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Site Web : <www.cac-accr.ca>.

A Survey of the Use of Cambridge White by Canadian Artists

Marie-Claude Corbeil[a], Eric J. Henderson[a] and Susan Walker[b]

[a]Canadian Conservation Institute, Department of Canadian Heritage, 1030 Innes Road, Ottawa, Ontario K1B 4S7, Canada; mccorbeil9@gmail.com; eric.henderson@canada.ca

[b]National Gallery of Canada, 380 Sussex Drive, Ottawa, Ontario K1N 9N4, Canada; SWalker@Gallery.ca

Previous research at the Canadian Conservation Institute (CCI) has demonstrated that Tom Thomson and artists from the Group of Seven made extensive use of a white pigment that consists of a mixture of lead sulfate ($PbSO_4$) and zinc white (ZnO) combined in specific proportions: Cambridge Colours' New Flake White or Cambridge white. Evidence of the use of Cambridge white by Canadian artist Kathleen Munn and archival research raised the question of its possible use by other Canadian artists. Therefore, a survey of the use of the pigment was undertaken on site at the National Gallery of Canada (NGC) that focussed on paintings executed during the period from 1894, when Madderton & Co. first produced the paint, to 1943, the year the company was dissolved. The paintings surveyed were analyzed using two non-destructive techniques, namely, hand-held X-ray fluorescence (XRF) spectrometry and Fourier transform infrared (FTIR) spectroscopy in external reflection mode with a portable instrument. This article presents the results of the survey as well as a compilation of results obtained for other Canadian paintings dated to the period of interest which had been analyzed previously at the CCI. Through the evaluation of results obtained for 88 paintings by Tom Thomson and the Group of Seven and 128 painting by other Canadian artists, it is clear that Tom Thomson and the Group of Seven remain the main users of Cambridge white identified so far. Although a relatively small number of other Canadian artists were surveyed in this study, results indicate that Cambridge white was used mainly in the Toronto area, where the paint was sold, and that most artists who used it were close to the Group of Seven.

Des recherches précédentes de l'Institut canadien de conservation (ICC) ont démontré que Tom Thomson et les artistes du Groupe des Sept ont abondamment fait usage d'un pigment blanc constitué de sulfate de plomb ($PbSO_4$) et de blanc de zinc (ZnO) combinés dans des proportions spécifiques : New Flake White de Cambridge Colours, ou blanc de Cambridge. L'obtention de preuves quant à l'utilisation du blanc de Cambridge par l'artiste canadienne Kathleen Munn et des recherches dans les archives ont soulevé des questions concernant son emploi par d'autres peintres canadiens. Par conséquent, un sondage sur l'utilisation du pigment a été entrepris sur place au Musée des beaux-arts du Canada (MBAC), lequel ciblait des tableaux exécutés pendant la période allant de 1894, quand Madderton & Co. a commencé à produire la peinture, à 1943, quand la compagnie a été dissoute. Les tableaux sondés ont été analysés à l'aide de deux techniques d'analyse non destructives, la spectrométrie de fluorescence des rayons X avec un appareil à main et la spectroscopie infrarouge à transformée de Fourier avec un appareil portable. Cet article présente les résultats du sondage ainsi que la compilation des résultats obtenus pour d'autres tableaux canadiens datant de la période concernée analysés auparavant à l'ICC. Sur la base des résultats obtenus pour 88 tableaux de Tom Thomson et du Groupe des Sept et de 128 tableaux d'autres artistes canadiens, il est clair que Tom Thomson et le Groupe des Sept demeurent les principaux utilisateurs du blanc de Cambridge identifiés à ce jour. Bien qu'un nombre relativement restreint d'autres artistes canadiens aient été sondés dans cette étude, les résultats indiquent que le blanc de Cambridge était surtout utilisé dans la région de Toronto, où le pigment était vendu, et que les artistes qui l'employaient étaient proches du Groupe des Sept.

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INTRODUCTION

Previous research at the Canadian Conservation Institute (CCI) has demonstrated that Tom Thomson and artists from the Group of Seven made use of a white pigment that consists of a mixture of lead sulfate ($PbSO_4$) and zinc white (ZnO) combined in specific proportions. The pigment was named Freeman's White after the patent holder,[1,2] one of several names used for this pigment in historical sources.[1] At the time of the research, it had not yet been identified at the CCI or reported in the literature in works of other artists, Canadian or foreign. Therefore, its presence in a painting tentatively attributed to Thomson or the Group of Seven was considered a positive element that supported attribution.

In 2014, the pigment was found in tubes of Cambridge Colours' New Flake White (**Figure 1**) in a paint box belonging to Canadian artist Kathleen Munn (1887–1974).[3]

Cambridge Colours were produced in England by Madderton & Co., a company established in 1890 by A.P. Laurie, with New Flake White introduced in 1894.[4] Madderton & Co. Ltd. closed their business in 1939; however, Cambridge Colours continued to be available in the United States, manufactured by Winsor & Newton, which suggests that Winsor & Newton may have bought out the remaining goodwill of the company.[4] The company was finally dissolved in 1943.[4]

Cambridge Colours were exported to Europe, Australia and North America.[4] In Canada, Cambridge Colours were distributed by the Artists' Supply Co. in Toronto,[4] established in 1906.[5] Recent archival research showed that the Artists' Supply Co. advertised Cambridge Colours in the 1906 edition of the Canadian National Exhibition catalogue, in subsequent editions of the same catalogue, as well as in issues of the *Prospectus* of the Central Ontario School of Art and Industrial Design (later the Ontario College of Art), which makes it likely that the Toronto art community was aware of this line of paints.[6] The archival evidence strongly suggests that the white pigment used by Tom Thomson and artists from the Group of Seven is Cambridge Colours' New Flake White.[6] "New Flake

Figure 1. Tubes of Cambridge Colours' New Flake White from Kathleen Munn's paint box.

White or Cambridge White" and "Freeman's White" were names given by Laurie to the mixture of lead sulfate and zinc white;[7] throughout this article the name Cambridge white will be used since it indicates the source of the pigment as Cambridge Colours.

More recently the pigment was identified in one of Munn's paintings executed around 1915–1920.[8] Evidence of the use of Cambridge white by Munn and archival research raised the question of its possible use by other Canadian artists. For instance, testimonials by Toronto artist Owen P. Staples (1866–1949) and Ottawa artist Franklin Brownell[9] (1857–1946) included on an advertisement for Cambridge Colours from the Artists' Supply Company[6] confirm that at least two other Canadian artists were aware of the product line, and suggest that knowledge of the paint brand extended beyond the Toronto region.

Therefore, to assess how widespread the use of Cambridge white was among Canadian artists, a survey of the use of the pigment was undertaken on site at the National Gallery of Canada (NGC) that focussed on paintings executed during the period from 1894, when Madderton & Co. first produced the paint, to 1943, the year the company was dissolved. In order to bring structure to the selection of paintings, it was decided to look first at the work of Canadian artists who were close to the Group of Seven and/or active in the Toronto area. After that, the survey was expanded to include several artists from Montreal. The paintings surveyed were analyzed using two non-destructive techniques, namely hand-held X-ray fluorescence (XRF) spectrometry and Fourier transform infrared (FTIR) spectroscopy in external reflection mode with a portable instrument. Hand-held XRF spectrometry allows for the detection of lead and zinc in a ratio indicative of Cambridge white,[10] and FTIR spectroscopy allows for the confirmation of the presence of the chemical compounds that make up the pigment (lead sulfate and zinc white).

This article presents the results of the NGC survey as well as a compilation of results obtained for other Canadian paintings dated to the period of interest which have been analyzed in the course of other projects at the CCI.

METHODOLOGY

Artists Selected for the Survey[11]

The founding members of the Group of Seven in 1920 were Franklin Carmichael (1890–1945), Lawren Harris (1885–1970), A.Y. Jackson (1882–1974), Franz Johnston (1888–1949), Arthur Lismer (1885–1969), J.E.H. MacDonald (1873–1932) and Frederick Varley (1881–1969). In 1926, after Johnston's resignation, A.J. Casson (1898–1992) joined the Group. Edwin Holgate (1892–1977), active in Montreal, joined in 1929 and L.L. Fitzgerald (1890–1956), active in Winnipeg, in 1932. Tom Thomson (1877–1917) played an important role in the emergence of the Group, although he died before its official formation. The Group disbanded in 1933 and several members were founding members of the Canadian Group of Painters, which was established that year. The Canadian Group of Painters counted 28 founding members and expanded through the years. It disbanded in 1969.

It was obvious from the start that the number of artists whose work could potentially be included in the survey was very large, and there was a need to narrow it down for the sake of time and logic. Therefore, the decision was made to focus first on artists who were close to the Group of Seven and/or active in Toronto, with later expansion to include Montreal-based artists. It is worth noting that the artists who were selected – and others who were not – may have intersected in other areas of their professional lives (such as formative training in Europe or the USA) and may have learned of Cambridge white in that way. However, the key intersections for the purpose of this study were a close acquaintance with members of the Group of Seven and/or access to a known source of the pigment – that is, the Artists' Supply Co. in Toronto. Another important criterion was, of course, that the artists selected be represented in the collection of the NGC by paintings executed during the period of interest, 1894 to 1943.

With those criteria in mind, the initial group of artists selected was as follows: Frederick Grant Banting (1891–1941), who was a friend of A.Y. Jackson and went on sketching expeditions with him; Bertram Brooker (1888–1955), who was friendly with members such as Lawren Harris

and who exhibited with the Group of Seven; Edwin Holgate, who, although based in Montreal, was invited to join the Group of Seven in 1929; Prudence Heward (1896–1947), also based in Montreal, who exhibited with the Group of Seven; Carl Schaefer (1903–1995), who studied at the Ontario College of Art under Lismer and MacDonald; Kathleen Munn, who, through her friendship with Bertram Brooker, was introduced to members of the Group of Seven, which led to Munn's inclusion in Group of Seven exhibitions in 1928 and 1930;[12] and George A. Reid (1860–1947), the first principal of the Ontario College of Art, and his second wife Mary E. Wrinch (1877–1969), a contemporary of the Group of Seven, who were important figures in the Toronto art scene.[13] To this list was added Group member Franklin Carmichael, whose use of Cambridge white was not confirmed during the initial research on the pigment, which included analysis of five works.[1,14]

When it quickly became apparent that the presence of Cambridge white was uncommon, even for an artist such as Kathleen Munn, whose use of the pigment was demonstrated by previous analysis, the selection of artists was broadened to include several artists from the Montreal area, another important artistic centre at the time with connections to the Group of Seven and Toronto art circles. These artists were: Regina Seiden Goldberg (1897–1991), Henrietta Mabel May (1877–1971), Kathleen Morris (1893–1986) and Anne Savage (1896–1971). All four artists were active in the Montreal art scene; Savage was of particular interest because she taught art at Concordia University and was a prominent figure in Canadian art during the 1920s and 1930s.

Paintings included in the survey were selected based on their date and on the use of white paint or pale colours, which makes the identification of Cambridge white more statistically probable.

Instrumental Methods

Several white or pale-coloured areas of the paintings selected for the survey were analyzed non-destructively by X-ray fluorescence (XRF) spectrometry using an Innov-X Model 440 hand-held spectrometer equipped with an X-ray tube (silver anode) and Si PIN diode detector. With this method, it is possible to determine elements of atomic number 19 (potassium) and greater present in the surface layers in areas of about 1 cm in diameter. Areas on the paintings were analyzed for 30 seconds each using the "Alloy Analysis/ Analytical" mode, which, although not designed specifically for paint analysis, has proven effective for quantitative analysis of Cambridge white. When results were clearly negative (for example, when only lead, zinc or titanium was detected) and when results were clearly positive (showing the presence of lead and zinc combined in the known specific proportions), analysis was limited to only two areas on each painting. When results were unclear or inconsistent between areas, more areas were analyzed.

Areas that tested positive or tentatively positive for the presence of Cambridge white by XRF spectrometry were subsequently analyzed by Fourier transform infrared (FTIR) spectroscopy. The analysis was done in external reflection mode (non-contact) using a Bruker Alpha portable spectrometer equipped with an extended focus external reflection sampling accessory. This technique provides identification of the molecular species present in the surface material. Reflection spectra were collected between 6000 and 400 cm^{-1} with the co-addition of 150 scans at 4 cm^{-1} resolution. Background spectra were collected on gold reference mirrors before every area analyzed. Kramers-Kronig transformations (KKT) were applied to the reflection spectra in order to compare the experimental spectra to reference transmission/absorption databases. In general, the relative intensities of the peaks associated with ZnO and $PbSO_4$ were similar for most of the areas in which Cambridge white was identified. However, calculation of relative peak areas, a more accurate comparative measure for FTIR spectroscopy, was not undertaken, as the influence of KKT on peak area is not known; and additional spectral corrections, such as line smoothing and baseline corrections, were not applied. Consequently, a discussion of the peak ratios (either intensity or area ratios) of ZnO to $PbSO_4$ is not included here.

RESULTS AND DISCUSSION

Review of Results Previously Obtained for Group of Seven and Tom Thomson Paintings

The initial survey on Cambridge white[1] focussed on members of the Group of Seven and Tom Thomson. Fifty-eight oil sketches and paintings were surveyed by XRF spectrometry. Samples were taken from 16 of these works when lead and zinc were found in a majority of areas in a constant ratio, indicative of a mixture of fixed composition; the samples were analyzed using other instrumental methods to confirm that the lead- and zinc-containing pigments were lead sulfate and zinc white.[1] A subsequent research project on the materials and techniques of Tom Thomson contributed to the statistics on the use of Cambridge white by the artist; it was confirmed in 23 out of 33 works analyzed.[2] The results from these two main studies were combined with results obtained on individual paintings by the Group of Seven and Tom Thomson analyzed throughout the years at the CCI. It is important to note that those individual studies were not necessarily designed in the same way as the two main studies, since the objective of the individual analyses was to answer specific questions, sometimes based only on a limited number of samples and/or not necessarily using all of the instrumental techniques required to detect Cambridge white.

Table I lists, for each artist, the number of paintings surveyed in the three sets of results described above, the period during which they were painted, the number of paintings in which Cambridge white was detected and the period during which these paintings were executed.

In total, 88 paintings were studied and Cambridge white was identified in 38 of them. Works by Tom Thomson represented 40% of the paintings studied and 63% of all occurrences of Cambridge white, followed by works by J.E.H. MacDonald (15% of paintings and 13% of occurrences) and works by Arthur Lismer and Lawren Harris (9% and 10% of paintings, respectively, and 8% of occurrences each). Although works by A.Y. Jackson represented 13% of the

Table I. Statistics on the use of Cambridge white by the Group of Seven and Tom Thomson based on previous analysis.

Artist	Number of paintings studied	Date of paintings studied	Number of paintings in which Cambridge white was detected*	Date of paintings in which Cambridge white was detected
Franklin Carmichael	5	1915 to c. 1932	0	
Lawren Harris	9	1911–12 to c. 1936	3	1912 to c. 1936
A.Y. Jackson	11	1915 to 1938–39?	1	1927
Franz Johnston	1	1933	0	
Arthur Lismer	8	1914 to 1930	2 or 3**	1920 to 1921
J.E.H. MacDonald	13	1912 to 1930	4 or 5**	1920 to 1927
Frederick Varley	5	1918–19 to 1943	1	1943
A.J. Casson	1	1931	1	1931
Tom Thomson	35	1912 to 1917	24	c. 1912–13 to 1917

*Through sample analysis

**In one instance, one component of Cambridge white (lead sulfate) was identified positively while the other (zinc white) was possibly identified, e.g., by detecting zinc through elemental analysis or zinc soaps by FTIR spectroscopy. However, identification of lead sulfate is considered indicative enough to include these occurrences in the statistics that follow.

paintings studied, there was only one occurrence of Cambridge white (3%). A later study of two A.Y. Jackson paint boxes showed that Cambridge colours were not found among the paint tubes in one box and Cambridge white was not identified in the remnants of paints sampled from the other.[15]

The first XRF spectrometry survey, conducted on sketches and paintings by the Group of Seven and Tom Thomson, showed that the method was effective for detecting Cambridge white: the presence of Cambridge white was confirmed through the subsequent analysis of samples from works where lead and zinc were found in a majority of areas in a constant Pb/Zn ratio. Another interesting observation was that the pigment was found in both sketches and paintings.[1] During this survey, nine sketches and paintings gave inconclusive results, the Pb/Zn ratio varying from area to area or diverging from the expected value. At the time, these works were not sampled to confirm the presence or absence of Cambridge white in order to restrict sampling to the minimum. However, three of the works with inconclusive results were by Tom Thomson and were sampled later as part of the research project on the artist's materials. Cambridge white was found in one of them. In the second painting, lead white or zinc white was found in paint samples, while in the third, lead white was used in the ground while zinc white was used in the paints. This explains the detection of lead and zinc by XRF spectrometry in ratios that were close, but not identical, to those observed for paint that contains Cambridge white. Therefore, there are instances where XRF spectrometry gives a false positive for the presence of Cambridge white, when the more common pigments zinc white and lead white are used, either in the same paint layer or in adjacent or superimposed layers, such as the ground and paint layers.

Examination of past results obtained on individual paintings through the years confirmed that detection of Cambridge white was not always straightforward. For instance, Cambridge white was identified in only two samples out of 16 taken from a single painting by Varley, during a project aimed at documenting the painting. This shows that the use of the pigment in a sketch or painting was not necessarily consistent.

Survey of Paintings by Other Canadian Artists

During the current survey, 34 paintings were analyzed by XRF spectrometry. The paintings included works by 14 artists and were dated from 1906 to 1943 (**Table II**). Some artists were represented by several paintings, others by a few or only one. Of the 34 paintings, a total of 14 by 8 artists tested positive or tentatively positive for the presence of Cambridge white, with sometimes only one area giving a positive or tentatively positive result. For the purpose of this survey, a tentatively positive result was a result whereby lead and zinc were detected by XRF spectrometry but in a ratio that diverged from the expected value. As noted above, it was necessary to consider that the ratio could be skewed by the presence of zinc white or lead white in the same layer or adjacent or superimposed layers. The eight artists were: Frederick Grant Banting, Regina Seiden Goldberg, Prudence Heward, Edwin Holgate, Henrietta Mabel May, George A. Reid, Carl Schaefer and Mary E. Wrinch.

Interestingly, the current XRF spectrometry survey confirmed the results previously obtained for Carmichael in that there was no indication of Cambridge white present in any of the seven NGC paintings analyzed. As well, although Cambridge white was found in Munn's paint box and in one of her paintings, there was no evidence for its use in the three NGC paintings analyzed.

Table II. Statistics on the use of Cambridge white by other Canadian artists included in the current survey.

Artist	Number of paintings studied	Date of paintings studied	Date of paintings in which Cambridge white was detected by FTIR
Frederick Grant Banting	1	1930	1930
Bertram Brooker	2	c. 1929, 1931	
Franklin Carmichael	7	1915 to c. 1939	
Regina Seiden Goldberg	1	c. 1919	not available for FTIR
Frank Hennessey	1	c. 1939	
Prudence Heward	2	1929, 1943	
Edwin Holgate	4	1921 to 1938	c. 1930
H. Mabel May	2	c. 1914, c. 1925	
Kathleen Moir Morris	1	c. 1927	
Kathleen Munn	3	c. 1916 to c. 1926–1928	
George A. Reid	1	1915	1915
Anne Savage	1	c. 1919	
Carl Schaefer	3	1934 to 1941	1935
Mary E. Wrinch	5	1906 to 1923	1923

The areas that tested positive or tentatively positive for the presence of Cambridge white by XRF spectrometry were selected for analysis by FTIR spectroscopy. **Figure 2** shows a representative FTIR spectrum of the Cambridge white paint from the Munn paint box obtained in reflection mode (after KKT corrections). The spectrum is dominated by peaks associated with lead sulfate at 1176, 1070, 968, 634 and 600 cm^{-1}, and the broad absorption band centered at c. 499 cm^{-1} from zinc white. The results obtained in external reflectance are very similar to those obtained in transmission/absorption mode.[6] The low intensity peak at 1740 cm^{-1} is from the glycerol esters in the drying oil binder.

Given that external reflection FTIR spectroscopy is a surface-sensitive technique, it became evident that any varnish present on the surface of the paintings interfered with the characterization of the paint underneath. Acrylic varnishes in particular gave strong signals that obscured absorption bands from the underlying paint. For example, the KKT-corrected reflection FTIR spectrum from an area on Edwin Holgate's *Nude in a Landscape* (c. 1930) (**Figure 3**) shows a series of peaks that are characteristic of an acrylic varnish (**Figure 4A**); there are no peaks present in the spectrum from components in the underlying paint. Therefore, varnish had to be removed from the area to be analyzed, creating a small window to the paint film large enough for the aperture of the extended focus external reflection sampling accessory (c. 1 cm^2). The effect of varnish removal is immediately evident, as shown in **Figure 4B**: after removing the varnish from the same area,

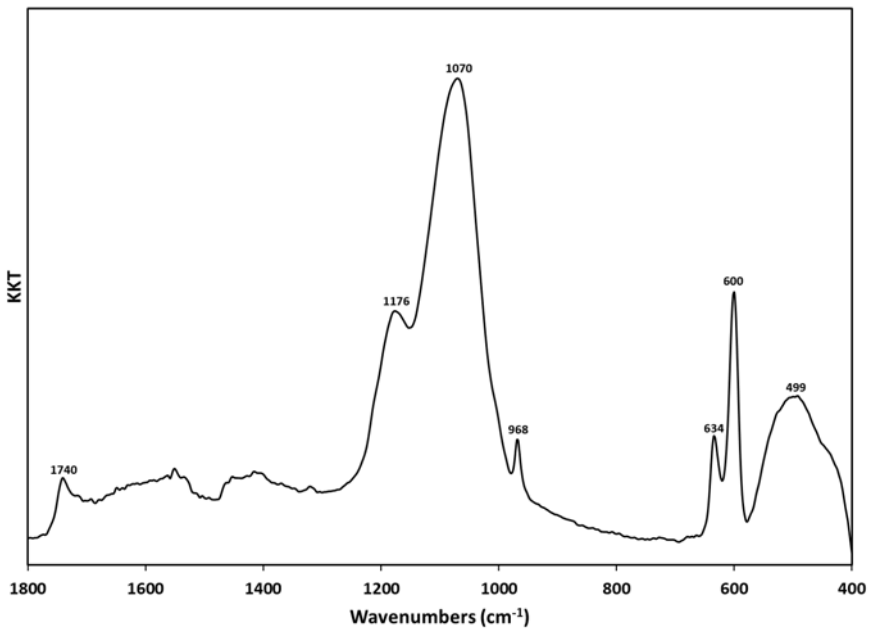

Figure 2. Representative KKT-corrected reflection FTIR spectrum of the Cambridge white paint from Kathleen Munn's paint box.

peaks associated with the acrylic varnish are gone, and the spectrum clearly shows the presence of Cambridge white in a drying oil medium.

In order to avoid opening too many test windows, FTIR analysis was limited as much as possible to one painting by each artist who was found to have used Cambridge white during the preliminary XRF spectrometry survey.

Figure 3. Edwin Holgate, *Nude in a Landscape*, c. 1930, oil on canvas, 73.1 cm x 92.3 cm, purchased 1930, National Gallery of Canada, Ottawa. © Estate of Edwin Holgate. Photo: NGC.

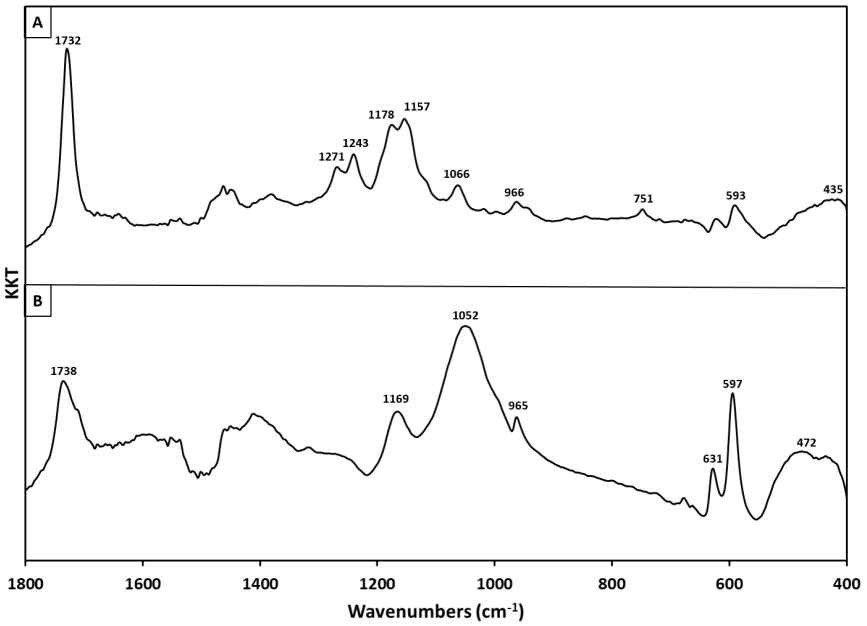

Figure 4. Representative KKT-corrected reflection FTIR spectra of the same area of the painting *Nude in a Landscape* (c. 1930) by Edwin Holgate: A) varnished, with peaks characteristic of an acrylic varnish; B) varnish removed, with peaks indicative of Cambridge white in a drying oil medium.

With that approach, 10 paintings were analyzed by FTIR spectroscopy. Cambridge white was identified in the paintings of the following five artists: Frederick Grant Banting, Edwin Holgate, George A. Reid, Carl Schaefer and Mary E. Wrinch (**Table II**). The painting by Regina Seiden Goldberg became unavailable between the XRF spectrometry and FTIR spectroscopy survey, so the presence of the pigment tentatively indicated by XRF spectrometry was not confirmed.

With the addition of Munn, the five artists listed above include several who were close to the Group of Seven (Munn, Banting, Holgate and Schaefer) and two who worked closely together (Reid and Wrinch). With the exception of Holgate, all were active primarily in Toronto.

Of the artists who testified as to the quality of Cambridge white in a 1913 advertisement for the Artists' Supply Co., Staples was active in Toronto, and Brownell in Ottawa. Staples was an active, well-established member of the Toronto art scene in the early decades of the 20th century.[16] As such, he was influential in the development of a number of artists, including Tom Thomson and A.J. Casson. Furthermore, he was a member of the Arts and Letters Club (founded in 1908), to which all the Group of Seven belonged. Interestingly, Staples first moved to Toronto in 1885 to study with George A. Reid, who has been shown to have used Cambridge white. Brownell was an American artist who moved to Ottawa in 1886, about the same time that Staples moved to Toronto. Brownell was involved with the Canadian Art Club (founded in 1907 in Toronto),[17] but it disbanded in 1915 and does not seem to have attracted the attention of the Group of Seven. In fact, there does not appear to have been any connection between Brownell and the Group of Seven, although Brownell was friendly with William Brymner, whom he met when both were training in Paris, and Brymner taught A.Y. Jackson at the Art Association of Montreal.

Review of Results Previously Obtained for Paintings by Other Canadian Artists

Results obtained through the years at the CCI for other Canadian paintings executed between 1894 and 1943 were compiled. As stated previously, in these cases, it is important to note that those studies were not necessarily designed for the same purpose as the current survey. Artists whose materials were systematically studied as part of the CCI's research on Canadian artists include Jean Dallaire,[18] Marc-Aurèle Fortin,[19] David B. Milne[20] and Alfred Pellan.[21]

Table III lists the artists that were identified through this review. Most artists were represented by only one painting, except for the ones whose materials were researched more extensively at the CCI.

Table III. Number and date of the paintings by other Canadian artists based on previous analysis.

Artist	Number of paintings studied	Date of paintings studied
Charles Comfort	2	1927, 1937
Maurice Cullen	1	1916
Jean Dallaire	4	1935 to 1938
J.W.L. Forster	2	1927, c. 1930
Marc-Aurèle Fortin	19	1918 to c. 1940
Prudence Heward	1	1933
Ozias Leduc	1	1920
David B. Milne	36	c. 1911–1912 to 1941
Jean-Paul Mousseau	1	1943
Kathleen Munn	4	c. mid-1910s to c. 1925
Lilias Torrance Newton	1	c. 1933
Pegi Nicol MacLeod	4	1934–1937 to c. 1940
Alfred Pellan	16	1928 to 1942
George A. Reid	1	1936
Carl Schaefer	1	1937

With the exception of the one occurrence in a painting by Kathleen Munn mentioned earlier, Cambridge white was not found in any of the 94 paintings by the 15 Canadian artists listed in **Table III**. Research done at the CCI on some of the artists, namely Milne and Fortin, provided evidence as to the brands of paints they favoured. A review of references to Milne's painting materials indicated that he used mostly Winsor & Newton paints for his oil paintings, with one reference to Devoe.[20] Two paint boxes attributed to Fortin, although not dated to any period in particular, contained paint tubes from Grumbacher, Winsor & Newton, Reeves & Sons Ltd. and George Rowney & Co. Ltd.[19] Therefore, in these two instances, archival evidence supports the findings made through analysis to the effect that the artists did not use Cambridge Colours.

Four artists listed in **Table III** were included in the current survey: Heward, Munn, Reid and Schaefer; paintings by Reid and Schaefer were found to include Cambridge white. Although different than the results in **Table III**, what the newest findings do emphasize is the rather random nature of Cambridge white use by artists other than Tom Thomson and the Group of Seven.

CONCLUSION

Through the survey of results obtained for 88 oil sketches and paintings by Tom Thomson and the Group of Seven and 128 paintings by other Canadian artists, it is clear that Tom Thomson and the Group of Seven remain the main users of Cambridge white identified so far. Therefore, its presence remains a positive factor for the authentication of their paintings.

Although a relatively small number of other Canadian artists were surveyed in this study, results indicate that Cambridge white was used mainly in the Toronto area, where the paint was sold, and that most artists who used it were close to the Group of Seven.

This study highlighted some of the difficulties in detecting this pigment using the available non-destructive analytical methods. Detection of lead and zinc by XRF spectrometry may give negative results if an artist did not use the pigment consistently in an artwork, so the presence of Cambridge white may go unnoticed in such preliminary surveys. On the other hand, XRF spectrometry may indicate the presence of Cambridge white when the more common pigments zinc white and lead white were used, either in the same paint layer or in adjacent or superimposed layers, such as the paint layer and the ground, or it may give skewed results if one or both of these pigments are present in addition to Cambridge white in the same layer or adjacent or superimposed layers. Confirmation of the presence of Cambridge white by FTIR spectroscopy in reflection mode can be compromised by the presence of a varnish or give negative results if the pigment happens to be located in a paint layer below the top paint layer. Although a survey approach that relies on non-destructive methods such as the ones used here is highly attractive, there will continue to be situations where Cambridge white can only be identified through the analysis of samples.

Given the very small number of positive results for the presence of Cambridge white in paintings by other Canadian artists active primarily in Ontario and Quebec, the survey was not extended to artists active outside these two provinces. As the CCI continues to analyze Canadian paintings, other occurrences of the pigment may be discovered that will shed additional light on its use by Canadian artists.

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[8] Henderson, Eric J. and Marie-Claude Corbeil, *Analysis of Samples from* Untitled (Landscape with Three Figures) *by Kathleen Munn* (Ottawa: Canadian Conservation Institute, 2019). Unpublished report.

[9] The name on the advertisement was misspelled "Bronnell."

[10] The proportions of lead sulfate and zinc oxide were determined by X-ray spectrometry in early research but are not disclosed here since the information could be used fraudulently. Thomson and the Group of Seven have been widely imitated and copied in Canada.

[11] Biographical information was taken from the National Gallery of Canada's website, unless indicated otherwise. "Search the Collection," in National Gallery of Canada website, https://www.gallery.ca/collection/search-the-collection. Accessed April 2020

[12] Uhlyarik, Georgiana, "Kathleen Munn," in: *The Canadian Encyclopedia* (Toronto: Historica Canada), <www.thecanadianencyclopedia.ca/en/article/kathleen-munn>. Last modified 15 May 2014. Accessed April 2020.

[13] Mary Heister Reid (1854–1921), George A. Reid's first wife, was also an important figure; however, her works were not included in the study because the surfaces of her paintings were not suitable for analysis by external reflection FTIR spectroscopy, a surface-sensitive technique.

[14] Use of Cambridge white was also not confirmed for Franz Johnston; however, in this case only one work was included in the initial research.

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[17] "Franklin Brownell," in *Wikipedia*, <https://en.wikipedia.org/wiki/Franklin_Brownell>. Accessed April 2020.

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