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Journal of the Canadian Association for Conservation (J. CAC), Volume 26.

J.CAC is a peer reviewed journal published annually by the Canadian Association for Conservation of Cultural Property (CAC), 207 Bank Street, Suite 419, Ottawa, Ontario K2P 2N2, Canada; Tel.: (613) 231-3977; Fax: (613) 231-4406; E-mail: coordinator@cac-accr.com; Web site: http://www.cac-accr.ca.

Journal de l'Association canadienne pour la conservation et la restauration (J. ACCR), Volume 26.

Le *J.ACCR* est un journal révisé par des pairs qui est publié annuellement par l'Association canadienne pour la conservation et la restauration des biens culturels (ACCR), 207, rue Bank, bureau 419, Ottawa (Ontario) K2P 2N2, Canada; Téléphone : (613) 231-3977; Télécopieur : (613) 231-4406; Adresse électronique : coordinator@cac-accr.com; Site Web : http://www.cac-accr.ca.

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This paper describes the scientific analysis of the original materials of an eighteenth-century japanned long case clock from the collection of the Royal British Columbia Museum in Victoria, British Columbia. Analysis showed that the wood was prepared with a thick gesso layer composed of calcium carbonate (chalk) in a protein medium. This white ground was followed with a single application of an opaque, light blue layer pigmented with indigo, lead white, and calcium carbonate, also in a protein medium. The coloured japanned layers, applied on top of the light blue layer, are composed of translucent layers of smalt in a natural resin medium, followed by layers of unpigmented natural resin. In both the coloured japanned layers and the unpigmented layers, the natural resin was found to be from a tree source rather than shellac. Raised decoration was produced with a paste of calcium carbonate mixed in a drying oil medium applied to the surface and then sealed with natural resin. Examination of selected surface decorations showed the use of gold leaf, powdered brass, and powdered tin, all applied to a mordant pigmented with vermilion. Pigments employed for the painted decoration included iron oxide pigments, carbon black, and vermilion. The materials identified on the clock are compared to those described in historic treatises on japanning.

Cet article traite de l'analyse scientifique des matériaux originaux d'une horloge de parquet laquée du XVIII^e siècle appartenant à la collection du Royal British Columbia Museum à Victoria en Colombie-Britannique. L'analyse a révélé que le bois a été enduit d'une épaisse couche de préparation composée de carbonate de calcium (craie) dans un liant protéique. Sur cette préparation a ensuite été appliquée une couche opaque bleu pâle contenant de l'indigo, du blanc de plomb, du carbonate de calcium et un liant protéique. Les couches colorées de laque, appliquées par-dessus la couche bleu pâle, consistent en couches translucides contenant du smalt et une résine naturelle. Plusieurs couches non pigmentées de résine naturelle ont été appliquées par-dessus les couches de laque. La résine naturelle dans les couches de laque et dans les couches de résine non pigmentées n'est pas de la gomme laque mais plutôt une résine provenant d'un arbre. Des décorations en relief ont été créées à l'aide d'une pâte faite de carbonate de calcium mélangé à une huile siccative. Cette pâte a été appliquée sur la surface laquée puis scellée par une couche de résine naturelle. L'examen de plusieurs décorations métalliques a montré que de la feuille d'or, de la poudre de laiton et de la poudre d'étain ont été employées, le métal étant dans tous les cas appliqué sur un mordant pigmenté avec du vermillon. Les pigments employés pour les décorations peintes incluent des pigments à base d'oxyde de fer, du noir de carbone et du vermillon. Les matériaux identifiés sur l'horloge sont comparés à ceux décrits dans des traités anciens.

Manuscript received April 2001; revised manuscript received September 2001

Introduction

The analysis of the original materials used on a japanned long case clock from the Royal British Columbia Museum, Victoria, British Columbia was carried out in conjunction with its conservation treatment at the Canadian Conservation Institute. The clock has a blue-green japanned surface with metallic and painted decoration in both flat and raised motifs. Visual examination of the japanned finish in protected areas indicates that the original colour of the clock was deep blue. This has altered over time to the current blue-green shade. The front panel of the clock during treatment is shown in **Figure 1**. The face of the clock mechanism is engraved with the maker's name: "W^{m} Webster, Exchange Alley, London." A 1992 appraisal indicates that the clock dates from circa 1760 and was made by William Webster's son.[1]

Examination of the clock using visible light and ultraviolet fluorescence showed the surface to be in good condition with little previous restoration, especially in the areas of metallic decoration. Since many areas of the original surface finish of the clock are intact, analysis provided useful information about eighteenth-century English japanning materials and technique. Analysis also allowed comparisons to be made between the materials used on the clock and published recipes in contemporaneous treatises on japanning.

Historic Recipes for Japanning

A number of artists' manuals and recipe books describe the materials and methods of japanning in some detail. Among the best known are: *A Treatise of Japanning and Varnishing* by Stalker and Parker,[2] *The Handmaid to the Arts* by Dossie,[3] and *L'art du peintre, doreur et vernisseur* by Watin.[4]

Certain recipes for japanning described in these sources have been published elsewhere.[5,6,7] Selected instructions from these manuals that relate to the type of japanned decoration used on the long case clock are briefly summarized here as a basis for comparison with the scientific analysis.

A Brief Summary of the Japanning Process

Wooden objects were generally prepared for japanning by coating them with a number of layers of whiting (calcium carbonate) mixed with size (a protein medium, generally a type of animal glue).[8,9] After the wood had been thus prepared and the ground smoothed, the japanning was applied. This involved the application of a number of translucent layers of pigment in an appropriate medium, such as a natural resin mixture or a type of fish glue. The amount of pigment in the japanning medium was initially high and was steadily diminished until only pure medium was used. Layers of transparent varnish sealed the japanning. Finally, surface decoration such as painting or gilding was applied. The colour of the finished japanned surface varied; popular colours for japanning included black, red, white, green, and blue.

Blue Japanning

While Watin describes only black japanning in detail, both Stalker and Parker and Dossie give specific instructions for blue japanning. Stalker and Parker indicate that “Blew Japan” should be pigmented with lead white and smalt. The lead white was first ground with gum arabic (“gum water”) and the smalt with a type of fish glue (“isinglass-size”) after which the pigments were mixed together and painted onto the prepared surface. Several applications of the smalt-lead white mixture, with varying amounts of smalt, were used. Stalker and Parker state that it may be necessary to use only smalt, without the addition of lead white, in the final pigmented applications in order to produce the desired shade of blue. After the pigmented layers were applied, the japanning was completed with several applications of unpigmented “isinglass-size.”[10]

While Stalker and Parker mention smalt as the only blue pigment to be used for “Blew Japan,” Dossie’s instructions state that blue japanning could be produced using Prussian blue, blue verditer, smalt or combinations of these pigments. Rather than the “isinglass-size” recommended by Stalker and Parker, Dossie indicates that a natural resin medium should be used for all types of japanning. He further states that although shellac is the most durable resin, other natural resin mixtures are less yellow and are preferred when a bright blue surface is desired. He suggests a mixture of mastic and “gum animi” (a term used for several different natural resins, including copal[11]) or a mixture of oil and “gum animi” as suitable media for blue japanning.[12] As Stalker and Parker describe,[13] and as Webb[14] has observed in the analysis of japanned objects, the amount of pigment in the varnish is initially high and is gradually decreased in subsequent layers to create a translucent finish.

After the coloured japanning layers were applied, the surface was sealed with a number of layers of clear varnish. Stalker and Parker indicate that seven or eight applications of white varnish (a complex mixture of natural resins) should be used,[15] while Dossie suggests five or six coats of a shellac-“gum animi” mixture to provide a durable upper surface.[16]

Surface Decorations

Japanned surfaces were decorated with paint and metallic leaf and powders applied to both flat areas of japanning and to areas that had been raised to produce an embossed, three-dimensional effect, as visible in the detail shown in **Figure 2**. The raised work for the decorative elements of the japanned finish was applied once the initial japanning and varnishing had been carried out. According to the instructions given by both Dossie and Stalker and Parker, a paste mixture of calcium carbonate (“whiting”) and a clay-rich red earth (“bole armoniac” or “Bole-Armoniak”) in gum arabic (“gum water” or “Gum-Arabick-water”) was used to create the raised decoration.[17,18] Watin, however, describes the best paste for this purpose as a mixture of equal parts of calcium carbonate (“*blanc d’Espagne*”) and umber in an oil-resin medium (“*Vernis gras*”).[19]

The instruction books list a variety of metallic powders for decorating both the flat and raised surfaces of the japanning. Stalker and Parker, for example, include “Brass-dust,” “Silver-dust”, “Green-gold” and “Dirty-gold” (both described as being “corrupted metal”), “Powder-Tinn,” and various types of copper powder.[20] Dossie and Watin also describe metal powders based on gold, silver, copper, and tin.[21,22] These powdered metals could be used to imitate an expensive gilded surface. The prices for the different varieties of metallic powder varied depending on the type of metal and its quality. According to Stalker and Parker, the least expensive were the copper powders, tin powder, and “Dirty-Gold” which are listed at 6 shillings per ounce. An average grade of “Brass-dust” cost 8 to 9 shillings per ounce. Powdered silver, on the other hand, cost at least 16 shillings per ounce and often more.[20] The metal powders could be used together to create specific colour effects, for example, shading areas of copper powder with powdered tin.[23]

Stalker and Parker state that the metallic powders could be laid on top of “Gold-size,” an oil mordant based on a heated drying oil-resin mixture containing red lead, umber, and vermilion. The metal powder could also be applied by mixing it with gum arabic (“Gum-water”).[24] In addition, they describe traditional oil and water gilding using gold or silver leaf.[25] Dossie also gives instructions in which powdered metals are either applied to gold size or painted on after mixing with gum arabic (“gum water”) or fish glue (“isinglass size”).[26] He states that there are a number of different recipes for gold size and gives detailed instructions for two of these. The first, similar to Stalker’s and Parker’s recipe, includes red lead, umber, and vermilion while the second, which he prefers, is pigmented only with vermilion. As in Stalker’s and Parker’s instructions, both size recipes are based on heated drying oil-resin mixtures.[27] Watin gives a recipe containing vermilion in amber varnish (“*Vernis d’ambre*”) to be used as a mordant for the metallic powders.[28]

Figure 1. The front panel of the clock during treatment.

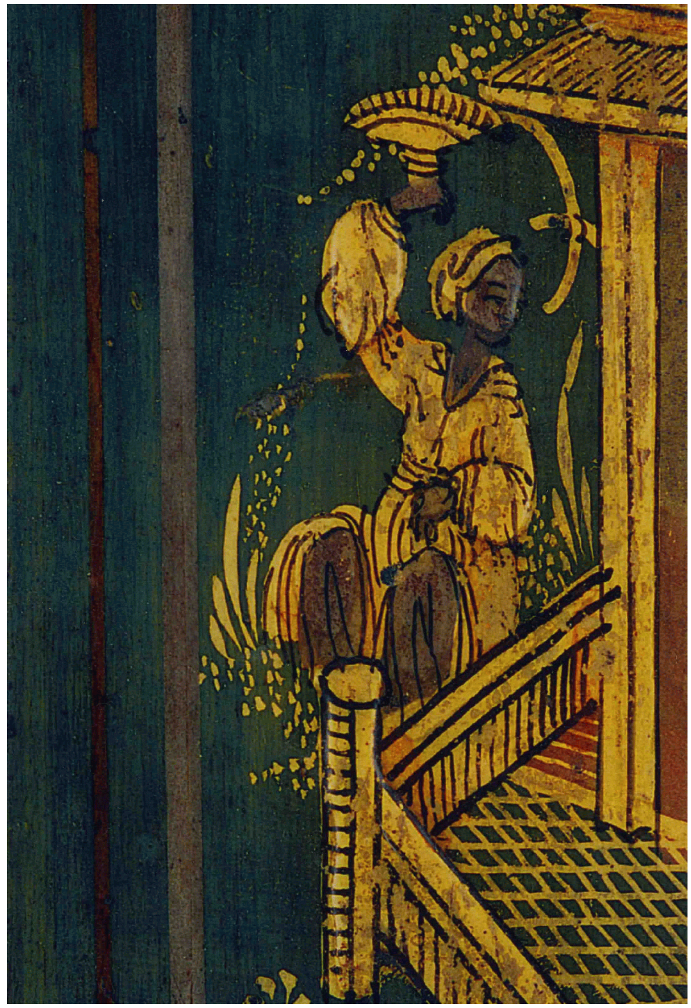

Figure 2. A detail of the front panel of the clock during treatment showing embossed decoration.

Materials Analysis and Comparison with Historic Recipes

Analytical Methods

Cross-section samples were removed from the body of the clock where different types of surface decoration were observed. The cross-sections were embedded in polyester resin then ground and polished using cushioned abrasive papers and observed using incident light and fluorescence microscopy. The auto-fluorescence of the cross-sections was observed using a mercury vapour lamp with an ultraviolet exciting filter with a band pass of 340 to 380 nm.

Specific layers in the cross-sections were analysed by x-ray microanalysis using an Hitachi S-530 scanning electron microscope integrated with a Tracor X-ray detector after carbon-coating the cross-sections to ensure conductivity. Using this technique, referred to as SEM/XES, elemental analysis of small volumes, down to a few cubic micrometers, can be obtained for elements from sodium to uranium with a sensitivity of about 1%.

Fragments of layers of interest were removed from unmounted cross-section samples and analysed by Fourier transform infrared spectroscopy (FTIR). The samples were mounted in a diamond anvil micro-sample cell and analysed using a Bomem Michelson MB120 spectrometer. In some cases, a Spectra-Tech IR-Plan infrared microscope accessory was used. In order to identify the medium in certain of the samples containing calcium carbonate, the samples were treated with dilute hydrochloric acid prior to analysis to remove interfering carbonate bands from the infrared spectrum.

Certain samples were also analysed by X-ray diffraction (XRD) using a Rigaku RTP 300 RC rotating anode generator with a cobalt target. Samples from layers of interest were mounted on glass fibres with silicone grease and analysed using a microdiffractometer employing a position sensitive proportional counter detector interfaced to a multichannel analyser.

In addition, selected samples were examined by polarized light microscopy (PLM) using Cargille Meltmount medium

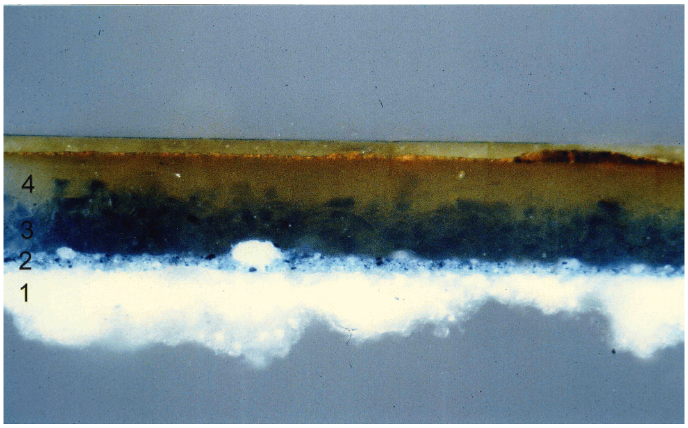

Figure 3. A cross-section of the japanned surface of the clock in an area with metallic decoration. The sample shows a thick, white preparation layer (layer 1) covered with a thin, light blue layer (layer 2). Over the light blue layer are several blue-green applications containing smalt in a resin medium (layer 3). Unpigmented, yellow varnish applications (layer 4) are present on top of the blue-green layers. Gilding and varnish layers are visible above the japanned finish. Full image width is 545 micrometers.

(n=1.66). Particles were characterized on the basis of their morphological and optical properties.

Analysis of the Blue-green Japanned Finish

Cross-sections from several areas of the clock allowed the structure of the japanned finish to be determined. A photomicrograph of a cross-section from an area with metallic decoration is shown in **Figure 3**. The sample shows a thick, white preparation layer, likely several applications, which has been covered with a thin, light blue layer. On top of the thin, blue layer are several translucent, blue-green layers composed of blue pigment in a yellow medium. An unpigmented yellow varnish, its thickness again suggesting multiple applications, is present on top of the blue-green layers. Above the varnish, the layer structure varies depending on the type of surface decoration present over the japanning.

Fragments of all four layers making up the japanned finish were analyzed: the white preparation layer, the light blue layer, the translucent blue-green layers and the transparent yellow varnish. The analytical results and the methods used to identify the components of each sample are given in **Table I**. The white preparation layer (layer 1) is composed of calcium carbonate (in the form of natural chalk[29]) in a protein binding medium. The thin, light blue layer (layer 2) contains indigo mixed with calcium carbonate and lead white in a protein medium. The translucent blue-green layers (layer 3) are pigmented with smalt; the yellow medium is a natural resin or mixture of resins. The transparent yellow varnish (layer 4) above the smalt layer is also a natural resin or resin mixture. The infrared spectrum of both the pigmented and unpigmented layers indicates that the major component of the varnish is a terpenoid (tree) resin or a mixture of terpenoid resins rather than shellac, an insect secretion.[30] The infrared spectrum of the transparent varnish layer is shown in **Figure 4**.[31]

The materials used for the japanning on the long case clock show a number of similarities to historic recipes, but also some differences. The chalk in protein medium used for the preparation layer on the clock is consistent with the mixture of whiting and size described in the treatises. Its thickness suggests that multiple applications were laid down to conceal the wood grain. The use of smalt in the japanned finish is also consistent with Stalker's and Parker's "Blew Japan" recipe, and with Dossie who indicates that smalt is one of the blue pigments that may be used to create a blue japanned surface. The build up of smalt layers visible in the cross-section, with the amount of pigment steadily diminished until only pure varnish layers are applied, is also in accordance with the instructions given in the treatises.

Table I: Analysis of the Blue-green Japanned Finish.

Layer Description*	Pigments and Media	Analytical Techniques Employed**
layer 1: white preparation	- calcium carbonate ($CaCO_3$) (chalk) - protein	SEM/XES, FTIR, PLM
layer 2: light blue	- lead white ($2PbCO_3 \cdot Pb(OH)_2$) - calcium carbonate ($CaCO_3$) - indigo ($C_{16}H_{10}N_2O_2$) - protein	SEM/XES, FTIR
layer 3: translucent blue-green	- smalt (K, Co, Al silicate) (glass) - natural resin (terpenoid)	SEM/XES, FTIR, PLM
layer 4: yellow varnish	- natural resin (terpenoid)	FTIR

*The first layer, applied directly to the wood, is designated as layer 1.
**SEM/XES = scanning electron microscopy/x-ray energy spectrometry (also referred to as x-ray microanalysis); FTIR = Fourier transform infrared spectroscopy; PLM = polarized light microscopy

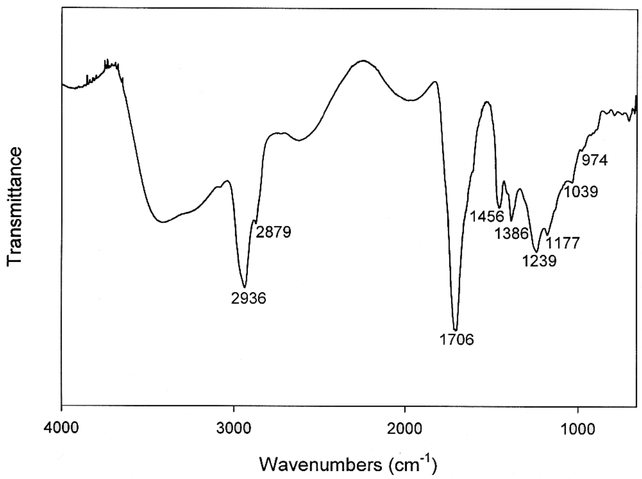

Figure 4. An infrared spectrum of the transparent varnish layer. The spectrum indicates that the varnish is a tree resin or mixture of tree resins rather than shellac.

However, rather than mixing lead white with smalt in the japanning layers, as Stalker and Parker suggest, lead white pigmented with indigo has been used as an opaque underlayer before applying the translucent smalt layers. Indigo, a natural blue dye, although mentioned by Dossie for painting in oil or varnish,[32] is not listed in either Dossie's or Stalker's and Parker's recipes for blue japanning. Although not described in the treatises, this indigo blue underlayer serves an important visual role, showing through the translucent smalt layers to add colour and depth to the final japanned surface.

The medium for the smalt layers in the japanning on the long case clock is a natural resin, or mixture of natural resins, not the "isinglass-size" indicated by Stalker and Parker. Since the major component of the resin used for the japanning on the clock was found to be a tree resin or tree resin mixture, it appears that Dossie's recommendation to avoid shellac for blue japanning was followed since it would give "to a true blue a cast of green".[33] Although shellac was not used, presumably in an attempt to avoid discolouration, yellowing of the chosen resin has occurred since the japanning was applied.

The major component of the transparent varnish layers over the smalt layers is also a natural resin from a tree source. More detailed analysis of the type of resin or resin mixture would be required to determine if this varnish corresponds to the recipes described by Dossie and Stalker and Parker.

Analysis of Surface Decorations

The analytical results and the methods used to identify the components of the surface decorations are given in **Table II** and **Table III**. Samples of the raised decoration, several painted surface finishes, and various colours of metallic finish were examined.

A cross-section from an area with raised metallic decoration showed that a white paste was used to create the embossed effect. Analysis indicates that the paste is composed of calcium carbonate in drying oil, or possibly an oil-resin mixture. This differs from the mixture of calcium carbonate and bole in a gum arabic medium described by both Dossie and Stalker and Parker. It also differs from the paste described by Watin which contains equal amounts of calcium carbonate and umber in an oil-resin medium. In addition, analysis shows that the paste was sealed with an unpigmented natural resin varnish prior to the application of the metallic surface decoration. This procedure, which isolates the decorative layers from the paste beneath, is not described in the treatises.

In all areas of metallic surface decoration, the metals were applied on top of a very thin mordant pigmented with vermilion,[34] a pigment listed in Stalker's and Parker's, Dossie's, and Watin's recipes for gold-size. The mordant layer was too thin to allow its medium to be identified. Different metallic finishes were used in different areas of the clock. The gold surfaces on the raised decoration are gold leaf, while the gold-coloured decorative borders are made of powdered brass. It is interesting that the borders, less important to the composition than the raised decoration, were produced with brass powder rather than gold, likely as a cost saving measure. Inexpensive powdered metal was also used on silver-coloured areas. The silver surface from a decorative border and from the flesh of the figures was found to be tin powder rather than genuine silver

Table II: Analysis of Metallic Decoration.

Sample Description	Elements Identified in Metallic Flakes/leaf by X-ray Microanalysis	Interpretation
silver-coloured metallic powder from decorative border	tin	tin powder
gold-coloured metallic powder from decorative border	copper, zinc	brass powder
gold-coloured metallic leaf from decorative panel	gold	gilding
bronze-coloured metallic powder from hills on decorative panel	tin copper, zinc	tin powder brass powder

Table III: Analysis of Other Surface Decorations.

Sample Description	Pigments and Media	Analytical Techniques Employed*
white paste, used to create raised design elements	- calcium carbonate ($CaCO_3$) (chalk) - drying oil	SEM/XES, FTIR, PLM
transparent sealing layer on raised paste	- natural resin (terpenoid)	FTIR
red preparation layer for metallic powders and gilding	- cinnabar/dry process vermilion (HgS)	SEM/XES, PLM, XRD
red-brown paint	- cinnabar/dry process vermilion (HgS) - lead white ($2PbCO_3 \cdot Pb(OH)_2$)	SEM/XES, FTIR, PLM, XRD
black paint	- finely divided carbon black (C)	SEM/XES, FTIR, PLM
red paint	- cinnabar/dry process vermilion (HgS)	SEM/XES, FTIR, PLM, XRD
orange wash	- chemical elements are consistent with iron oxide pigments	SEM/XES

*SEM/XES = scanning electron microscopy/x-ray energy spectrometry (also referred to as x-ray microanalysis); FTIR = Fourier transform infrared spectroscopy; PLM = polarized light microscopy; XRD = X-ray diffraction

leaf. The hills of the raised decoration, which have a shaded, bronze-like effect, contain both powdered brass and powdered tin. This is similar to Stalker's and Parker's description of shading copper powder with powdered tin.

As well as the metallic decoration, selected painted decoration was analysed. All the paints examined showed the use of common pigments. Black areas are pigmented with a finely divided form of carbon black, consistent with lampblack. The red and red-brown paint contains vermilion[34] and lead white. Elemental analysis of a thin orange wash over areas of gilding suggests the use of iron oxide pigments. As in the case of the mordant, the paint layers were too thin to allow their medium to be identified.

Conclusions

Scientific analysis provided important information about the materials and techniques used on the japanned long case clock. Analysis also allowed comparisons to be made between the materials found on the clock and published recipes in historic treatises on japanning. The materials identified on the long case clock showed many similarities to historic recipes, but also showed that actual practices sometimes varied from these descriptions. For example, analysis indicated that an opaque underlayer, pigmented with lead white and indigo, was present beneath the translucent japanning layers. Although not described in the treatises, the indigo blue underlayer serves an important role, showing through the translucent layers above to add colour and depth to the final surface.

It would be of interest to carry out further work on the characterization of the natural resin varnish used in the japanning layers. In this study, the major component of the varnish was determined to be a terpenoid (tree) resin using Fourier transform infrared spectroscopy. However, it is clear from the treatises that the varnishes used for japanning were often complex mixtures of resins and oils. Although Fourier transform infrared spectroscopy allows the major component of a varnish to be identified, it is less useful for characterizing such mixtures. More detailed analysis using a technique such as gas chromatography/mass spectrometry would allow specific identification of the components of the varnish.

Acknowledgments

The author would like to acknowledge the contribution of Deborah Bigelow of American Burnish who carried out a detailed visual examination of the clock and undertook the initial steps in its conservation treatment. The author would also like to thank the Royal British Columbia Museum for allowing the work to be published and two anonymous reviewers for helpful comments.

References

1. Wardop, James, Royal British Columbia Museum, personal communication.

2. Stalker, John and Parker, George, *A Treatise of Japanning and Varnishing 1688*, with an introduction by H. D. Molesworth (Chicago: Quadrangle Books, 1960).

3. Dossie, Robert, *The Handmaid to the Arts* (London: Printed for E.Nourse,1758).

4. Watin, *L'art du peintre, doreur, vernisseur : ouvrage utile aux artistes & aux amateurs qui veulent entreprendre de peindre, dorer & vernir toutes sortes de sujets en batiments, meubles, bijoux, équipages, etc*., *Seconde Édition* (Paris: Grangé, Durand et L'Auteur, 1773).

5. Rushfield, Rebecca Anne, " 'No damp air, no mouldring worm, or corroding time can possibly deface it.' John Stalker and George Parker, *A Treatise of Japanning and Varnishing*, 1688," in: *Papers Presented at the Art Conservation Training Programs Conference* (Cambridge, Mass: The Fogg Art Museum, Harvard University, 1979), pp. 55-66.

6. Ballardie, Margaret, "Historical Colours Used in 17th Century and 18th Century Japanning,"*ICOM Committee for Conservation*, *Preprints of the 11th Triennial Meeting, Edinburgh*, edited by Janet Bridgeland (London: James & James, 1996), vol. 2, pp. 911-914.

7. Webb, Marianne, *Lacquer: Technology and Conservation. A Comprehensive Guide to the Technology and Conservation of Asian and European Lacquer* (Oxford: Butterworth-Heinemann, 2000).

8. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, p. 35.

9. Dossie, *The Handmaid to the Arts*, pp. 410, 411.

10. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, p. 23.

11. Webb, *Lacquer: Technology and Conservation*, p. 172.

12. Dossie, *The Handmaid to the Arts*, pp. 414-416.

13. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, pp. 19, 20.

14. Webb, *Lacquer: Technology and Conservation*, pp. 121, 122.

15. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, pp.10, 23.

16. Dossie, *The Handmaid to the Arts*, pp. 414-416.

17. Dossie, *The Handmaid to the Arts*, p. 422.

18. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, p. 33.

19. Watin, *L'art du peintre, doreur, vernisseur*, p. 294.

20. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, pp. 5, 6.

21. Dossie, pp. 386-388, 401-403, 404-406.

22. Watin, *L'art du peintre, doreur, vernisseur*, pp. 297-299.

23. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, p. 49.

24. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688,* pp. 26-29.

25. Stalker and Parker, *A Treatise of Japanning and Varnishing 1688*, pp. 53-61.

26. Dossie, *The Handmaid to the Arts*, pp. 384, 403, 405.

27. Dossie, *The Handmaid to the Arts*, pp. 384, 385.

28. Watin, *L'art du peintre, doreur, vernisseur*, p. 292.

29. The calcium carbonate was characterized as natural chalk by the presence of coccoliths observed using polarized light microscopy. See Gettens, Rutherford J., FitzHugh, Elisabeth West, and Feller, Robert L., "Calcium Carbonate Whites," in: *Artists' Pigments: A Handbook of their History and Characteristics*, vol. 2, edited by Ashok Roy (Washington: National Gallery of Art, 1993), pp. 203-226.

30. Derrick, Michele, "Fourier Transform Infrared Spectral Analysis of Natural Resins Used in Furniture Finishes,"*Journal of the American Institute for Conservation*, vol. 28, no.1, 1989, pp. 43-56.

31. Gas chromatography/mass spectrometry would be required to allow more specific identification of the components of the varnish. Fourier transform infrared spectroscopy (FTIR) allows the major component of a varnish to be identified but is less useful for identifying mixtures. For example, although the main component of the varnish is a terpenoid resin, it is not possible to determine the exact type of resin or whether small quantities of other materials, such as a drying oil, are present.

32. Dossie, *The Handmaid to the Arts*, pp. 162, 176.

33. Dossie, *The Handmaid to the Arts*, p. 416.

34. Using polarized light microscopy, the pigment was found to be either synthetic vermilion produced by the dry process or natural mineral cinnabar. See Gettens, Rutherford J., Feller, Robert L., and Chase, W. T., "Vermilion and Cinnabar" in: *Artists' Pigments: A Handbook of their History and Characteristics*, volume 2, edited by Ashok Roy (National Gallery of Art: Washington, 1993), pp. 159-182.