary of observations of each duct that was inspected is outlined in table 4.9. The thin metal heating ducts likely corroded as a result of the moisture content of the concrete floor slab. Condensation of moisture vapor on the

TABLE 4.9

Observations of the heating ducts.

Duct Length Number	Observations
1) Living room; grille to junction	Measured 7 ft. (2.1 m) from grille to junction.
2) Living room; grille to main line	Measured 2 ft. (0.6 m) from grille to junction; obstruction after 18 ft. (5.5m).
3) Living room; grille to junction	Broken metal divider at the entrance; junction probably at 5 ft. (1.5m); retracting at 10 ft. (3 m) (already in the main line).
4) Living room; grille to junction	Loose metal lining at the entrance; retracting at 11 ft. (3.4 m) from the entrance.
5) Living room; grille to junction	First 45° bend at 14 ft. (4.3 m); second 45° bend at 16 ft. (4.9 m); retracting at 19 ft. (5.8 m), close to where the duct bends upward to exit the slab and go to the furnace.
6) Kitchen; grille to main line	Metal lining at the entrance was found to be in a better condition than the others; conditions of metal lining became worse after 5 ft. (1.5 m); junction was found at 8 ft. (2.4 m); at 16 ft. (4.9 m) this duct bends to join the living room duct and go in the direction of the furnace; duct turns upward to exit slab at 24 ft. (7.3 m); retracting from 26 ft. (7.92).
7) Under staircase; return duct	Section size 10 × 20 in. (25 × 50 cm); 7 ft. (2.1 m) until the end at the furnace entrance; this duct is not lined with metal sheet, it is an open trench, concrete surface seems to be painted with a tar-like (black) material.
8) Upstairs bedroom 2	Grille removal revealed a duct in very good conditions, there was no sign of corrosion. Inspection was performed by the valuation of images taken by a digital camera. The duct camera was not used.
9) Upstairs bathroom 2	Grille removal revealed a duct in very good conditions, there was no sign of corrosion at the duct, just at the grille (grille vent is located above the shower area). Inspection was performed by the valuation of images taken by a digital camera. The duct camera was not used.

FIGURE 4.48

Deteriorated condition of the metal lined heating duct at a floor vent in the living room, 2011. Photo: David Carson

FIGURE 4.49

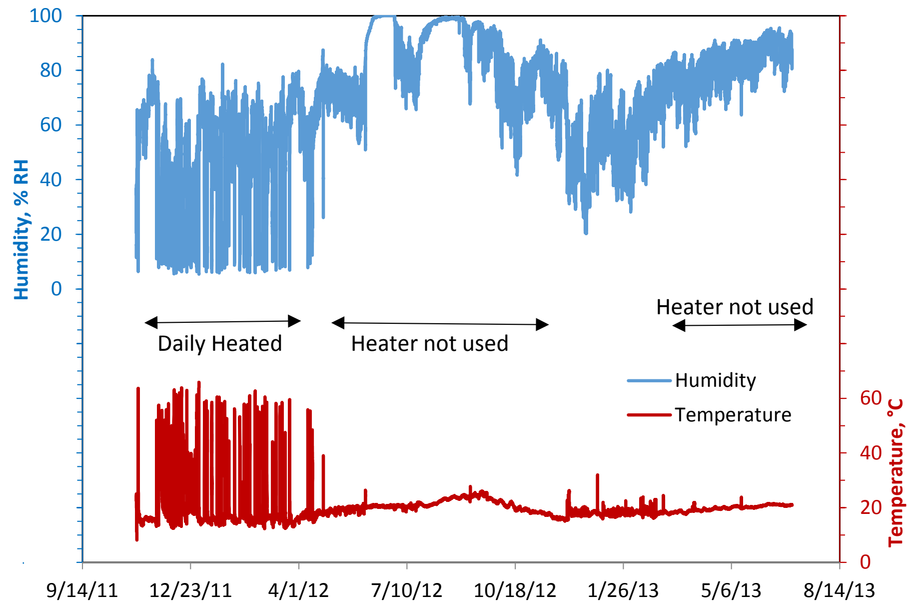
Debris sample of the deteriorated metal lining from a heating duct, 2011. Photo: Ana Paula Arato Gonçalves

interior surface of the cool duct when the heating system is not used may also be a contributing factor. Environmental monitoring in the living room duct showed 80%–100% RH humidity during summer months and 80% RH humidity during winter months (fig. 4.50). However, no condensation was observed. The heating duct in the kitchen showed 100% RH humidity during summer months with condensation throughout the year. This moisture in the kitchen heating ducts may contribute to a high-humidity environment in the kitchen.

The investigation indicated that the ducts could possibly be thoroughly cleaned and relined for use, since the surrounding concrete appears to be in good condition.

After a contractor had performed cleaning of the ducts, an inspection on August 14, 2013, showed that a significant amount of debris still remained in the ducts. This observa-

FIGURE 4.50
Temperature and humidity in heating duct of the living room.



tion indicates that if the untreated ducts continue to be used as supply air ducts, alkaline dust and corroded debris may be blown into the residence environment.

4.5.5 Existing Heating System

The existing forced-air unit (FAU) produces heated air, between 104°F and 140°F (40°C and 60°C) at supply air diffusers. Rates of the airflow vary significantly among diffusers depending on the distance from the FAU and the airflow setting of each diffuser. The analog thermostat located in the alcove controls the FAU, turning the system on when the temperature in the alcove drops below a set temperature (set point), and turning it off when it reaches the set point plus a dead-band value, normally 41°F (5°C). The thermostat was manually set to approximately 60°F (15.9°C) for most of winter months in 2012 and 2013, although occasionally, the FAU was manually turned off at the thermostat. From April 2014 until December 2014, the FAU was not turned on.

Figure 4.51 shows temperature and humidity trends at various locations in the house over twenty-four hours between December 24 and 25, 2013, when the FAU was not operated during the night. The temperature started to drop throughout the house at about 3:00 p.m. on December 24, and continued to decrease; the lowest temperatures of the period were recorded from 3:00 a.m. to 8:00 a.m. Between 8:00 p.m. and 8:00 a.m., temperatures remained constant throughout the residence with less than the 0.9°F (0.5°C) variation among the sensors. These stable and consistent temperature trends translated to stable and consistent humidity values, between 35% and 40% RH, throughout the residence.

Figure 4.52 shows temperature and humidity trends on December 9 and 10, 2013, a typical winter night, with the FAU operating. Temperatures at all locations started to drop at about 3:00 p.m. and continued to drop until about 7:00 p.m. The thermostat enabled the FAU when the temperature of the alcove/living room dropped below 60°F (15.8°C), which occurred at about 7:00 p.m. The temperature in the bedrooms started to rise immediately. This quick response was due to a heating duct delivering the hot air directly to the bedroom. Buoyant hot air released from the ground-floor slab registers also rose to the second floor

FIGURE 4.51
Temperature and humidity at various locations in the house over a twenty-four-hour period between December 24 and 25, 2013, without gas furnace operation during the night.

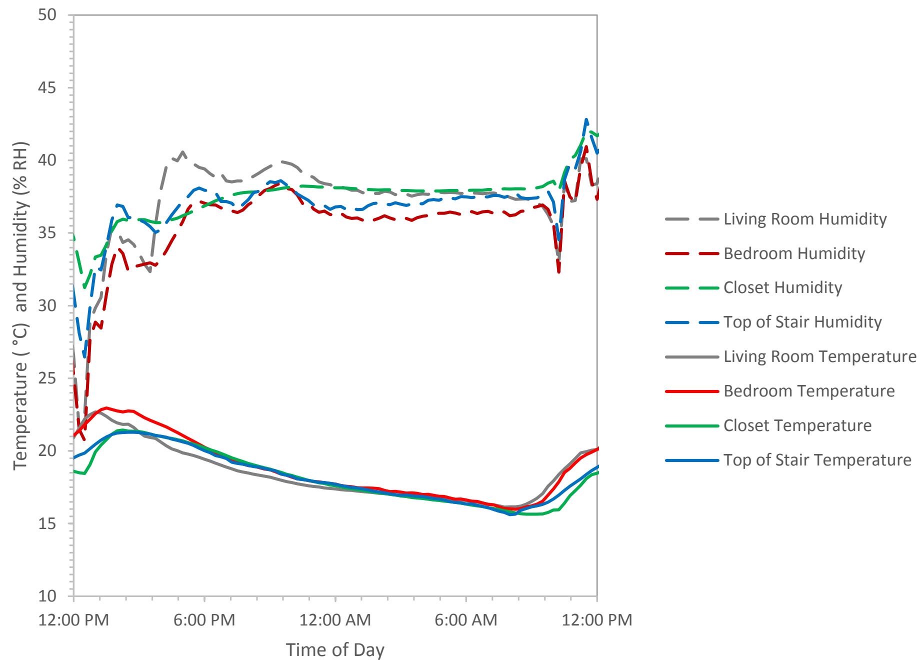
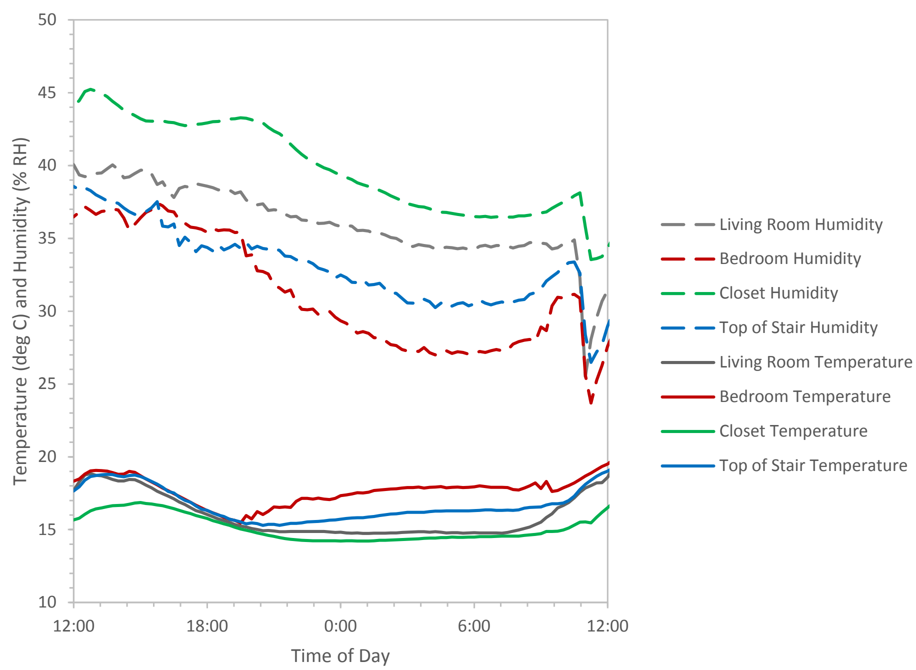


FIGURE 4.52
Temperature and humidity at various locations in the house over a twenty-four-hour period between December 9 and 10, 2013, with gas furnace operation during the night.



and added heat to the bedrooms and the top of the stairway. In spite of several diffusers present on the living room floor, the living room temperature remained unaffected, that is cold, during the operation of the heating system. It took nearly two hours of continuous heat before the temperature in the living room started to warm and stabilize. The temperature difference between the living room and the bedrooms was greater than 5.4°F (3°C) by the morning. The temperature in the closet on the second floor was the coldest in the afternoon, and remained the coldest during the night in spite of the FAU, closer to temperature of the living room rather than the temperatures of other second floor spaces. The temperature increase was less than 1.8°F (1°C). Operating the FAU resulted in approximately 10% RH reduction of humidity at each location, and maximum spatial variations were 10%–13% RH between the bedroom, the driest location, and the closet, the most humid location.

In summary, the FAU has some effect in decreasing the temperature and humidity in the residence, but it does not do so evenly, as temperature and humidity spatial variations remain throughout the residence.

4.6 Results of Monitoring

4.6.1 Climate at the Eames House (Exterior)

The Eames House is located in the Warm-Marine climate, which typically has a warm summer and a cool winter, with rain in the winter and high humidity throughout the year. The maximum, minimum, and average temperatures were 90.1°F (32.3°C), 38.3°F (3.5°C), and 61.9°F (16.6°C), respectively, over 2012 to 2014. Average humidity and dew point temperature were 70% RH and 52.2°F (11.2°C), respectively. The building complex is protected from strong winds by large trees and its location against the hillside. Annual precipitation was, 8.1 in. (206.8 mm), 3.0 in. (77.0 mm), and 3.3 in. (84.3 mm) for 2012, 2013, and 2014, respectively, and all three years were drought years; the historic average annual rainfall is 14.7 in. (373.4 mm). The site's climate was similar to that of the Santa Monica Airport, which publishes its climate data, with the exception of less wind.

4.6.2 Eames House Environment (Interior)

EFFECTS OF NATURAL VENTILATION AND OPERABLE WINDOWS

Natural ventilation, facilitated by open windows on the east elevation and sliding doors on the north and south elevations, limited temperature increases and provided a stable temperature in the living room and throughout the first floor. Natural ventilation allowed exterior humidity changes to directly affect conditions in the ground floor spaces. On the second floor, however, open windows did not contribute to lowering the humidity and temperature, as demonstrated by temperature differences between the south and north portions, and the high humidity in closets. An effective ventilation (cross ventilation) could not be established in the second floor spaces due to the number and location of operable windows, segregated small spaces, and closed-door closets.

Although airborne particulates, air pollution, or insect populations are yet to be studied in detail, visual observations indicate that all are present in the residence. The interior of the residence is vulnerable to their intrusions because the windows are unscreened and the sliding doors are frequently opened during hours of operation. Deposition of airborne particles and dusts results in increased soiling, and cleaning of particulates can abrade material surfaces. Intrusion of animals and/or insects will also threaten severe loss of collection materials.

TEMPERATURE

Due to the small thermal mass of the building envelope, the temperature in the residence tracks the daily and seasonal climate changes, although the interior of the residence generally remains warmer than the outside. Daily temperature variations were found to be greater in summer months than winter months, due to higher solar heating in summer. Daily and seasonal variations were noticeably higher in bedrooms and at the top of the stairway, as the envelope is exposed to daytime heating and nighttime heat loss and air circulation is limited in second floor spaces.

HUMIDITY

The humidity of the ground floor spaces also tracks that of the outside, indicating a well ventilated space. During summer months, however, significantly higher humidity was found in bedrooms and closets on the second floor, indicating low air circulation in these spaces. A comparison of the humidity outside, on the ground floor, and on the second floor indicates that the source of humidity in the residence is the humid outside air.

The daily insolation and insufficient air circulation produces thermal stratification in the residence. During summer months, high temperatures, above 77°F (25°C), were recorded daily at the top of the stairway and in the second floor bedrooms. The closet on the second floor was 3.6°F–11.0°F (2°C –5°C) cooler than the bedrooms, and its humidity was sufficient to trigger fungal activities, which was verified by the presence of fungal activities in items stored in the closets.

The average temperature in the residence was 68.9°F (20.5°C) with 59% RH. Although the interior of the residence is affected by exterior climate conditions, it generally has a relatively cool and stable living room, warm and dry second floor bedrooms, and cool and humid second-floor closets.

AIR INFILTRATION

When the windows and doors were closed, the building envelope was reasonably airtight, which limited the effect of outside humidity variations on the interior. Furthermore, the interior hygroscopic mass of the collections in the residence buffered humidity changes affected by temperature changes. If doors and windows are closed and the indoor air is well mixed, the humidity in the building will be reasonably stable.

The air infiltration rate of the building envelope compares favorably with many other buildings of the same age with similar amounts of glazing and openings. The low air infiltration rate increases the possibility that when the windows and doors are closed, successful environmental management is achievable by utilizing passive strategies or relatively small mechanical systems.

The Eames Foundation has responded by keeping windows and doors closed, when possible. They continue to open the doors and windows during hours of operation for interpretation and presentation purposes. The Eames Foundation has also made a number of improvements to the building envelope, repairing the steel frame and window frames in 2012, and replacing the roof in 2014–2015, which has improved insulation and water runoff.

UV RADIATION AND VISIBLE LIGHT

The living room is exposed to extreme light intensity. Visible light of 9,000 to 65,000 lux was recorded in sunny areas along the south elevation of the living room. Daylight intensity was less than 5,000 lux in shaded areas, but that is still more than ten times the recommended limit for conservation, which is a maximum of 300 lux. The light intensity decreased with the distance from both the east and south elevations. Similarly, between 12:00 p.m. and 4:00 p.m. high intensity daylight was also found on the bookcase and wood panel near the south wall. Higher intensities were recorded on vertical surfaces of the bookcase compared to horizontal surfaces, indicating both the reflection on the floor as well as more exposure to daylight. Consistent ratios of UV radiation to visible light were recorded, ranging from 0.2 mW/lumen in the overcast morning to near 0.4 mW/lumen in sunny afternoon.

4.6.3 Concrete Retaining Wall

SOIL INVESTIGATIONS

The soil excavated adjacent to the retaining wall is classified as silty, clayey sand with gravel and has a plastic limit well within the semirigid range. High soil compaction as well as the clay-rich soil may have been the reason for limited penetration of surface water (from rainfall and irrigation). Water, between the hillside and the retaining wall, appears to drain off to the sides of the residence and studio rather than penetrate the soil and disperse through the weep holes in the concrete.

All soil samples had 100% relative humidity. Although no liquid moisture was observed in the soil during the excavation, the water vapor saturated condition was present in the soil at all depths. Even with the moisture barrier on the soil side of the retaining wall, the vapor may have permeated through the wall into the cavity.

EXTERIOR RETAINING WALL INVESTIGATIONS

The excavation on the exterior of the concrete retaining wall confirmed that the original waterproofing membrane appears mostly intact with some areas of damage due to roots. Because the GCI only excavated to 5 ft. (1.5 m), the condition of the membrane at the base of the retaining wall was not investigated.

INTERIOR RETAINING WALL INVESTIGATIONS

No fungal activity or other evidence of a humid environment was found in the cavity between the retaining wall and wood panel of the living room, with the exception of the deteriorated condition of the furring strip at the base of the wall. The lack of evidence of microbial activity in the wall cavity suggests that humidity in the cavity remains below 75% RH. The wall cavity is also open to the living room environment at both the floor and ceiling, allowing the buoyancy-driven natural convection of the air (ventilation) to dilute the water vapor in the cavity. Nonetheless, tidemarks of rust from the nails were seen on the majority of furring strips, indicating that there had been periods of condensation in the space.

The furring strip at the base of the wall has rotted, possibly due to moisture and a lack of convection in such a small and confined space. The source of the moisture is likely from the concrete floor slab and/or retaining wall.

4.6.4 Concrete Floor Slab

MOISTURE IN FLOOR SLAB

Investigations of the concrete floor slab indicate that water vapor permeates the floor slab into the interior of the building and may contribute to the humidity in the residence, which is a likely cause of the deterioration of the living room and kitchen floor tiles and the furring strips at the base of the cavity. Investigation results confirmed the need for a moisture vapor barrier to be installed as part of the new flooring system. The “water membrane” described in the historic records as the base of the concrete floor slab was either not installed or its condition has deteriorated.

METAL DUCTS UNDER SLAB

The heating metal ducts were found to be corroded or disintegrated. The thin metal heating ducts corroded due to the moisture content of the concrete floor slab and possibly condensation of moisture vapor on the interior surface of the cool duct when the heating system was off. The moisture in the kitchen heating ducts may contribute to a high-humidity environment in the kitchen.

When the FAU is turned on, the debris in the ducts may be blown into the residence environment. The ducts could be cleaned and relined for use, as the surrounding concrete appears to be in good condition.

EXISTING HEATING SYSTEM (FAU)

Operation of the FAU for heating does not improve environmental conditions for conservation of interiors and collections. Although the FAU does effectively control the temperatures in the bedrooms, it does not adequately heat the rest of the residence, especially closets and first floor spaces. When operating, the FAU somewhat decreases humidity in the residence, but temperature and humidity variations nonetheless remain throughout the residence.

4.7 Recommendations for Environmental Improvements

This section provides recommendations for environmental improvements based on the results of the environmental monitoring. It also describes improvements made to the residence by the Eames Foundation based on the monitoring results as they were collected and interpreted over the years. The recommended improvements to the residence include roof replacement, living room floor tile replacement, reinstallation and increased use of curtains, envelope repairs, improved water management, and ongoing monitoring of conditions by Foundation staff.

4.7.1 Reduce UV and Visible Light

Extremely high intensity levels (1,000 to 65,000 lux) from direct and indirect sunlight irradiate the collection and the interior for several hours each day. During monitoring, collection materials were subjected to approximately 90% of ultraviolet, visible, and infrared components of daylight. Visible results of the high exposure to daylight are bleached and yellowed paper objects as well as color faded collections. Although curtains cover all windows, they were not being used continuously for reducing direct and indirect daylight.

The UV content of daylight could be reduced to 0.075 mW/lumen (75 μW/lumen) or less (90% reduction) with the use of a UV absorbing and/or reflecting film or glass for glazing the building envelope. Measurements documented that the unfiltered daylight contains up to six times higher UV contents than the museum conservation limit.

The Eames Foundation reinstalled the curtains in the living room and they are now used frequently throughout the day for shading.

4.7.2 Develop a New Heating and Cooling Approach

The FAU was originally installed in the residence to provide thermal comfort for occupants and visitors, but thermal comfort is no longer the main requirement in the residence since it is not continuously occupied. The FAU is fueled by natural gas supplied directly to the unit, and these natural gas pipes can leak and become a fire and explosion risk, so consideration should be given to permanently discontinuing use of the FAU and disconnecting its gas service, and designing a new heating system for the residence.

Improved preservation of the collections and the interior of the Eames House must be balanced with visitor access, interpretation, and sustainability. The priority for material preservation has to be established before targeted environmental criteria for temperature and relative humidity can be established. It will not be economically and technologically feasible to install an HVAC system in the Eames House to produce and maintain the environmental conditions that meet national museum standards because the equipment and ductwork would intrude excessively on the building's original architecture. Even if such a mechanical system were to be installed, the building envelope lacks the necessary thermal mass or insulating properties necessary to maintain this environment in a sustainable or economical manner.

In the Warm-Marine climate, introducing thermostatically controlled heating and cooling systems to maintain a stable collection environment can introduce unexpected risks to both the buildings and the collections. These risks include increased microbial damage to collections and building interiors, the damaging mobilization of salts to the surface of building materials and architectural finishes, and dimensional changes in hygroscopic materials. When considering how to best conserve significant elements of cultural heritage in this climate, the Foundation must understand these potential risks so they can select and implement appropriate environmental management strategies.

Due to its low thermal mass and building envelope's lack of thermal insulation, it will be difficult to eliminate daily and seasonal temperature variations in the Eames House even with the use of an HVAC system. The use of a cooling system during summer would increase humidity problems throughout the residence, possibly leading to condensation on the slab floors, on the inside face of the retaining wall, on interior wall surfaces, and in floor cavities. The Eames Foundation may consider prioritizing the conservation of the building and collection over thermal comfort of staff members and visitors. If they do, efforts should be taken to eliminate extreme conditions and minimize variations using feasible strategies for historic house museums. The use of humidity control equipment, such as dehumidifiers, should be considered in the residence in concert with improved air circulation, especially in the north side of the second floor. Dehumidification directly removes moisture from the air without elevating the air temperature, so that thermal stratification in the interior would not be exacerbated. Dehumidification is effective, however, only when windows and doors of the building are closed.

4.7.3 Reduce Interior Temperatures

Temperature control in the residence is considered to be a thermal comfort issue rather than a conservation issue, although higher interior temperatures will result in higher chemical reaction rates on chemically sensitive materials in the collection. The surface heating effects of exposure to high intensity daylight also result in high rates of chemical deterioration, higher than those caused by elevated air temperatures.

Since temperatures in the residence are generally 11°F–12.8°F (5°C–6°C) warmer than the outside, the temperature can be reduced by simply improving ventilation. Although the ground floor of the residence is well ventilated, the air circulation, and thus ventilation, in the second floor spaces is limited, which results in higher temperatures and greater fluctuations. Increasing ventilation to a rate of six air changes per hour should lower the interior house temperature. If effective cross ventilation cannot be achieved through natural ventilation on the second floor, a mechanical (forced-air) ventilation system and the introduction of ducts might be an answer. Reduced indoor temperature, however, may result in higher interior humidity and an increased risk of fungal damage.

Natural ventilation is simple and quiet, but it also uses unfiltered air, so the building interior is more vulnerable to increased dust, air pollutants, and insect populations. Mechanical ventilation, although difficult to successfully integrate into a historic building interior like the Eames House, would provide for the control of interior air quality through filtration of the supply air and could establish good air circulation throughout the house.

4.7.4 Control Interior Humidity

Humidity greater than 60% RH is commonly found inside the residence, which does not pose a risk of fungal outbreak except in the closet on the second floor, where humidity levels above 75% RH occur more than 10% of the year. Microenvironments are also evident at different humidity levels. Reducing the quantity of materials stored in the closets would improve air circulation while effective venting of closets would eliminate the high humidity. Warmer air in the bedrooms and at the top of the stairway can be brought into the closets and the north side of the second floor to increase temperature and thereby reduce humidity. Extremely low humidity conditions in the residence during winter Santa Ana winds can be reduced by closing windows and doors during Santa Ana events.

4.7.5 Avoid High Humidity in Closets on the Second Floor

As described earlier, clothing and fabrics adsorb moisture from humid air and desorb moisture to dry air. Rates of adsorption are significantly faster, however, than those of desorption. Moisture adsorbed by the clothing and fabrics per volume are two to three orders of magnitude higher than that of air. It is essential, therefore, to reduce the contents in second-floor closets in order to reduce the total moisture and to improve air circulation. One solution for maintaining moderate equivalent moisture content (EMC) values for the contents of the closets is to avoid high humidity conditions by maintaining good ventilation. Increased ventilation will raise the temperature and reduce the humidity.

Although an increase in heat can reduce humidity, increased temperatures can also increase rates of chemical reactions/aging as well as insect activity, if they are present. It is therefore essential to remove chemically active materials from the closet and limit the temperature increase to a minimum when applying conservation heating.

Portable dehumidifiers remove moisture from the air and reduce humidity without altering the temperature of the space. Their capacities are limited to specific volumes of air (room or space volumes), so they will not be effective if the targeted space has ventilation or continuous visitors. EMC values of materials will be reduced as the dehumidifier continues to remove moisture from the materials through the environment. Ample open spaces should be provided, therefore, to allow air to circulate through the dehumidifier and around the materials.

4.7.6 Protect the Collection from Daylight and Ultraviolet Radiation

If museum lighting standards were sought at the Eames House, the daylight intensity throughout the living room would need to be reduced to less than 300 lux. This light level is desirable in order to protect collection materials and the interior from light damage, increased chemical reactions, and aging. Adding exterior shading devices is a highly effective method for reducing daylight in the building. However, reduced interior daylight levels using exterior shading might be unacceptable because of the effect on the appearance of the building. Curtains and blinds, along with the installation of a UV film on all glazing, are recommended.

The use of interior shading devices, such as the existing curtains, can also significantly reduce daylight. Laboratory tests have shown that a typical brown or Tuscany color curtain blocks nearly 90% of daylight (appendix 4.3). Adding blinds to the existing curtains, or replacing the existing unlined curtains with lined ones, will further block daylight. Installing a UV film on the glass will reduce 10% of the visible component and virtually eliminate the UV component of daylight, which would reduce light damage, even without curtains. If daylight cannot be reduced, original objects should be moved to a protected environment.

During the sunrise on sunny mornings, the entire living room receives direct sunlight. It is important to eliminate the sunlight during this period. At a minimum, the curtains can be closed, but other light-blocking devices should be considered for the east elevation. Since the Eames House is not open to visitors during these early hours, this would have no effect on the experience. The living room has been subjected to high levels of direct and indirect light for many years and the light damage is cumulative. Limiting the amount of sunlight entering the residence whenever possible, such as during morning hours and on days when the site is closed to visitors, will reduce the total dosage of light on the collection and interiors.

4.7.7 Reduce Moisture at Concrete Floor Slab and Retaining Wall

Soil moisture permeates the concrete slab floor and potentially the retaining wall, bringing moisture into the building interior. Soil moisture is present throughout the year in the bottom portion of the concrete floor slab. Warmer indoor temperatures reduce relative humidity values near the surface of the concrete, eliminating the possibility of condensation on the floor surface as well as in building envelope cavities, including the retaining wall on the west side of the building. However, the bottom edges of the retaining wall, where the floor slab abuts the retaining wall, was sufficiently damp to cause a wood nailer to deteriorate. Soil moisture and concrete moisture in the lower portions of the floor assembly were also high enough to cause the embedded metal sheet ducts to corrode.

Many of the kitchen floor tiles are cracked and visibly loose. It is likely that the visible damage to the kitchen floor tiles is also attributable to moisture in the concrete slab.

In early 2012, the Eames Foundation and Escher GuneWardena Architecture undertook a living room floor tile replacement project. The deteriorated original floor tiles in the living room and part of the hallway were removed. Substrate preparation was undertaken prior to the installation of the replacement tiles, and included asbestos abatement, acetone cleaning to remove old adhesive, and bead blasting to remove adhesive residues. The flooring system includes a vapor barrier, which prevents vapor in the concrete slab from dissipating into the living room and hallway. Consideration should be given to installing new tiles in the kitchen with a new vapor barrier like the one used in the living room. The Eames Foundation also discontinued use of the sprinkler adjacent to the retaining wall to reduce any potential impacts, such as moisture infiltration through the retaining wall. Adjustments to the sprinklers near the retaining wall should be made to permanently prevent them from wetting the house.

4.7.8 Recommended Additional Monitoring and Studies

The GCI team recommends that environmental management strategies be further developed and that additional studies be undertaken, including studies of pests, particulate matters, and air pollutants in the building:

- A pest study should identify insect species and populations in various locations of the house as well as intrusion points. This study should be conducted for at least a year to identify seasonal trends.
- A survey of particulate matter could be conducted through the use of deposition plates or an airborne particulate counter. The advantage of the former method is that a deposition plate can be placed in multiple locations in the house so that results can help identify problem areas. Because this method measures the total weight of all deposits on the plate, it does not allow information on size distribution nor does it include small size particles (less than 2.5 micron) that remain airborne for an extended period. Nonetheless, airborne particulate counters provide a total number for each range of particle size (particle size distribution), from larger than 10 micron to smaller than 0.3 micron. This information is useful for selecting a filtration system for the environmental management system. Due to its high cost, the measurement is often taken at only one location at a time. Although the method allows the continuous measurement of particulates, it does not show the distribution of the particulate matters in the building, which would require a sophisticated add-on device to multiply the intake of sample air.
- Missing from this current study is an airflow simulation in the building using a computational fluid dynamic (CFD) model. Although impacts of the air movement on temperature and humidity are analyzed in the present study, it is as yet unknown how conditioned (heated or dehumidified) air would circulate in the building. The model would estimate flow fields of natural ventilation, during the operation of the FAU, and during operation of any new dehumidifier. The CFD simulation could also evaluate the efficacy and estimate the operating cost of various design options for new mechanical systems.

Works Cited

Arnfield, A. John. 2017. Köppen climate classification. In *Encyclopedia Britannica*. https://www.britannica.com/science/Koppen-climate-classification (accessed December 28, 2017).

Eames Office. 1948. Case Study House Number 8, architectural drawing, sheet 3, October 14, 1948, Eames Office files.

Sherman, M.H. 1990. Tracer-gas techniques for measuring ventilation in a single zone, *Building and Environment* 25 (4): 365-74.

D7 Consulting. 2011. Building Evaluation, Eames House October 17 2011. Unpublished report.

NOTES

1 In this assessment “climate” is used to describe exterior, or outdoor, conditions and “environment” is used to describe interior, or indoor, conditions.

2 A 2011 consultant’s report identified the potential for infiltration of humid air through gaps and joints of exterior wall panels, doors, and windows (D7 Consulting 2011).

APPENDIX 4.1

Grain Size Distribution and Classification of Soil Behind the Retaining Wall

The Getty Conservation Institute
Science Department

1200 Getty Center Drive, Suite 700
Los Angeles, CA 90049-1684 USA
Tel 310 440 7325 or 310 440 + extension
Fax 310 440 7702
www.getty.edu/conservation

Analysis Report

Building Materials Laboratory

Date: April 3rd, 2012

Site: Eames House (Case Study N°8), designed by Charles and Ray Eames, 1949.

Address: 203 Chautauqua Blvd, Pacific Palisades, CA, 90272.

Project: CMAI- Eames House Conservation Project

Prepared for: Shin Maekawa and Kyle Normandin (GCI- Field Projects)

Prepared by: Beril Bicer-Simsir, Assistant Scientist

Grain Size Distribution and Classification of Soil Behind the Retaining Wall

An analysis of the soil samples collected from an excavated inspection shaft behind the retaining wall of the Eames House was requested by Shin Maekawa and Kyle Normandin in order to determine the grain size distribution and the classification of the soils according to the Unified Soil Classification System (USCS). Eight soil samples from varying depths were collected by Shin Maekawa and submitted for analysis.

Sample weights and their depth of collection are summarized in Table 1. The samples were regrouped into two soil samples: Soil No.1 representing the soil between 46 cm and 97 cm of depth and Soil No.2 representing the soil between 107 cm and 160 cm of depth. Both soil samples were sieved through a stack of sieves to obtain the grain size distribution of the coarse fraction of the soil larger than 4.75 mm. Soil-water suspension was made by mixing the soil grains smaller than 4.75 mm with plenty of water. The density of the suspension, which decreases with time as more and more particles settle out of suspension, was measured by a soil hydrometer with respect to time. Stokes Law was used to determine the grain size (diameter of equivalent spheres) and hydrometer reading is used to calculate the percent finer than this grain size for the silt- and clay-size grains (smaller than 0.075 mm). Soil-water suspension was sieved through a No. 200 Sieve (0.075 mm) and washed free of fines (silt and clay). The soil retained on sieve No. 200 was dried, weighed and then sieved through a stack of sieves. This

1

final sieving provided the grain size distribution for the coarse fraction of the soil grain size between 4.75 mm and 0.075 mm. Similar grain size distribution curves were obtained for both soil samples (Figure 1), supporting the fact that the tested soils are refill soils.

Soil finer than Sieve No. 40 (0.42 mm) of both soil samples was combined and used for determining liquid (LL)[1] and plastic (PL)[2] limits. Combining both soil samples was necessary since the quantity of each sample was not enough for individual testing, and also considered as introducing an acceptable level of error since the grain size distributions of the two soil samples were very close. Grain size distribution and Atterberg Limit results used for USCS classification are summarized in Table 2. Both soils are classified as silty, clayey sand with gravel (SC-SM)[3]. The existing clay size particles in the tested soils is the main source of observed high to very high dry strength of these soil.

Table 1:.Soil sample weight and depth information

Soil No.	Depth (cm)	Soil sample weight (g)	Total sample weight (g)
1	46	62	242
	76	51	
	86	64	
	97	65	
2	107	53	228
	117	62	
	155	59	
	160	54	

The Getty Conservation Institute
Science Department

Analysis Report
Building Materials Laboratory
CMAI - Eames House Conservation Project

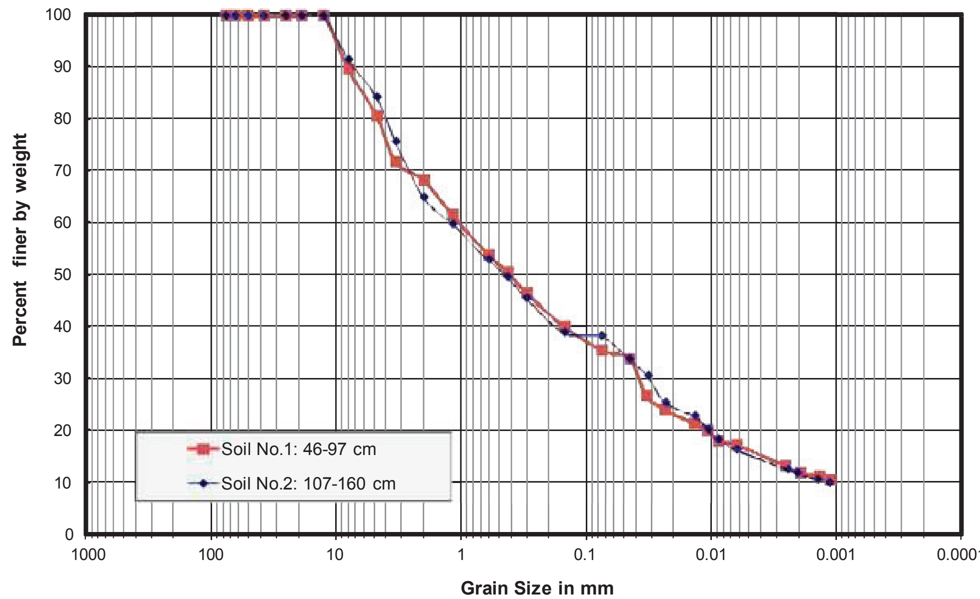


Figure 2: Grain size distribution curves

Table 2:.Summary of grain size distribution and Atterberg limit results [3]

Soil No.	1	2
D > 75 mm (%)	0	0
D <4.75 mm (%)	84.4	80.7
D <0.075mm (%)	38.4	35.6
D_{10} (mm)	0.001	0.001
D_{30}(mm)	0.03	0.04
D_{60}(mm)	1.18	1
LL	22	
PL	16	
PI	6	

3

The Getty Conservation Institute
Science Department

Analysis Report
Building Materials Laboratory
CMAI - Eames House Conservation Project

Table 3: Soil Classification (USCS- ASTM D 2487)[4]

Sample No	Group Symbol	Group Name
1	SC-SM	Silty, clayey sand with gravel
2	SC-SM	Silty, clayey sand with gravel

[1] Liquid limit (LL) is the water content of a soil at the arbitrarily defined boundary between liquid and plastic states. This is the water content at which soil placed in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of 2 drops per second. The soil undergoes a dynamic slope stability failure (undrained failure) and the undrained shear strength of the soil at the liquid limit is approximately 0.2 kg/cm^2 (= 2 kPa) or 0.28 psi.

[2] Plastic limit (PL) is the boundary between plastic and semi-solid brittle states. It is defined as the water content at which a soil can no longer be deformed by rolling into a 3.2 mm (1/8 in) diameter threads without crumbling.

[3]

PI	Plasticity Index, calculated as the difference between LL and PL
D	Diameter
D_X	Diameter at X percent

[4]

SC	Clayey Sand
SM	Silty Sand
SC-SM	Plasticity Index (PI) between 4 and 7 are borderline cases requiring use of dual symbols

Submitted by:

Beril Bicer-Simsir

April 3rd, 2012

4

APPENDIX 4.2

Brown Stains on the Rear-Facing Wall of the Eames House

THE GETTY

CONSERVATION INSTITUTE

SCIENTIFIC PROGRAM: ORGANIC ANALYSIS LABORATORY

ANALYSIS REPORT

October 25, 2011

Object Description: Brown stains on the rear facing wall of the Eames House (Case Study House No. 8) 203 North Chautauqua Boulevard in the Pacific Palisades neighborhood of Los Angeles.

Prepared for: Shin Maekawa and Susan Macdonald
Analysis by: Joy Mazurek, Assistant Scientist

A microbiological examination of an area on the rear facing wall of the living room (adjacent to the retaining wall) of the Eames House was requested by Shin Maekawa and Susan Macdonald in order to determine if active bio-deterioration was occurring on the wooden panels. Upon closer inspection, there was a pattern that resembled fungal staining; however it is a brown varnish material that was easily removed with water swab. On the floor (below this area of the wall) the same brown varnish material was observed. Samples were taken from both the wall and the floor with water swabs, and analyzed for organic components by Fourier-transform infrared spectroscopy (FTIR).[1] FTIR spectra best matched a water soluble type adhesive on both the wall and the floor. The brown material is not a fungus, bacteria or water stain, rather it is due to this "water soluble type adhesive" that was applied on the ground and then splattered onto the adjacent wall and darkened over time. A summary of the findings is given in the table below.

Sample	FTIR
Floor water swab	Water soluble type adhesive
Wall water swab	Water soluble type adhesive

[1] Fourier-transform infrared microspectroscopy (FTIR) is a technique that has a number of advantages over GC-MS. FTIR can be used directly on a paint sample without requiring aggressive chemical pre-treatment. Because samples may be recovered for subsequent analysis by other methods, it is termed a non-destructive technique. Furthermore, it can also identify pigments and other non-volatile species (such as acrylic media) that cannot be detected by GC-MS. However, it can only detect components present in concentrations above five to ten weight percent, although many substances are well below that level in commercial paints.

A representative sample particle was placed on a Diamond window, and analyzed by transmitted infrared beam with an aperture of approximately 100 x 100 microns, using a 15X objective. Each spectrum was the sum of 200 scans at a resolution of 4 cm^{-1}. Based on the initial analysis results of bulk material, extraction was made by placing a microdroplet of solvent on the sample, and analysis was performed on the resultant extracted dry solvent ring. Infrared spectra of the samples contain bands that correspond to the paint components. To identify materials in a paint sample, the infrared spectrum may be matched to spectra for reference materials using a computer algorithm. Of course, other components may be present in the samples at concentrations below the 5% detection limit. For more details see M. R. Derrick, Practical Guide to Infrared Microspectroscopy, edited by Howard J. Humecki, (New York: Marcel Dekker, 1995).

Submitted by:

Joy Mazurek

October 27, 2011

APPENDIX 4.3

UV and Visible Light Transmission through Windows and Various Light-Reduction Schemes

UV and Visible Light Transmission through Windows and Various Light-Reduction Schemes

Prepared by Shin Maekawa
May 20, 2015
Revised: July 9, 2015

Introduction

UV and visible light measurements conducted in the living room of the Eames House residence indicate that both the UV and visible light must be reduced to protect the collection and original interior. Either exterior or interior in combination with an UV filtering film over the existing wall and window grazing will reduce harmful light in the living room.

Ray and Charles Eames used textile curtains. Depending on characteristics of the textile used, a curtain could effectively reduce light; it could also filter the transmitting light, however, by limiting the transmission of certain wavelengths of the light, changing the appearance of collections in the building. For example, non-transmitting textiles, such as metallic and dark black textiles, do not alter the light characteristics, but translucent textiles, such as thin white textiles, often filter out shorter wavelength light and produce a creamy tint.

Several textiles were tested using a photo transmission spectrometer in order to characterize their efficacy in reducing the light level (both the UV and visible ranges) in the building (Figure 1). Figure 1 shows the textiles as well as a 1/4"-thick standard glass and a proposed UV film used for the tests. The manufacturer's specification for the UV film is listed in Table 1. Measurements were performed to identify photo spectral transmission between 300 and 700 nm through the standard glass plate, standard glass plate with the UV film, and combinations of the textile and the standard glass with the UV film.

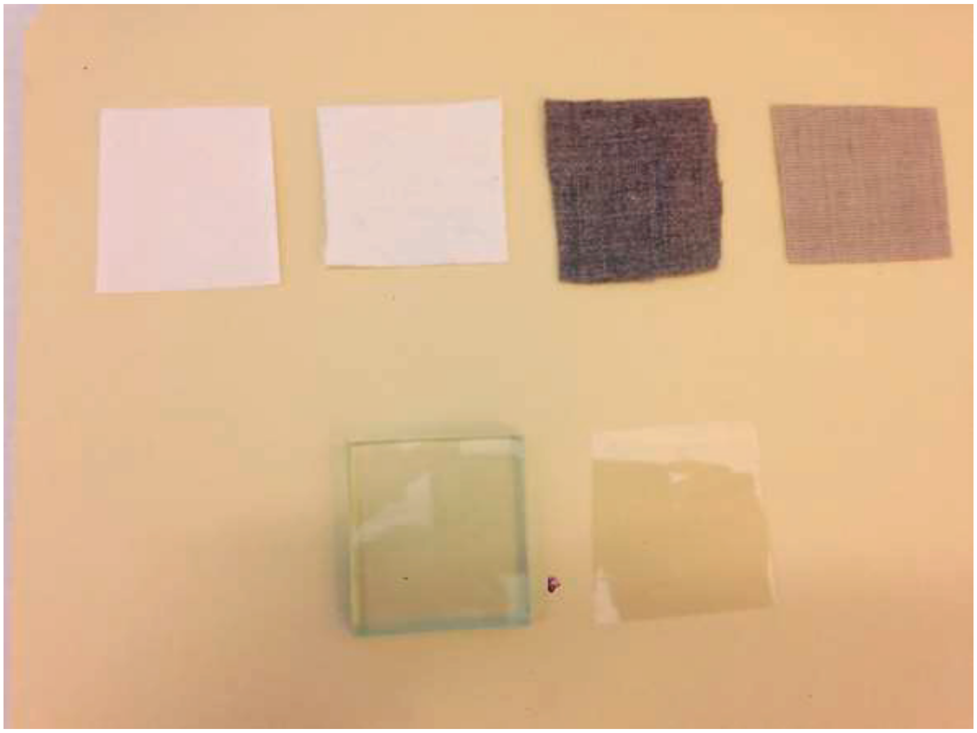


Figure 1 Tested curtain fabrics, glass, and UV film. From the top row left to right - white, white flannel, Tuscany, and brown fabrics. Bottom left to right – standard ¼" glass, and Anti-Graffiti film.

Table 1 Manufacture's specification on American Standard Window Films (ASWF) Protection Series Anti-graffiti film

Description: ASWF is an architectural film designed to protect window panes from vandals. It also provides the UV rejection with no color alteration. The 4 mm film allows for ease of installation.

Thickness	% Total Solar Refl.	% Total Solar Absrb.	% Total Solar Trans.	% Visible Light Trans.	% Visible Light Refl (int)	% Visible Light Refl (ext)	%U/V Reject.	%Glare Reduct.	Shading Coeff.	Solar Heat Gain Coeff.	%Total Solar Energy Reject.
4 mil	9%	10%	81%	89%	10%	10%	99%	1%	0.97	0.84	16%

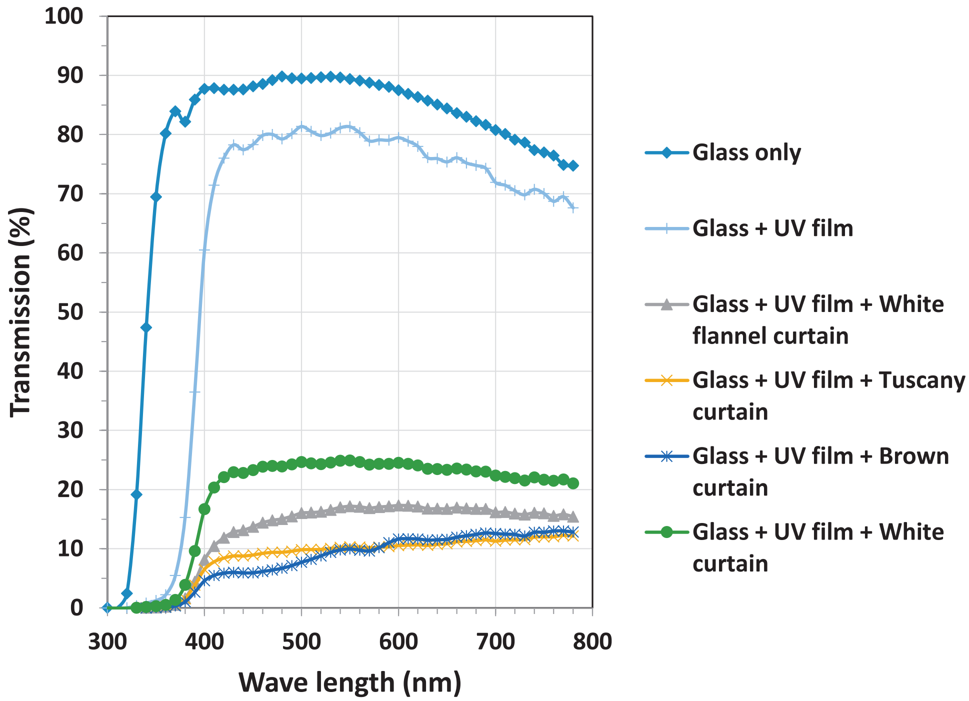


Figure 2 UV and visible light transmission through window with various light reduction schemes

Results

Without the UV film, the glass panel allow less than 3% of UVA (290 – 320 nm) and 3 - 87% of UVB (320 – 400 nm). 90% of the visible light with less than 600 nm passed through the glass. The light transmission linearly reduced to 75% at 780 nm. A slight blue-greenish tint of the standard glass is the result of the slope in the transmission spectrum. With the UV film, the UVA was completely eliminated, and the transmission of UVB reduced to 0% (to 350 nm) - 60% (at 400 nm). An approximately 10% reduction was achieved at visible wavelengths.

With the use of the textiles in combination with the glass and the UV film, the visible light was reduced to between 10% and 25% of the original intensity. The white textile on the glass+UV film allowed the highest transmission of approximately 25%. White flannel on the glass+UV film allowed 16-18% transmission with slightly reduced transmission of the blue (400-550 nm) component.

The brown textile produced the best overall reduction; however, a larger reduction at 400 – 550 nm produced a tint or color alteration. The Tuscany textile reduced the transmission to about 10%, the second best overall reduction, while it maintained an almost flat spectrum indicating minimal color alteration.

Conclusions

The UV film was effective in eliminating 99% of the UV component; the UV elimination was limited to wavelength below 380 nm, however, and the film only eliminated 10% of visible light component, indicating the need for additional light reduction. Textile curtains further reduced the light transmission to 10-25% of the original intensity. The best result was obtained from the “Tuscany” textile curtain which not only reduced the light transmission to approximately 10%, but also only allowed minimal color distortion.

During the September 2012 field measurement of daylight in the residence living room, the indirect sunlight ranged 500-3,000 lux. One layer of the Tuscany textile curtain reduced the indirect sunlight to less than 300 lux, which is within the recommended range.

The direct sunlight can be as high as 65,000 lux, however, and a single layer of the Tuscany textile curtain will only reduce that to 6,500 lux, which vastly exceeds the recommended 300 lux or less. A double curtain, with a thicker inner curtain, could be used to significantly reduce the transmitting light.

It is important to note that although moving light-sensitive objects out of direct sunlight can reduce the risk of their photo-chemical degradation, the reflecting light can damage other light-sensitive materials.

If the reduction in UV and visible light cannot be achieved, light-sensitive objects may need to be removed from where they are currently exhibited to a protected environment, or their long-term preservation is in jeopardy.

CHAPTER 5

Geotechnical Evaluation

In 2014, Leighton Consulting was engaged to provide geotechnical evaluation services for the Eames House site and produce a topographic map (appendix 5.1). The following report documents their findings and provides recommendations to address conditions including slope stability, irrigation, surface drainage, and seismicity. The accompanying topographic map documents the entire site, including perimeter edges, as well as the building complex.

GEOTECHNICAL EVALUATION SERVICES
EAMES HOUSE
203 CHAUTAUQUA BOULEVARD
PACIFIC PALISADES, CALIFORNIA

Prepared for:

The Getty Conservation Institute
1200 Getty Center Drive, Suite 700
Los Angeles, California 90049-1684

Project No. 10733.001

August 22, 2014
(Revised September 30, 2014)

Leighton Consulting, Inc.
A LEIGHTON GROUP COMPANY

Leighton Consulting, Inc.
A LEIGHTON GROUP COMPANY

August 22, 2014
(Revised September 30, 2014)

Project No. 10733.001

The Getty Conservation Institute
1200 Getty Center Drive, Suite 700
Los Angeles, California 90049-1684

Attention: Mr. Benjamin Marcus, Project Specialist

Subject: **Geotechnical Evaluation Report**
Eames House
203 Chautauqua Boulevard
Pacific Palisades, California

In response to your request and authorization, Leighton Consulting, Inc. (Leighton) has conducted a geotechnical evaluation for the existing residential development at 203 Chautauqua Boulevard in Pacific Palisades, California. The purpose of this report is to provide a follow-up geotechnical evaluation to our previously issued reports (Leighton, 1993 and 1994).

This site is not located within a currently designated Alquist-Priolo Earthquake Fault Zone. However, as is the case for most of Southern California, strong ground shaking has occurred and will occur at the site. Primary geotechnical aspects of the site that may affect the existing property are earthquake-induced slope failures of the bluff, specifically along the southeast boundary, and surficial slope failures and erosion of friable sandy soils along the slope face, particularly in the areas of unmaintained site drainage.

This report presents our findings and recommendations based on the review of available geotechnical and geologic information pertaining to the site and site reconnaissance and topographic survey. No additional subsurface exploration was performed as a part of this evaluation. At the time of our evaluation, no immediate geotechnical hazards were observed.

17781 Cowan ▪ Irvine, CA 92614-6009
949.250.1421 ▪ 949.250.1114 Fax

10733.001

We appreciate the opportunity to be of service to you on this project. If you have any questions regarding this report, please call us at your convenience.

Respectfully submitted,

LEIGHTON CONSULTING, INC.

Evan B. Price, PG, CEG 2589
Project Geologist

Sreekar Pulijala, PE 82535
Project Engineer

Reviewed by:

Djan Chandra, PE, GE 2376
Senior Principal Engineer

EBP/SP/DJC/gv

Distribution: (2) Addressee

Leighton

10733.001

TABLE OF CONTENTS

Leighton

10733.001

List of Figures

Leighton

10733.001

1.0 INTRODUCTION

1.1 Purpose and Scope

This report presents our findings and recommendations for the existing residential development at 203 Chautauqua, Pacific Palisades, California. This report is based on review of available geotechnical and geologic information pertaining to the site and site reconnaissance and topographic surveys. No additional subsurface exploration was performed as a part of this evaluation. The purpose of this report is to provide a follow-up geotechnical evaluation to our previously issued reports (Leighton, 1993 and 1994). The scope of our work included the following tasks:

- In preparation of this report, we performed a background review of readily available, relevant, historic aerial photographs, geotechnical and geological literature pertinent to the site, including previous geotechnical reports for the site and adjacent properties by Leighton (1993 and 1994). We also performed a public records search at the City of Los Angeles Department of Building and Safety for other previous geotechnical reports, grading plans, and any other records that pertained to the geotechnical conditions at the site and the westerly adjacent lot at 14880 Corona Del Mar (Lots 3 and 4, Tract 6753). The documents reviewed are listed in Section 5.0.
- We performed a site reconnaissance on July 30, 2014, to map exposed geologic conditions at the project site and the accessible surrounding slopes to evaluate slope stability. Visible cracking, seepages, drainages, and erosional features were also mapped if observed.
- For use in our geologic mapping a topographic survey was performed in July, 2014.
- The data obtained from our background review, site reconnaissance and topographic survey were used in our geotechnical evaluation.
- Preparation of this report summarizing our findings and recommendations.

Leighton

10733.001

1.2 Site Description

The site is located at 203 Chautauqua Boulevard in Pacific Palisades, California, on an east-facing slope at the southern mouth of the Santa Monica Canyon (Figure 1, *Site Location Map*). The site is occupied by single family residence that consists of two, two-story rectangular shaped buildings within the relatively flat northwestern portion of the subject property. Steep slopes descend approximately 50 feet from the southeastern side and 150 feet from the southern side of the subject property to Chautauqua Boulevard and Pacific Coast Highway, respectively. The top of the southeastern slope is located approximately 150 feet southeast of the residence and the top of the southern slope is located approximately 170 feet south of the residence. The site is bordered to the northwest and southwest by an approximately 40-foot-tall slope that ascends to a higher terraced area containing Corona Del Mar and an unoccupied level graded pad. The slope is partially retained by the northwestern walls of the two buildings and a retaining wall connected between the buildings. The site is bordered to the northeast by houses built on relatively level ground. The relatively flat areas of the site are generally occupied by lawn and large trees while the slopes have less extensive vegetation. Limited onsite improvements included stone and wooden pathways, a small parking area in the northeastern corner, planters around the buildings, minimal aboveground irrigation systems, and signage for historic and educational purposes.

Leighton

10733.001

2.0 GEOTECHNICAL FINDINGS

2.1 Property Background and Previous Work by Leighton

Based on our review of background documents and historic aerial photographs, the subject lot was undeveloped until the construction of the Eames House in 1948, which consisted of the two separate two-story buildings that are currently present. Construction of the buildings consisted of a cut into the slope northwest of the buildings, which the buildings partially retain. The site appears to roughly exist in its current configuration with no gross changes to the site topography within the property and the adjacent slopes. In 1988, the residence was designated as a Historic-Cultural Monument by the Los Angeles County Cultural Heritage Commission.

In 1993, Leighton was asked to evaluate surface ground cracks that were discovered near the top of the bluff. These cracks were concluded to have resulted from the shrink/swell process of the upper few inches of soil and were deemed to pose no immediate slope stability issues at the site. In 1994, Leighton was asked to perform a post-earthquake reconnaissance, research, and documentation of the slope stability at the site after the Northridge Earthquake. It was concluded that strong ground shaking from the earthquake resulted in the failure of the bluff at the southwestern extent of the property, which was made susceptible by undercutting of the bluff for the construction of a building to the east of the slope and Pacific Coast Highway to the south of the slope. It was concluded that the existing onsite buildings were probably safe from surficial failures and did not have an adverse effect on the surficial stability of the surrounding slopes.

2.2 Southwestern Adjacent Residential Development – Tract 6753, Lots 3 and 4

Research was conducted at the offices of the City of Los Angeles regarding the previous residential development and more recent grading of the lot adjacent to the subject site to the southwest, Lots 3 and 4 of Tract 6753. The previous address of the since demolished residence was 5643 Corona Del Mar. The intent of the research was to locate and review geotechnical reports prepared for that development in the anticipation that the subsurface conditions on that property could be related to the conditions encountered at the subject site.

10733.001

Review of the multiple geotechnical reports by Leighton, J. Byer Group Inc., and Grover Hollingsworth and Associates (see Section 5.0 References) indicates a site history that has been affected by landsliding from prehistoric to present times. Bluff failures have been recorded along the south facing slope from 1952 to 1994. In an effort to stabilize the bluff failures, Caltrans constructed a compacted fill buttress between the bluff face and Pacific Coast Highway (Leighton, 1982). The most recent failure of the bluff occurred during the January 17, 1994 Northridge earthquake, which caused the top of the slope to recede up to 38 feet. A portion of the existing residence at that time was undercut and collapsed as a result. Grading of the site was conducted from 2006 to 2007 to construct pads for redevelopment of the lots. Once grading was complete no additional construction activities were reported on the lots. The lots are presently undeveloped and currently for sale.

Review of the geotechnical exploration report (J. Byer Group, 2000) and the geotechnical investigation report (Leighton, 1993) indicates six test borings were excavated at the site to explore the subsurface conditions. Of the exploration locations, Boring 1 by J. Byer was closest to the subject site, located approximately 250 feet north of the property line common to the subject site. The ground surface elevation at Boring 1 is estimated to have been approximately El. 176 feet prior to redevelopment. The boring was advanced to a depth of 165 feet, or to El. 11 feet mean sea level (MSL). The soil profile described at the boring location consisted of terrace materials of medium dense to very dense sands, silty sands, and gravelly sands with layers of gravel and cobbles.

2.3 Site Reconnaissance

During the site reconnaissance no gross surficial slope stability features such as cracking, slumping, and seeps were observed, although portions of the site were unmappable due to dense vegetation and leaf litter. Minor amounts of animal burrows and erosional features were noted along the top of the southeastern slope face and along the top of the ascending slope west of the property. Where exposed, the slope faces were observed to be comprised of friable sandy soils with gravels and cobbles.

2.4 Geologic Setting

The site is located on a coastal bluff in the Santa Monica Mountains. The immediate vicinity of the site is underlain by a thick sequence of nonmarine and marine terrace deposits. The Santa Monica Mountains, as is most of southern California, are complicated by faults, folding and varied bedrock formations. The alluvial terrace deposits have been uplifted over 100 feet, relative to their original elevation with respect to sea level, and fault movement along the Potrero Canyon fault has occurred periodically within the last 100,000 years.

Geologic units exposed in the vicinity of the site consist of Quaternary old alluvial valley deposits (Qoa) and Quaternary old fan deposits (Qof) as described below and presented on Figure 2, *Geotechnical Map* and Figure 5, *Regional Geology Map*. Landslides have been mapped in the vicinity of the project site that resulted from heavy rainfall and seismic shaking. A smaller failure of a portion of the bluff south of the site is mapped by McGill (1989) which failed onto 101 Chautauqua below the site.

Quaternary Old Alluvial Valley Deposits (Qoa)

Quaternary age old alluvial valley deposits underlie the eastern portion of the site. The deposits are locally derived from stream terraces that were developed during high stands of sea levels during the late Pleistocene (McGill, 1989). This material generally consists of interbedded yellowish brown, gravel, sand, and silt with varying amounts of cobbles.

Quaternary Old Alluvial Fan Deposits (Qof)

Quaternary age old alluvial fan deposits underlie the western slopes and building pads at the site and are mantled by the old alluvial valley deposits were present. The deposits are non-marine cover on marine terrace from old alluvial fan deposits derived from the erosion on the Santa Monica Mountains to the north (McGill, 1989). This material generally consists of gravel, sand, silt, and clay with varying amounts of cobbles.

A nearby borings performed within the old alluvial fan deposits by J. Byer in 1998 (J. Byer Group, 2000) at the adjacent Lots 3 and 4 indicate the subsurface profile generally consisted of medium dense to very dense sands and silty sands with vary amounts of gravel and cobbles to a depth of 165 feet below grade.

2.5 Groundwater

Review of the seismic hazard zone report (CGS, 2001) for the Topanga Quadrangle indicates the historically high groundwater table exists at a depth greater than 10 feet below grade. The reported historic high groundwater data does not extend past the base of the surrounding bluffs and appears to not report upon the actual groundwater in the area of the project site. Fluctuations of the groundwater level, localized zones of perched water, and an increase in soil moisture should be anticipated during and following the rainy seasons or periods of locally intense rainfall or storm water runoff.

Based upon our review of available geotechnical reports for the adjacent Lots 3 and 4 of Tract 6753, groundwater was encountered in a boring drilled by J. Byer Group Inc. (2000) at the westerly adjacent property at an approximate elevation of 11 feet mean sea level (MSL) with an approximate ground surface elevation of 121 MSL. Therefore, the groundwater table is considered to exist below 110 feet below ground surface at the time the boring was drilled. However, seepage has been noted along slope faces within nearby properties. Vertical infiltration of surface water may become perched on less permeable layers within the subsurface materials and may move laterally until it seeps onto a slope face.

2.6 Faulting and Seismicity

Our review of available in-house literature indicates that there are no known active or potentially active faults traversing the sites and the sites are not located within a State of California designated Alquist-Priolo Earthquake Fault Zone (Bryant and Hart, 2007). A fault is considered active if there is either directly observable or inferred evidence of movement along one or more of its segments in the last 11,000 years. The principal seismic hazard that could affect the site is ground shaking resulting from an earthquake occurring along any one of several major active faults (Figure 6, *Regional Fault Map*) in the region. Known regional active and potentially active faults that could produce significant ground shaking at the site include the Santa Monica, Malibu Coast, Anacapa Dume, Palos Verdes, Hollywood, Newport Inglewood and Northridge Thrust faults among others.

The intensity of ground shaking at a given location depends primarily upon the earthquake magnitude, the distance from the source, and the site response characteristics. The peak ground acceleration for the Maximum Considered Earthquake (MCE_G) adjusted for the Site Class effects (PGA_M) is 0.85g. Based on the USGS online interactive deaggregation program (USGS, 2008), the modal seismic event is Moment Magnitude (M_W) 7.2 at a distance of 1.3 miles.

Leighton

10733.001

2.7 Historic Seismicity

Although Southern California has been seismically active during the past 200 years, written accounts of only the strongest shocks survive the early part of this period. Early descriptions of earthquakes are rarely specific enough to allow an association with any particular fault zone. It is also not possible to precisely locate epicenters of earthquakes that have occurred prior to the twentieth century.

A search of historical earthquakes was performed using the computer program EQSearch (Blake, 2000) for the time period between 1800 and 2014. A general view of recorded historical seismic activity is presented on Figure 7, *Historical Seismicity Map*. Within that time frame, 487 earthquakes were found within a 60-mile (100 kilometer) radius of the project site. Of these earthquakes, the closest was located 2.3 miles (3.8 kilometers) southeast of the site and occurred on June 22, 1920. This earthquake registered a 4.9 Mw and induced recorded peak ground acceleration at the site of about 0.216g. The largest recorded peak ground acceleration at the site was 0.243g from the January 17, 1994 Northridge earthquake with magnitude of 6.7 Mw and located at a distance of 12.7 miles (20.4 kilometers) east of the site. Ground shaking during that event resulted in multiple failures of bluff faces in the project vicinity and resulted in the loss of property at neighboring lots. Given that the project site is located is a seismically active area, as is most of Southern California, the probability of an event with equivalent or greater ground accelerations is high and may result in seismic slope failures.

2.8 Seismically Induced Landslides

Significant slopes are located around the site. Based on the State of California Seismic Hazard Zones Map for the Topanga Quadrangle (CGS, 1997a), the southeastern slopes are mapped as an area that has been identified by the State of California as being potentially susceptible to seismically induced landslides (Figure 8). Previous seismically induced failures near the site include portions of the south facing bluff adjacent to Pacific Coast Highway (PCH) and a smaller failure of the bluff area south of the site that failed onto 101 Chautauqua below the site; both of which failed from the effects of the January 17, 1994 Northridge earthquake. The failure south of the westerly adjacent property that failed onto PCH resulted in the undermining and ultimate demolition of the residence. The potential for future seismically induced landslides along the bluffs are high.

Leighton

10733.001

3.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the findings of our evaluation the subject site, the geotechnical aspects of the site appear to be in good condition. No slope failures or geotechnical hazards were observed, and the general maintenance of the subject site and its adjacent slopes appeared to be satisfactory. Site areas that potentially require maintenance and/or additional study are discussed in the following sections.

3.1 Slope Stability

3.1.1 Seismic Slope Stability

Ground shaking during the January 17, 1994 Northridge earthquake resulted in multiple failures of bluff faces in the project vicinity and resulted in the loss of property at neighboring lots. Given that the project site is located is a seismically active area, as is most of Southern California, the probability of an event with equivalent or greater ground shacking is high and may result in seismic slope failures. A potential failure to the slope adjacent to the western site of the subject residence has the potential to cause damage to the property. In order to adequately assess the seismic slope stability of the surrounding slopes, an additional geotechnical evaluation that includes subsurface explorations would be required.

3.1.2 Surficial Slope Stability

The onsite slope faces were observed to be comprised of friable sandy soils with varying amounts of gravel and cobbles. Due to the highly friable nature of this material, the slope faces may exhibit high erosional rates from natural and artificial sources. Proper care and maintenance may limit the impact from these sources and slow down the erosional process. The long term performance and surficial stability of slopes can be enhanced through the selection of landscaping. Typically, surficial stability is increased by establishing vegetation that includes shallow- and deep-rooted shrubbery and trees with ground cover to prevent erosion. A qualified landscape architect should be consulted to evaluate and provide specific recommendations for landscaping that meets these criteria. Specialized erosion control measures such erosion control mats may be required to prevent erosion. If any large trees in the slope areas are to be cut down, the tree roots and stump should be left in place to prevent a loss of slope stability.

Burrowing rodents should be exterminated. When encountered, burrows should be backfilled to prevent water from entering the subsurface causing a loss of soil support. A rodent control program should be established and maintained.

3.2 Irrigation

Irrigation of landscaping should be controlled to maintain, as much as possible, consistent moisture content sufficient to provide healthy plant growth without overwatering. Solid pipes intended for irrigation should be periodically monitored and be repaired as needed so water does not flow over the slope face.

3.3 Surface Drainage

Surface drainage should be to direct water away from slope faces and toward approved drainage devices. Evidence of ineffective and/or unmaintained erosion control practices were observed in the adjacent Lots 3 and 4 where concentrated runoff at the southwestern fence line had resulted in rilling along the slope below. Additional areas with minor rilling were observed along the eastern slope that appear to be the result of onsite stormwater runoff concentrating in areas of lower topography and draining down the slope face. Notification of the ineffective erosion control should be given to the property owner and/or County of Los Angeles so that appropriate erosion control can be developed and maintained on the property.

3.4 Future Geotechnical Observations

After any significant rainfall the slope faces should be monitored for any seepage. Leighton should be notified if any seepage is observed so that remedial recommendations can be provided, if necessary, as seepage has the potential to erode the soil and could lead to loss of soil support along the slope face. Leighton should also be notified if cracks, movement or any signs of slope instability are observed so that proper remediation can be developed before they turn into slope failures. The slopes should also be evaluated after an earthquake along any faults in the region that results in ground shaking at the site. A periodic inspection program can be established, if desired, in which Leighton will provide an inspection of the slope and site conditions on an annual basis to identify and document areas with potential distress and maintenance issues so that preventive measures can be developed and implemented.

10733.001

3.5 CBC Seismic Design Parameters

To accommodate effects of ground shaking produced by regional seismic events, seismic design can, at the discretion of a Structural Engineer, be performed in accordance with the 2013 edition of the California Building Code (CBC). Table 1, *2013 CBC Seismic Parameters*, lists seismic design parameters based on the 2013 CBC methodology, which is based on ASCE/SEI 7-10:

2013 CBC Seismic Parameters

Seismic Design Parameters	Value
Site Latitude (decimal degrees)	34.0300
Site Longitude (decimal degrees)	-118.5194
Site Class Definition (ASCE 7 Table 20.3-1)	D
Mapped Spectral Response Acceleration at 0.2s Period, S_s (Figure 1613.3.1(1))	2.139
Mapped Spectral Response Acceleration at 1s Period, S_1 (Figure 1613.3.1(2))	0.798
Short Period Site Coefficient at 0.2s Period, F_a (Table 1613.3.3(1))	1.0
Long Period Site Coefficient at 1s Period, F_v (Table 1613.3.3(2))	1.5
Adjusted Spectral Response Acceleration at 0.2s Period, S_{MS} (Eq. 16-37)	2.139
Adjusted Spectral Response Acceleration at 1s Period, S_{M1} (Eq. 16-38)	1.197
Design Spectral Response Acceleration at 0.2s Period, S_{DS} (Eq. 16-39)	1.426
Design Spectral Response Acceleration at 1s Period, S_{D1} (Eq. 16-40)	0.798
Peak Ground Acceleration, PGA_M (Eq. 11.8-1 of ASCE 7-10)	0.846

10733.001

4.0 LIMITATIONS

Our professional services were performed in accordance with the prevailing standard of professional care as practiced by other geotechnical engineers in the area. We make no other warranty either express or implied. The report may not be used by others or for other projects without the written consent of our client and our firm.

The conclusions and recommendations in this report are based in part upon data that were obtained from a limited number of visual observations, site visits, and the referenced background materials. Such information is by necessity incomplete. The nature of many sites is such that differing geotechnical or geological conditions can occur within small distances and under varying climatic conditions. Due to vegetation cover on most slopes, it may be likely that some potential issues may not have been addressed by this report. If any issues related to slope stability arise in the future, we should be notified so that we can observe and document the condition and provide recommendations for slope remediation as warranted.

10733.001

5.0 REFERENCES

Bryant, W.A., (compiler), 2005, "Digital Database of Quaternary and Younger Faults from the Fault Activity Map of California, Version 2.0" California Geological Survey Web Page, http://www.consrv.ca.gov/cgs/information/publications/Pages/QuaternaryFaults_ver2.aspx .

Bryant, W.A., and Hart, E.W., 2007, *Fault Rupture Hazard Zones in California, Alquist-Priolo Earthquake Fault Zoning Act with Index to Earthquake Zones Maps*, Department of Conservation, California Geological Survey, Special Publication 42, 2007 Interim Revision.

California Building Code (CBC), 2013.

California Division of Mines and Geology (CDMG), 2000, CD-ROM containing digital images of Official Maps of Alquist-Priolo Earthquake Fault Zones that affect the Southern Region, DMG CD 2000-003 2000.

California Department of Conservation, Division of Mines and Geology, State of California, 1997a, Seismic Hazard Zones Official Map, Topanga Quadrangle, 7.5-Minute Series, Scale 1:24,000, Open-File Report 97-06, dated April 7.

______, 1997b, Special Publication 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California; adapted March 13, 1997, by the State of Mining and Geology Board, in Accordance with the Seismic Hazards Mapping Act of 1990.

California Geological Survey (CGS), 2001, Seismic Hazard Zone Report for the Topanga 7.5-Minute Quadrangles, Seismic Hazard Zone Report No. 01.

Converse Foundation Engineers, 1966, Project No. 66-560-EH, Slide Conditions 14880 Corona Del Mar, Pacific Palisades, California, report dated November 16, 1966.

Grover Hollingsworth and Associates, Inc., 1995, Additional Comments and Recommendations, Proposed Residence Reconstruction, Lot 3, Block 6, Tract 6753. 14880 Corona del Mar, Pacific Palisades, California, report dated August 8, 1995.

Leighton

10733.001

J. Byer Group, Inc., 2006, Geologic and Soils Engineering Update proposed Residential Estate Lots 3 and 4, Tract 6753, 14868 and 14880 Corona del Mar, Pacific Palisades, California, report dated February 8, 2006.

______, 2004, Addendum Geologic and Soils Engineering Exploration #3 Proposed Residential Estate Lots 3 and 4, Tract 6753, 14868 and14880 Corona del Mar, Pacific Palisades, California, report dated June 24, 2004, revised August 4, 2004.

______, 2003, Addendum Geologic and Soils Engineering Exploration, Proposed Residential Estate, Lots 3 and 4, Tract 6753, 14868 and 14880 Corona del Mar, Pacific Palisades, California, report dated August 6, 2003.

______, 2002, Geologic and Soils Engineering Memorandum Erosion Control Plan Review, Lots 3 and 4, Tract 6753, 14868 and 14880 Corona del Mar, Pacific Palisades, California, report dated August 27, 2002.

______, 2000, Geologic and Soils Geotechnical Engineering Exploration Proposed Residential Estate Lots 3 and 4, Tract 6753 14868 and 14880 Corona del Mar Pacific Palisades, California, report dated November 1, 2000.

Jennings, C.W., 2010, "Fault Activity Map of California," California Geological Survey," Geologic Data Map No. 6, 1:750,000.

Land and Air Surveying, 2014, Architectural Survey, 203 Chautauqua Boulevard, Pacific Palisades, California, survey date 7/03-10/14.

Leighton and Associates, Inc., 1993, Geotechnical Investigation of Surface Ground Cracks, 203 Chautauqua Boulevard, Pacific Palisades, California, Project No. 2920739-01, dated January 8, 1993.

______, 1993, Geotechnical Investigation for Bluff Stabilization Measures at 14868 Corona del Mar, Pacific Palisades, California, Project No. 2820246-07, dated October 19, 1993.

______, 1994, Post-Northridge Earthquake Reconnaissance Research and Documentation of Slope Stability, Eames House, 203 Chautauqua Boulevard, Pacific Palisades, California, Project No. 2920739-02, dated January 8, 1993.

McGill, John T., 1973, Map Showing Landslides in the Pacific Palisades Area, City of Los Angeles, California, 1:4,800.

Leighton

______, 1982, Map Showing Relationship of Historic to Prehistoric Landslides, Pacific Palisades Area, City of Los Angeles, California, 1:4,800.

______, 1982, Preliminary Geologic Map of the Pacific Palisades Area, City of Los Angeles, California, 1"=1,500'.

______, 1989, Geologic Maps of the Pacific Palisades Area, Los Angeles, California, 1:4,800.

______, 1989, Geologic Maps of the Pacific Palisades Area, Los Angeles California, Map Showing Contours on Wave-Cut Platforms of Emergent Marine Terraces, Pacific Palisades Area, Los Angeles, California, 1:4,800.

United States Geological Survey and California Geological Survey, 2005, "Preliminary Geologic Map of the Los Angeles 30'x 60' Quadrangle, Southern California," 2005, Version 1.0. 1:100,000.

United States Geological Survey (USGS), 2008a, National Seismic Hazard Maps Fault Parameters http://geohazards.usgs.gov/cfusion/hazfaults_search/hf_search_main.cfm

______, 2008b, Interactive Deaggregations, http://geohazards.usgs.gov/deaggint/2008/

______, 2008c, National Seismic Design Maps – Fault Parameters, http://earthquake.usgs.gov/designmaps/us/application.php

______, 2013, *U. S. Seismic Design Maps* Application: http://geohazards.usgs.gov/designmaps/us/application.php (2010 ASCE 7, with July 2013 errata).

United States Geological Survey, 1952 (Photorevised 1981), Topanga, California Quadrangle Map, 7.5 Minute Series: Scale 1:24,000.

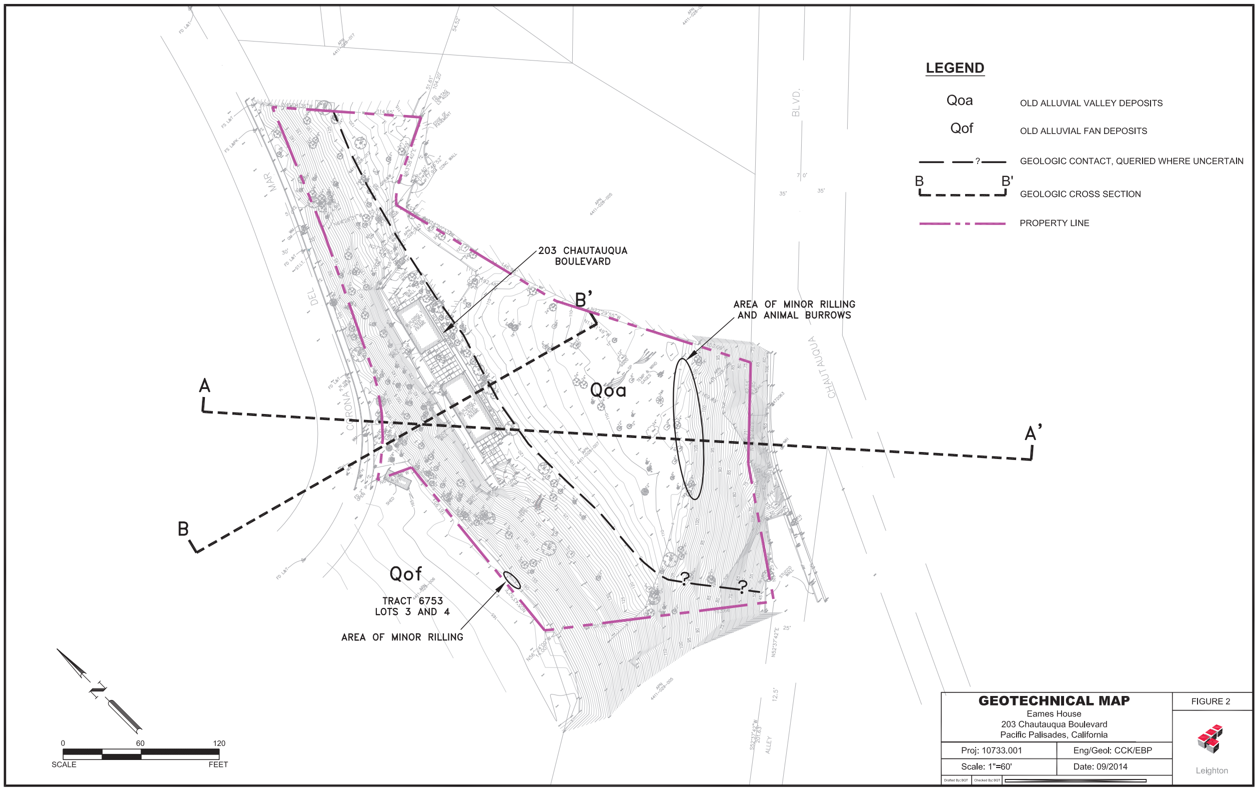
Aerial Photographs Reviewed

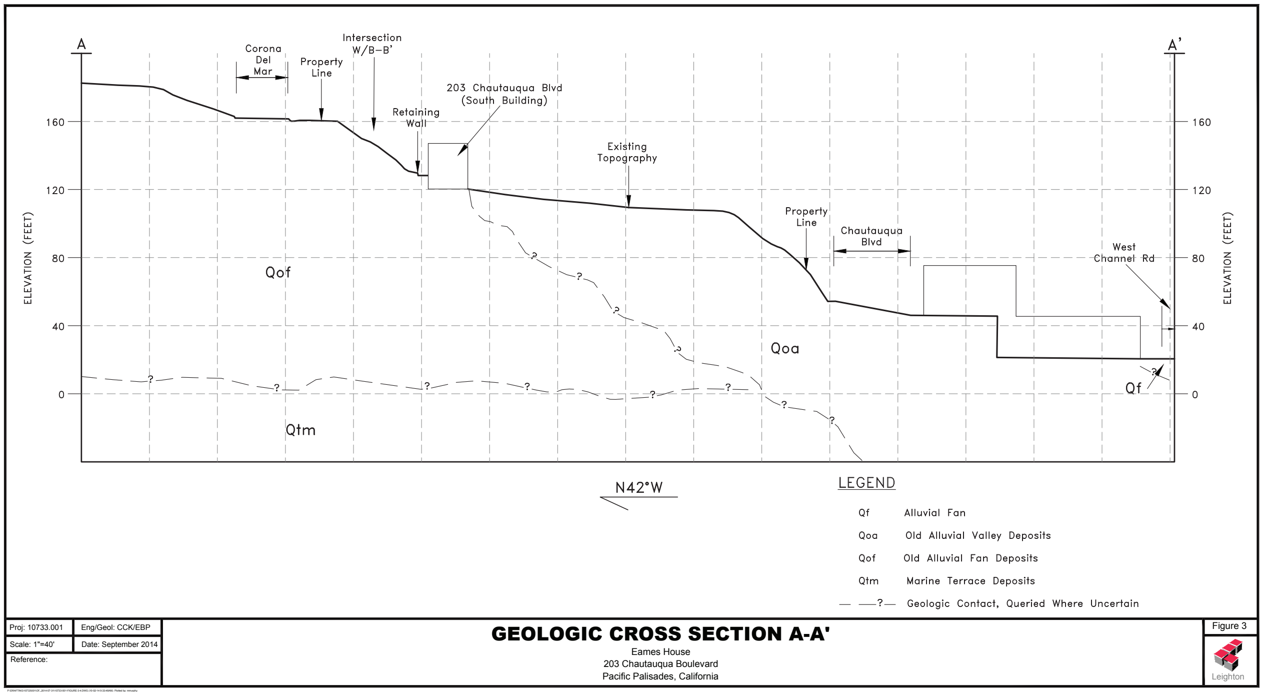
Date	Flight No.	Frame Nos.	Approx. Scale	Source
5-22-38	AXJ	26-80	1"=2,000'	U.S. Department of Agriculture
11-4-52	AXJ-3K	121	1"=2,000'	U.S. Department of Agriculture
6-17-74	271-10	18-2 and 18-3	1"=500'	City of L.A. Survey Division

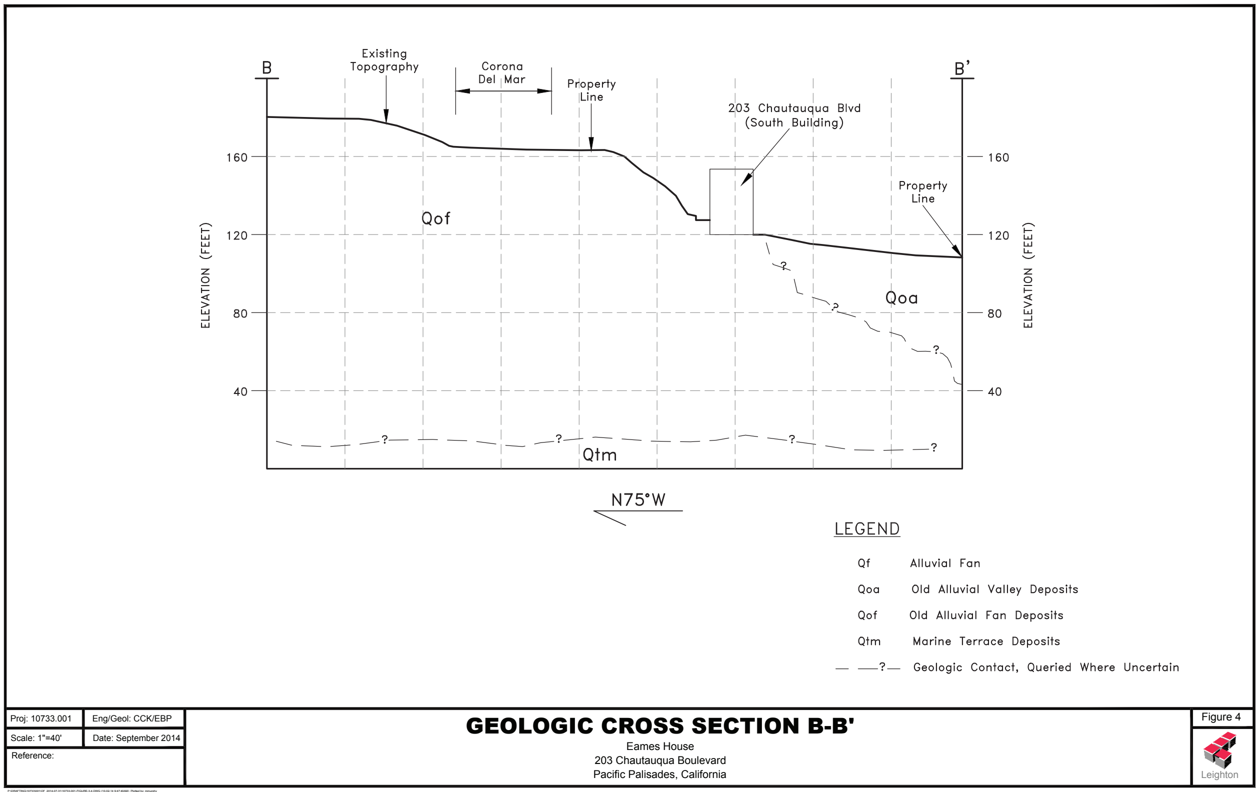
Leighton

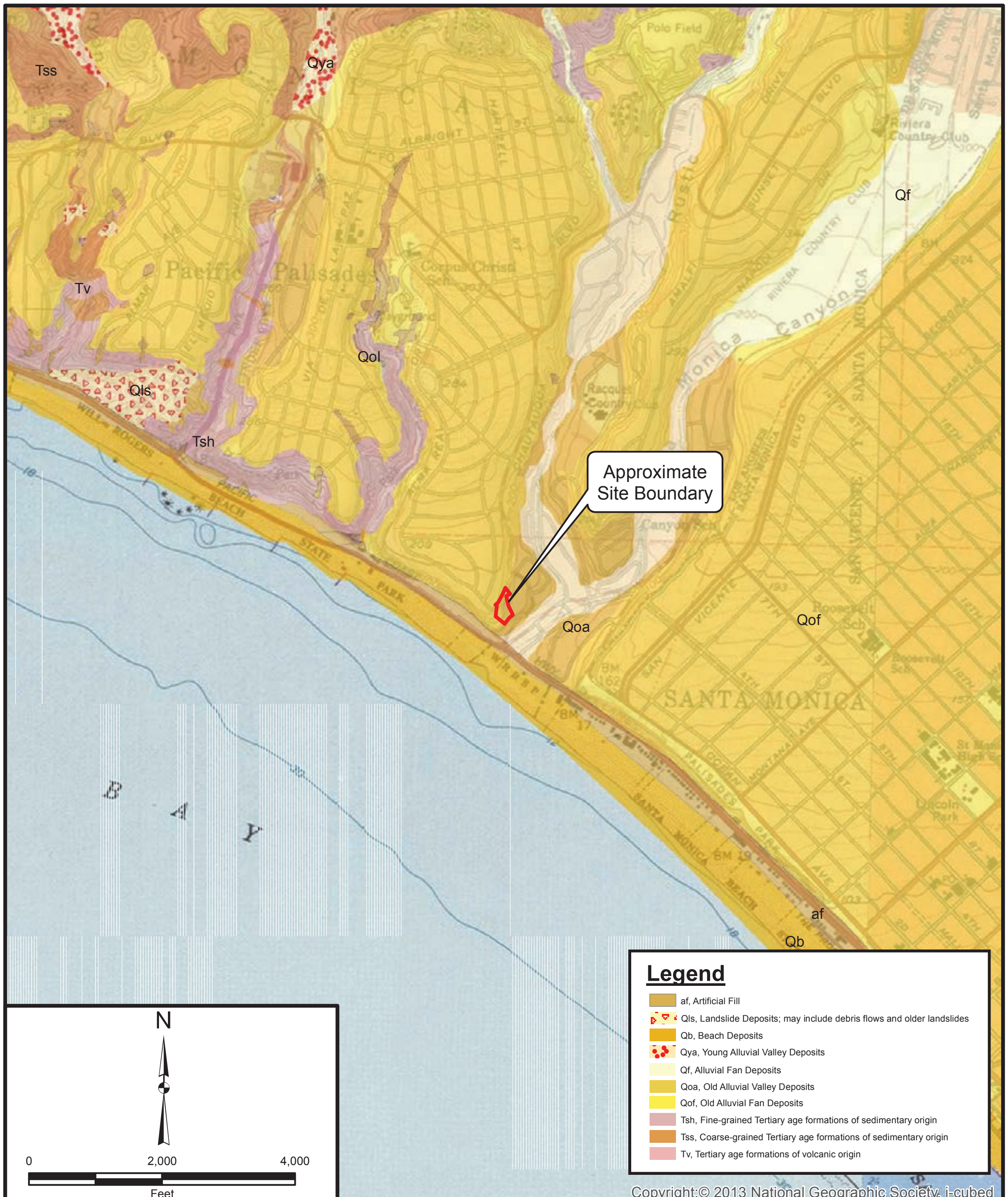
Project: 10733.001	Eng/Geol: CCK/EBP	**SITE LOCATION MAP** Eames House 203 Chautauqua Boulevard Pacific Palisades, California	Figure 1
Scale: 1 " = 1,000 '	Date: September 2014		Leighton
Base Map: ESRI Resource Center 2014 Thematic Info: Leighton Author: Leighton Geomatics (mmurphy)			

Map Saved as V:\drafting\10733\001\OF_2014-07-31\GIS Figures\10733-001-Figure1 SLM.mxd on 8/7/2014 10:58:42 AM


LEGEND
Qoa
OLD ALLUVIAL VALLEY DEPOSITS
Qof
OLD ALLUVIAL FAN DEPOSITS
GEOLOGIC CONTACT, QUERIED WHERE UNCERTAIN
B B'
GEOLOGIC CROSS SECTION
PROPERTY LINE
203 CHAUTAUQUA BOULEVARD
AREA OF MINOR RILLING AND ANIMAL BURROWS
A
A'
B
B'
Qoa
Qof
TRACT 6753 LOTS 3 AND 4
AREA OF MINOR RILLING
N
0 60 120
SCALE FEET
GEOTECHNICAL MAP
Eames House
203 Chautauqua Boulevard
Pacific Palisades, California
FIGURE 2
Proj: 10733.001
Eng/Geol: CCK/EBP
Scale: 1"=60'
Date: 09/2014
Leighton


A
A'
Corona
Del
Mar
Property
Line
Intersection
W/B-B'
203 Chautauqua Blvd
(South Building)
Retaining
Wall
Existing
Topography
Property
Line
Chautauqua
Blvd
West
Channel Rd
ELEVATION (FEET)
160
120
80
40
0
Qof
Qoa
Qtm
Qf
N42°W
LEGEND
Qf Alluvial Fan
Qoa Old Alluvial Valley Deposits
Qof Old Alluvial Fan Deposits
Qtm Marine Terrace Deposits
?— Geologic Contact, Queried Where Uncertain
Proj: 10733.001
Eng/Geol: CCK/EBP
Scale: 1"=40'
Date: September 2014
Reference:
GEOLOGIC CROSS SECTION A-A'
Eames House
203 Chautauqua Boulevard
Pacific Palisades, California
Figure 3
Leighton


B
B'
Existing Topography
Corona Del Mar
Property Line
203 Chautauqua Blvd (South Building)
Property Line
160
120
80
40
ELEVATION (FEET)
Qof
Qoa
Qtm
?
N75°W
LEGEND
Qf Alluvial Fan
Qoa Old Alluvial Valley Deposits
Qof Old Alluvial Fan Deposits
Qtm Marine Terrace Deposits
— —?— Geologic Contact, Queried Where Uncertain
Proj: 10733.001
Eng/Geol: CCK/EBP
Scale: 1"=40'
Date: September 2014
Reference:
GEOLOGIC CROSS SECTION B-B'
Eames House
203 Chautauqua Boulevard
Pacific Palisades, California
Figure 4
Leighton



Project: 10733.001	Eng/Geol: CCK/EBP
Scale: 1 " = 2,000 '	Date: September 2014

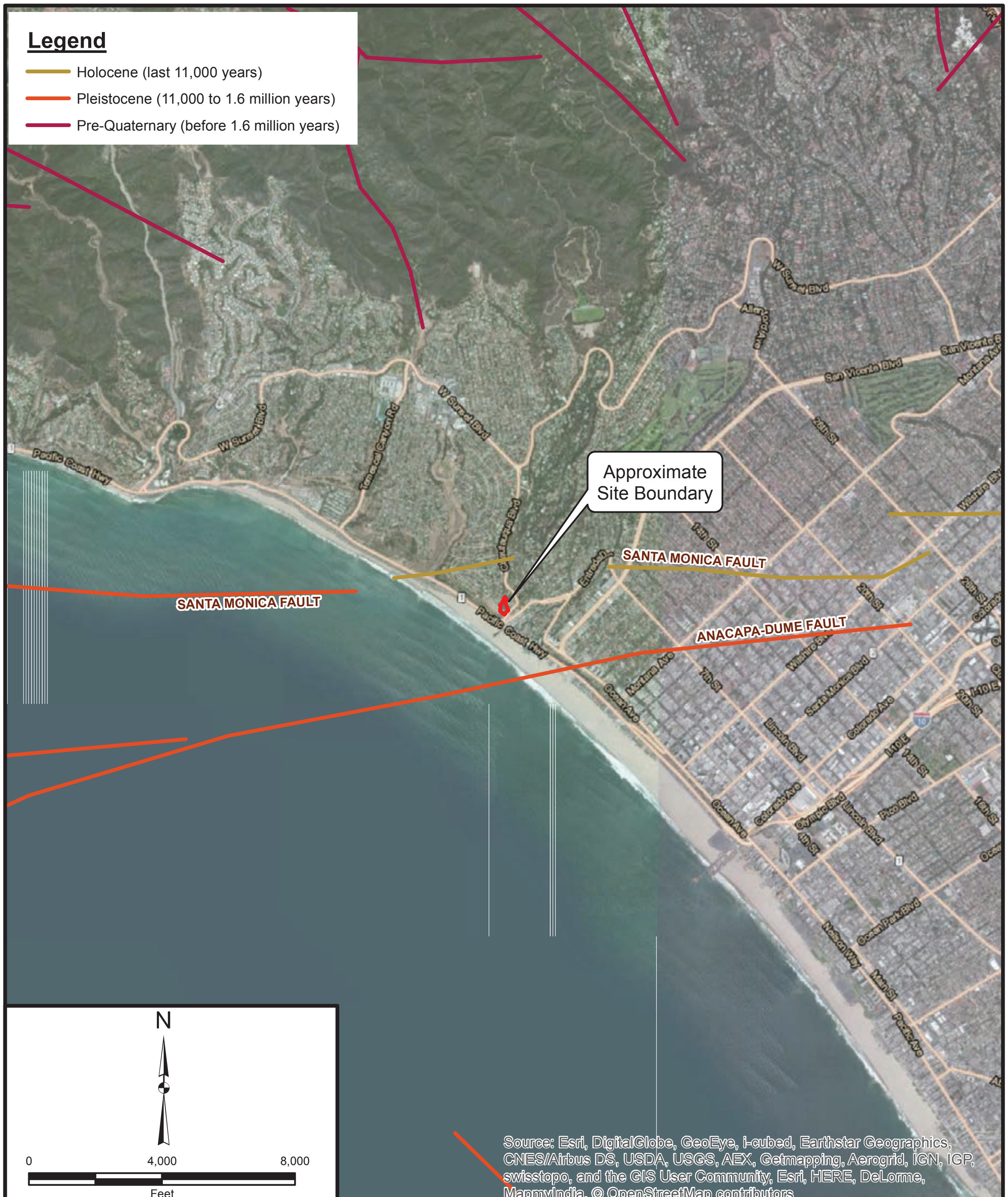
Base Map: ESRI Resource Center 2013
Thematic Info: Leighton
Author: Leighton Geomatics (mmurphy)

REGIONAL GEOLOGY MAP
Eames House
203 Chautauqua Boulevard
Pacific Palisades, California

Figure 5

Leighton

Map Saved as V:\drafting\10733\001\OF_2014-07-31\GIS Figures\10733-001-Figure5 RGM.mxd on 8/7/2014 11:02:43 AM



Project: 10733.001	Eng/Geol: CCK/EBP
Scale: 1 " = 4,000 '	Date: September 2014

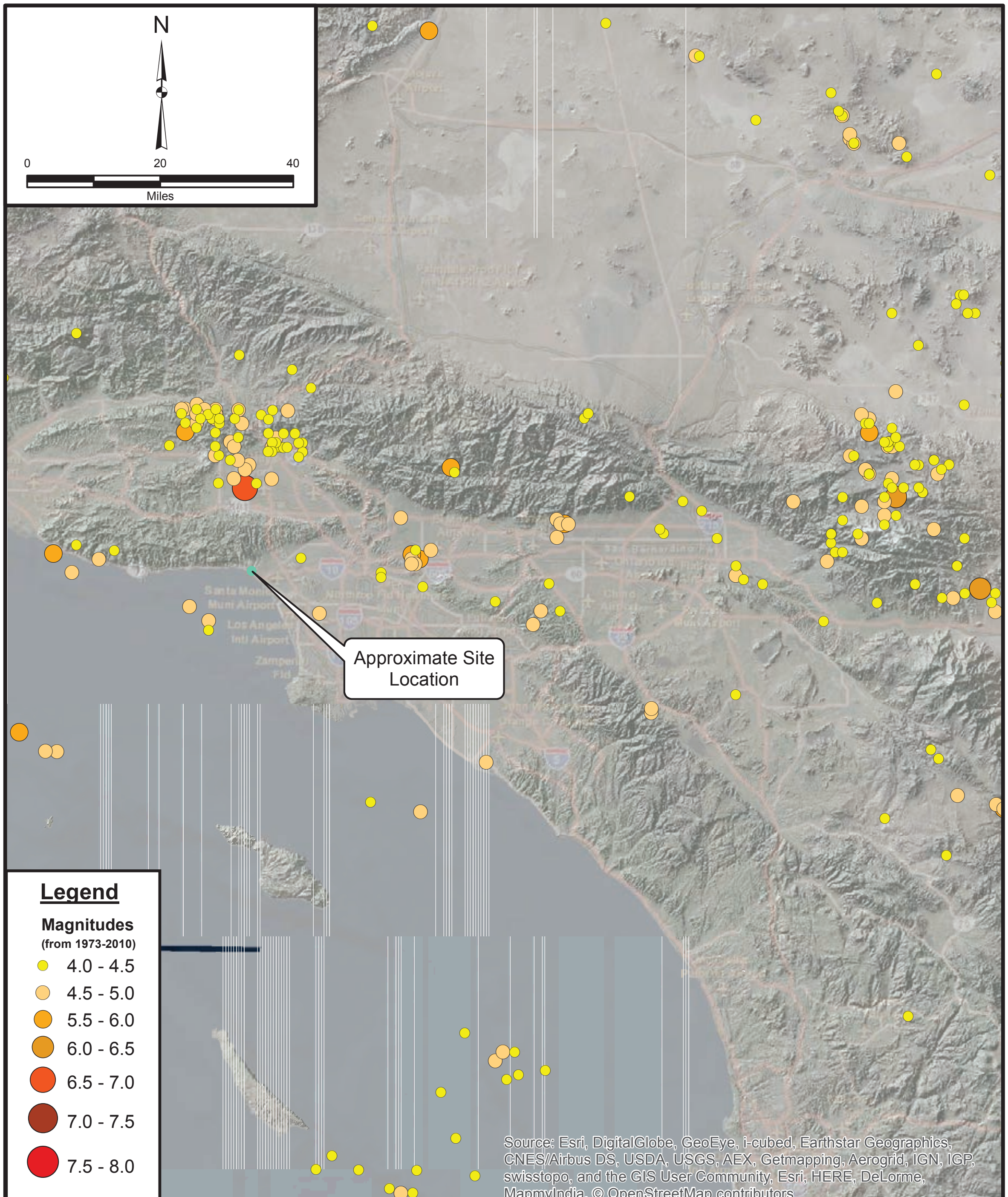
Base Map: ESRI Resource Center 2013
Thematic Info: Leighton
Author: Leighton Geomatics (mmurphy)

REGIONAL FAULT MAP
Eames House
203 Chautauqua Boulevard
Pacific Palisades, California

Figure 6

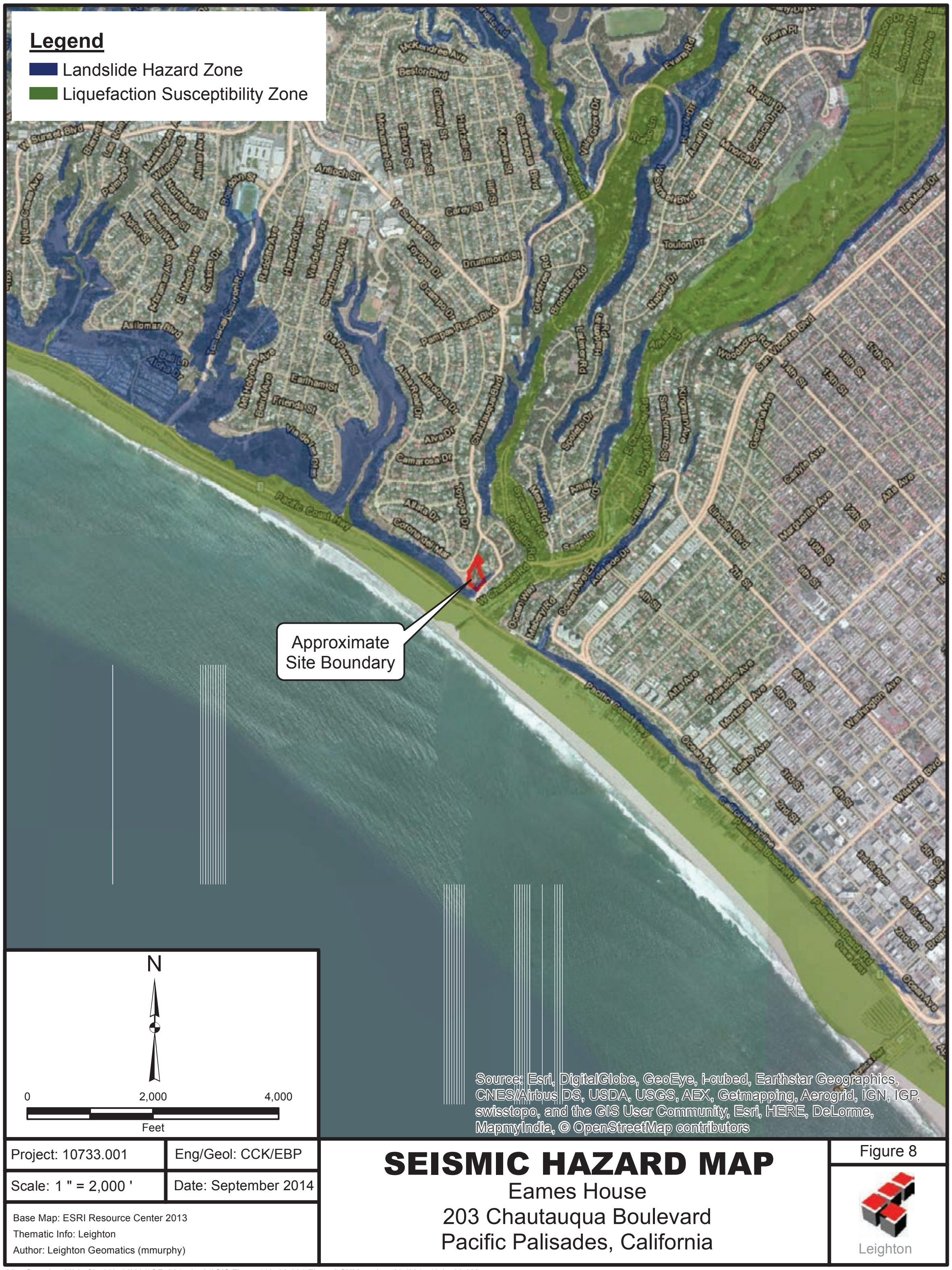
Leighton

Map Saved as V:\drafting\10733\001\OF_2014-07-31\GIS Figures\10733-001-Figure6 RFM.mxd on 8/8/2014 10:51:34 AM



Project: 10733.001	Eng/Geol: CCK/EBP	**HISTORICAL SEISMICITY MAP** Eames House 203 Chautauqua Boulevard Pacific Palisades, California	Figure 7
Scale: 1 " = 20 miles	Date: September 2014		Leighton
Base Map: Microsoft Bing 2012 Thematic Info: Leighton Author: kthomas (mmurphy)			

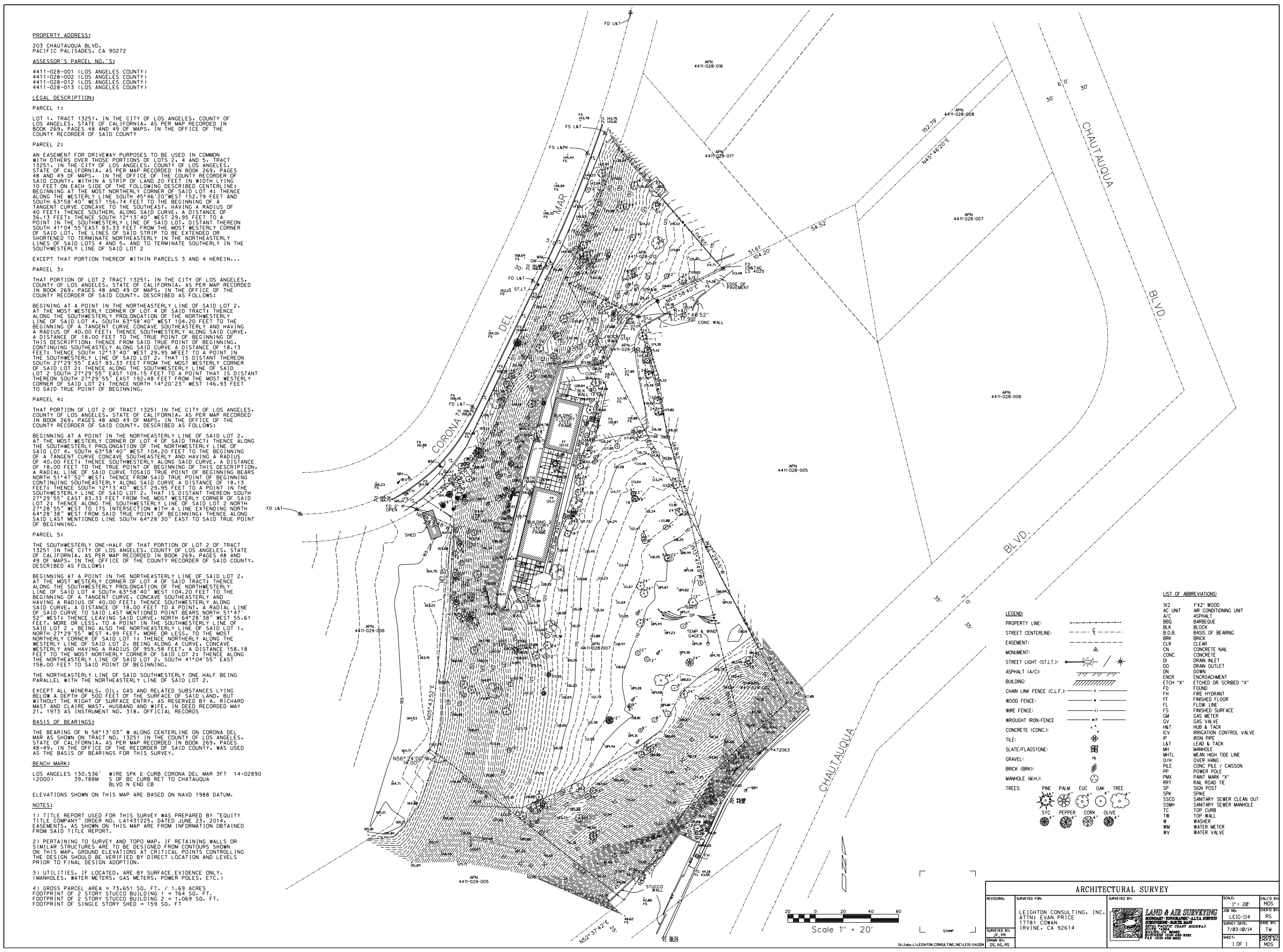
Map Saved as V:\drafting\10733\001\OF_2014-07-31\GIS Figures\10733-001-Figure7 HSHM.mxd on 10/2/2014 9:54:12 AM



Map Saved as V:\drafting\10733\001\OF_2014-07-31\GIS Figures\10733-001-Figure8 SHM.mxd on 8/7/2014 11:05:08 AM

APPENDIX 5.1

Topographic Map of the Eames House Site



CHAPTER 6

Eames House Landscape Survey and Assessment

In 2014, Carlberg Associates, horticulturists and registered consulting arborists, was engaged to evaluate the Eames House landscape and setting, and assess the condition of the site's numerous trees. Carlberg prepared a survey and inventory of the site's plants and trees, as well as its softscape and hardscape components. The base layer topographic map produced by Leighton Consulting (chapter 5) served as the foundation for Carlberg's site and detail maps.

A detailed survey and assessment was completed of trees with trunks greater than four inches in diameter, as well as of smaller trees in prominent locations. Each tree's physical health and structural condition was evaluated and a Safe Useful Life Expectancy (S.U.L.E.) rating applied; action recommendations, such as removal, were made where appropriate. Survey and condition assessment data were recorded on 246 individual tree evaluation forms. A representative sample of 20 of these forms is reproduced in appendix 6.1. These include a selection of four red gums, and one sheet each for the other sixteen types of trees surveyed. Maps identify the locations and types of the surveyed trees (appendices 6.2 and 6.3). Shrubs, groundcovers, potted plants, and hardscape materials were surveyed and inventoried, and were identified on a series of maps (appendix 6.4).

Carlberg ASSOCIATES
Horticulturists and
Registered Consulting
ARBORISTS

EAMES HOUSE CONSERVATION PROJECT
THE EAMES HOUSE
203 NORTH CHAUTAUQUA BOULEVARD
PACIFIC PALISADES, CALIFORNIA 90272
SUMMARY REPORT

SUBMITTED TO:

THE GETTY CONSERVATION INSTITUTE
ATTN: SUSAN MACDONALD
HEAD, FIELD PROJECTS
1200 GETTY CENTER DRIVE, SUITE 700
LOS ANGELES, CALIFORNIA 90049-1684

PREPARED BY:

CY CARLBERG
ASCA REGISTERED CONSULTING ARBORIST #405
ISA CERTIFIED ARBORIST #WE 0575A
ISA QUALIFIED TREE RISK ASSESSOR
CAUFC CERTIFIED URBAN FORESTER #013

Santa Monica Office
2402 California Avenue
Santa Monica, California 90403
Office: 310.453.TREE (8733)

Sierra Madre Office
80 West Sierra Madre Boulevard, #241
Sierra Madre, California 91024
Office: 626.248.8977

www.cycarlberg.com

REVISED: FEBRUARY 9, 2015

EAMES HOUSE CONSERVATION PROJECT

TABLE OF CONTENTS

Carlberg ASSOCIATES
Horticulturists and
Registered Consulting
ARBORISTS

February 9, 2015

Susan Macdonald
Head, Field Projects
The Getty Conservation Institute
1200 Getty Center Drive, Suite 700
Los Angeles, California 90049-1684

Re: The Eames House Conservation Project – Summary Report

Dear Ms. Macdonald,

This report summarizes the data and conclusions arising from our evaluation of 246 trees located at the Eames House (Case Study House No. 8) in Pacific Palisades, California. Carlberg Associates was retained in July 2014 to document the plant material (trees, shrubs, and groundcover) and hardscape (Task 1) and provide recommendations for (1) the reduction of risk associated with trees, and (2) the improvement or stabilization of tree health (Task 2). Task 3, to be completed at a later date, will address conservation strategies and succession planning. Individual sheets containing tree data, specific recommendations, and photographs were submitted under a separate cover.

We inventoried trees with trunk diameters of four inches or greater (dbh[1]), unless a smaller tree was in a prominent location and would have the potential of becoming a specimen tree. We inventoried 246 trees throughout the property; an astounding 212 (86% of the tree population) are eucalypts. Many have naturalized and are sprouting from seed or distal roots from existing trees; we refer to these as “volunteers.” There could be as many as 75 additional volunteer species on the slope that were under four inches dbh and less. Some were identified in circa 1949 photographs as mature trees, indicating that they may have been part of the Abbott Kinney planting of the late 1800s. Aside from photographs, we relied on our experience, knowledge, and judgment to determine whether a eucalypt had been intentionally planted or grew as a volunteer.

The remaining 34 trees comprise 12 different species. The California pepper tree at the southeast edge of the meadow is the only tree of these 34 that appears in historic photographs. Unfortunately, all but two of the 14 Victorian box trees appear to have succumbed to bacterial leaf scorch and are in irreversible decline. Data on these 34 trees appears in the individual data sheets.

[1] **dbh** (diameter at breast height) – a forestry term referring to a tree’s trunk diameter measured at 4.5 feet above natural grade. Often used as a representation of tree height.

Santa Monica Office
2402 California Avenue
Santa Monica, California 90403
Office: 310.453.TREE (8733)

Sierra Madre Office
80 West Sierra Madre Boulevard, #241
Sierra Madre, California 91024
Office: 626.248.8977

www.cycarlberg.com

Carlberg ASSOCIATES

In general, most trees are in good condition and show good vigor. With the minimal rainfall the trees in the outlying (and un-irrigated) areas have received, it is remarkable that the eucalypts, in particular, show minimal signs of drought stress. It is important to note here that **Physiological Condition**, or tree health, describes a tree's general state of well-being and obvious presence of disease or pests. **Structural Condition** refers to the relative strength and stability of a tree's root and branch architecture and is distinctly different from physiological condition. A tree may be outwardly healthy but still have structural weaknesses. Physiologically, a tree requires only a thin shell to transport water and nutrients. Thus, a tree can be hollow on the inside and still be "healthy."

Eucalyptus Trees

A number of the eucalypts at the top of the slope (along Corona del Mar) were "topped" many years ago by adjacent neighbors, presumably seeking views of the ocean. There are also large trees throughout the property that have some history of topping, perhaps when this was an approved practice and the negative effects of topping were unknown. There is a congregation of topped trees mid-slope above the residence: these could have been topped to reduce the potential of damage to the structures.

Topping is a substandard pruning technique used to reduce tree size. Resultant growth from these typically large pruning cuts is in the form of long, weakly connected shoots. Often many shoots arise from a topping cut; as they develop in size and weight, individual shoots can "break out" of the tree. If branch end weight is not kept light, or if interior branches are removed (negating good branch distribution throughout the tree), entire branches or trunks are subject to breakage. Overall, topping is bad for trees because it:

- leads to stress by removing food producing foliage;
- leads to sunburn of exposed bark and death of the conductive tissues underneath;
- leads to decay at the pruning points and behind sunburned bark;
- leads to weakly-attached secondary growth;
- may lead to unacceptable risk of failures

All of the "topped" trees have since been restoratively pruned to remove weakly connected shoots and re-establish natural tree form. Pruning performed by the Eames Foundation has been excellent; we encourage them to continue this high quality work and cyclical pruning schedule. If continued, the topped trees will become less prone to breakage at the site of topping cuts as the years ensue.

S.U.L.E. (Safe Useful Life Expectancy) is a classification for trees, developed by Jeremy Barrell of Barrell Tree Consultancy and published in 1993. It summarizes information on age, species lifespan, life expectancy, health, and structure in a context of tree management. S.U.L.E. is the length of time that the arborist believes that an individual tree can be retained with an acceptable level of risk based on the information gathered at the time of the inspection.

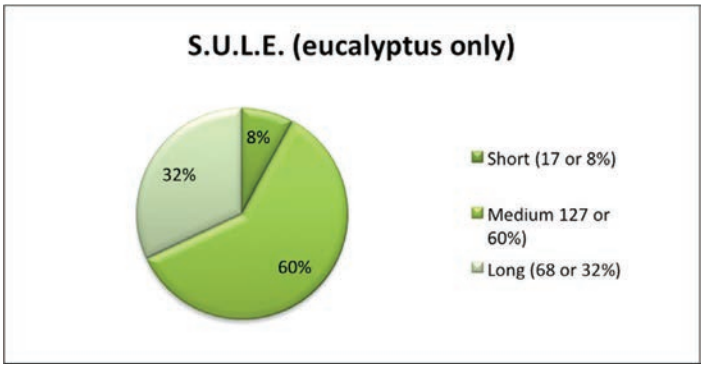
There are five categories:

Long S.U.L.E. – Trees that appear to be retainable with an acceptable level of risk for more than 40 years.

Medium S.U.L.E. – Trees that appear to be retainable with an acceptable level of risk for 15 to 40 years.

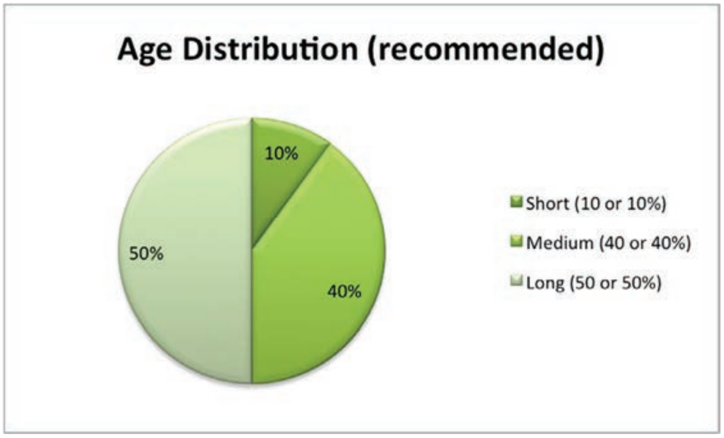
Short S.U.L.E. – Trees that appear to be retainable with an acceptable level of risk for 5 to 15 years.

The following chart summarizes our S.U.L.E. ratings for the eucalyptus trees at the Eames House.



Remove – Trees with a high level of risk that would need removing within the next 5 years.

Young or small trees – (a) trees that are less than 16.4 feet in height, (b) trees that are over 16.4 feet in height but less than 15 years old. In this study we used "long" S.U.L.E. for young or small trees. Traditional urban forestry guidelines[2] aim for a tree population with 10% short S.U.L.E., 40% medium S.U.L.E., and 50% long S.U.L.E. As the above chart indicates, the S.U.L.E. ratings for the Foundation's eucalyptus trees would ideally be adjusted by successional planting, cultivation of volunteer specimens, and careful maintenance. Recommendations must always allow for the historic nature of the eucalyptus grove to have precedence.



[2] Phillips, Jr., Leonard, *Urban Trees: A Guide for Selection, Maintenance, and Master Planning* (New York: McGraw-Hill Book Companies, 1993).

Carlberg ASSOCIATES

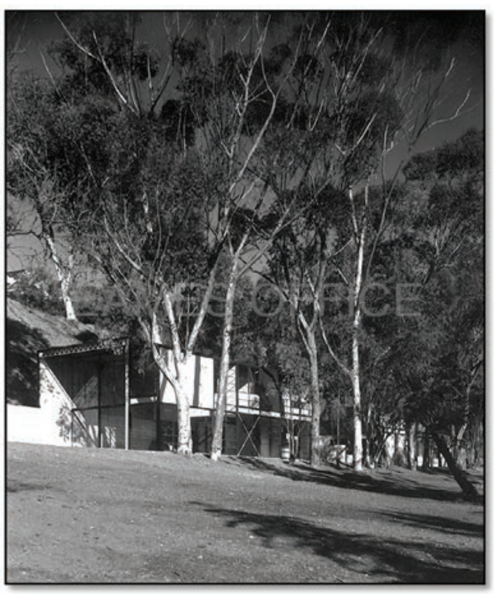
Species Diversity

The eucalyptus trees are historic and defining features of the Eames House. They should and will always be integral to the landscape. To avoid devastation if a serious pest or disease were to strike the eucalypts, it is recommended that the Foundation introduce a diversity of tree species in some of the less prominent areas of the property: the slope behind (to the west of) the residence and studio, as well as the slopes to the east and south of the traversable area of the property. It is generally recommended that urban forest populations contain no more than 30% from any one family, no more than 20% from any one genus and no more than 10% from any one species (Myrtaceae is the family, *Eucalyptus* is the genus, and *camaldulensis* is the dominant species).

Eucalyptus "Volunteers"

We noted 132 "volunteer" eucalypts throughout the property. Based on our conversations with the Foundation, we expect that they will cull the aging and high-risk eucalyptus trees to make room for the volunteer specimens to become defining features in the more prominent areas of the landscape. The individual data sheets and the symbols in Exhibit 'A' define the information and locations of these volunteers.

To re-establish eucalypts in the historic row in front of the residence and studio, it may be possible to propagate seeds from the existing trees and plant in open spaces beneath the larger trees. Trees develop the strongest root systems and are often the most vigorous if grown from seed. Once the young trees are of a sufficient size, the older, senescing trees could be carefully removed.



Risk Management

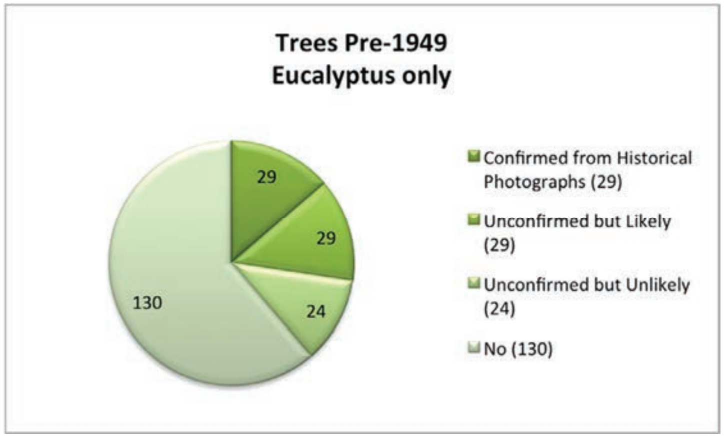
We evaluated the trees from not only a physiological (health) standpoint, but also with an eye toward structural problems. Aside from topping, weak branch connections, past root pruning, tree conformation (lean or aspect), wounds, and other defects can all undermine a tree's structural stability. Of the 15 eucalyptus trees recommended for removal, 11 of them contain sufficient structural defects to warrant their removal (two trees have specific pruning recommendations and two others are in poor health and should be removed). A summary of these recommended removals in set forth in Table 2. Individual tree data can be found in the data sheets. Tree owners, including the Eames Foundation, has their own tolerance for risk, informed by the historic nature of the eucalypts as well as the need to protect historic structures. Some reduction of risk can be achieved through structural pruning.

FEBRUARY 9, 2015 – THE GETTY CONSERVATION INSTITUTE

PAGE 4 THE EAMES HOUSE CONSERVATION PROJECT

Carlberg ASSOCIATES

Tree Age and Longevity



The vast collection of historic photographs assisted us in determining which trees may have preceded the development of the site (~1949). If it is true that the older trees were indeed planted as part of an Abbott Kinney installation, then these trees are upward of 125 years. SelecTree[3] gives a range of 50 to 150 years for a typical eucalyptus lifespan: climate, soils, irrigation, and management all play a role in a tree's lifespan, but many of the subject eucalyptus have short S.U.L.E. ratings and limited lifespans. Succession planning and cultivation of young, volunteer specimens will be on the forefront for the Foundation.

Pruning and Irrigation Management

As noted, the quality of pruning in recent years has been excellent and well within arboricultural industry standards. We encourage the Foundation to continue to contract such high quality work. While the Foundation prunes trees according to available funds, it nevertheless demonstrates a satisfactory standard of care.

Irrigation of the slope behind the residence and studio is by way of Rain Bird® impact sprinklers. Other areas of the property are irrigated by hand or not at all. The Foundation is studying an irrigation retrofit; for the time being, the impact heads, although not water-thrifty, are sufficient. Hand watering of the pots at the toe of the slope must be done carefully to avoid water penetration into the structures or behind the retaining walls. The irrigation system should be tested periodically and any broken pipes or heads be repaired or replaced.

Eucalyptus and Fire

We have observed eucalypts in various stages of health after fires of different severities. Sometimes they are killed straight out (usually the younger trees). Trees that survive often lose their heat-scorched leaves, which are replaced with new leaves in the spring following the fire. The trunks seem to be somewhat resistant to heat and fire. It is important to keep eucalyptus trees pruned of lower branches, so that grass fires (common in southern California) are less likely to reach the upper canopies. Dead twigs and fallen branches should always be picked up and either disposed of or cut into small pieces and left on the ground to decompose, but it would be impossible to keep the slopes free from accumulated leaf litter. Keeping the shrub material (plumbago and cape honeysuckle) pruned to a height of two-three feet, well irrigated, and free of dead material is an important fire management strategy.

[3] "SelecTree," California State Polytechnic University, San Luis Obispo, accessed October 15, 2014, http://selectree.org.

Carlberg ASSOCIATES

<u>Erosion Management and Removal of Invasive Exotics</u>
The future execution of Task 3 will address the management of the other slopes (to the east and south of the property). Maintaining a combination of trees, shrubs, and ground cover is an approved practice to enhance slope stability. The removal of invasive exotic species should also be accomplished.

We have thoroughly enjoyed participating in these two phases of the project and look forward to assisting the Foundation in putting the preceding concepts into practice.

Please feel welcome to contact me at our Santa Monica office if you have any immediate questions or concerns.

Respectfully submitted,

Cy Carlberg, Registered Consulting Arborist
Principal, Carlberg Associates

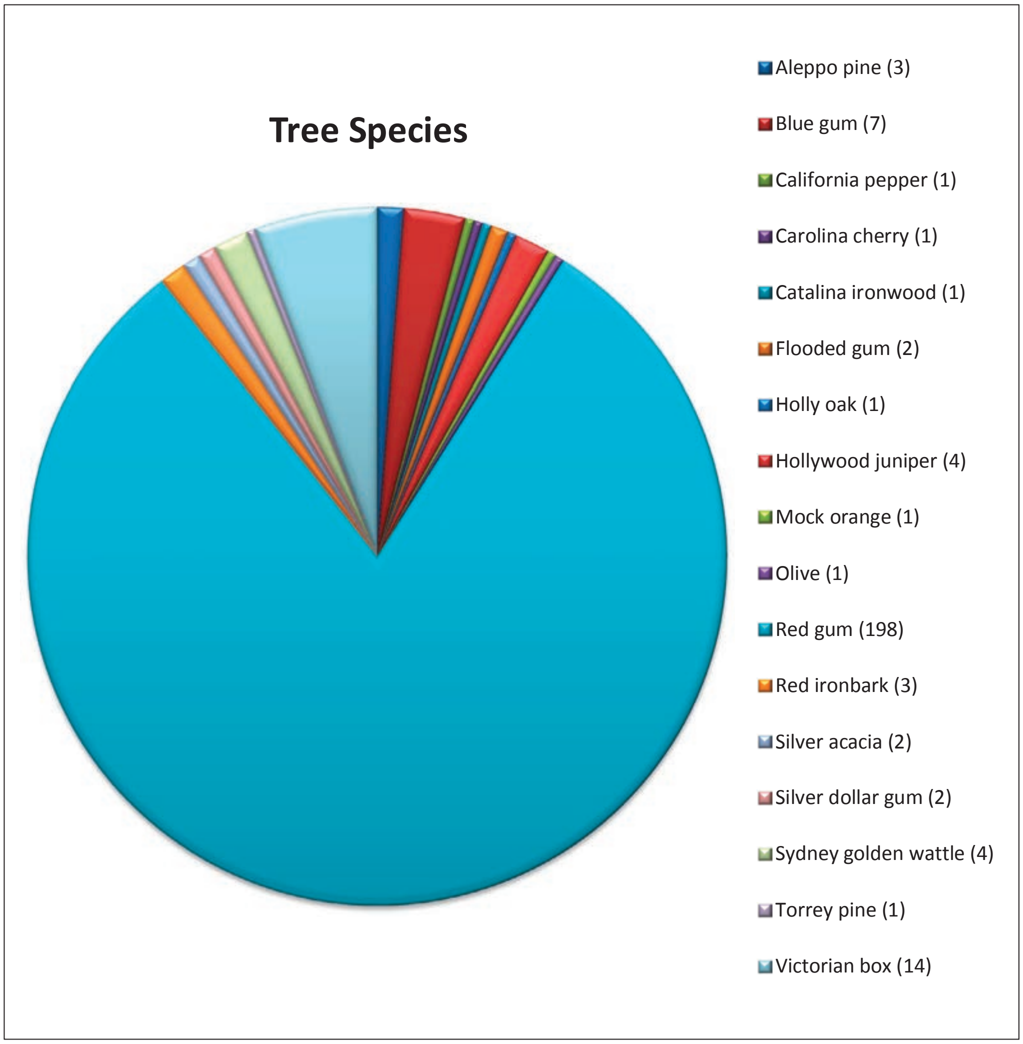
Santa Monica Office
cy@cycarlberg.com

Carlberg ASSOCIATES

TABLE 1 – SUMMARY OF TREE SPECIES THAT HAVE ACTION RECOMMENDED

Common Name	Botanical Name	Total Quantity	Quantity Proposed to be Removed	Comments
Aleppo pine	*Pinus halepensis*	3	0	
Blue gum	*Eucalyptus globulus*	7	0	
California pepper	*Schinus molle*	1	0	
Carolina cherry	*Prunus caroliniana*	1	0	
Catalina ironwood	*Lyonothamnus floribundus ssp. asplenifolius*	1	0	
Flooded gum	*Eucalyptus rudis*	2	0	
Holly oak	*Quercus ilex*	1	0	
Hollywood juniper	*Juniperus chinensis 'Torulosa'*	4	0	
Mock orange	*Pittosporum tobira*	1	0	
Olive	*Olea europaea*	1	0	
Red gum	*Eucalyptus camaldulensis*	198	13*	Tree nos. 64, 77, 123, & 139 are recommended for removal due to poor health; others due to structural issues
Red ironbark	*Eucalyptus sideroxylon*	3	1	Tree no. 141 recommended to be pruned; tree no. 71 recommended for removal
Silver acacia	*Acacia dealbata*	2	0	
Silver dollar gum	*Eucalyptus polyanthemos*	2	0	
Sydney golden wattle	*Acacia longifolia*	4	0	
Torrey pine	*Pinus torreyana*	1	0	Recommended to be restoratively pruned to re-establish conical form
Victorian box	*Pittosporum undulatum*	14	12	Due to irreversible infection by *Xylella* (bacterial leaf scorch)
		246		

*Tree nos. 4, 64, 77, 89, 112, 117, 123, 139, 219, 221, 224, 232, 236


Tree Species
Aleppo pine (3)
Blue gum (7)
California pepper (1)
Carolina cherry (1)
Catalina ironwood (1)
Flooded gum (2)
Holly oak (1)
Hollywood juniper (4)
Mock orange (1)
Olive (1)
Red gum (198)
Red ironbark (3)
Silver acacia (2)
Silver dollar gum (2)
Sydney golden wattle (4)
Torrey pine (1)
Victorian box (14)

Carlberg ASSOCIATES

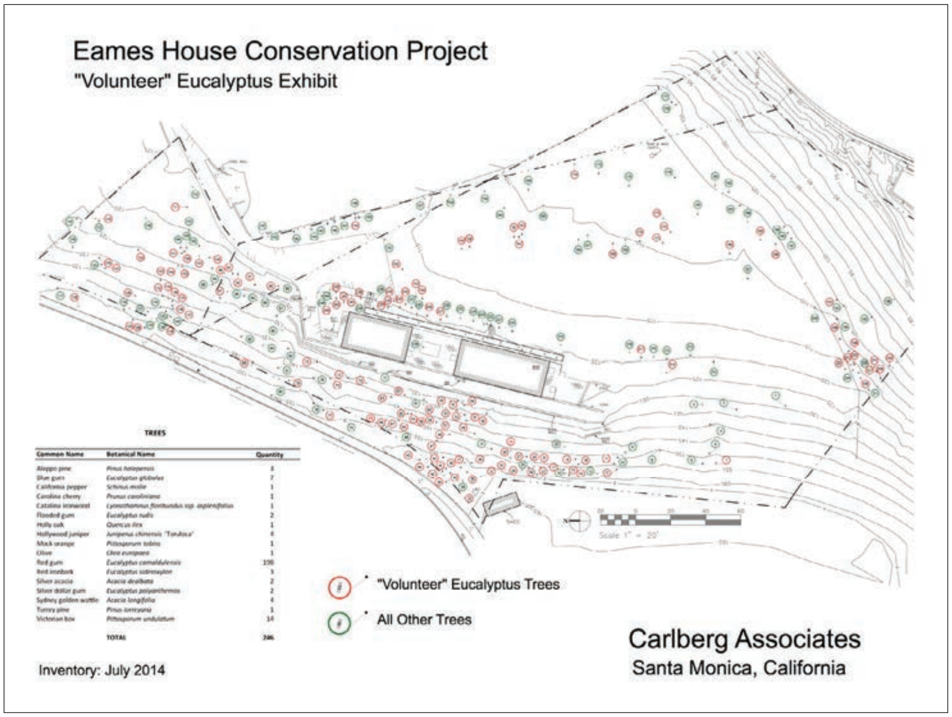
ARBORIST DISCLOSURE STATEMENT

Arborists cannot detect every condition that could possibly lead to the structural failure of a tree. Trees are living organisms that fail in ways we do not fully understand, and conditions are often hidden within trees and below ground. Trees can be managed, but they cannot be controlled with absolute predictability, despite even extraordinarily prudent efforts. No arborist can guarantee that trees will be healthy or safe under all circumstances, or for a specified period of time. Likewise, remedial treatments, like any medicine, cannot be guaranteed.

Trees contribute greatly to our enjoyment and appreciation of life. Nonetheless, they are subject to the laws of gravity and physiological decline. Therefore, neither arborists nor tree owners can be reasonably expected to warrant unfailing predictability or elimination of risk. A certain level of risk must be accepted to experience the benefits that trees provide. By employing a balanced and proportionate approach to tree risk management at the Eames House, and planning for the future succession of the trees, the Foundation will continue the tradition of eucalypts as envisioned by Charles and Ray Eames.

Carlberg ASSOCIATES

EXHIBIT A – VOLUNTEER SPECIES



TREES

Common Name	Botanical Name	Quantity
Aleppo pine	Pinus halepensis	3
Blue gum	Eucalyptus globulus	7
California pepper	Schinus molle	1
Carolina cherry	Prunus caroliniana	1
Catalina ironwood	Lyonothamnus floribundus ssp. asplenifolius	1
Flooded gum	Eucalyptus rudis	2
Holly oak	Quercus ilex	1
Hollywood juniper	Juniperus chinensis 'Torulosa'	4
Mock orange	Pittosporum tobira	1
Olive	Olea europaea	1
Red gum	Eucalyptus camaldulensis	198
Red ironbark	Eucalyptus sideroxylon	3
Silver acacia	Acacia dealbata	2
Silver dollar gum	Eucalyptus polyanthemos	2
Sydney golden wattle	Acacia longifolia	4
Torrey pine	Pinus torreyana	1
Victorian box	Pittosporum undulatum	14
	TOTAL	246

Carlberg ASSOCIATES

TABLE 2 – TREES THAT COMPRISE RECOMMENDATIONS FOR ACTION

Tree #	Common Name	Scientific Name	Diameter at 4.5 feet (dbh) In inches	Height Range	Physiological Condition (A-F)	Structural Condition (A-F)	S.U.L.E.	Pre-1949	Volunteer	Comments	Recommendations	Topped
2	Victorian box	*Pittosporum undulatum*	9.5	0 - 20	C-	B+	Short	No		In irreversible decline; likely drought, disease	Remove	
3	Victorian box	*Pittosporum undulatum*	4 @ 3'	0 - 20	C-	B+	Short	No		In irreversible decline; likely drought, disease	Remove	
4	Red gum	*Eucalyptus camaldulensis*	9, 15, 16, 22	20 - 40	B-	C-	Short	Unconfirmed; likely		Bleeding; large trunk cuts	Remove; no building target (tree would likely not strike building if entire tree failure occurred.	Yes
64	Red gum	*Eucalyptus camaldulensis*	9	0 - 20	C-	D	Short	No	Yes	Epicormic growth; tree may be in decline	Remove	Yes
71	Red ironbark	*Eucalyptus sideroxylon*	10.5, 14	60 +	B+	C+	Short	**Confirmed from historical photos**		Next to building; heavily topped	Phased removal	Yes
77	Red gum	*Eucalyptus camaldulensis*	9, 9	20 - 40	D	D	Short	No	Yes	Almost dead; heavily pruned; codominant stems	Remove	Yes
86	Victorian box	*Pittosporum undulatum*	4.5	0 - 20	D-	D-	Short	No		In irreversible decline; likely drought, disease	Remove	
89	Red gum	*Eucalyptus camaldulensis*	6, 14	20 - 40	B-	C-	Short	Unconfirmed; not likely		Root-pruned; topped; sparse; leans over driveway	Remove	Yes
98	Victorian box	*Pittosporum undulatum*	3, 3, 3.5	0 - 20	C-	C	Short	No		In irreversible decline; likely drought, disease	Remove	Yes
110	Victorian box	*Pittosporum undulatum*	4	0 - 20	C-	B-	Short	No		In irreversible decline; likely drought, disease	Remove	Yes
112	Red gum	*Eucalyptus camaldulensis*	25	40 - 60	B+	B-	Short	Unconfirmed; likely		Leans northeast over driveway	Phased removal	Yes

Carlberg ASSOCIATES

Tree #	Common Name	Scientific Name	Diameter at 4.5 feet (dbh) In inches	Height Range	Physiological Condition (A-F)	Structural Condition (A-F)	S.U.L.E.	Pre-1949	Volunteer	Comments	Recommendations	Topped
117	Red gum	*Eucalyptus camaldulensis*	27	40 - 60	C-	C-	Short	Unconfirmed; likely		Appears to be in decline; large pruning wounds	Phased removal	Yes
123	Red gum	*Eucalyptus camaldulensis*	10	20 - 40	C-	C	Short	No	Yes	Appears to be in decline; epicormic sprouting	Remove	Yes
139	Red gum	*Eucalyptus camaldulensis*	6	0 - 20	C-	C-	Young	No	Yes	~10% canopy remaining from topping	Remove	Yes
141	Red ironbark	*Eucalyptus sideroxylon*	25.5	20 - 40	B+	B	Medium	Unconfirmed; likely		Defect in branch	Keep branches over driveway light in weight	Yes
142	Victorian box	*Pittosporum undulatum*	7	0 - 20	D-	B-	Short	No		In irreversible decline; likely drought, disease	Remove	
143	Victorian box	*Pittosporum undulatum*	4.5	0 - 20	D-	B-	Short	No		In irreversible decline; likely drought, disease	Remove	
145	Victorian box	*Pittosporum undulatum*	4.5	20 - 40	D-	B-	Short	No		In irreversible decline; likely drought, disease	Remove	
146	Victorian box	*Pittosporum undulatum*	4	0 - 20	D-	B-	Short	No		In irreversible decline; likely drought, disease	Remove	
147	Victorian box	*Pittosporum undulatum*	11	20 - 40	D-	B-	Short	No		In irreversible decline; likely drought, disease	Remove	
148	Victorian box	*Pittosporum undulatum*	6.5	0 - 20	D-	B-	Short	No		In irreversible decline; likely drought, disease	Remove	
215	Victorian box	*Pittosporum undulatum*	4, 4, 4, 4, 6	0 - 20	D-	D-	Short	No		In irreversible decline; likely drought, disease	Remove	Yes
219	Red gum	*Eucalyptus camaldulensis*	9, 12.5, 38	60 +	B+	C+	Short	**Confirmed from historical photos**		Spiral (barber pole); leans away from house; two large wounds west and east	Remove	Better pruning than most

Carlberg ASSOCIATES

Tree #	Common Name	Scientific Name	Diameter at 4.5 feet (dbh) In inches	Height Range	Physiological Condition (A-F)	Structural Condition (A-F)	S.U.L.E.	Pre-1949	Volunteer	Comments	Recommendations	Topped
221	Red gum	*Eucalyptus camaldulensis*	49	60 +	B+	B	Short	**Confirmed from historical photos**		History of breakage; significant lean toward house.	Remove	Better pruning than most
224	Red gum	*Eucalyptus camaldulensis*	12, 32.5	60 +	B+	C	Short	**Confirmed from historical photos**		Dead wood tissue within spiral (barber pole)	1st removal of this row	Better pruning than most
228	Torrey pine	*Pinus torreyana*	8	20 - 40	B-	B	Medium	No		Misshapen from prior pruning; could be restoratively pruned	Restoratively prune	
232	Red gum	*Eucalyptus camaldulensis*	6	0 - 20	B-	C-	Young	No	Yes	Leans and bark is split; mechanical damage on trunk	Phased removal*	
236	Red gum	*Eucalyptus camaldulensis*	12.5, 26	60 +	B+	C+	Short	**Confirmed from historical photos**		Leans to east over driveway; history of breakage	Phased removal	Yes

* - Phased removal refers to a strategy that could be applied by the Foundation. Realizing that these trees are historic and significant to the residence, tree removal, especially those adjacent to the residence, will have a profound impact. I have identified those that in my professional opinion can be deferred, as "phased."

EXPLANATION OF CODES

Physiological Condition

A - Healthy crown with normal shoot growth during current season—good leaf color. Condition is very good—no decline noted.

B - Crown with a moderate level of pest infestation or shoot growth that is less than reasonably expected. Leaf color may be less than optimal. Still healthy, but with moderately diminished vigor due to pest or minor foliar and/or twig disease. Good condition—no significant decline noted.

C - Significant small deadwood in outer crown areas; decreased shoot growth and diminished leaf color and mass. Significant pest or foliar and/or twig disease that is compromising the tree. Tree may be in early decline. Treatment or cultural changes may improve conditions.

D - Significant dieback of wood in crown, possibly accompanied by epicormic sprouting, bark checking, significant cracks, or other sign of irreversible decline. Severe levels of pests and/or disease. Tree is likely in an irreversible decline and treatment or cultural changes are not likely to improve conditions.

F - Dead or in spiral of decline with very little foliage or other signs of life.

Structural Condition

A - Full or partial failure is apparently unlikely.

B - Risk of full or partial failure is slightly elevated but is still apparently unlikely.

C - Risk of full or partial failure appears to be only moderately elevated, and no preventive or corrective action is necessarily indicated at this time.

D - Risk of full or partial failure appears to be moderately elevated, and tree should be scheduled for preventive or corrective action.

E - Risk of full or partial failure appears to be greatly elevated, and tree should be scheduled for corrective intervention or removal.

Carlberg ASSOCIATES

CY CARLBERG

CARLBERG ASSOCIATES
2402 California Avenue, Santa Monica, California 90403
(310) 453-TREE
cy@cycarlberg.com

Education	B.S., Landscape Architecture, California State Polytechnic University, Pomona, 1985 Graduate, Arboricultural Consulting Academy, American Society of Consulting Arborists, Chicago, Illinois, February 2002 Graduate, Municipal Forestry Institute, Lied, Nebraska, 2012
Experience	Consulting Arborist, Carlberg Associates, 1998-present Manager of Grounds Services, California Institute of Technology, Pasadena, 1992-1998 Director of Grounds, Scripps College, Claremont, 1988-1992
Certificates	Certified Arborist (#WE-0575A), International Society of Arboriculture, 1990 Registered Consulting Arborist (#405), American Society of Consulting Arborists, 2002 Certified Urban Forester (#013), California Urban Forests Council, 2004 Certified Tree Risk Assessor (#1028), International Society of Arboriculture, 2011

AREAS OF EXPERTISE

Ms. Carlberg is experienced in the following areas of tree management and preservation:

- Tree health and risk assessment
- Master Planning
- Tree inventories and reports to satisfy jurisdictional requirements
- Expert Testimony
- Post-fire assessment, valuation, and mitigation for trees and native plant communities
- Value assessments for native and non-native trees
- Pest and disease identification
- Guidelines for oak preservation
- Selection of appropriate tree species
- Planting, pruning, and maintenance specifications
- Tree and landscape resource mapping – GPS, GIS, and AutoCAD
- Planning Commission, City Council, and community meetings representation

PREVIOUS CONSULTING EXPERIENCE

Ms. Carlberg has overseen residential and commercial construction projects to prevent damage to protected and specimen trees. She has thirty-five years of experience in arboriculture and horticulture and has performed tree health evaluation, value and risk assessment, and expert testimony for private clients, government agencies, cities, school districts, and colleges. Representative clients include:

The Huntington Library and Botanical Gardens
The Los Angeles Zoo and Botanical Gardens
The Rose Bowl and Brookside Golf Course, Pasadena
Walt Disney Concert Hall and Gardens
The Art Center College of Design, Pasadena
Pepperdine University
Loyola Marymount University
The Claremont Colleges (Pomona, Scripps, CMC, Harvey Mudd, Claremont Graduate University, Pitzer, Claremont University Center)
Quinn, Emanuel, Urquhart and Sullivan (attorneys at law)
The City of Claremont
The City of Beverly Hills
The City of Pasadena
The City of Los Angeles
The City of Santa Monica
Santa Monica/Malibu Unified School District
San Diego Gas & Electric
Los Angeles Department of Water and Power
Rancho Santa Ana Botanic Garden, Claremont
Latham & Watkins, LLP (attorneys at law)

AFFILIATIONS

Ms. Carlberg serves with the following national, state, and community professional organizations:

- California Urban Forests Council, Board Member, 1995-2006
- Street Tree Seminar, Past President, 2000-present
- American Society of Consulting Arborists Academy, Faculty Member, 2003-2005, 2014
- American Society of Consulting Arborists, Board of Directors, 2013-Present
- Member, Los Angeles Oak Woodland Habitat Conservation Strategic Alliance, 2010-present

APPENDIX 6.1

Tree Inventory and Evaluation

Carlberg ASSOCIATES

Horticulturists and Registered Consulting ARBORISTS

EAMES HOUSE CONSERVATION PROJECT
THE EAMES HOUSE
203 NORTH CHAUTAUQUA BOULEVARD
PACIFIC PALISADES, CALIFORNIA 90272

SUBMITTED TO:

THE GETTY CONSERVATION INSTITUTE
ATTN: SUSAN MACDONALD
HEAD, FIELD PROJECTS
1200 GETTY CENTER DRIVE, SUITE 700
LOS ANGELES, CALIFORNIA 90049-1684

PREPARED BY:

CY CARLBERG
ASCA REGISTERED CONSULTING ARBORIST #405
ISA CERTIFIED ARBORIST #WE 0575A
ISA QUALIFIED TREE RISK ASSESSOR
CAUFC CERTIFIED URBAN FORESTER #013

Santa Monica Office
2402 California Avenue
Santa Monica, California 90403
Office: 310.453.TREE (8733)

Sierra Madre Office
80 West Sierra Madre Boulevard, #241
Sierra Madre, California 91024
Office: 626.248.8977

www.cycarlberg.com

OCTOBER 2014

Carlberg ASSOCIATES
Horticulturists and
Registered Consulting
ARBORISTS

October 16, 2014

The Getty Conservation Institute
Attn: Susan Macdonald
Head, Field Projects
1200 Getty Center Drive, Suite 700
Los Angeles, California 90049-1684

Re: Eames House Conservation Project

Dear Ms. Macdonald,

It is with pleasure that we submit these tree data sheets, which comprise the bulk of our work so far on the Eames House Conservation Plan. The graphic exhibits are part of a separate submittal.

We inventoried 246 trees throughout the property; an astounding 212 (86% of the tree population) are eucalypts. Many have naturalized and are sprouting from seed or distal roots from existing trees; we refer to these as “volunteers.” Some were identified in circa 1949 photographs as mature trees, indicating that they may have been part of the Abbott Kinney planting in the late 1800s. Part of our future conversation will be how to make sense of these many volunteers, and how we begin to phase out some of the older, high-risk trees. The Eames Foundation will assist us in these recommendations, by defining their relative tolerance of risk adjacent to the residence and where the public traverses the site.

In general, most trees are in good condition and are certainly defining features in the landscape. Previous “topping” of trees has been replaced by excellent pruning practices.

The data we have collected thus far helps us gain a better understanding of the quality/condition, remaining lifespans, and suitability of the tree, shrub, and groundcover population currently existing on the property. Based on this information, and in future phases, we can develop a plan that addresses succession of older plants to new, plant species that were popular during the era in which the Eames lived and worked, and plants that provide required screening, noise abatement, and slope stabilization.

Santa Monica Office
2402 California Avenue
Santa Monica, California 90403
Office: 310.453.TREE (8733)

Sierra Madre Office
80 West Sierra Madre Boulevard, #241
Sierra Madre, California 91024
Office: 626.248.8977

www.cycarlberg.com

Carlberg ASSOCIATES

Wildfire is a major concern for the Eames Foundation, and eucalyptus trees, with their preponderance of oils and gums, can be problematic. With appropriate pruning and irrigation practices, the potential for catastrophic wildfire damage can be reduced. Further, some of the older trees are reaching the end of their useful lifespan, and will eventually begin to decline. Succession planning for older trees will avoid the decline of all trees at one time.

The native hillside areas adjacent to the residence can and should be addressed to exploit their optimal use for protection against soil erosion, and reduction of fire potential by creating defensible space. Future tasks will address these kinds of issues in detail. The landscape plan would address specific plant species that are best suited for wildfire-prone areas.

We look forward to assisting the Foundation as they move forward with future phases of the Conservation Plan.

Respectfully submitted,

Cy Carlberg, Registered Consulting Arborist
Principal, Carlberg Associates

Santa Monica Office
cy@cycarlberg.com

Carlberg ASSOCIATES

EXHIBIT A – TREE EVALUATION SHEETS

Explanation of Terms:

Tree Number – Unique number assigned to each tree; also appears on graphic exhibits

Common Name: Commonly used name for the plant

Botanical Name: Binomial (Genus and Species)

Trunk Diameter: The diameter of a trunk measured at 4.5 feet above natural grade. Often used as a representation of tree size.

S.U.L.E. – Safe Useful Life Expectancy

Physiological Condition: Tree health; general state of well-being, obvious presence of disease or pests – that which describes normal growth and development.

Structural Condition: The relative health of a tree's root and branch architecture. Distinctly different from physiological condition. Used when evaluating risk.

Volunteer (Y/N): Naturalized trees; may have grown from seed or distal roots from existing trees.

Carlberg ASSOCIATES

Tree Evaluation Form – Eames House

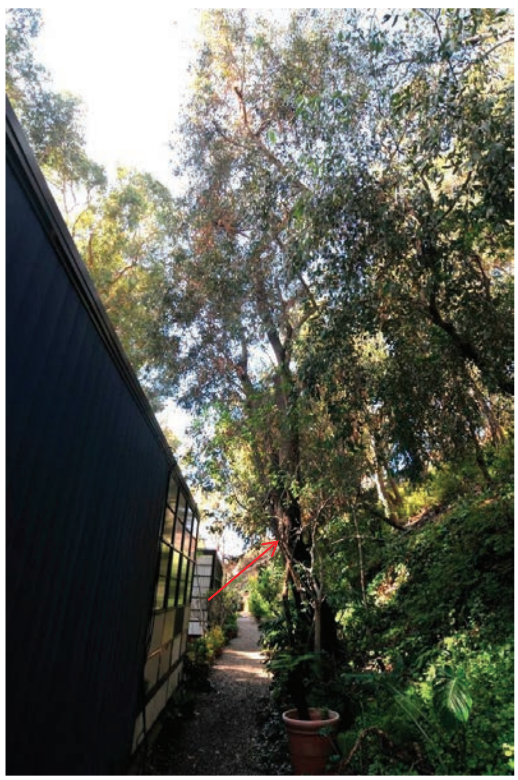
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

Tree Number:	2			**Common Name:** **Botanical Name:**	Victorian box *Pittosporum undulatum*		
Trunk Diameter: (in inches)	9.5			**Approximate Height Range:** (in feet)	0 - 20	**S.U.L.E. Rating:**	Short
Physiological Condition:	C-	**Structural Condition:**	B+	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:	In irreversible decline; likely drought, disease						
Recommendations:	Remove						

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

Tree Number:	71	**Common Name:** / **Botanical Name:**	Red ironbark / *Eucalyptus sideroxylon*		
Trunk Diameter: (in inches)	10.5, 14	**Approximate Height Range:** (in feet)	60+	**S.U.L.E. Rating:**	Short
Physiological Condition:	B+	**Structural Condition:**	C+	**Volunteer:** (Y/N)	No
Pre-1949: (Y/N)	**Confirmed from historical photos**				
Comments:	Next to building; heavily topped				
Recommendations:	Phased removal				



Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	82		**Common Name:** **Botanical Name:**	Flooded gum *Eucalyptus rudus*			
Trunk Diameter: (in inches)	4, 8, 10.5		**Approximate Height Range:** (in feet)	20 - 40		**S.U.L.E. Rating:**	Medium
Physiological Condition:	B	**Structural Condition:**	B-	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	Unconfirmed; not likely
Comments:	Bees in trunk; may indicate large pocket of decay; wouldn't damage much if this section failed. (no target)						
Recommendations:							

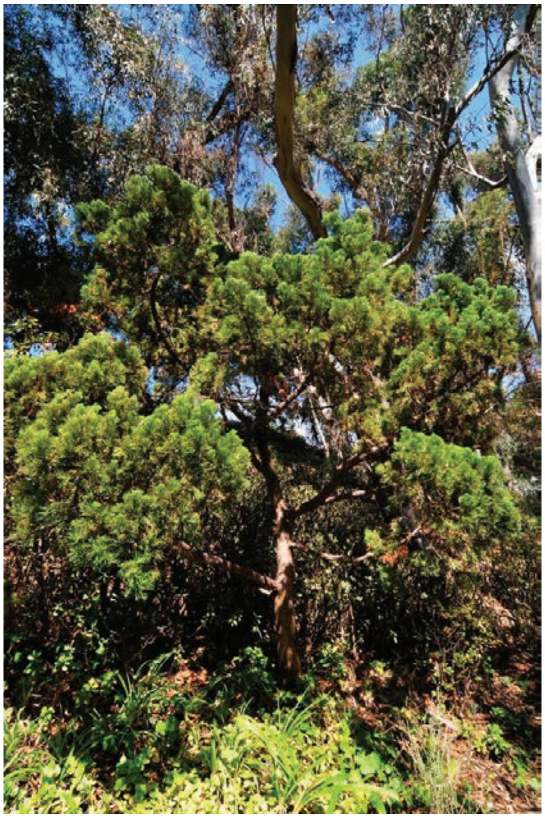
OCTOBERR 2014 / EAMES HOUSE CONSERVATION PROJECT
TREE DATA SHEETS

PAGE 85

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

Tree Number:	94		**Common Name:** **Botanical Name:**	Hollywood juniper *Juniperus chinensis* 'Torulosa'			
Trunk Diameter: (in inches)	4.5		**Approximate Height Range:** (in feet)	0 - 20		**S.U.L.E. Rating:**	Medium
Physiological Condition:	A-	**Structural Condition:**	A-	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:							
Recommendations:							



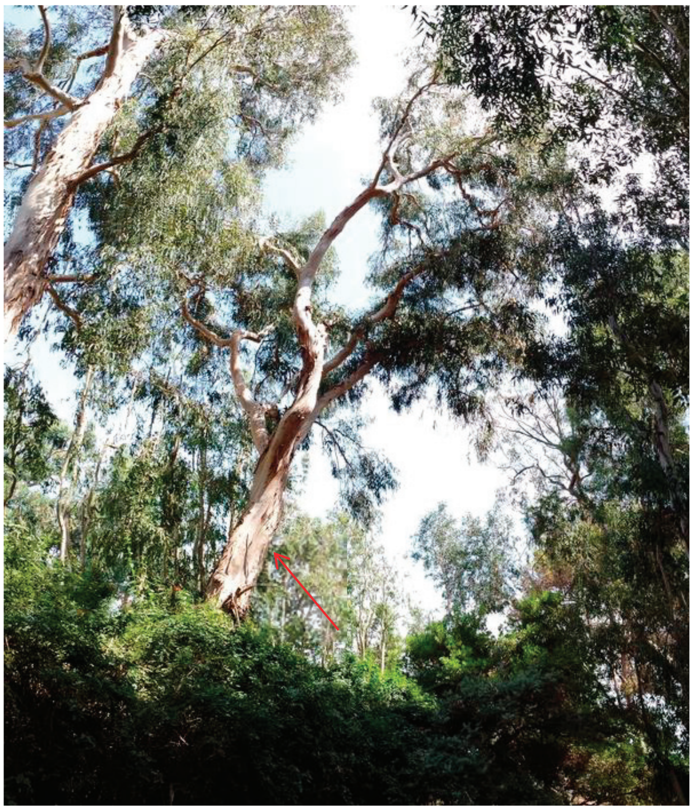
Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

Tree Number:	102			**Common Name:** **Botanical Name:**	Mock orange *Pittosporum tobira*		
Trunk Diameter: (in inches)	3, 3.5			**Approximate Height Range:** (in feet)	0 - 20	**S.U.L.E. Rating:**	Long
Physiological Condition:	A-	**Structural Condition:**	B-	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:	Topped						
Recommendations:							

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	159		**Common Name:** **Botanical Name:**	Blue gum *Eucalyptus globulus*			
Trunk Diameter: (in inches)	~35		**Approximate Height Range:** (in feet)	60+		**S.U.L.E. Rating:**	Medium
Physiological Condition:	B+	**Structural Condition:**	B+	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	Unconfirmed; likely
Comments:	Nice tree; not topped						
Recommendations:							



Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	160	**Common Name:** **Botanical Name:**	Silver acacia *Acacia dealbata*				
Trunk Diameter: (in inches)	4	**Approximate Height Range:** (in feet)	0 - 20			**S.U.L.E. Rating:**	Medium
Physiological Condition:	A-	**Structural Condition:**	B	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:	Leans to the south						
Recommendations:							

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	164		**Common Name:** **Botanical Name:**	Sydney golden wattle *Acacia longifolia*			
Trunk Diameter: (in inches)	11		**Approximate Height Range:** (in feet)	20 - 40		**S.U.L.E. Rating:**	Medium
Physiological Condition:	A-	**Structural Condition:**	B-	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:	Lying on side; still "healthy"						
Recommendations:							

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	175		**Common Name:** **Botanical Name:**	Carolina cherry *Prunus caroliniana*			
Trunk Diameter: (in inches)	6.5, 7		**Approximate Height Range:** (in feet)	20 - 40		**S.U.L.E. Rating:**	Long
Physiological Condition:	A-	**Structural Condition:**	B+	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:							
Recommendations:							

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES HOUSE 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	179			**Common Name:** **Botanical Name:**	Aleppo pine *Pinus halepensis*		
Trunk Diameter: (in inches)	21			**Approximate Height Range:** (in feet)	60+	**S.U.L.E. Rating:**	Medium
Physiological Condition:	B-	**Structural Condition:**	B+	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	Unconfirmed; not likely
Comments:							
Recommendations:							

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	181	**Common Name:** **Botanical Name:**	Olive *Olea europaea*				
Trunk Diameter: (in inches)	4, 4, 4, 4, 6	**Approximate Height Range:** (in feet)	0 - 20			**S.U.L.E. Rating:**	Long
Physiological Condition:	B+	**Structural Condition:**	B+	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:							
Recommendations:							

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

Tree Number:	182		**Common Name:** / **Botanical Name:**	Catalina ironwood / *Lyonothamnus floribundus*			
Trunk Diameter: (in inches)	3, 4, 4		**Approximate Height Range:** (in feet)	0 - 20		**S.U.L.E. Rating:**	Medium
Physiological Condition:	B	**Structural Condition:**	B	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No

Comments:

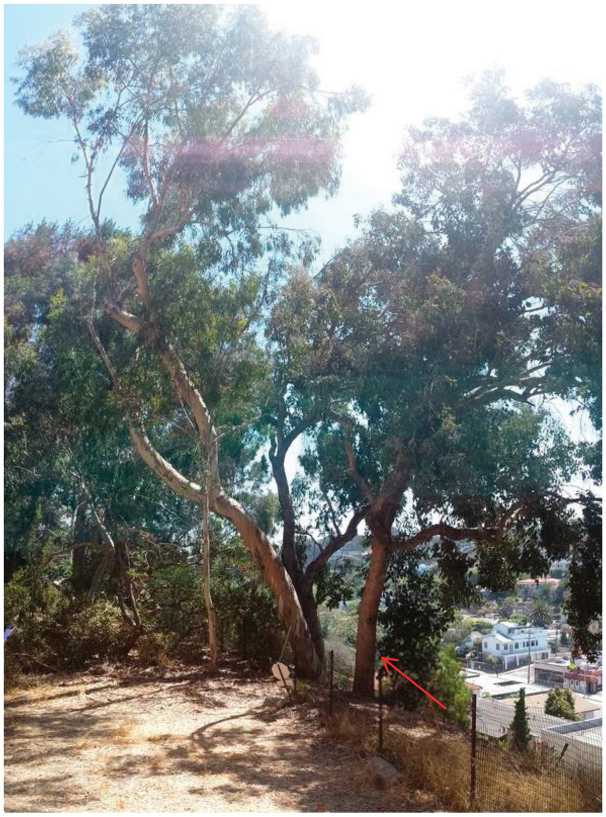
Recommendations:

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	187		**Common Name:** **Botanical Name:**	California pepper *Schinus molle*			
Trunk Diameter: (in inches)	4, 4, 4, 6		**Approximate Height Range:** (in feet)	0 - 20		**S.U.L.E. Rating:**	Medium
Physiological Condition:	B	**Structural Condition:**	A-	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	**Confirmed from historical photos**
Comments:							
Recommendations:							

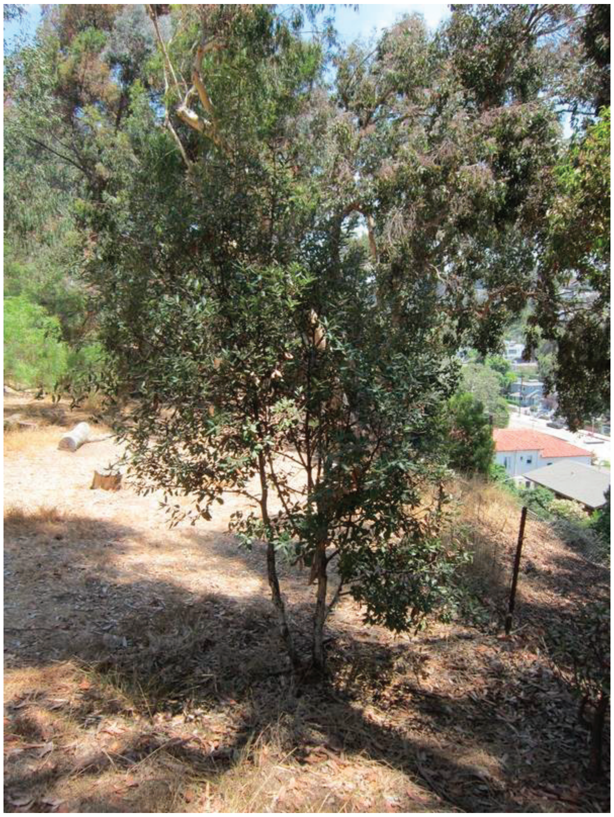
Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	191	**Common Name:** **Botanical Name:**	Silver dollar gum *Eucalyptus polyanthemos*				
Trunk Diameter: (in inches)	14.5	**Approximate Height Range:** (in feet)	20 - 40			**S.U.L.E. Rating:**	Medium
Physiological Condition:	A-	**Structural Condition:**	B+	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	Unconfirmed; not likely
Comments:	Nice tree						
Recommendations:							



Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	200		**Common Name:** **Botanical Name:**	Holly oak Quercus ilex			
Trunk Diameter: (in inches)	2. 2.5		**Approximate Height Range:** (in feet)	0 - 20		**S.U.L.E. Rating:**	Small
Physiological Condition:	A-	**Structural Condition:** A	**Volunteer:** (Y/N)	No		**Pre-1949:** (Y/N)	No
Comments:							
Recommendations:							



Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	208		**Common Name:** **Botanical Name:**	Red gum *Eucalyptus camaldulensis*			
Trunk Diameter: (in inches)	6		**Approximate Height Range:** (in feet)	20 - 40		**S.U.L.E. Rating:**	Long
Physiological Condition:	B+	**Structural Condition:**	B	**Volunteer:** (Y/N)	Yes	**Pre-1949:** (Y/N)	No
Comments:	Shaded						
Recommendations:							

Carlberg ASSOCIATES

Tree Evaluation Form – Eames House
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

Tree Number:	224		**Common Name:** **Botanical Name:**	Red gum *Eucalyptus camaldulensis*			
Trunk Diameter: (in inches)	12, 32.5		**Approximate Height Range:** (in feet)	60+		**S.U.L.E. Rating:**	Short
Physiological Condition:	B+	**Structural Condition:**	C-	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	Confirmed from historical photos
Comments:	Dead wood tissue within spiral (barber pole); better pruning than most						
Recommendations:	1st removal of this row						



Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

Tree Number:	226		**Common Name:**	Red gum			
			Botanical Name:	*Eucalyptus camaldulensis*			
Trunk Diameter: (in inches)	5, 22		**Approximate Height Range:** (in feet)	60+		**S.U.L.E. Rating:**	Medium
Physiological Condition:	B+	**Structural Condition:**	B	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	Confirmed from historical photos
Comments:	Better pruning than most						
Recommendations:							

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House 203 Chautauqua Boulevard, Los Angeles, California Date of Inspection: July 2014							
Tree Number:	228		**Common Name:** **Botanical Name:**	Torrey pine *Pinus torreyana*			
Trunk Diameter: (in inches)	8		**Approximate Height Range:** (in feet)	20 - 40		**S.U.L.E. Rating:**	Medium
Physiological Condition:	B-	**Structural Condition:**	B	**Volunteer:** (Y/N)	No	**Pre-1949:** (Y/N)	No
Comments:	Misshapen from prior pruning; could be restoratively pruned						
Recommendations:	Restoratively prune						

OCTOBERR 2014 / EAMES HOUSE CONSERVATION PROJECT
TREE DATA SHEETS

PAGE 231

Carlberg ASSOCIATES

TREE EVALUATION FORM – EAMES House
203 Chautauqua Boulevard, Los Angeles, California
Date of Inspection: July 2014

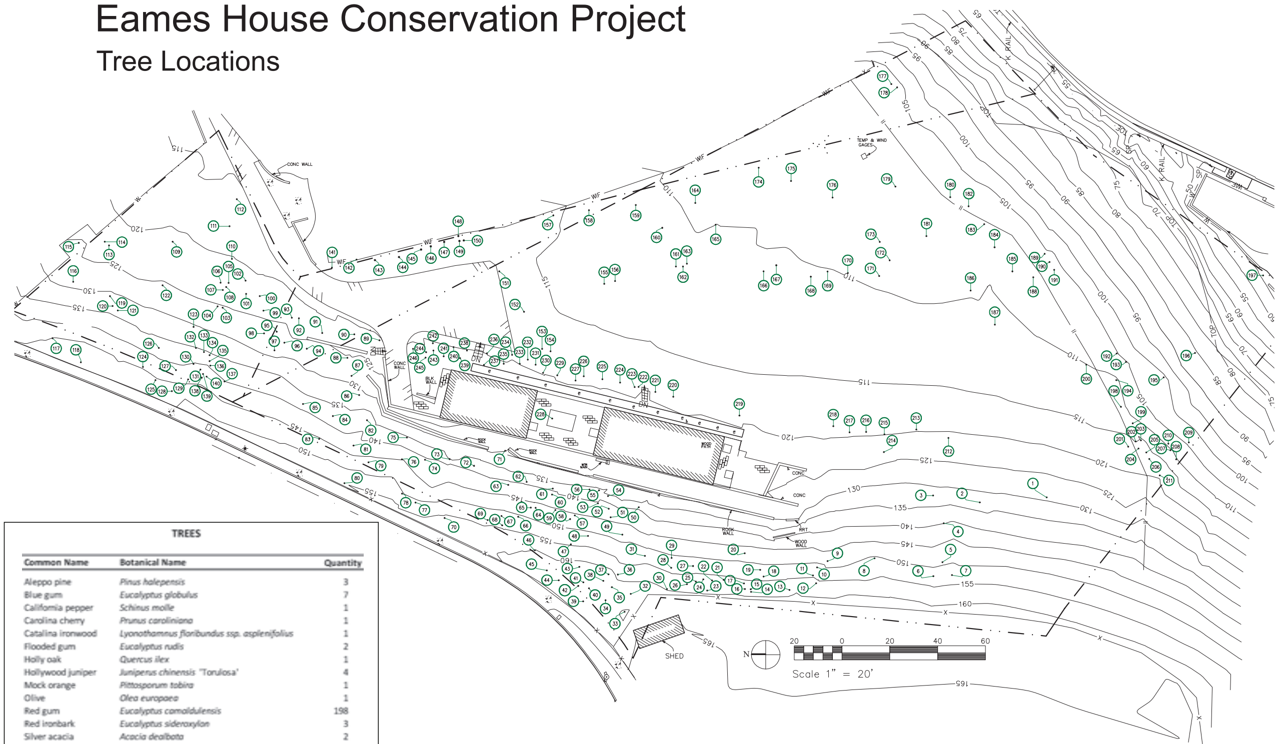
Tree Number:	240			**Common Name:** / **Botanical Name:**	Red gum / *Eucalyptus camaldulensis*		
Trunk Diameter: (in inches)	7			**Approximate Height Range:** (in feet)	20 - 40	**S.U.L.E. Rating:**	Medium
Physiological Condition:	B	**Structural Condition:**	C-	**Volunteer:** (Y/N)	Yes	**Pre-1949:** (Y/N)	No
Comments:	Large basal trunk wound with associated wood decay; leans to east; topped						
Recommendations:							

APPENDIX 6.2

Tree Location Map

Eames House Conservation Project

Tree Locations



TREES

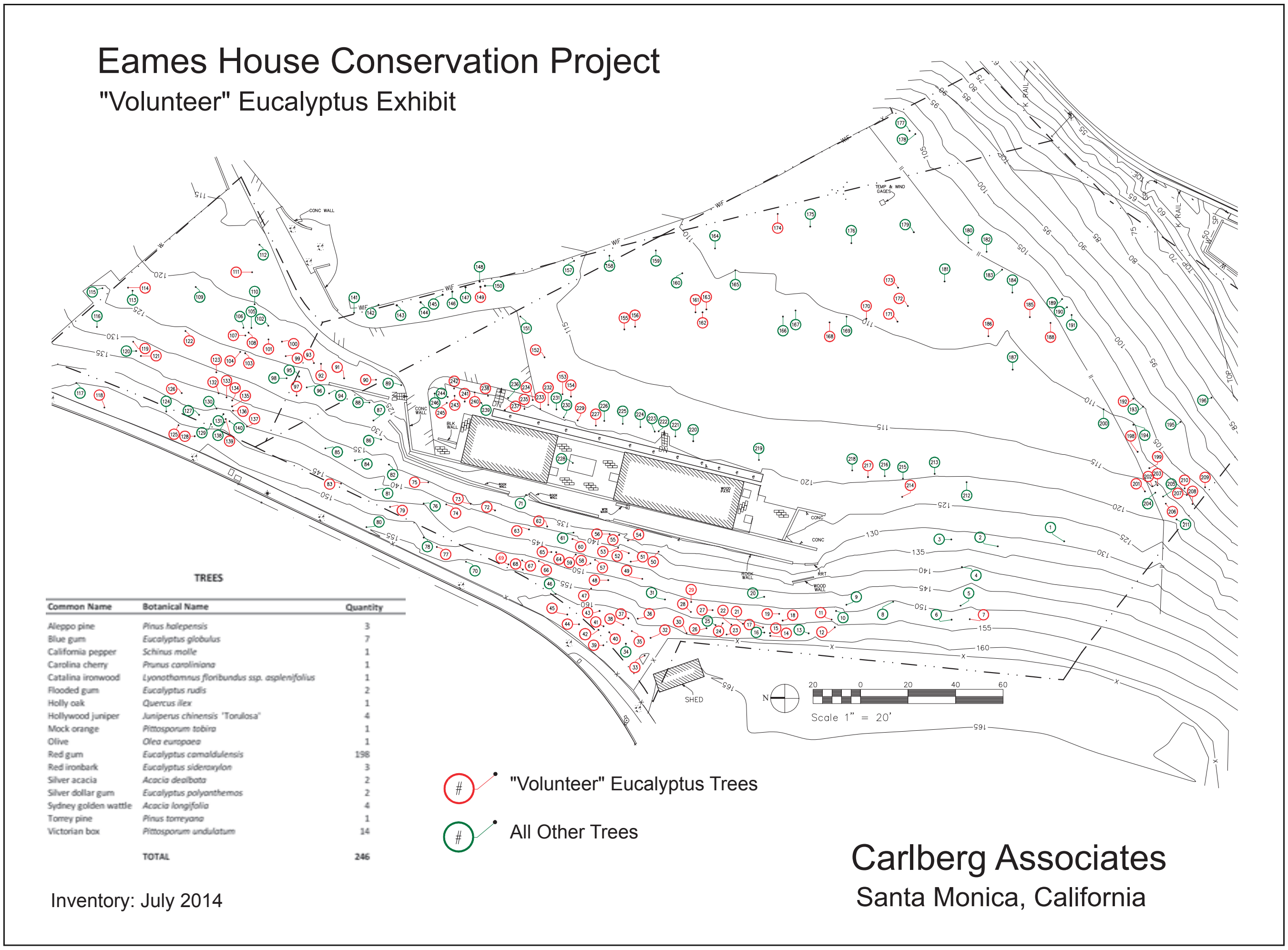
Common Name	Botanical Name	Quantity
Aleppo pine	*Pinus halepensis*	3
Blue gum	*Eucalyptus globulus*	7
California pepper	*Schinus molle*	1
Carolina cherry	*Prunus caroliniana*	1
Catalina ironwood	*Lyonothamnus floribundus ssp. asplenifolius*	1
Flooded gum	*Eucalyptus rudis*	2
Holly oak	*Quercus ilex*	1
Hollywood juniper	*Juniperus chinensis* 'Torulosa'	4
Mock orange	*Pittosporum tobira*	1
Olive	*Olea europaea*	1
Red gum	*Eucalyptus camaldulensis*	198
Red ironbark	*Eucalyptus sideroxylon*	3
Silver acacia	*Acacia dealbata*	2
Silver dollar gum	*Eucalyptus polyanthemos*	2
Sydney golden wattle	*Acacia longifolia*	4
Torrey pine	*Pinus torreyana*	1
Victorian box	*Pittosporum undulatum*	14
	TOTAL	**246**

Inventory: July 2014

Carlberg Associates
Santa Monica, California

APPENDIX 6.3

Volunteer Eucalyptus Map



TREES

Common Name	Botanical Name	Quantity
Aleppo pine	*Pinus halepensis*	3
Blue gum	*Eucalyptus globulus*	7
California pepper	*Schinus molle*	1
Carolina cherry	*Prunus caroliniana*	1
Catalina ironwood	*Lyonothamnus floribundus ssp. asplenifolius*	1
Flooded gum	*Eucalyptus rudis*	2
Holly oak	*Quercus ilex*	1
Hollywood juniper	*Juniperus chinensis* 'Torulosa'	4
Mock orange	*Pittosporum tobira*	1
Olive	*Olea europaea*	1
Red gum	*Eucalyptus camaldulensis*	198
Red ironbark	*Eucalyptus sideroxylon*	3
Silver acacia	*Acacia dealbata*	2
Silver dollar gum	*Eucalyptus polyanthemos*	2
Sydney golden wattle	*Acacia longifolia*	4
Torrey pine	*Pinus torreyana*	1
Victorian box	*Pittosporum undulatum*	14
	TOTAL	**246**

APPENDIX 6.4

Shrubs, Groundcovers, Potted Plants, and Hardscape Materials

Map Designation	Name	Botanical Name	Comments
	Grecian bay laurel	*Laurus nobilis*	
	Algerian ivy	*Hedera canariensis*	
S9	Fortnight lily	*Moraea iridiodes*	
	Algerian ivy	*Hedera canariensis*	
	English ivy	*Hedera helix*	
	Vinca	*Vinca minor*	
	Star jasmine	*Trachelospermum jasminoides*	
S10	Pampus grass	*Cortaderia selloana*	
S11	Carolina cherry	*Prunus caroliniana*	
	Nastiurtium	*Tropaeolum majus*	
S12	Algerian ivy	*Hedera canariensis*	
	Jade plant	*Crassula ovata*	
	Hottentot fig	*Carpobrotus edulis*	
S13	Plumbago	*Plumbago auriculata*	
	Jade plant	*Crassula ovata*	
	Algerian ivy	*Hedera canariensis*	
S14	Bigleaf periwinkle	*Vinca major*	
	Algerian ivy	*Hedera canariensis*	
	Cape honeysuckle	*Tecomaria capensis*	
	Fairy crassula	*Crassula multicava*	
	Plumbago	*Plumbago auriculata*	
S15	Algerian ivy	*Hedera canariensis*	
	English ivy	*Hedera helix*	
	Sword fern	*Polystichum munitum*	
	Indian hawthorn	*Raphiolepis indica*	
	Vinca	*Vinca minor*	
S16	Bermuda grass	*Cynodon sp.*	
	Spider plant	*Chlorophytum comosum*	
	Palmer's sedum	*Seum palmeri*	
S17	Fescue	*Festuca sp.*	

2 February 2015

Eames House Shrub, Pots, and Hardscape

Map Designation	Name	Botanical Name	Comments
	Grecian bay laurel	*Laurus nobilis*	
	Algerian ivy	*Hedera canariensis*	
S9	Fortnight lily	*Moraea iridiodes*	
	Algerian ivy	*Hedera canariensis*	
	English ivy	*Hedera helix*	
	Vinca	*Vinca minor*	
	Star jasmine	*Trachelospermum jasminoides*	
S10	Pampus grass	*Cortaderia selloana*	
S11	Carolina cherry	*Prunus caroliniana*	
	Nastiurtium	*Tropaeolum majus*	
S12	Algerian ivy	*Hedera canariensis*	
	Jade plant	*Crassula ovata*	
	Hottentot fig	*Carpobrotus edulis*	
S13	Plumbago	*Plumbago auriculata*	
	Jade plant	*Crassula ovata*	
	Algerian ivy	*Hedera canariensis*	
S14	Bigleaf periwinkle	*Vinca major*	
	Algerian ivy	*Hedera canariensis*	
	Cape honeysuckle	*Tecomaria capensis*	
	Fairy crassula	*Crassula multicava*	
	Plumbago	*Plumbago auriculata*	
S15	Algerian ivy	*Hedera canariensis*	
	English ivy	*Hedera helix*	
	Sword fern	*Polystichum munitum*	
	Indian hawthorn	*Raphiolepis indica*	
	Vinca	*Vinca minor*	
S16	Bermuda grass	*Cynodon sp.*	
	Spider plant	*Chlorophytum comosum*	
	Palmer's sedum	*Seum palmeri*	
S17	Fescue	*Festuca sp.*	

2 February 2015

Eames House Shrub, Pots, and Hardscape

Map Designation	Name	Botanical Name	Comments
P1	Victorian box	*Pittosporum undulatum*	Terra cotta pots + whiskey barrels (~31)
	Hollywood juniper	*Juniperus chinensis* 'Torulosa'	Terra cotta pots range from 4 to 18 inches in diameter (at lip)
	Papyrus		
	New Guinea impatiens	*Impatiens hawkeri*	
	Maidenhair fern	*Adiantum spp.*	
	Needlepoint ivy	*Hedera helix* 'Needlepoint'	
	Begonia	*Begonia sp.*	
	Geranium	*Pelargonium sp.*	
	Spider plant	*Chlorophytum comosum*	
	Shrub rose	*Rosa sp.*	
	Chain fern	*Woodwardia fimbriata*	
	Kentia palm	*Howea forsteriana*	
	Dwarf schefflera	*Schefflera arboricola*	
	Philodendron	*Philodendron bipinnatifidum*	
	Christmas cactus	Schlumbergera sp.	
P2	Azalea	*Rhododendron sp.*	~62 Terra Cotta pots 6-18" diamter lip
	Spider plant	*Chlorophytum comosum*	
	English ivy	*Hedera helix*	
	Geranium	*Pelargonium x hortorum*	
	Sweet alyssum	*Lobularia maritima*	
	Pink breath of heaven	*Coleonema pulchrum*	
	Petunia	*Petunia x hybrida*	
	New Guinea impatiens	*Impatiens hawkeri*	
	Shamrock plant	*Oxalis sp.*	
	Cyclamen	*Cyclamen persicum*	
	Carnation	*Dianthus caryophyllus*	
	Lacecap hydrangea	*Hydrangea macrophylla*	
	Impatiens	*Impatiens sp.*	
	Kalanchoe	*Kalanchoe blossfeldiana*	
	Mondo grass	*Ophiopogon japonicus*	
	Peppermint geranium	*Pelargonium tomentosum*	
	Fuchsia	*Fuchsia sp.*	

3 February 2015

Eames House Shrub, Pots, and Hardscape

Map Designation	Name	Botanical Name	Comments
P3	Impatiens	*Impatiens walleriana*	Terra Cotta pots 3-18" diameter lips; whiskey barrels (small, 14"; large, 26")
	Hollywood juniper	*Juniperus chinensis* 'Torulosa'	
	Rubber tree	*Ficus elastica*	
	Kentia palm	*Howea forsteriana*	
	Needlepoint ivy	*Hedera helix* 'Needlepoint'	
	Maidenhair fern	*Adiantum spp.*	
	Sweet alyssum	*Lobularia maritima*	
	Begonia	*Begonia sp.*	
	Philodendron	*Philodendron selloum*	
	Sasanqua camellia	*Camellia sasanqua*	
	Camellia	*Camellia japonica*	
	Chain fern	*Woodwardia fimbriata*	
	Deodar cedar	*Cedrus deodara*	
	Lobelia	*Lobelia erinus*	
	Poinsettia	*Euphorbia pulcherrima*	
	Gardenia	*Gardenia jasminoides*	
	Fuchsia	*Fuchsia sp.*	
	Persimmon	*Dirospyros sp.*	
P4	Azalea	*Rhododendron sp.*	Terra Cotta 5-18" diameter lips; whiskey barrels
	Rose	*Rosa sp.*	
	Austrailian rosemary	*Westringia fruticosa*	
	Gardenia	*Gardenia jasminoides*	
	Needlepoint ivy	*Hedera helix* 'Needlepoint'	
	Jade plant	*Crassula ovata*	
	Philodendron	*Philodendron selloum*	
	Pink breath of heaven	*Coleonema pulchrum*	
P4A	Rose	*Rosa sp.*	Terra Cotta pots 7-16" diameter lips
P5	Bamboo	*Phyllostachys sp.*	45 Terra Cotta pots
	Impatiens	*Impatiens walleriana*	
	Lemon	*Citrus limon*	

4 February 2015

Eames House Shrub, Pots, and Hardscape

Map Designation	Name	Botanical Name	Comments
	Marguerite daisy	*Anthemis sp.*	
	Jade plant	*Crassula ovata*	
	Zonal geranium	*Pelargonium x hortoum*	
	English ivy	*Hedera helix*	
	Lobelia	*Lobelia erinus*	
	Rose	*Rosa sp.*	
	Tupidanthus	*Tupidanthus calyptratus*	
P6	Chain fern	*Woodwardia fimbriata*	About 70 pots
	Begonia	*Begonia sp.*	
	Cyclamen	*Cyclamen persicum*	
	English ivy	*Hedera helix*	
	Philodendron	*Philodendron selloum*	
	Azalea	*Rhododendron sp.*	
	Rose	*Rosa sp.*	
	Weeping fig	*Ficus benjamina*	
	Pink breath of heaven	*Coleonema pulchrum*	
	Impatiens	*Impatiens walleriana*	
	Australian tree fern	*Dicksonia antarctica*	
	Kalanchoe	*Kalanchoe blossfeldiana*	
	Hebe	*Hebe speciosa*	
P7	Lavendar	*Lavandula sp.*	
	Cosmos	*Cosmos bipinnatus*	
	Fortnight lily	*Moraea iridiodes*	
	Iris	*Iris sp.*	
	Yarrow	*Achillea millefolium*	
	Wormwood	*Artemesia* 'Powis Castle'	
	Larkspur	*Delphinium sp.*	
P8	Carnation	*Dianthus caryophyllus*	
	Ornamental ginger	*Alpinia formosana*	
	Spider plant	*Chlorophytum comosum*	
P9	Spider plant	*Chlorophytum comosum*	
	Parney cotoneaster	*Cotoneaster parneyi*	
	Jade plant	*Crassula ovata*	
	Gardenia	*Gardenia jasminoides*	
	Sword fern	*Polystichum munitum*	

5 February 2015

Eames House Shrub, Pots, and Hardscape

Map Designation	Name	Botanical Name	Comments
	Hardscape Material	**Size**	
A1	Dry set brick	3" x 7"	
A2	Asphalt concrete	N/A	
A3	Small river rock	1/4" - 3/4"	
A4	Medium river rock	1/2" - 1-1/2"	
A5	Large river rock	1" - 2"	
A6	Marble pavers	13" x 16"	
A7	Inverted wood ends	1" x 3"	
A8	Timber (redwood?)	6" wide x 27" long x 3" deep	"Railroad Ties"
A9	Gravel	1/2" - 3/4"	
A10	Native rocks	2" - 12"	Likely from site
	TREES		
	Common Name	**Botanical Name**	**Quantity**
	Aleppo pine	*Pinus halepensis*	3
	Blue gum	*Eucalyptus globulus*	7
	California pepper	*Schinus molle*	1
	Carolina cherry	*Prunus caroliniana*	1
	Catalina ironwood	*Lyanothamnus floribundus ssp. Asplenifolius*	1
	Flooded gum	*Eucalyptus rudis*	2
	Holly oak	*Quercus ilex*	1
	Hollywood juniper	*Juniperus chinensis* 'Torulosa'	4
	Mock orange	*Pittosrporum tobira*	1
	Olive	*Olea europaea*	1
	Red gum	*Eucalyptus camaldulensis*	198
	Red ironbark	*Eucalyptus sideroxylon*	3
	Silver acacia	*Acacia dealbata*	2
	Silver dollar gum	*Eucalyptus polyanthemos*	2
	Sydney golden wattle	*Acacia longifolia*	4
	Torrey pine	*Pinus torreyana*	1
	Victorian box	*Pittosporum undulatum*	14
		TOTAL	**246**

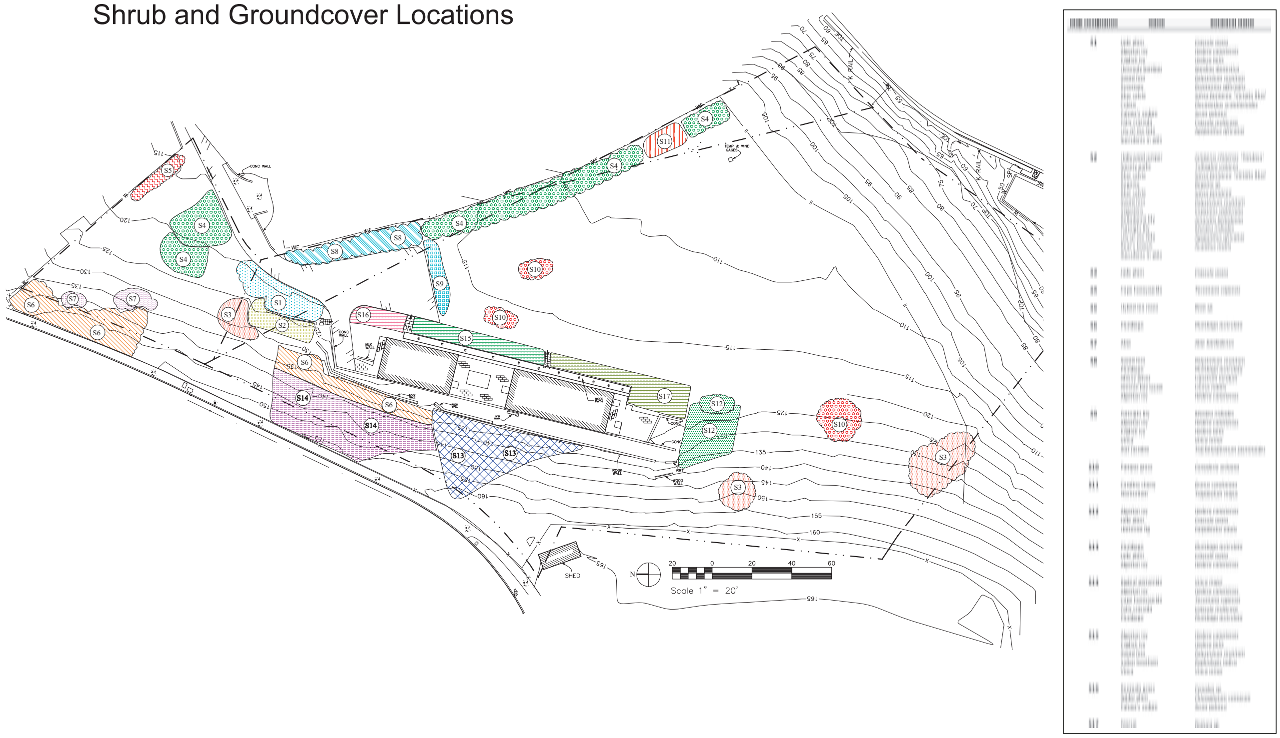
6 February 2015

Eames House Shrub, Pots, and Hardscape

Map Designation	Name	Botanical Name	Comments
	Note: There may be plants that were part of the Eames plant palette that were not observed during this inventory, and are therefore omitted in these lists.		

Eames House Conservation Project

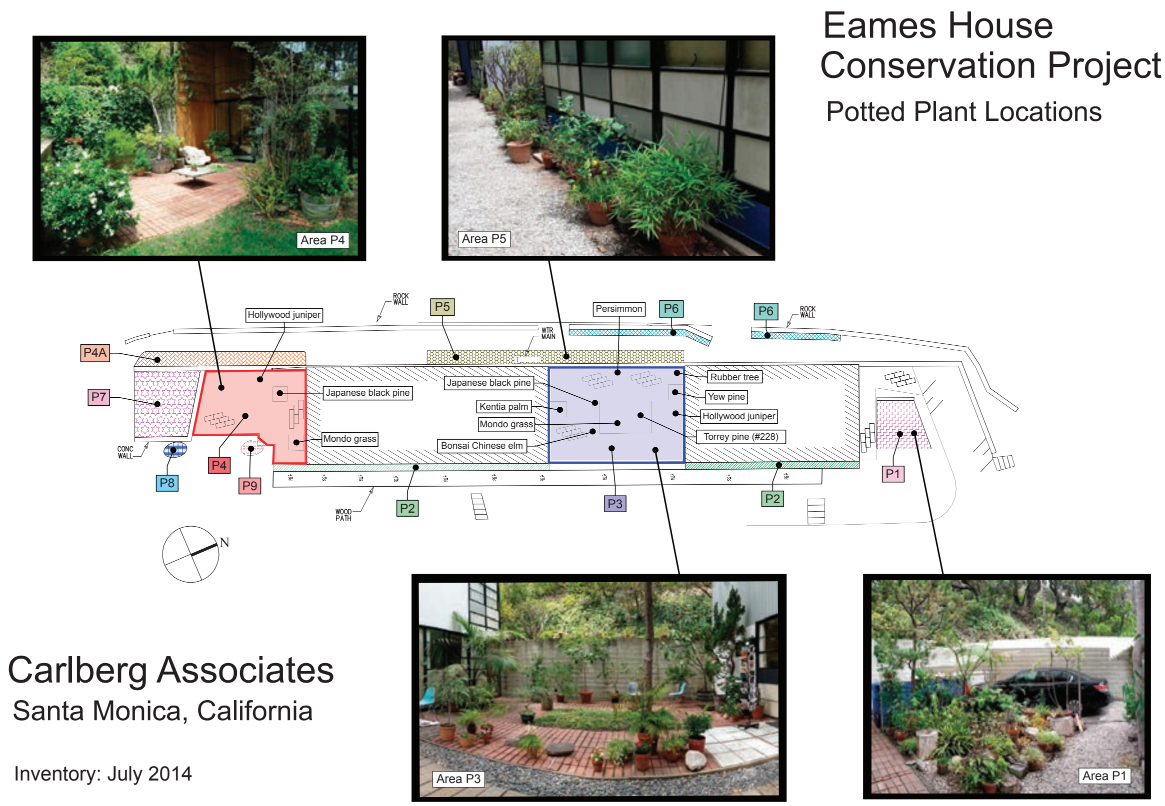
Shrub and Groundcover Locations

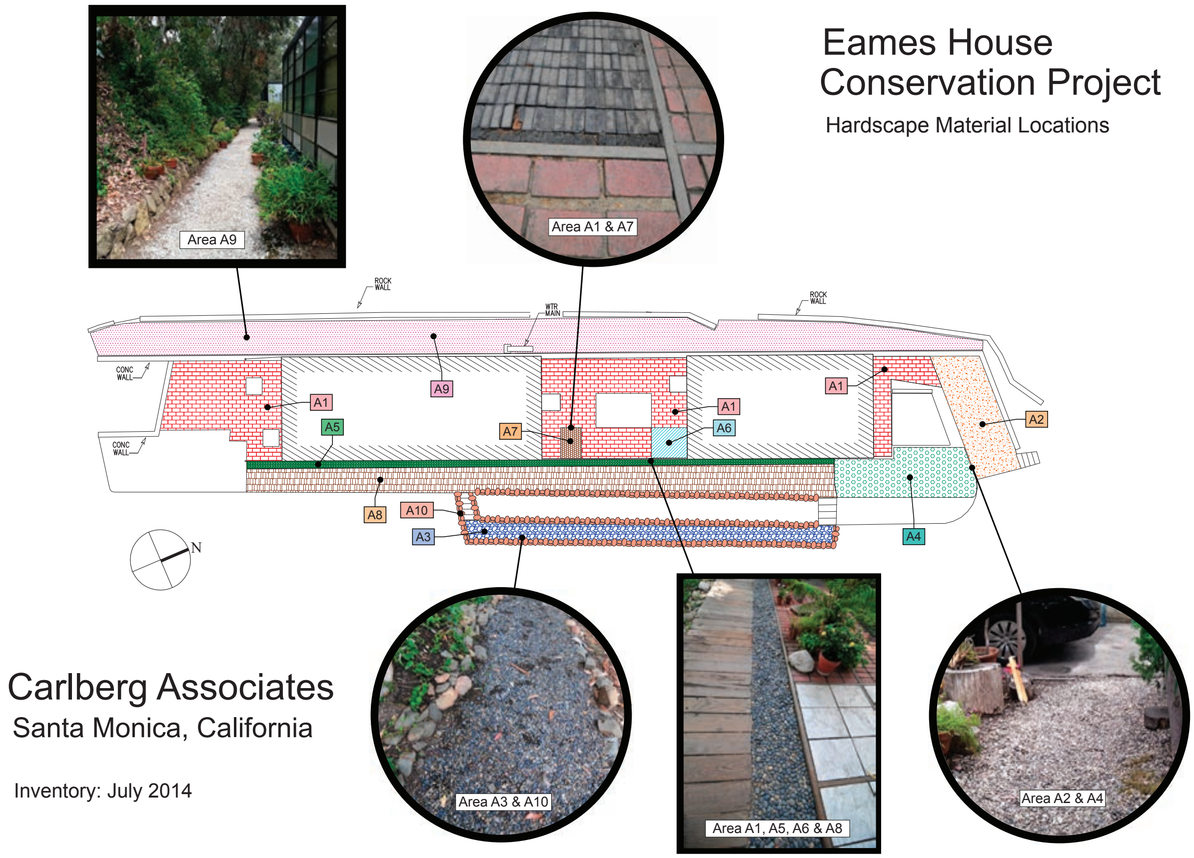


Carlberg Associates

Santa Monica, California

Inventory: July 2014


Eames House
Conservation Project
Potted Plant Locations
Area P4
Area P5
Hollywood juniper
ROCK WALL
P5
Persimmon
P6
P6
ROCK WALL
WTR MAIN
P4A
P7
Japanese black pine
Mondo grass
Japanese black pine
Kentia palm
Mondo grass
Bonsai Chinese elm
Rubber tree
Yew pine
Hollywood juniper
Torrey pine (#228)
CONC WALL
P8
P4
P9
P2
WOOD PATH
P3
P2
P1
N
Carlberg Associates
Santa Monica, California
Inventory: July 2014
Area P3
Area P1


Eames House
Conservation Project
Hardscape Material Locations
Area A9
Area A1 & A7
ROCK WALL
WTR MAIN
ROCK WALL
CONC WALL
CONC WALL
A1
A9
A1
A1
A5
A7
A6
A2
A8
A10
A3
A4
N
Carlberg Associates
Santa Monica, California
Inventory: July 2014
Area A3 & A10
Area A1, A5, A6 & A8
Area A2 & A4

The Getty Conservation Institute