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TECHNICAL NOTE

An easy-to-use method for preparing paint cross sections

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ABSTRACT

The optimized method for preparing paint cross sections described here advances our understanding of the structure of multilayered modern and contemporary paintings. Conducted in micrometer scale with nondestructive characterization, this method of sample preparation preserves the morphological integrity of the paint layers, while achieving a high-quality surface suitable for imaging and inorganic mapping studies. The preparation begins by positioning the paint cross section face down on a restickable, double-sided acrylic adhesive dot affixed to a glass slide. A molded nylon ring is then placed around the sample and filled with Bio-Plastic resin. After curing, the sample is released from the ring. The paint layers are fully exposed because the dot does not bond with the cured resin. The sample requires minimal dry polishing for a high-quality surface because the cross section is not fully embedded in the resin; instead, the face of the cross section sits at the resin's surface. These samples can be prepared in one day. In this study, we obtained data from a single paint sample from the twentieth century painting *The Big Egg* (1968) by Ed Clark, from the Smithsonian's National Museum of African American History and Culture (NMAAHC). At least 15 layers were identified from one paint sample and were characterized using digital microscopy and SEM–EDS.

RÉSUMÉ

La méthode optimisée de préparation des coupes transversales picturales décrite ici fait progresser notre compréhension de la structure des peintures modernes et contemporaines multicouches. Conduite à l'échelle du micromètre avec caractérisation non destructive, cette méthode de préparation d'échantillon préserve l'intégrité de la morphologie des couches picturales, tout en produisant une surface de haute-qualité adaptée aux études par imagerie et cartographie des éléments inorganiques. La préparation commence par le positionnement de la coupe transversale picturale face vers le bas sur une pastille d'adhésif acrylique double-face repositionnable collée sur une lame de verre. Un anneau en nylon moulé est ensuite placé autour de l'échantillon et rempli de résine Bio-Plastic. Après durcissement, l'échantillon est retiré de l'anneau. Les couches picturales sont entièrement exposées car la pastille ne colle pas à la résine durcie. Les échantillons requièrent un minimum de polissage à sec pour obtenir une surface de haute qualité car la coupe transversale n'est pas complètement incrustée dans la résine, la face de la section transversale se trouvant à la surface de la résine. Ces échantillons peuvent être préparés en un jour. Au cours de cette étude, nous avons obtenu des informations à partir d'un seul échantillon de la peinture du vingtième siècle Big Egg (1968) par Ed Clark, provenant du Smithsonian's National Museum of African American History and Culture (NMAAHC). Au moins 15 couches ont été identifiées à partir d'un échantillon de peinture et ont été caractérisées par microscopie électronique et MEB-EDS. Traduit par Elsa Thyss.

RESUMO

O método aprimorado para preparar os cortes estratigráficos de pintura descritos nesse artigo aumentam nosso conhecimento da estrutura multilaminar de pinturas modernas e contemporâneas. Conduzido em escala micrométrica com característica não destrutiva, o método de preparação de amostras preserva a integridade morfológica das camadas de pintura, e ao mesmo tempo obtém uma superfície de alta qualidade própria para estudos de mapeamento inorgânico e de imagens. A preparação começa com o posicionamento da seção transversal da pintura voltada para baixo sobre um ponto de adesivo acrílico readerentes, de dupla face, afixado em lâmina de vidro. Um anel de nylon moldado é então colocado em volta da amostra e preenchido com resina Bio-Plastic. Depois de curada, a amostra é retirada do anel. As camadas de tinta ficam totalmente expostas porque o ponto não liga à resina curada. A amostra requer um polimento mínimo a seco para alcançar alta qualidade de superfície porque as seções transversais não estão completamente embebidas na resina; em vez disso, a face da seção transversal repousa na superfície da resina. Estas amostras podem ser preparadas em um dia. Nesse estudo, obtivemos dados de uma amostra simples da pintura do século XX, Big Egg

KEYWORDS

Ed Clark; paint cross section; SEM–EDS; poly (vinyl acetate); modern and contemporary paintings

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(1968) de Ed Clark, do Smithsonian's National Museum of African American History and Culture (NMAAHC). Ao menos 15 camadas foram identificadas a partir de uma amostra simples e foram caracterizadas através de microscopia digital e SEM-EDS. Traduzido por Sandra Baruki.

RESUMEN

El método optimizado para preparar secciones transversales de pintura que se describe aquí, mejora nuestra comprensión de la estructura de las pinturas modernas y contemporáneas de varias capas. Realizado en escala micrométrica con caracterización no destructiva, este método de preparación de muestras preserva la integridad morfológica de las capas de pintura, al mismo tiempo que logra una superficie de alta calidad adecuada para estudios de imagen y de mapeo inorgánico. La preparación comienza colocando la sección transversal de la pintura hacia abajo sobre un punto adhesivo acrílico de doble cara que se puede pegar a un portaobjetos de vidrio. Luego se coloca un anillo de nylon moldeado alrededor de la muestra y se llena con resina Bio-Plastic. Después del curado, la muestra se libera del anillo. Las capas de pintura están completamente expuestas porque el punto no se une con la resina curada. La muestra requiere un pulido en seco mínimo para obtener una superficie de alta calidad porque la sección transversal no está totalmente incrustada en la resina; en cambio, la cara de la sección transversal se asienta en la superficie de la resina. Estas muestras se pueden preparar en un día. En este estudio, obtuvimos datos de una sola muestra de pintura del siglo XX que pintaba Big Egg (1968) de Ed Clark, del Museo Nacional de Historia y Cultura Afroamericana del Smithsonian (NMAAHC). Se identificaron al menos 15 capas de una muestra de pintura y se caracterizaron mediante microscopía digital y SEM-EDS. Traducción: Amparo Rueda.

1. Introduction

Cross-sectional analysis is a powerful diagnostic tool for understanding the chemical and morphological features of the layered interior structure of a painting, yielding information on paint condition (changes and aging) and composition (artist's technique and alterations). Analyzing stratified paint layers by embedding a cross section sample in resin has been a common practice for conservators and conservation scientists since the 1950s (Plesters 1956). Art conservators began studying paint cross sections about a century ago. Laurie (1914), Gettens (1936), and Plesters (1956) conducted pioneering studies of paint cross sections, and studies have continued to the present (Tsang and Cunningham 1991; Derrick et al. 1994; Martin 1991, 1998; Langley and Burnstock 1999; Wachowiak 2004; Wolbers et al. 2012). A comprehensive review by Khandekar (2003) summarized techniques of paint cross section analysis from 1930 to 2003. Since then, advances in instrumental analysis and data processing software have led to new techniques for analyzing paint cross sections, such as synchrotron radiation-based Fourier transform infrared spectroscopy (van Loon 2008; Bartoll et al. 2008), attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy (Prati et al. 2012), reflective FTIR imaging of paint cross sections (van deer Weerer, brammer et al. 2002; van deer Weerd, Ron et al. 2004), static secondary-ion mass spectrometry (Khandekar 2003; van Loon 2008), and environmental scanning electron microscopy (Hochleitner et al. 2003). These new technologies have necessitated changes in sample preparation. Moreover, analysis and interpretation of data have evolved from the work of a single researcher into a collaborative effort by groups of specialists.

The first objective of this study was to design a simple and effective method of preparing paint cross sections that can be carried out in any paintings conservation studio. During the course of this study, conservators, conservation technicians, and conservation scientists mastered the method after a brief training period. While many traditional methods of cross section sample preparation require a dedicated technician to employ microtoming or extensive wet polishing to expose the sample, our novel preparation method requires no extra staff, no grinding or planing, and minimal polishing (Martin 1998; Weilhammer 2000). Our second objective was to ensure that the cross section had a high-quality surface that retained its chemical and morphological integrity for light microscopy and scanning electron microscopy–energy-dispersed spectroscopy (SEM–EDS) analytical techniques. Our third objective was to establish parameters for preparing samples specifically for modern and contemporary art materials. Water and solvents are used in traditional techniques of cross section preparation; however, the acrylic and mixed media materials used in modern and contemporary art are often water- and solvent-sensitive (Jablonski et al. 2018).

The Big Egg (1968) (Figure 1) by American artist Ed Clark (b. 1926) is a large, oval-shaped abstract painting on canvas, created while the artist was working in France. Clark is known for placing a canvas on the floor, pouring and splashing many thin layers of paint onto the canvas, and pushing the paint around with a large broom. Much of the paint surface has a matte,

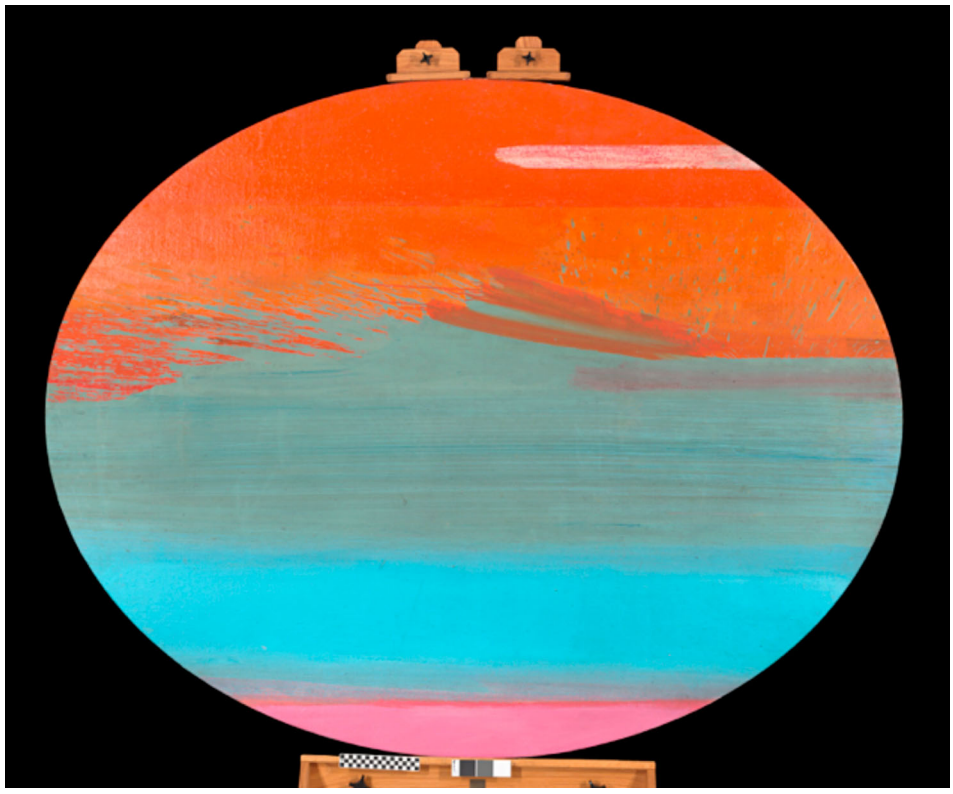

Figure 1. *The Big Egg* (1968) by Ed Clark from NMAAHC, after conservation funded by a grant from the Bank of America Art Conservation Project 2014–2016. Photo by Don Hulbert, NMAH imaging department. H × W: 64½ × 83 in. (163.8 × 210.8 cm).

chalky appearance. *The Big Egg*, currently exhibited at the Visual Art Gallery at the Smithsonian's National Museum of African American History and Culture (NMAAHC), underwent technical study and conservation at the Smithsonian's Museum Conservation Institute (MCI) in 2016. The painting's many layers provide an ideal sample for assessing the relative quality of polishing, in terms of preservation of microstructural integrity, as the presence of polishing artifacts can distort stratigraphy of the horizontal layers of a cross section.

2. Materials and methods

2.1 Sampling and mounting

A cross section sample of *The Big Egg* was obtained from the edge of the painting in an area of sustained paint flaking using a sharp scalpel blade. The cross section is approximately 1.6 mm × 4.0 mm (h × l), which is relatively large for a paint sample. Sample size for this methodology can range from 1 to 4 mm. Samples of different shapes and sizes can be a challenge to properly position for embedding. Samples that are much taller than they are wide can be difficult to keep upright, as top-heavy samples tend to fall over during the resin-embedding process. Manipulating samples with dental scalers or fine tweezers can help in addition to using Scotch restickable dots as the mounting adhesive. Scotch restickable dots are clear pre-cut circles of double-sided flexible acrylic adhesive that bonds on contact. In contrast to liquid adhesives used in the past (Martin 1998; Khandekar 2003), Scotch restickable dots provide easy, mess-free, instant adhesion. Unlike superglue, the acrylic adhesive of Scotch restickable dot does not have to cure and therefore the paint chip does not have to be stabilized or held in place. A restickable dot (2.2 cm x 2.2 cm) is placed in the center of a glass slide. Under the microscope, the cross section is positioned so that the stratified layers of interest are in contact with the restickable dot, as the resin block will later be inverted. If repositioning cannot be avoided, the restickable dots are still easier to use than liquid adhesives. This technique for mounting a cross section sample is similar to that described by Martin (1998) but has modifications that make the process simpler and reduce polishing time. See Figure 2 for an expanded schematic of the layout of materials.

2.2 Embedding

Circular nylon spacers (2 cm OD, 1.2 cm ID, 1 cm high, opaque white) can be purchased at a hardware store for less than 50¢ each. The spacer's smooth interior allows the resin to be cast and released without the use of a

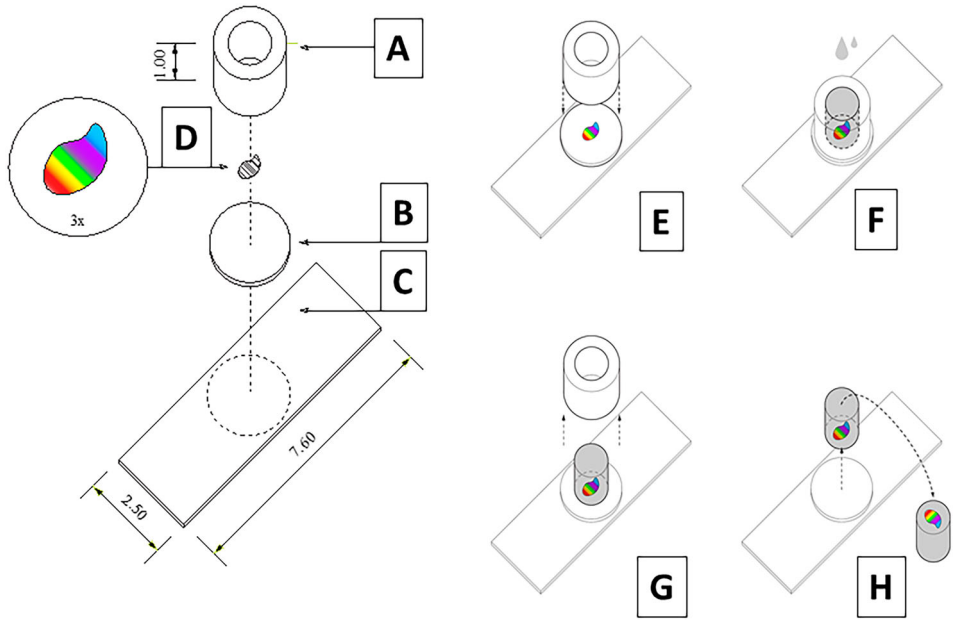

Figure 2. Paint Cross Section Embedding Materials: (A) ring mold 2.00 cm exterior, 1.20 cm interior and 1.00 cm height. (B) Scotch restickable dot 2.20 cm. (C) Glass slide 7.6 × 2.5 cm. (D) Paint sample cross section. Paint Cross Section Preparation: (E) To mount, place restickable dot onto a glass slide and position the cross section with layers visible, with a side of interest facing down. (F) To embed, place nylon ring mold around sample on top of the restickable dot; prepare, pour, and cure Bio-Plastic resin. (G) Release sample from ring mold, dot, and glass slide. (H) Sample requires minimal polishing since cross section is at the surface of the resin. Polish sample with a series of 9 Micro-Mesh sheets (1500–12,000).

lubricating agent. Casting in small molds reduces polishing and potential scratching of the sample surface but requires more careful calculation of the ratio of casting resin when embedding. The ring mold is placed around a sample that has been positioned on top of a restickable dot. The restickable dot is larger than the ring mold, virtually eliminating resin leakage. Bio-Plastic is a two-part synthetic polyester resin that hardens to a clear solid. The liquid polyester casting resin is combined with a methyl ethyl ketone peroxide catalyst (50 cc liquid casting resin + 20 drops catalyst) and mixed slowly to avoid bubble formation. Mixing in a disposable cup with a wooden tongue depressor is recommended. A single disposable 25 cc medicine cup with measuring marks is perfect for mixing a half batch of resin (enough to cast up to eight samples in the molds described above). Resin should be mixed under a well-ventilated hood to avoid inhaling the styrene vapor that is released during mixing. Pour resin to the top of the ring mold and heat at 48°C for 3 h in a well-ventilated area.

2.3 Polishing

The polishing technique used in this process is similar to that described in Wolbers (2012). The main difference is that the use of a restickable dot during curing and detaching allowed the sample surface to be directly exposed. In other embedding techniques, a sample can have a tendency to become partially submerged in the resin. Our samples were polished without the use of water or solvents. When working with moisture-sensitive materials such as acrylic emulsion paint, dry polishing preserves the morphology of paint layers and prevents them from swelling. We dry-polished our samples with Micro-Mesh regular sheets, which have a silicon carbide grit with standard backing. The #MMK1 kit contains nine 4 × 6-inch sheets ranging in grit size from 1500–12,000 (30–2 µm). The sheets are used dry and in sequence from highest (1500) to lowest (12,000) grit size.

3. Examination with analytical instrumentation

3.1 Digital microscopy

We used a Hirox KH-8700 digital microscope with an MXG-2500REZ dual illumination lens and a 2.11-megapixel CCD sensor to observe and capture digital images at high magnification. We used the reflected bright-field mode to examine sample surfaces for scratches caused by polishing.

3.2 Scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM–EDS)

Paint cross sections were not coated with a conductive layer therefore the nonconductive samples were analyzed

using a variable pressure SEM (Hitachi S-3700N). SEM–EDS was performed last because the electron beam can chemically alter the bonding of organic components within the sample. Additional dry polishing with Micro-Mesh sheets can restore the integrity of the sample surface. Samples were analyzed at a working distance of approximately 10 mm, 15 kV accelerating voltage. SEM images were collected in backscattered electron (BSE) mode. An EDS map was collected with a Bruker XFlash 4010 detector from which EDS spectra were extracted from select regions (data cube) using ESPRIT software.

3.3 Attenuated total reflection (ATR-FTIR) and transmission through an infrared microscope (μ-FTIR)

A Thermo Nicolet 6700 FTIR spectrometer with Golden Gate ATR and MTC-A detector was used, and data were collected at 4 cm^{-1} resolution for 64 scans. Two measurement methods are generally used at MCI for infrared analysis, ATR-FTIR or transmission μFTIR. Paint samples that were not embedded were placed on a diamond window and the arm was closed and tightened to provide good contact with the samples. When possible, prior to analysis, the layers can be mechanically separated under magnification.

4. Results and discussion

4.1. Hirox digital microscopy

At least 15 layers of paint were clearly identified from *The Big Egg* paint cross section (Figure 3). The structure of layers, water-sensitive poly (vinyl acetate) (PVAc) binder (Barnes, Kavich, Tsang 2015a, 2015b, 2015c), dyes, and filler particles appear to have remained intact during the polishing process. The effects of polishing were evaluated with a Hirox digital microscope in reflected bright-field mode. Occasionally, the surface of the resin block and sample revealed fine scratches. A fresh sheet of the finest grade (12,000 grit size) Micro-Mesh can minimize these marks. For the microscopic image to be perfectly focused, the planes of the objective lens and the resin block must be parallel. The rough back end of the resin block can be polished with rough sandpaper or trimmed with a slow-speed saw. Alternatively, securing the mounted sample into a top reference holder (such as an EM-Tec R4) can provide a level top plane and reduce vibration, allowing for improved digital microscopy. If a top reference holder is not available, a sample affixed onto a glass slide with modeling clay can be leveled using a bubble level tool. A device such as an Olympus metallographic sample leveling press can also be used to level a sample that is supported with molding putty.

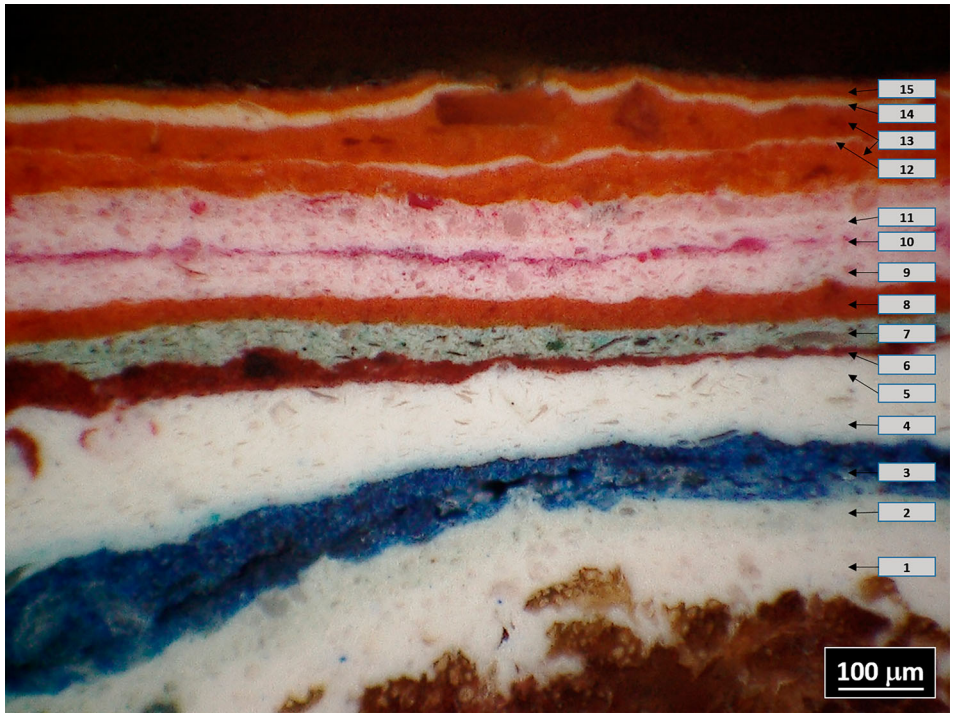

Figure 3. Digital micrograph of a cross section sample from *The Big Egg*. The sample was used in SEM–EDS elemental maps. The numbers of the layers from ground (1) to top layer (15) correspond to the numbers of layers presented in Table 1.

4.2 SEM–EDS analysis

Figure 4 shows a cross section of paint viewed by digital microscopy (Figure 4A), BSE imaging (Figure 4B), selected EDS maps overlaid on the BSE image (Figure 4C–K), and a composite EDS map (Figure 4L) showing mixed channels of S (yellow), Ti (green), Ca (blue), Mg (magenta), and Cl (red). The optical (Figure 4A) and BSE (Figure 4B) images show that the stratigraphy of the layers is preserved. In the BSE image (Figure 4B), four layers stand out in brighter contrast (arrows): a top orange layer, a layer of white below the orange layer, a second white layer below the first, and a third white layer just above a blue layer (Figure 4A).

SEM observations are summarized in Table 1, where sample layers were numbered from the ground to the top layer (1–15), corresponding to the SEM–EDS elemental maps (Figure 4). All paint layers contain low concentrations of fillers (i.e., Si, Al, Ca, and Mg), as also reported in ATR and X-ray fluorescence (XRF) analysis with non-embedded samples (Barnes 2015; Kavich 2015). The EDS map focused on higher-concentration elements. SEM–EDS mapping was performed

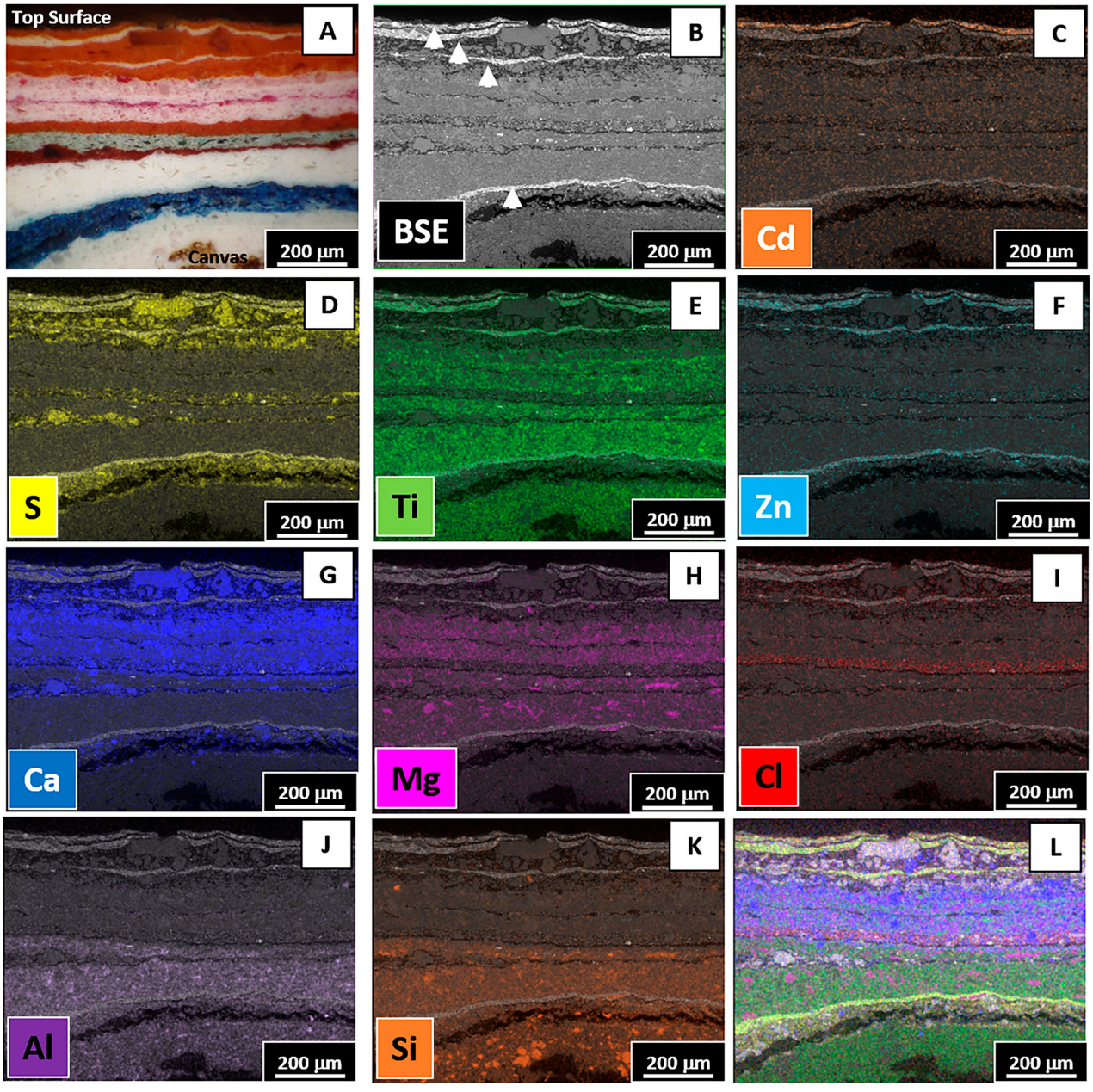

Figure 4. (A) Digital micrograph of the cross section. (B) BSE micrograph of the cross section. (C–K) Selected individual EDS elemental maps overlaid on the BSE image. (L) Composite EDS map of Cl (red), Ca (blue), Ti (green), Mg (magenta), and S (yellow) overlaid on the BSE image.

Table 1. SEM paint layer analysis from SEM–EDS and digital microscopy.

Layer no.	Layer color	Elements	Suggested materials
15	Orange	Cd, S, Zn	Cadmium lithopone orange and zinc white
14	White	S, Ti, Zn	Titanium oxide and zinc white
13	Orange	Cd (trace) Ca, S	Cadmium lithopone orange and calcium sulfate[a]
12[b]	White	S, Ti, Zn	Titanium oxide and zinc white
11	Light pink	Ti, Ca, Mg	Organic dye in titanium oxide, magnesium carbonate, and calcium carbonate
10	Bright pink	C-rich	Organic dye
9	Light pink	Ti, Ca, Mg	Organic dye in titanium oxide, magnesium carbonate, and calcium carbonate
8	Red	Ca, Cl	Organic dye with calcium carbonate
7	Gray	Ti, Mg, Al, Si	Ultramarine (synthetic), titanium oxide, magnesium carbonate, and mica
6	Deep red	Ca, S	Synthetic red dye and calcium carbonate
5	White	Ti, Mg, Si, Al	Titanium oxide, magnesium carbonate, and mica
4	White	S, Ti, Zn	Titanium oxide, zinc white, and quartz
3	Blue	S, Ca, Al, Si	Ultramarine (synthetic) and quartz
2	White	Ti, Al, Si	Titanium oxide, mica, and quartz
1	White	Ti, Al, Si	Titanium oxide, mica, and quartz

[a]The concentration of Cd was too low to be detected by EDS.
[b]White layer in 12 is in between the two orange layers of layer 13.

under variable pressure, without the need for a conductive coating. Even though an electron beam broadens the image and is not ideal for semi-quantitative analysis, the mapping of layers is distinguishable. Specifically, the chemistries of fine mica particles in layers 1, 2, and 4 are resolvable.

Pigments have been identified when possible; however, this should be confirmed with a complementary technique. Aside from the detection of C, N, and O, SEM–EDS' strength is not the identification and characterization of organic materials. In the case of ultramarine, SEM–EDS did not detect Fe but XRF analysis did. The detection limit for SEM–EDS is approximately 0.1 wt.% for most elements. Depending on conditions and the element analyzed, XRF is capable of detecting approximately 10 ppm and higher (Friel et al. 2017). Nevertheless, it should be noted that characteristic x-rays below 3.7 keV will have a less intense signal when XRF is performed in the atmosphere, and therefore the resulting peaks are not scaled in relation to concentration. The difference between EDS and XRF analysis may also be due to the fact that the analytical volume of the X-rays generated in XRF is larger than the interaction volume for EDS. When non-invasive XRF was used to identify the elemental composition of the pigments (Kavich 2015) on the intact painting, the multilayered structure of the artwork rendered an interpretation of the pigments difficult. This difficulty is alleviated through rapid cross section preparation and 2D elemental analysis using SEM–EDS.

4.3 ATR-FTIR or transmission μFTIR analysis of The Big Egg *paint binder*

Three separate ATR-FTIR or transmission μFTIR paint binder analyses (Barnes 2015) carried out on *The Big Egg* paint samples found that the paint binder was PVAc-based. PVAc paints, widely used as interior house paints in the UK and much of Europe have more fillers such as calcium carbonate, mica, and quartz than acrylic paints (Standeven 2011). The presence of these fillers was detected by Hirox microscopy and SEM–EDS pigment analysis. As a complementary technique to digital microscopy and SEM–EDS, we used reflective FTIR imaging to investigate the presence and distribution of organic compounds in the cross section's paint layers (Van der Weerd 2002, 2004). Cross sections can also be examined by reflectance μ-FTIR for potential correlative spectroscopy studies. However, unprocessed reflectance μ-FTIR spectra from cross section samples are noisy and shifted (van der Weerd et al. 2002; Cotte et al. 2009). The Kramers–Kronig correction of the spectra is in many cases unnecessary or ineffective. Work is underway to apply principal component analysis to deconvolute the reflectance spectra.

5. Conclusion

The preparation of cross section samples described above has the advantages of ease and speed. Minimal dry polishing maintained the structure of the water-sensitive PVAc paint, keeping its dyes, calcium carbonate, mica, and quartz particles intact, and reduced cross section preparation time. This cross section sample preparation is cost-effective because the necessary materials are available in stores and online, it is easier to learn, and can be completed in a few hours. During the course of this study, conservators, conservation technicians, and conservation scientists were able to master the method after a brief training period. Our preparation method requires no grinding or planing and only minimal polishing. The method described in this study can accommodate a variety of artists' materials and minimizes mechanical post-embedding polishing. It has proven to be an easy, effective, nondestructive technique for chemical characterization and identification of inorganic

compounds within complex paint mixtures in cross sections and other samples of interest to cultural heritage. However, establishing the stability and longevity of resin-embedded samples will be noted of future studies, which must determine whether discoloration or shrinkage of the resin over time will negatively affect paint samples and future attempts to image or chemically analyze them. The preparation of cross section samples described here, in combination with SEM–EDS mapping, is a mature technology in paintings conservation.

6. Materials and suppliers

Bio-Plastic Part A 470178-342
Liquid casting plastic: polyester resin, styrene monomer, methyl methacrylate

Bio-Plastic Part B 470178-34215100
Ketone peroxide catalyst: 2,2,4- trimethyl-1,3-pentanediol diisobutyrate, methyl ethyl ketone peroxide, hexylene glycol, methyl ethyl ketone, hydrogen peroxide, proprietary component
Ward's Science
5100 Henrietta Rd.
PO Box 92912
Rochester, NY, USA
https://www.wardsci.com/store/product/8879572/liquid-bio-plastic

Metallographic Sample Leveling Press #813–540
https://www.tedpella.com/Material-Sciences_html/pelcoplast.htm.aspx#press

Micro-Mesh Kit # MMK1
Polishing cloth
Scientific Instrument Services, Inc.
https://www.sisweb.com/part/MMK1

Natural Nylon Spacers Used as Ring Molds
(3/4×1/2×3/8") Item 409908
www.hillmangroup.com
Suppliers: Home Depot, Lowe's, Tractor Supply, 84 Lumber, Menards, etc.

PELCO Plast Support Putty for Microscopy
Prod #813–530 used with metallographic sample leveling press
https://www.tedpella.com/Material-Sciences_html/pelcoplast.htm.aspx#plast

Scotch Restickable Dots for Mounting
Dot is a flexible acrylic adhesive (personal communication with 3M technical support division) and dot is covered and protected with silicone coated Mylar in the package. Package of 18 clear dots, 2.2 cm × 2.2 cm each.
3M, Scotch Division
https://www.scotchbrand.com/3M/en_US/scotch-brand/products/catalog/~/Scotch-Restickable-Dots-7-8-in-x-7-8-in-Clear?N=4335+3294529207+3294602783&rt=rud
Sold on Amazon
https://www.amazon.com/Scotch-Restickable-8-inch-18-Dots-R105/dp/B007Y17T70

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Disclosure Statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Jia-sun Tsang is a senior paintings conservator at the MCI, where she conserves paintings for Smithsonian museums. She holds an M.Sc. from the Winterthur/University of Delaware Program in Art Conservation and an M.Sc. in chemistry from Bowling Green State University, OH. Since 2007 her work has focused on the conservation and analysis of paintings from the visual art collections of the NMAAHC, and the installation of artworks for the grand opening of the museum in autumn 2016. She specializes in modern materials research and the conservation of modern and contemporary art.

Thomas Lam has a Ph.D. in ceramics from Alfred University, NY. After earning his Ph.D., he completed a postdoctoral fellowship at the National Institute of Standards and Technology. He is a physical scientist at the MCI, where he applies his knowledge of material science and characterization skills (including SEM–EDS, cathodoluminescence, X-ray fluorescence, and microfade testing) as part of the MCI technical studies team.

Elle Friedberg is a paintings conservation and analytical studies intern at the MCI (Suitland, MD), 2017–2018. Her current projects include optimizing paint cross section preparation techniques and assisting with preventive conservation at the NMAAHC. She is also a paintings conservation volunteer at the Smithsonian's National Gallery of Art (Washington, DC). She received a B.A. from Wellesley College, MA, with a double major in chemistry and studio art.

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