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A Technical Study of the Materials and Methods Used by David B. Milne in his Oil Paintings

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The opportunity to collect samples from David Milne's work presented itself in 1991 when a large number of his paintings were assembled for a Milne exhibition organized by the McMichael Canadian Art Collection (MCAC) and the Vancouver Art Gallery. Initially a group of paintings was visually examined to determine Milne's working methods and materials. In collaboration with the conservation department of the MCAC, over 250 samples were taken from a representative selection of 39 oil paintings spanning most of Milne's career. The sampled paintings belonged to the Milne Family Collection, the MCAC, the National Gallery of Canada, the Art Gallery of Ontario, the Agnes Etherington Art Centre and the University of Toronto. Samples of paints from David Milne's paintbox, loaned to the Canadian Conservation Institute by David Milne Jr., were also available for analysis. The analyses were carried out using the following techniques: X-ray microanalysis, X-ray diffraction, Fourier Transform Infrared Spectroscopy, polarised light microscopy and gas chromatography coupled with mass spectrometry. Cross-sections of selected samples were also prepared and analysed by incident light microscopy, fluorescence microscopy, and scanning electron microscopy/energy dispersive spectrometry. The most common pigments identified were: lead white, zinc white, viridian, ultramarine blue, vermilion, cadmium yellow, yellow ochre, and ivory black.

La possibilité de recueillir des échantillons des œuvres de David Milne s'est présentée lorsque la Collection McMichael d'art canadien (CMAC) et la Vancouver Art Gallery ont organisé, en 1991, une exposition sur sa carrière. Un groupe de tableaux a d'abord fait l'objet d'examens visuels pour déterminer les méthodes de travail de Milne et les matériaux qu'il a utilisé. De concert avec le service de conservation-restauration de la CMAC, plus de 250 échantillons ont été prélevés sur 39 peintures à l'huile représentatives des oeuvres couvrant la majeure partie de la carrière de Milne. Les peintures choisies appartiennent à la collection de la famille de David Milne, à la CMAC, au Musée des beaux-arts du Canada, au Musée des beaux-arts de l'Ontario, au Centre d'Art Agnes Etherington ainsi qu'à l'Université de Toronto. De plus, des échantillons provenant de la palette de l'artiste, que David Milne fils a mis à la disposition des auteurs aux fins de cette étude, ont aussi été analysés. Les techniques suivantes ont été utilisées : micro-analyse par rayons X; diffration des rayons X; spectroscopie infrarouge par transformée de Fourier; microscopie à lumière polarisée; et chromatographie en phase gazeuse couplée à la spectrométrie de masse. Des coupes transversales de certains échantillons ont été préparées et analysées par microscopie en lumière incidente, par microscopie par fluorescence, ainsi que par microscopie par balayage électronique avec analyse par rayons X à dispersion d'énergie. Les pigments les plus communément identifiés ont été : le blanc de plomb, le blanc de zinc, le vert émeraude (viridian), le bleu d'outremer, le vermillon, le jaune de cadmium, le jaune ocre et le noir d'ivoire.

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Introduction

The Project

An opportunity to study the paintings of Canadian painter, David B. Milne (1882-1953), arose in 1991 when the McMichael Canadian Art Collection and the Vancouver Art Gallery collaborated on a Milne retrospective exhibition, titled *David Milne*. Many of Milne's paintings were brought together for this exhibition, affording the possibility of sampling a representative selection of the oil paintings created throughout his lifetime. A visual examination and condition survey of 39 of Milne's paintings, undertaken just prior to the exhibition, revealed many technical details but also generated many questions. What was Milne's palette and how did it change over time? Were his blacks a mixture of colours, or simply black pigment? What type of size was used on the canvases? What were the ground layers made of? With what did Milne thin his paints? One of the purposes of this study was to provide answers to some of these technical questions. Another goal was to provide information on Milne's materials and techniques in order to assist with attribution, provenance, and conservation treatment of his paintings.

This study focused on Milne's oil on canvas works. It did not include his colour drypoints or watercolours. The participation of the National Gallery of Canada, the McMichael Canadian Art Collection, the Milne Family, and the Art Gallery of Ontario ensured that a representative selection of oil paintings throughout most of Milne's career was included in this project.

As part of this introduction, information gleaned from the literature about the artist, his working methods and life circumstances, is reviewed. This provided clues as to what areas needed to be investigated as well as to support interpretation of the analytical results. A section on observations from the visual examination of 39 of Milne's oil paintings, undertaken prior to the exhibition, then follows. Results from the analysis of the materials from a selection of 39 of Milne's paintings and his paintbox are described in the *Results and Discussion* section.

For the purpose of this study, the paintings examined are divided into four chronological groups based on Milne's location at the time of painting:

Group 1:
1911-1918, New York City and Boston Corners, N.Y.
1918-1919, war artist in Canada, Britain, and France
Group 2:
1920-1928, Boston Corners, N.Y.; Montreal, Quebec; Ottawa, Ontario; Toronto, Ontario; and the Adirondacks
Group 3:
1929-1939, Ontario, including Six Mile Lake
Group 4:
1940-1953, Toronto, Uxbridge, and Bancroft, Ontario

The Artist

David Brown Milne was an important Canadian artist who "created three thousand paintings throughout his lifetime and as many colour drypoints, etchings and drawings and wrote over a million and a half words".[1] The youngest of ten children, he was born in 1882 in a log cabin farmhouse in Saugeen Township, Bruce County, Ontario. He lived in Paisley, Ontario, between Port Elgin and Owen Sound from the time he was eight years old until he set off for art school in New York City in 1903 at the age of 21.

Milne's first exhibit was in 1909 with the American Watercolour Society. He hit his full stride as an artist in 1911[2] and exhibited almost every year from 1910 to 1922.[2,3,4,5] In 1914-1915 Milne made summer trips to the Hudson Valley and after 1915 he left New York City to settle at Boston Corners, N.Y.[2] He returned to Canada, arriving in Toronto on March 1st, 1918[6] and enlisted in the army.[7] He then sailed for England in September 1918[8] and later was appointed an official war artist, travelling in 1919 to paint camp scenes in Britain and deserted battlefields in France and Belgium. Milne painted in watercolours rather than in oils during his war years and produced "well over a hundred watercolours."[2] Milne sent some watercolours to New York in 1919 to be included in an exhibition and some of his work was also exhibited in London that year.[9] He was back in Boston Corners by December of 1919.[7] After the war, Milne settled in upper New York State until 1929. This era includes Milne's time in Big Moose and Lake Placid, as well as, periods of isolation spent painting in the wilderness.

Milne returned to Canada in 1929 where he spent the summer painting in Temagami, Ontario.[10] He then moved to Weston, a village located seven kilometers northwest of Toronto, in the fall of 1929.[11] From 1929 until 1933 Milne lived in Palgrave, Ontario, a town 60 km northwest of Toronto. The Palgrave period was particularly spartan for Milne, as his income was minimal. In 1933 he installed himself at Six Mile Lake, a remote site in Muskoka near Georgian Bay. There, Milne built himself a cabin where he stayed until 1939.[12]

In 1939 and 1940 Milne spent time in Toronto, before settling in Uxbridge in the fall of 1940. He built a cabin at Baptiste Lake, eight miles west of Bancroft, Ontario in 1948. He lived in both Uxbridge and at Baptiste Lake until 1952 when the Milne family moved to Bancroft, Ontario. David Milne died in Bancroft in 1953.

Clues to Milne's Working Methods

The literature regarding Milne's work mentions brands of materials, paints, and working techniques.[1,13] Much of this information was obtained through the examination of Milne's painting notes, letters, diaries, and study of his paintings. One of the goals of the present technical study was to augment the written information with physical evidence. As Milne himself expressed, "Never believe what an artist says, except on canvas-not even on canvas. He probably isn't making statements he is just feeling and mumbling to himself...".[14]

Winsor and Newton materials are frequently mentioned as having been used in Milne's paintings and colour drypoints. For example, he is known to have purchased watercolour supplies at Winsor and Newton during the War Records painting period (1918-1919).[15,7] In a letter to Alan Jarvis (October 26, 1936) Milne mentions the use of Winsor and Newton oil colours working well for his colour drypoints:

> … About the drypoints! I have used only W & N oils for colour, usually just as they come from the tube. Some work well, some don't,
> French Ultramarine works well
> Chinese Vermilion works well
> Orange Vermilion works well
> Most of the opaque earth colours, burnt sienna, light red, etc. are good. Viridian is hard to use. Have to ink first with an opaque green or yellow, say yellow ochre, wipe, then ink with viridian.[16]

Ivory black and permanent violet were also mentioned in this letter. In a letter to his wife, Patsy, Milne requested "one more tube of New Blue, W & N oil; one tube Zinc White Devo(e) oil …".[17] Devoe, being another paint manufacturer, indicates that he did not always choose Winsor and Newton colours. It is probable that Milne used the same oil paints for both his colour drypoints and oil paintings. He frequently worked in more than one medium at a time as is discussed below.

In the introduction of *Reflections in a Quiet Pool*, Rosemarie Tovell outlines the interdependence of the three techniques that Milne often employed.

> Milne employed primarily three media: painting, watercolour and print. Usually he worked in any two of these media simultaneously; at times he worked in all three. Each medium was nourished by the other, and in turn nourished its companion. They formed the bridge between his two careers. After 1920, when he began to consciously work in series (i.e. the development and reworking of identical compositions), the various media took on a closer almost symbiotic, relationship.

> A series could consist of a subject rendered in oil and/or watercolour and/or colour drypoint. Each new version of a subject would attempt to improve upon its predecessor or to capture a different nuance. By switching the medium within a series, Milne often found that an aspect of one medium could be a solution or a new direction in the other.[18]

This interdependence of media would most likely encourage the introduction of materials from one technique to another.

Oil colour names that were mentioned by Milne in conjunction with specific colour drypoints as listed by Tovell[13] include: Permanent Middle Green, Yellow Ochre, Indian Red, Sienna, Chinese Vermilion, Payne's Grey, Light English Red, Alizarin Crimson, Cobalt Blue, Zinc White, French Ultramarine, Viridian, New Blue and Special Red. Payne's grey was listed in a Winsor and Newton catalogue as "an intimate combination of Davy's Gray,[19] Red Ochre, and French Ultramarine." Special Red and Light English Red were not found in the Winsor and Newton oil paint lists reviewed.[20,21,22] A pigment called Light Red, however, is listed as calcined yellow ochre.[23] It is possible that these two reds were not Winsor and Newton paints or they were not offered by Winsor and Newton in certain years. Some of the paints used by Milne were purchased as pre-made pigment mixtures, such as Payne's grey, described above, and Winsor and Newton Permanent Green, described as a mixture of viridian and zinc yellow.[24] Milne also mentioned using zinc white and a green made with viridian and a cadmium pigment (presumably cadmium yellow) in a letter from 1941.[25] It is important to know which pigments were purchased as mixtures, since these pigment combinations may occur frequently and can have an impact on the interpretation of the paint analysis.

During the Palgrave period (1929-1933) Milne's income was minimal. As a result, Milne re-used some canvases. Many paintings from this period were scraped off or painted over and many canvases from this time were painted on both sides.[26]

During Milne's Six Mile Lake Period (1933-1939) he mentions "rubbing out" his pictures or parts of his pictures in several of his letters.[27] Mid-way through 1937 Milne shifted to watercolour.[28] His production of oil paintings plummeted during that year and in 1938 he painted no oils at all.[29] By 1940 Milne was concentrating on watercolours; however, he also painted in oils, to some degree, until at least 1947.

Examination of Paintings: Visual Examination and Technical Survey

The 39 paintings examined visually in preparation for the retrospective exhibition are listed in **Table I**. The earliest paintings examined are *Grey Billboard* and *Blossom Pickers* (see **Figure 1**), both dating from c. 1911-12. The latest, from 1946, is *Campfire in Winter*. The features examined included the support, the first ground layer, the imprimatura-like tint layer, the drawing layer, the paint layers, and a final category referred to as "underlying layers" that includes features such as paint layers from earlier paintings on the same canvas.

Supports

Visual examination of the canvas supports of Milne's paintings revealed some consistent trends. With the exception of the Group 3 paintings (executed from 1929-1939), plain weave linen canvas was used. In the Group 3 paintings, however, several types of canvas were observed. Among the canvases that could be identified, three were a 2x2 weave linen canvas, one was a coarse bast fibre canvas, and two were plain weave linen. After 1940, fine to very fine, plain weave linen canvas was used.

Ground Layers

From 1911 until 1931 the grounds on Milne's canvases were commercially applied in various pale shades. All but one of the grounds from 1933 to 1937, part of Milne's Six Mile Lake period, appeared to be artist-applied. These grounds had an uneven

Figure 1. David B. Milne, *Blossom Pickers*, c. 1911-12, Milne Family Collection, oil on canvas. Photo: Courtesy Catherine Stewart.

Table I: Milne Paintings Visually Examined and/or Sampled. (Paintings indicated by an * were visually examined; those in bold type were sampled; those indicated by a † were paintings originally analysed for specific institutions, the data later included in the project.)

Title	Date	Collection	Accession Number
Group 1 1911 - 1919 New York City & Boston Corners			
*Grey Billboard**	c. 1911	Milne Family	L1990.30.1
***Blossom Pickers **	**c. 1911-12**	**Milne Family**	**L1990.30.22**
*Bright Leaves Dark Woods**	1911-14	McMichael Canadian Art Collection	1969.26.2
Columbus Monument	**1912**	**Milne Family**	**L1990.30.3**
Billboards	**c. 1912**	**National Gallery of Canada**	**NGC 9850**
*Black**	1914	McMichael Canadian Art Collection	1966.16.23
Red	**1914**	**Milne Family**	**L1990.30.4**
*Chestnut and Laurel**	1914	Private Collection	L1990.39
*Alcove**	c. 1914	Milne Family	L1990.30.14
*Lilies**	c. 1914	McMichael Canadian Art Collection	1966.16.18
(Woman with Umbrella)	**1915/17**	**Milne Family**	**TD 1991.9.3**
Boston Corners	**1917**	**National Gallery of Canada**	**NGC 4603**
*Track in the Field**	1919	Milne Family	L1990.37.1
Group 2 1920 - 1928 Boston Corners, Canada, & Adirondacks			
The Gully II*	**1920**	**McMichael Canadian Art Collection**	**1966.16.21**
White the Waterfall (The White Waterfall)	**1921**	**National Gallery of Canada**	**NGC 7156**
*Black Waterfall**	1921	Milne Family	L1990.30.15
*Snowbound**	c. 1922-23	National Gallery of Canada	NGC 6366
Haystack*†	**1923**	**McMichael Canadian Art Collection**	**1966.16.26**
*Clouds Below Mountain Tops**	1923-24	Private Collection	1966.16.15
Dominion Square †	**c. 1924**	**Agnes Etherington**	**07-007**
Waterfall Adirondacks	**c. 1925**	**Art Gallery of Ontario**	**AGO 51/69**
Winter Carnival Dominion Square	**1925**	**National Gallery of Canada**	**NGC 16598**
*Valley at Lake Placid III**	1925	McMichael Canadian Art Collection	1966.16.25
*Boathouses Glenmore Hotel**	1926	McMichael Canadian Art Collection	1966.16.20
Clouds Below the Mountain	**1926**	**Milne Family**	**L1990.30.16**
Sparkle of Glass	**1926-27**	**National Gallery of Canada**	**NGC 28429**
*Whiteface at Sunset**	c. 1927	National Gallery of Canada	NGC 6368
*Mountain Beyond Valley**	c. 1927	National Gallery of Canada	NGC 1658
Young Pine at Sunset (R)*	**1928**	**McMichael Canadian Art Collection**	**1982.3 RV**
Untitled (V)	**1928**	**McMichael Canadian Art Collection**	**1982.3 RV**
*Steps to Ski Jump**	1928	National Gallery of Canada	NGC 15512
*Waterlilies and Sunday Paper**	1928	Hart House, University of Toronto	L1990.38
Outlet of the Pond II *	**c. 1928**	**Milne Family**	**L1990.30.24**
Attic †	**1928**	**Art Gallery of Ontario**	**AGO 58/19**
Group 3 1929 - 1939 Ontario			
Prospect Shaft	**1929**	**National Gallery of Canada**	**NGC 15517**
*Flowers and Easel**	1929	Victoria University, University of Toronto	L1990.42.1
Elevator*	**1930**	**McMichael Canadian Art Collection**	**1980.22.1**
Ollie Matson's House is Just a Square Red Cloud	**1931**	**National Gallery of Canada**	**NGC 15521**
*Serenity**	1931	Private Collection	L1990.45
Snow Scene with Fence	**1932**	**Art Gallery of Ontario**	**AGO 89/886**
Red House and Red Barn†	**1932**	**Art Gallery of Ontario**	**AGO 70/85**
Passing Clouds (Ontario Village)†	**c. 1932**	**University College Art Collection,**	**UC 368**

Title	Date	Collection	Accession Number
		University of Toronto	
*Bright River**	1933	McMichael Canadian Art Collection	1969.12
Cabin Shelf	**1934**	**Art Gallery of Ontario**	**AGO 77/150**
Sugarbush - Red House and Red Barn (verso)†	**c. 1935**	**Art Gallery of Ontario**	**AGO 70/85**
*The Waterlily**	1935	McMichael Canadian Art Collection	1983.7
*Yellow Coat**	1936	Milne Family	L1990.30.8
*Salmon Can**	1936	Hart House University of Toronto	L1991.18
Summer Colours*	**1936**	**Milne Family**	**L1990.30.17**
The Big Dipper	**1936**	**National Gallery of Canada**	**NGC 6370**
Raspberry Jam	**1936**	**National Gallery of Canada**	**NGC 16601**
Bare Rocks Begin to Show	**1936**	**National Gallery of Canada**	**NGC 16426**
Across the Still Lake	**1936**	**Art Gallery of Ontario**	**AGO 86/91**
Snowy Oak Branch	**1936**	**Art Gallery of Ontario**	**AGO 86/90**
Picture on the Blackboard*	**1937**	**Milne Family**	**L1990.30.18**
New Shelf *	**1937**	**Milne Family**	**L1990.30.9**
Group 4 1940 - 1953 Toronto & Uxbridge			
Chocolates and Flowers*	**1940**	**Milne Family**	**L1990.30.19**
Stars Over Bay Street Dark Version*	**1941**	**Milne Family**	**L1990.50.1**
Earth Sky and Water I*	**1944**	**Milne Family**	**L1990.30.12**
Monkey and Orange Lilies*	**1944**	**Milne Family**	**L1990.30.11**
*Pansies and Yellow Box**	1945	Milne Family	L1990.30.13
Campfire in Winter*	**1946**	**Milne Family**	**L1990.37.2**
Scaffolding Yonge Street	**1947**	**Art Gallery of Ontario**	**AGO 70/86**

texture, a lack of uniformity, and many were observed to have seeped through to the back of the canvases. During the Group 4 period (1940-1953), the ground layers were again primarily commercially applied.

The use of areas of exposed or unpainted ground layers as part of the picture composition is an often-noted feature of Milne's paintings.

Tint Layers and Underdrawing

Thin "tint layers," which are imprimatura-like paint layers that Milne applied over his ground layers, were found in many paintings. These layers are more uneven and patchy than a typical imprimatura layer would be. Rather than having translucency as an inherent characteristic of the tint layer, the tint becomes translucent in most places as a result of a thin, "scrubbed-on" application. In some places, where denser patches of tint occur, the translucency is lost.

Figure 2. David B. Milne, *Chocolates and Flowers*, 1940, Milne Family Collection, oil on canvas. Photo: Courtesy Catherine Stewart.

Milne often drew on the ground and tint layers in either pencil or a thicker black drawing medium. This feature is visible in his work after about 1917.

Paint Layers

Milne's painting technique changed as his career progressed. He applied thicker paint layers with more impasto in his early years (1911 to 1914) and later on used thinner, "scrubbed-on" paint layers. The first painting observed to have thinned and scrubbed on paint dates from 1919. The white paints from the years 1926 to 1930 generally have a "paste-like" or "creamy" consistency. The other colours are usually thinned and scrubbed-on. The paintings from the 1940s have oil paint with some impasto; however, most of the paint is thin and scrubbed on (**Figure 2**).

Many of Milne's paintings are multi-layered, often with portions of an underlying painting used as elements of the later, visible painting. In some paintings, early paint layers were observed under a ground layer, indicating an intended obliteration of earlier painting. Examples of multiple paintings are described in the Results and Discussion section of the present paper in *Part II. Analysis of the Artist's Technique.*

Varnishes

Varnishes were not usually observed on Milne's paintings.

Analysis of Milne's Painting Materials

Materials Analysis

The visual examination, carried out as part of the preparation for the retrospective Milne exhibition, was used to assist in the selection of paintings and samples for analysis. Of the 39 paintings that were visually examined, sixteen were chosen for sampling and analysis. An additional 17 paintings, not included in the original retrospective exhibition, were also sampled for this study to ensure better representation of paintings spanning Milne's lifetime. The paintings sampled are listed in **Table I**. Data has also been included from six paintings, not originally part of the project, that were analysed at the request of the McMichael Canadian Art Collection, the Art Gallery of Ontario, the Agnes Etherington Art Centre, and the University of Toronto.

David Milne's Paint Box

To assist with the study, David Milne Jr. graciously loaned David Milne's paintbox (**Figure 3**) to the Canadian Conservation Institute (CCI) for analysis of its contents. While the exact date of the paintbox is not known, it is thought to come from late in Milne's life. It contained a wooden palette, two palette knives, 34 brushes, 31 tubes of Winsor and Newton oil paints, one small cup, and a paint- stained cloth. The 31 tubes of paint ranged from 1910 to 1953, the dates being determined by examining their labels. Winsor and Newton's head office moved from Rathbone Place to Wealdstone in 1938.[30] Some of the paints in Milne's paintbox predate this move, while others were purchased after Winsor and

Figure 3. David Milne's paintbox, compliments of David Milne Jr. Photo: Courtesy Canadian Conservation Institute.

Newton had moved to its new location. Since there were duplicate tubes of many colours with the same labels in the paintbox, 15 representative paint tubes were chosen for analysis.

Sampling

The sampling of Milne's paintings for this project was undertaken on-site at the McMichael Canadian Art Collection, the National Gallery of Canada, and the Art Gallery of Ontario. The samples were taken under magnification using a scalpel with a #11 blade; the paint fragments removed were generally less than a millimeter in diameter. The painting materials that were sampled included size, ground, tint layers, drawing media if present, and paint. Multi-layer samples were taken for the preparation of cross-sections in order to observe the sequence of paint and drawing layers. No samples of canvas were taken. Size was obtained from a limited number of paintings as often the cross-section samples extended only from the ground layer up.

Analytical Techniques

The paint samples taken from the Milne paintings were analysed by a combination of the following four techniques:

- scanning electron microscopy/energy dispersive x-ray spectrometery (SEM/EDS)
- polarized light microscopy (PLM)
- Fourier transform infrared spectroscopy (FTIR) and
- x-ray diffraction (XRD).

Almost all samples were analysed by both SEM/EDS and FTIR. As well, XRD and PLM were performed on approximately 75% of the samples, depending on the type and size of the sample, with the most appropriate technique being chosen to identify the components of the sample. The results obtained from a minimum of two and up to four analytical techniques were considered together in the final interpretation of each sample. Samples of the thin tint layers and the drawing media were analysed by PLM.

Scanning electron microscopy/energy dispersive x-ray spectrometry (SEM/EDS) was performed using an Hitachi S-530

Table II: Ground Layers and Tint Layers.

	Painting	Ground Layer		Tint Layer
		Chemical Elements*	Composition	
c. 1911-12	*Blossom Pickers*		lead white, lead carbonate, drying oil, trace of starch	
1912	*Columbus Monument*	**Pb**, Zn, Ca, Si	lead white, lead carbonate and drying oil	
c. 1912	*Billboards*	**Zn, Pb**, Si, Ca	lead white, lead carbonate, drying oil, lead soaps	pink: madder
1914	*Red*	**Pb**	lead white, trace calcium carbonate	red: vermilion, green layer over the ground (certain areas only –– painting examination)
1915/17	*(Woman with Umbrella)*		lead white, drying oil	
1917	*Boston Corners*	**Ba, S**, Si, Zn	barium sulfate, drying oil, possibly zinc white	
1920	*The Gully II*	**Pb/S, Ba, Zn**		
1921	*White the Waterfall*	**Ba, S/Pb, Al,** Ca, Zn		
c. 1924	*Dominion Square*	**Pb** (Zn, Fe, Cu)	lead white, drying oil, starch and zinc oxide	
1925	*Winter Canival Dominion Square*	**Pb/S, Ca**		
1926-27	*Sparkle of Glass*	**Pb/S**, Zn, Ca, K	lead white, lead carbonate, drying oil	
c. 1928	*Outlet of the Pond II*	**Pb/S,** Zn		thin paint layers over ground
1928	*Attic*		lead white, drying oil	
1929	*Prospect Shaft*	**Pb,** Zn		
1931	*Ollie Matson's House*	**Ca**, Zn	calcium carbonate, zinc white, drying oil	orange tint layer: iron oxide
1932	*Snow Scene with Fence*	**Pb, Ca**		thin green paint over ground: **Pb/S**, Cd, Cr, Zn, Al
1932	*Red House & Red Barn*	**Ca, Zn** (Al, Si, P, Fe)	calcium carbonate, zinc white	thin red tint layer: Fe, Hg, S
c. 1932	*Passing Clouds*	**Ca, Pb**	lead white, calcium carbonate, drying oil	
1934	*Cabin Shelf*	**Ba, S/Pb**, Zn (Ca, Si)	barium sulfate, trace lead white, zinc soaps, drying oil	
1936	*The Big Dipper*	**Pb** (Si, Ba, Fe, Zn)		red & grey tint layers: vermilion, yellow iron earth, viridian, orange tint layers **Fe**, Zn, Si (Mg, Ca, As)
	Exudate (verso)		lead white, lead carbonate drying oil	
1936	*Summer Colours*	**Pb/S**	lowest ground layer	
		Zn, S/Pb, Ba, Zn/Na (Al, Si, Ca, Pb)	upper ground layer: zinc white, barium sulfate, zinc soaps, drying oil	
	Exudate (verso)	**Pb/S, Pb,** Al, Si, Cd	lead white, lead carbonate, lead soaps, drying oil	
1936	*Raspberry Jam*	**Pb** (Fe, Zn)		orange tint layers: **Fe, Zn, Si**, Al, S/Pb, Ca
	verso		barium sulfate, zinc oxide, zinc soaps, drying oil	
1936	*Bare Rocks Begin to Show*	**Zn**, Ba, S		
	verso		zinc oxide, barium sulfate, zinc soaps, drying oil	
1937	*Picture on the Blackboard*	**Zn, Ba**, S	barium sulfate, zinc soaps, drying oil	
1937	*New Shelf*	**Pb**, Zn		tint layers: vermilion
1940	*Chocolates and Flowers*	**Ca**, Pb/S		
1944	*Monkey and Orange Lilies*	**Pb/S, Ca**	lead white, lead carbonate, calcium carbonate, barium sulfate, drying oil	
1944	*Earth, Sky and Water I*	**Pb/S**, Ba		
1946	*Campfire in Winter*	**Pb/S**, Ba, Zn (Fe)	lead white, barium sulfate, drying oil	pink tint layers: vermilion and viridian

* **Major**, Minor, (Trace); x/y = either element x and/or y; if underlined, the presences of the element is confirmed.

SEM integrated with a lithium-drifted silicon energy dispersive x-ray detector and a Noran Voyager II x-ray microanalysis system. Using this technique, elemental analysis of volumes down to a few cubic micrometers can be obtained for elements in the periodic table from sodium (Na) to uranium (U) at a level of approximately 1% or greater.

X-ray diffraction analysis (XRD) was used to identify the major crystalline components present in the sample. The powder samples were prepared by mounting them on glass fibres with silicone grease. A Rigaku RTP 300 RC x-ray generator, equipped with a rotating anode, cobalt target, and a curved PSPC microdiffractometer, was used to analyse powder pigment samples and paint layers in some cross-sections. The generator was operated at 45 kV and 160 mA.

Paint, varnish, and size samples were analysed by FTIR. A portion of the sample was mounted in a low pressure diamond anvil microsample cell and was analysed using a Bomem Michelson MB-120 spectrometer interfaced to a SpectraTech IR-Plan microscope. Organic constituents and certain inorganic constituents can be identified by this technique.

Powdered samples of the paint were examined by polarized light microscopy using a Leica DMRX polarizing light microscope. The optical and morphological properties of the particles were used to assist in the identification of the pigments.

Cross-sections were prepared by embedding the samples in polyester casting resin, followed by grinding and polishing using standard techniques. They were then examined by incident light microscopy, fluorescence microscopy, and SEM/EDS to distinguish between the individual layers. Starch size layers in cross-section samples were identified using a potassium iodide/iodine spot test. Some cross-sections from early paintings contained paint layers of sufficient thickness for XRD analysis.

Gas chromatography-mass spectrometry (GC-MS) was performed on 16 paint samples, including four samples from tubes of zinc white paint taken from Milne's paintbox. Following saponification (0.5N KOH) and methylation (BF_3:methanol), the samples were analysed using a Hewlett Packard 5890 gas chromatograph interfaced with a 5970B mass selective detector. This technique is used to determine the type of drying oil and the presence of natural resins and waxes in the paint samples.

Results and Discussion

Part I. Analysis of Painting Materials

Size

Starch and protein were identified by FTIR in size samples obtained from two paintings, *Blossom Pickers* (c.1911-12) and *Boston Corners* (1917). A starch size layer was identified in *Dominion Square* (c. 1924). The size layer of most paintings was not analysed, as the samples usually extended only down to the ground layer.

Grounds

As shown in **Table II**, the ground layers on Milne's canvases contained a drying oil medium. Lead white was usually the principal white pigment and it was often mixed with either calcium carbonate or barium sulfate as an extender. Four paintings from 1936 had either exudates (*Big Dipper*, *Summer Colours*) or whitish paint layers (*Raspberry Jam*, *Bare Rocks Begin to Show*) on the verso of the painting. The grounds in paintings *Winter Carnival Dominion Square*, *Snow Scene with Fence*, *Monkey and Orange Lilies*, and *Chocolates and Flower*, dating from 1925 to 1944, all contained calcium carbonate. Barium sulfate was identified in *Campfire in Winter*, *Earth, Sky and Water I*, and *Monkey and Orange Lilies*, all from the 1940s.

Tint Layers

Tint layers were evident in 10 of the Milne paintings that were studied. These tints were generally orange, pink, or grey in colour. **Table II** contains either pigment identification using PLM or elemental data obtained from SEM/EDS of tint layers from cross-sections. Vermilion was identified in the tint layer from the painting *Red* (1914) and madder was identified in the tint layer from *Billboards* (c. 1912). Grey and reddish tint layers in *The Big Dipper* (1936) contained vermilion, viridian, and a yellow iron oxide pigment.

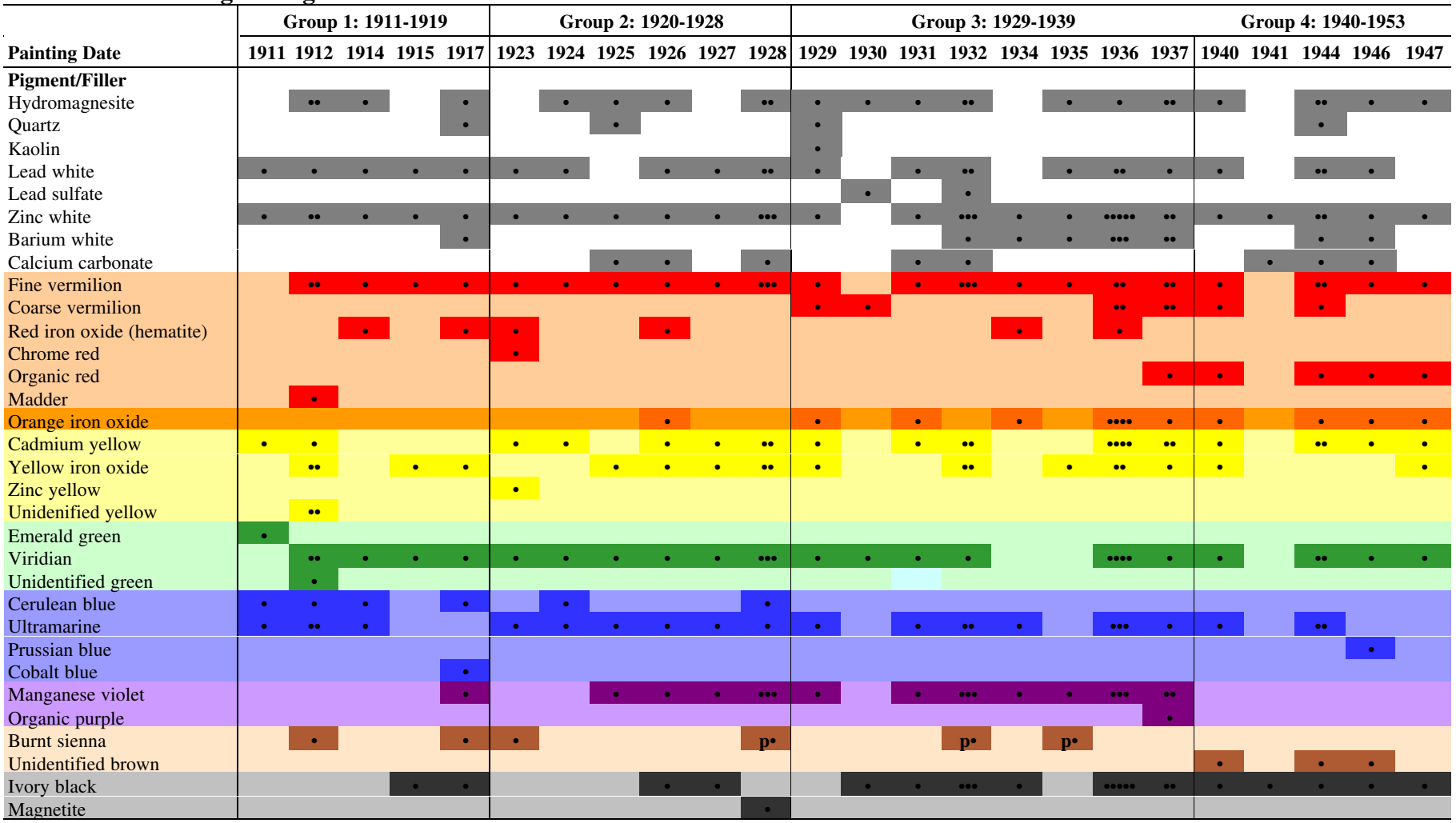
Drawing Media

Drawing media samples were taken from 12 of Milne's paintings dating from 1926 to 1944. Paintings were chosen in which the drawing media was an obvious part of the composition, was not mixed with other painting materials, and could be sampled unobtrusively. The results of analysis are presented in **Table III**. The drawing medium most often identified had microscopical characteristics consistent with graphite. Ivory black was identified in four samples. Four samples were unidentified.

Table III: Drawing Media Analysis.

Painting	Date	Identification
Sparkle of Glass	1926-27	graphite
Outlet of the Pond II	c. 1928	unidentified
Prospect Shaft	1929	unidentified
Cabin Shelf	1934	graphite, possibly ivory black
The Big Dipper	1936	brown/black particles, possibly graphite
Summer Colours	1936	unidentified
Raspberry Jam	1936	graphite, ivory black
Bare Rocks Begin to Show	1936	ivory black, graphite
Across the Still Lake	1936	graphite
Snowy Oak Branch	1936	graphite, ivory black
Chocolates and Flowers	1940	unidentified
Earth, Sky and Water I	1944	graphite

Table IV: Chronological Pigment Chart.



p = possibly

Each dot represents a painting which may have several occurrences of the indicated pigment.

If unknown, the vermilion is indicated as fine.

Pigments used in the ground and tint layers are included in this table.

Pigments and Paints

The pigments and fillers identified in the 39 paintings that were analysed are listed in **Table IV** in order of the chronological occurrence of each pigment and filler. **Table V** lists the analytical results from the paints in Milne's paintbox. **Table VI** provides the chemical formulae of all of the pigments identified.

Milne's choice of colours at the beginning of his career was likely influenced by the Impressionists, whose work he would have seen exhibited in New York City.[31] The use of a basic colour palette, which was used consistently throughout the years, was observed in Milne's oil paintings. These basic pigments listed in **Table IV** were: lead white (found in 23/39 paintings), zinc white (34/39), viridian (27/39), ultramarine blue (22/39), vermilion (both coarse and fine, 32/39), cadmium yellow (23/39), yellow ochre (18/39), and ivory black (22/39). Other colours were also used by Milne throughout his career; however, some colours were more prevalent at different times.

A detailed discussion of the pigments and fillers identified in Milne's paintings is presented below:

Red: Vermilion was used by Milne throughout his career. Two types, a coarse and a fine vermilion, were identified by polarized light microscopy. Two tubes of Winsor and Newton vermilion were present in Milne's paintbox. One, labelled as "vermilion", was identified as a dry process vermilion. The other, "Field's orange vermilion", was identified as a wet process vermilion mixed with hydromagnesite. The dry process vermilion was more coarsely crystalline[32] while the wet process vermilion was very finely divided and homogeneous.

Red iron oxide (hematite structure) was identified in the painting *Red* (1914), among others. Red iron oxide pigments (Winsor and Newton Indian Red and Light English Red) were mentioned as having been used in Milne's colour drypoints.[33] It was not determined whether the hematite was synthetic or natural, nor which specific iron oxide pigments were used.[34]

Table V: Analytical Results From the Paintbox Contents.

Paint Tube Label	Results
Vermilion	dry processed vermilion, hydromagnesite, drying oil
Field's Orange Vermilion	wet processed vermilion, hydromagnesite, drying oil
Alizarin Crimson	alizarin, possibly aluminum phosphate, drying oil
Rose Madder, Genuine	madder (alizarin and purpurin), aluminum sulphate hydrate substrate, possibly aluminum phosphate, natural calcium carbonate, drying oil
Alizarin Orange (Rathbone Place)	goethite, quartz, alizarin, calcium carbonate, possibly aluminum phosphate, fibrous plant material, drying oil
Cadmium Yellow (Wealdstone)	cadmium sulfide (greenockite structure), hydromagnesite, drying oil
Cadmium Yellow Deep (Rathbone Place)	cadmium sulfide (greenockite structure), hydromagnesite, drying oil
Yellow Ochre	natural iron earth pigment: goethite, kaolinite, quartz, hydromagnesite
Viridian	viridian, chromium oxide green, drying oil
French Ultramarine (Wealdstone)	ultramarine, hydromagnesite, drying oil
Permanent Violet (Rathbone Place)	manganese violet, drying oil
Burnt Sienna	silicate, hydromagnesite, iron earth pigment, drying oil
Tierra de....	goethite, silicate, hydromagnesite, drying oil
Ivory Black (London)	ivory black, drying oil
Zinc white	zinc white, zinc soaps, drying oil, safflower oil

Table VI: Chemical Formulae of Pigments Identified.

Pigment Name	Formula
Vermilion	HgS
Red iron oxide (hematite)	Fe_2O_3
Cadmium yellow	CdS
Yellow ochre	$FeOOH$
Emerald green (copper acetoarsenite)	$3Cu(AsO_2)_2{\cdot}Cu(CH_3COO)_2$
Viridian (chromium (III) oxide dihydrate)	$Cr_2O_3{\cdot}2H_2O$
Ultramarine blue	$(Na,Ca)_8(AlSiO_4)_6(SO_4,S,Cl)_2$
Cerulean blue	$CoO{\cdot}nSnO_2$
Prussian blue	$Fe_4[Fe(CN)_6]_3{\cdot}xH_2O$
Cobalt blue	$CoO{\cdot}Al_2O_3$
Permanent violet (manganese violet)	$(NH_4)_2Mn_2(P_2O_7)_2$
Ivory black (hydroxylapatite)	$Ca_5(PO_4)_3(OH)$
Lead white	$Pb_3(CO_3)_2(OH)_2$
Zinc white	ZnO
Barium sulfate	$BaSO_4$
Calcium carbonate	$CaCO_3$
Lead sulfate	$PbSO_4$
Hydromagnesite (a hydrated basic carbonate of magnesium)	$MgCO_3{\cdot}3Mg(OH)_2{\cdot}11H_2O$
Kaolin	$Al_4[Si_4O_{10}](OH)_8$
Quartz	SiO_2

Organic reds were also identified in paint samples using polarized light microscopy. Winsor and Newton paint tubes labeled "Alizarin Crimson," "Alizarin Orange," and "Rose Madder, Genuine," were all found in Milne's paintbox.

Yellow: Both cadmium yellow (cadmium sulfide) and yellow ochre were identified in samples taken from paintings executed throughout Milne's career. Two tubes of cadmium yellow were found in Milne's paintbox: a Winsor and Newton "Cadmium Yellow" from Wealdstone and a "Cadmium Yellow Deep" from Rathbone Place. There are two different crystalline forms of cadmium sulfide having a greenockite-type structure which is hexagonal, and a hawleyite-type structure which is cubic. Analysis of both tubes of cadmium yellow from the paintbox revealed that the cadmium sulfide was of the greenockite structure (hexagonal). Both cadmium sulfides (greenockite and hawleyite structures) were identified in the paint samples. A Winsor and Newton Yellow Ochre from the paintbox was composed of a natural iron earth pigment consisting of goethite, kaolin, and quartz.

The cadmium sulfide identified in *Billboards* (c. 1912) and *Chocolates and Flowers* (1940) had the hawleyite structure (the cubic form). "According to Böhm and Niclassen (1924) precipitation of cadmium sulfide using hydrogen sulfide following the common historical recipe results in the formation of the cubic type."[35] The greenockite type structure was identified more frequently however, in the paint samples. In general, more occurrences of the greenockite type structure (the hexagonal form) than of the hawleyite type structure have been reported in the literature on the analysis of artists' pigments.[36]

Cadmium sulfide remained limited to artists due to its high cost until about 1917 when the amount employed in industry began to increase rapidly. Manufacturing techniques also improved, thus removing most of the problems associated with the early pigment.[36] Early cadmium sulfide had the reputation of being unstable, darkening on exposure to air and light.[35] Also, exposure of the pigment to moisture was considered to cause bleaching.[35,36] Mustard coloured paints in some early Milne paintings were noted to be sensitive to moisture.

Green: In this study, emerald green was identified only once, in one of Milne's early paintings (*Blossom Pickers*, c. 1911-12). Emerald green (copper acetoarsenite) is incompatible with sulfur-containing pigments, cadmium sulfide in particular.[37] This, as well as the fact that it is poisonous, could explain why Milne stopped using emerald green early on in his career.

Some pigments were identified only infrequently. For example, emerald green in *Blossom Pickers* (c. 1911-12) and cobalt blue in *Boston Corners* (1917) were identified only in his early works. The earliest painting in which manganese violet was identified was in the 1917 painting *Boston Corners*. It was commonly found in paintings after this date. Lead sulfate was identified in two paintings from Group 3 (1929-1939); *Elevator* (1930) from the Temagami period and *Passing Clouds* (c. 1932) from the Palgrave or Six Mile Lake period. An absence of purple pigments was apparent in the Group 4 paintings analysed (1940-1953).

There are many specific colour mixtures that Milne used repeatedly throughout his career. One very prominent feature in all samples is the presence of traces of many additional pigments combined with the main colouring pigment. This characteristic of Milne's paints, encountered especially with whites, may be due to the artist's deliberate mixing of small quantities of other colours into the main colour or the result of brush or palette contamination.

Viridian (hydrated chromium oxide), was the most commonly identified green pigment found in paintings throughout Milne's career, as were recurring mixtures using this pigment. Yellow ochre and ultramarine blue mixed with some viridian, or cadmium yellow mixed with viridian, were two common mixtures that were identified. Cadmium green is a mixture of cadmium yellow and viridian.[35] It is not possible to determine whether the mixtures of cadmium yellow and viridian were prepared by the artist or whether they were purchased as the premixed oil colour cadmium green.

Blue: Ultramarine blue, cerulean blue, cobalt blue, and Prussian blue were identified in the Milne paintings that were analysed. Cobalt blue and Prussian blue were identified only once each. The two blue pigments most frequently identified were cerulean blue and synthetic ultramarine blue. Winsor and Newton French Ultramarine (from Wealdstone) was found in Milne's oil paint box. Ultramarine blue was found in paint samples of blues, purples, and greens, and traces of this pigment were present in most samples.

The cerulean blue sample from *Boston Corners* (1917) contained tin oxide in addition to the main colouring compound, cobalt tin oxide. The two methods of preparation for cerulean blue involve combining "oxide of tin and cobalt nitrate"[38] or "precipitating potassium stannate with cobalt chloride, and then mixing with pure silica."[38] The presence of tin oxide in this pigment sample is likely related to its method of manufacture.

Violet: Permanent violet (manganese violet) was identified in Milne's paintings from 1917 through 1937 (Groups 2 and 3). This colour was described in Winsor and Newton brochures from 1910 and 1937 as phosphate of manganese with a little French blue (synthetic ultramarine blue) added to the oil colour.[20,24] Ultramarine blue was occasionally present in some of the earlier purple paint samples. In paintings from the Group 4 period (1940-1953) the purples were found to be mixtures and very few purple/violet pigments were identified.

Brown: Brown pigments that Milne was using in his colour drypoints are listed in a letter he wrote to Alan Jarvis in 1936: "most of the opaque earth colours, burnt sienna, light red, etc."[16] Analysis, however, revealed that many of the browns analysed in his oil paintings were in fact mixtures of other colours in the painting. For example, in the painting *Outlet of the Pond II* (c. 1928) ultramarine blue, vermilion, viridian, and yellow iron

oxide were combined to make the brown. Burnt sienna, and from 1940 and 1944, an unidentified brown pigment were infrequently identified in Milne's paintings. No burnt sienna was identified in paintings from the Group 4 period (1940-1953), the browns being predominantly pigment mixtures, some of which contained the unidentified brown pigment.

Black: The pigment ivory black figured prominently throughout Milne's career; as a colour in its own right, as an outline, and also mixed into his colours. This pigment was identified in 22 of the 39 paintings analysed, more frequently in works from 1930 onwards. Unidentified blacks were present in three paintings. Milne's paintbox contained a tube of Winsor and Newton ivory black.

White: White is prominently used in Milne's paintings, so much so that multiple whites are used in the same painting. Lead white and zinc white were the most commonly occurring white pigments observed. Barium sulfate and calcium carbonate were found less frequently; they appear in varying proportions mixed with lead white or zinc oxide within a single painting. They may be present as fillers or they may have been added to the white paint to alter the shade or degree of opacity of white used in certain instances. Barium sulfate becomes quite common after 1932 and calcium carbonate was identified in works from 1925 onward in ground layers and some paint samples. Lead sulfate was found in only two Milne paintings, from 1930 and 1932. A sample from the painting *Passing Clouds* (c. 1932) contained both zinc oxide and lead sulfate.

Fillers: Hydromagnesite was the most common filler identified in the samples taken from paintings throughout Milne's career. It was also identified in the Winsor and Newton paints in Milne's paintbox with a "Wealdstone" address on the label. Hydromagnesite, a hydrated basic carbonate of magnesium, is a very fine powder and has been used as a flatting agent. In recent years it has been displaced to a considerable extent by the hydrated silicas.[39] The use of basic magnesium carbonate in some formulations of Winsor and Newton paints was confirmed by the manufacturer.[40] Kaolin and quartz were occasionally found as fillers in the Milne paintings.

Media

Drying oil was identified as the paint medium in all 39 paintings examined. A limited number of paint samples from nine paintings were analysed by GC-MS to attempt to identify the oils used in some of Milne's paintings. Safflower oil, linseed oil, and poppy seed oil were identified in various paints.

The medium identified in a light blue paint sample containing cerulean blue from the painting *Red* (1914) was poppyseed oil. The medium identified in the four tubes of zinc white from Milne's paintbox was likely safflower oil.[41]

In one sample from *Stars over Bay Street* (1941), paraffin wax was identified in addition to linseed oil. In this case, wax may have been introduced to the painting during an earlier conservation treatment rather than added to Milne's paints.

Zinc soaps were identified in almost all the paintings examined. Zinc white tends to react with the acidic component of the vehicle. With oil, this involves a reaction between the fatty acid component of the drying oil and the zinc oxide to form zinc soaps, such as zinc stearate. In linseed oil-zinc oxide paints, the formation of soaps is considered to harden the paint films.[42] Some of Milne's paintings (e.g. *Boston Corners*) showed cracking in the areas of zinc white paint.

Varnish

Varnish was rarely found on Milne's paintings. Of the 39 paintings included in this project, four were observed to have some evidence of varnish in the samples but no identification was undertaken.

Part II. Analysis of the Artist's Technique

The combination of materials analysis, examination of paint cross-sections, visual examination of the paintings, and literature research has led to the conclusion that Milne used specific techniques at different times throughout his career. The salient features of each of the chronological groups are described below.

Group 1 (1911-1919)

Canvases suspected of having paste sizing, based on the pale, squashed appearance of the canvas surface, were observed in paintings from Milne's early period, 1911 to 1914. Size samples from *Boston Corners* (1917) and *Blossom Pickers* (c. 1911-12) were identified as protein and starch.

Commercially-applied ground layers were used from 1911 to 1931 in a variety of muted colours including, most often, off-white, but also blue-grey, beige, and pink-grey. The grounds of the New York City paintings (1911-1915) were lead white in drying oil in *Blossom Pickers* (c. 1911-12) and *Columbus Monument* (1912). In one painting, *Red* (1914), the lead white ground contained traces of calcium carbonate. The painting, *Boston Corners* (1917), done after Milne left New York City, was the earliest painting analysed with a predominantly barium sulfate ground. Minor quantities of zinc were also detected by SEM/EDS in this layer, most likely indicating the presence of zinc oxide.

In this early period, three out of nine paintings included in the visual examination had green and terra-cotta coloured tint layers over the ground. Vermilion was identified in the tint layer from the painting *Red* (1914) and madder in the tint layer in *Billboards* (c. 1912). Another feature in the early period is that drawing was not generally observed beneath the paint layers. Many of these paintings had relatively thick paint layers where some impasto was seen.

At this time in Milne's career, the paint layers were comparatively thick and the colours were bright. **Figure 1** shows

an overall colour image of the painting *Blossom Pickers* (c. 1911-12). A cross-section from *Blossom Pickers* (c. 1911-12), given in **Figure 4**, shows Milne's early technique. The thinly applied starch and protein size layer is seen on the bottom, followed by a ground layer comprising lead white, zinc white, and drying oil. A light blue paint layer, an emerald green layer, an olive green layer, a blue layer, and then a light blue layer were present over the ground.

Blossom Pickers (c. 1911-12) was the only painting analysed in which the pigment emerald green was found. The olive green layer contained zinc white, cadmium yellow (greenockite), and cerulean blue. The darker blue layers consisted of ultramarine blue and zinc white. All layers contained drying oil.

Group 2 (1920-1928)

The same type of paste-like size seen in Group 1 paintings was also observed in some canvases from Group 2. The ground layers identified in Group 2 were variable, with more than one ground layer present in some paintings. In *White the Waterfall* (1921), a barium sulfate ground and three white layers were identified above the size layer. Lead white with drying oil was identified in the ground of *Young Pine at Sunset* (1928). Based on the elements detected, lead white and calcium carbonate were present in the ground of *Winter Carnival Dominion Square* (1925). Lead white, barium sulfate, and a zinc-rich pigment (probably zinc oxide) were likely present in *The Gully II* (1920) based on the chemical elements detected.

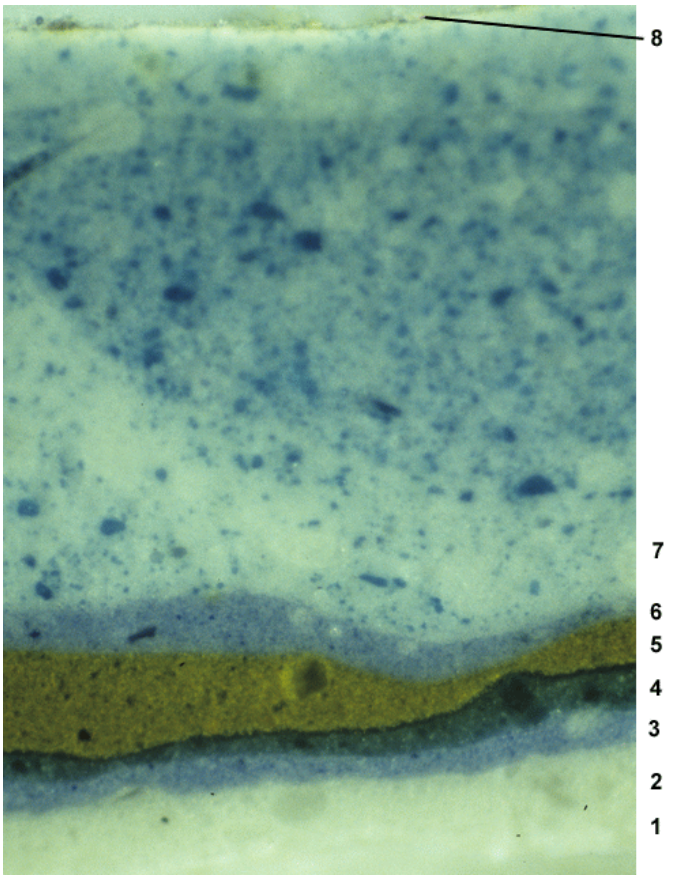


Figure 4. Incident light micrograph of a cross-section from the painting *Blossom Pickers*, c. 1911-12. The starch and protein size layer (1) is seen on the bottom, followed by a white ground layer (2). A light blue paint layer (3), an emerald green layer (4), an olive green layer (5), a blue layer (6), and then a light blue layer (7) were present over the ground. A dirt layer (8) is present on the surface. The painting is shown in **Figure 1**. Full image width = 275 µm.

Many of the paintings examined from this period did not have tint layers; however, the painting *White the Waterfall* (1921) contained thin green and beige paint or tint layers. The oil paint layers applied to the ground were thinner than previously observed; Milne's thin "scrubbed-on" oil paint layers are often seen during this period. Drawing with a black pencil over the ground and the tint layers present, became a common feature of Milne's oil paintings at this time. He also began to use oil paints to achieve effects similar to those in his watercolours. In his painting notes from 1921, Milne mentioned the following goals for his oil painting at the time:

> Aim at the following:
> 1. To use the differences between the pasty oil texture and watercolour. Formerly tried to keep the oil method as close as possible to the more familiar watercolour method. For this reason am using oil to thin the colours instead of kerosene.[43]

"Reworking" paintings is mentioned in Milne's notes and letters throughout the 1920s as is seen in an excerpt from a letter written by Milne to his friend James Clarke in 1925: "lots of working over — 2, 3, even four times."[44] Milne also mentions eliminating an unsatisfactory element in a composition by "painting out."[17] Multi-layer works appear commonly between 1920 and 1928 and again in 1937.

A reworked, multi-layer painting from 1921, *White the Waterfall* (**Figure 5**), was painted during a period when Milne was living in a cabin at Alander Mountain in rural New York State. A cross-section from this painting showed 13 layers that are much thinner than those in *Blossom Pickers* (c. 1911-12). **Figure 6** is an incident light micrograph of the cross section; **Figure 7** is a secondary electron micrograph of the same cross-section. From the canvas upward, the layers are as follows: a size layer, a barium sulfate-containing ground layer, a zinc white paint layer, two lead white layers, and a blue paint layer that contained tin, cobalt, and aluminum, suggesting the presence of cerulean blue and possibly cobalt blue. Another white lead paint layer lies over the blue paint, then a layer that is observed in the secondary electron image as a thicker dark layer, which is a blue paint layer containing zinc, tin, and a trace of cobalt. More lead white covers the second blue layer and is followed by a tint layer containing red and blue pigment. On top, visible on the right side of the secondary electron image, is an intermittent zinc white layer. The surface varnish layer is not visible in the secondary electron image but was discernible with ultraviolet-induced visible fluorescence.

Group 3 (1929-1939)

The Group 3 paintings had the most variable grounds of all,

Figure 5. David B. Milne, *White the Waterfall* (*The White Waterfall*), 1921, National Gallery of Canada, Ottawa. Oil on canvas. Photo © National Gallery of Canada, Ottawa.

particularly from 1931 to 1939. Some canvases from 1933 to 1937 showed material that had seeped through to the back of the canvas. This period corresponds to Milne's time at Six Mile Lake (1933-1939). Four paintings from 1936 had exudate on the verso and many of the paintings from this era have more than one ground layer. For example, *Summer Colours* (1936) has a ground layer that contains zinc white and barium sulfate over a lower, lead white ground layer. The same type of zinc white and barium sulfate layer was present in *Picture on the Blackboard* (1937). *Cabin Shelf* (1934) contained barium sulfate as the major compound in the ground layer with a trace of lead white.

Tint layers, usually orange in colour, were encountered in nearly all of the paintings examined from Group 3. *Ollie Matson's House is Just a Square Red Cloud* (1931) had an orange tint layer that was pigmented with iron oxide. *Raspberry Jam* (1936) also had an orange tint layer, most likely containing vermilion and iron oxide pigments, based on the elemental analysis. As in the Group 2 paintings, drawing was visible over the tint layer. Most of the coloured paint layers were thin, with the white/off-white paint layers being generally thicker.

Milne's browns and blacks were identified as being mixtures of other coloured pigments in many of the brown paint samples from paintings throughout his career (Groups 1-4). Black pigment is still present as part of the pigment mixture in the black and brown paints in Group 3; however, most browns analysed in Group 3 did not contain brown pigments. After 1936, three different whites are often used in the same painting: lead white, zinc white, and barium sulfate.

Multiple paintings were encountered more frequently in Groups 2 and 3. One example is the painting *Raspberry Jam* (1936), whose cross-section showed two distinct sets of paint layers including two tint layers. This painting also has a landscape on the verso covered by a white tint.

Group 4 (1940-1953)

The paintings sampled for the last phase of Milne's career date from 1940 to 1947. Milne painted less in oil after 1947 and was more interested in watercolour. Visual examination of the paintings showed that plain weave linen canvases with off-white or beige commercially-applied grounds were being used again. Based on the elements detected, lead white was present in all the ground layers, with the addition of calcium carbonate (lower ground layer in *Chocolates and Flowers*), barium sulfate (*Earth, Sky and Water I*), or both (*Monkey and Orange Lilies*). Lead white, barium sulfate, and a zinc compound (most likely zinc oxide) were indicated in the ground of *Campfire in Winter* (1946). Orange or pale pink tint layers are usually present, as are drawing and thin oil paint layers. *Campfire in Winter* (1946) had

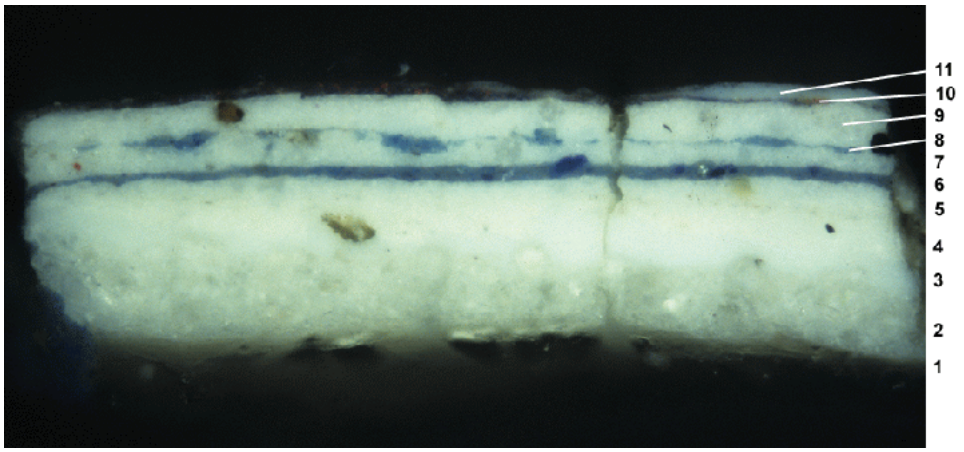


Figure 6. Incident light micrograph of a cross-section from the painting *White the Waterfall*, 1921. From the canvas upward the layers are: a size layer (1), a white ground layer (2), three white paint layers (3, 4, 5) and a blue paint layer (6). This is followed by another white paint layer (7), a second blue paint layer (8), a white paint layer (9), a tint layer containing red and blue pigment (10), and an intermittent white layer (11) on the top right. The surface varnish layer is not visible. Full image width = 510 µm.

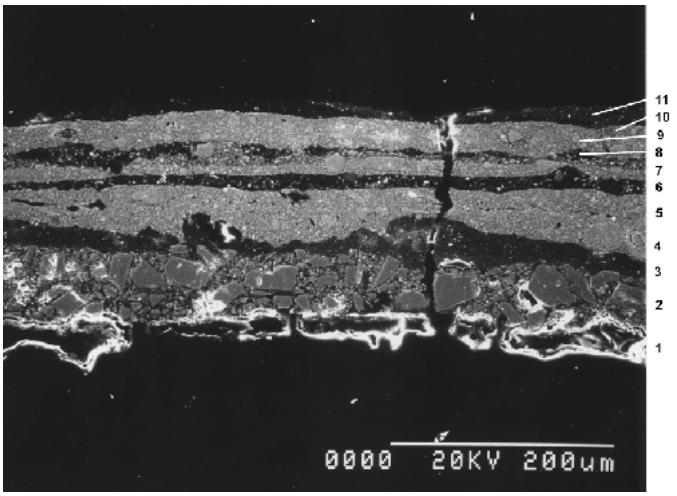


Figure 7. Secondary electron micrograph of a cross-section from the painting *White the Waterfall*, 1921. The layers from the bottom up are: a size layer (1), a barium sulfate-containing ground layer (2), a zinc white paint layer (3), two lead white layers (4, 5), and a blue paint layer containing tin, cobalt, and aluminum (6). This is followed by another white lead paint layer (7) and a thicker dark layer, which is a blue paint layer containing zinc, tin, and a trace of cobalt (8). Lead white covers the second blue layer (not visible in this micrograph) (9) and is followed by a tint layer containing red and blue pigment (10). On top, visible on the right side of the secondary electron image, is an intermittent zinc white layer (11). The surface varnish layer is not visible in the secondary electron image.

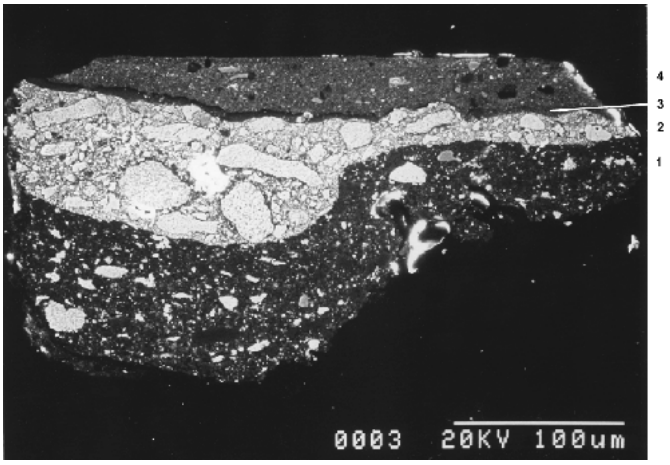


Figure 8. Secondary electron micrograph of a cross-section from the painting *Chocolates and Flowers*, 1940. The layers, from the bottom upward are: a ground layer containing elements indicating lead white and calcium carbonate (1); a lead white layer (2); a thin, unpigmented fluorescent layer (3); and a white paint layer (4) containing chemical elements suggesting zinc white, barium sulfate, and calcium carbonate.

a pink tint pigmented with viridian and vermilion. The paintings in this group have less complicated layer structures than the earlier paintings, suggesting less reworking. Some impasto is present in these paintings.

The 1940 painting *Chocolates and Flowers* (**Figure 2**) shows a paint layer structure representative of Milne's later period. A secondary electron micrograph of a cross-section from this painting is given in **Figure 8**. The layers from the bottom upward are: a ground layer containing elements indicating lead white and calcium carbonate; a lead white layer; a thin, unpigmented fluorescent layer; and a white paint layer containing chemical elements suggesting zinc white, barium sulfate, and calcium carbonate. This painting is an example of one of Milne's paintings in which whites are particularly prominent.

Conclusions

Many features of Milne's oil paintings were characterized during this study: the canvases were catalogued, the ground layers were examined, the different types of paint layers were described and much information on his materials was obtained through analysis.

A core selection of pigments was used throughout Milne's career: lead white, zinc white, viridian, ultramarine blue, vermilion, cadmium yellow, yellow ochre, and ivory black. These pigments are consistent over time, while others come and go throughout the years. Pigments identified that were used less consistently include: lead sulfate, barium sulfate, red iron oxide, chrome red, madder, an organic red, orange iron oxide, zinc yellow, emerald green, cerulean blue, cobalt blue, Prussian blue, manganese violet, organic purple, burnt sienna and magnetite.

Early on in his career, Milne prepared his blacks and browns using ivory black and also brown pigments such as burnt sienna. The blacks and browns were found to be either mixtures of the colours used in the painting with some black or brown added, or relatively pure black or brown pigments. Later in his life, however, many dark grey/black or brown paint samples from his paintings appeared to be a mixture of other pigments, often without black and brown pigments included.

Some trends in the techniques Milne used at specific times during his career were observed. Milne developed devices that were commonly employed for a time, including:

- areas of the ground layer were left unpainted or visible, forming part of the composition as early as 1911 to 1912;
- imprimatura-like tint layers were used over the grounds;
- subjects were outlined with black pencil or a thicker black line starting in Group 2 from 1923 onward;
- thin scrubbed-on paint layers were used;
- broad areas of different whites were used in his compositions;
- different textures were favoured at certain times;
- paintings were reworked more frequently in some periods than in others. Group 2 and 3 paintings had the most complicated stratigraphy and the technique involved more "painting out," reworking, and more layers in general in the painting structure;
- varnishes were rarely observed.

The examination of cross-sections helped in interpreting the structure of the paintings as they revealed "painting-out" layers, tint layers, and multiple paintings.

Milne worked to achieve different effects in his paintings at various stages of his career. He was a very creative and

experimental painter, one example being his attempt to incorporate into his oil paintings qualities that he liked in his watercolours. We understand more about some of Milne's devices after having analysed samples from his paintings; but of others we do not. Even though much has been learned about Milne's materials and techniques through the study described, many mysteries still remain with the artist.

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Notes and References

1. Silcox, David P., *Painting Place: The Life and Work of David B. Milne* (Toronto: University of Toronto Press Inc., 1996), p. ix.

2. Silcox, David P., "The Thing That Makes a Picture," in: *David Milne*, edited by Ian M. Thom (Vancouver: Douglas and McIntyre Ltd., 1991), pp. 11-20.

3. Silcox, David P., *Painting Place: The Life and Work of David B. Milne*, p. 78.

4. O'Brian, John, *David Milne: The New York Years 1903-1916* (Edmonton: Edmonton Art Gallery, 1981), pp. 48-50.

5. Thom, Ian M. (ed.), *David Milne* (Vancouver: Douglas and McIntyre Ltd., 1991), pp. 209-210.

6. Silcox, David P., *Painting Place: The Life and Work of David B. Milne*, p. 89.

7. Thom, Ian M., "Boston Corners," in: *David Milne* edited by Ian M. Thom (Vancouver: Douglas and McIntyre Ltd., 1991), pp. 63-98.

8. Silcox, David P., *Painting Place: The Life and Work of David B. Milne*, p. 90.

9. Ibid., p. 94.

10. Ibid., pp. 193-195.

11. Ibid., pp. 204-205.

12. Ibid., pp. 246-247.

13. Tovell, Rosemarie L., *Reflections in a Quiet Pool: The Prints of David Milne* (Ottawa: National Gallery of Canada, 1980).

14. Boyanoski, Christine, "Milne and his Contemporaries," in: *David Milne* edited by Ian M. Thom (Vancouver: Douglas and McIntyre Ltd., 1991), pp. 21-36.

15. Silcox, David P., *Painting Place: The Life and Work of David B. Milne*, p. 92.

16. Tovell, Rosemarie L., *Reflections in a Quiet Pool*, p. 235.

17. Stewart, Cathy, *Milne: Materials and Techniques*, lecture, Hedley Forum, April 1992, Queen's University, Kingston, Unpublished Report.

18. Tovell, Rosemarie L., *Reflections in a Quiet Pool*, p. 1.

19. Davy's Grey, "A new colour prepared from a special variety of Slate and suggested by Mr. Henry Davy." See "Winsor and Newton Catalogue 1925", p. ix.

20. *Winsor and Newton's Catalogue of Colours and Materials*. (London: William Clowes and Sons. Ltd., 1910).

21. *Winsor and Newton's Catalogue of Colours and Materials*. (London: William Clowes and Sons. Ltd., 1915).

22. Robertson, H.R. "Winsor and Newton's Catalogue of Colours and Materials for Oil and Water Colour Painting," in: *The Art of Painting on China*, No. 34. (London: Winsor and Newton, 1915).

23. *Winsor and Newton Catalogue*, 1925.

24. Winsor and Newton Ltd. *Tint Book* (London: Winsor and Newton Ltd., 1937), p. 10.

25. Tovell, Rosemarie L., *Reflections in a Quiet Pool*, p. 236.

26. Silcox, David P., *Painting Place: The Life and Work of David B. Milne*, p. 215.

27. Ibid., pp. 272-274.

28. Ibid., p. 280.

29. Ibid., p. 281.

30. Winsor and Newton Website, <http://www.winsornewton.com/index2.php> accessed January 25, 2007.

31. The principal pigments included in the Impressionist Palette were: zinc white, lead white, "lemon yellow" (barium chromate), chrome yellow (lead chromate), cadmium yellow, Naples yellow (lead antimonate), yellow ochre, chrome orange, (basic lead chromate), vermilion, red ochre, natural madder lake, crimson (cochineal) lake, Scheele's green

(copper arsenite) emerald green (copper acetoarsenite), viridian (hydrated chromic oxide), chrome green (Prussian blue mixture with chrome yellow), cerulean blue (cobalt stannate), artificial ultramarine, ivory or bone black. See Bomford, David, Kirby, Jo, Leighton, John and Roy, Ashok, *Art in the Making Impressionism* (London: National Gallery, 1990), p. 52.

32. Gettens, Rutherford J. and Stout, George L., *Painting Materials: A Short Encyclopaedia* (New York: Dover Publications, 1942).

33. Tovell, Rosemarie L., *Reflections in a Quiet Pool*, pp. 78, 92-93.

34. The name Indian red has been given to several different types of hematite based pigments: a heavy, purple-red native red ochre named after its place of origin, the island of Ormus in the Persian gulf in the 18th century; a manufactured iron oxide with a less purple cast used to imitate the native Indian red (Harley); a variety of hematite known as Crawshay Red from the mine of the same name and a ground hematite coming from Bengal.[35] Light red was used in the 18th century to refer to a brownish red prepared by burning yellow ochre.(Harley) English red was also used to describe calcined yellow ochres. See reference 35, pp. 183, 321 and Harley, R.D., *Artists' Pigments c. 1600 - 1835* (London: Butterworths, 1970), pp.108-109.

35. Eastaugh, Nicholas; Walsh, Valentin; Chaplin, Tracy and Siddall, Ruth, *The Pigment Compendium: A Dictionary of Historical Pigments* (London: Elsevier, 2004), pp. 70-73.

36. Fiedler, Inge and Bayard, Michael A., "Cadmium Yellows, Oranges and Reds," in: *Artists' Pigments: A Handbook of their History and Characteristics*, vol. 1, edited by Robert L. Feller (Washington: National Gallery of Art, 1997), pp. 65- 108.

37. Fiedler, Inge and Bayard, Michael A. "Emerald Green and Scheele's Green," in: *Artists' Pigments: A Handbook of their History and Characteristics*, vol. 3, edited by Elizabeth West Fitzhugh, (Washington: National Gallery of Art, 1997), pp. 219-271.

38. Carlyle, Leslie, *The Artist's Assistant* (London: Archetype Publications, 2001), p. 472.

39. Morgans, W.M., *Outlines of Paint Technology* (London: Charles Griffin and Company Ltd., 1982).

40. Foster, Alun, (Chief Chemist, Winsor and Newton), personal communication, 1995.

41. The identification of the safflower oil was based on three criteria: the fatty acid ratio obtained by GC/MS, the fact that the samples were removed directly from the tubes and the Winsor and Newton product literature which stated that their zinc white is ground in safflower oil. GC/MS palmitic to stearic (P:S) fatty acid ratios are similar for safflower, walnut as well as mixtures of linseed/poppy oil.

42. Kuhn, Hermann, "Zinc White," in: *Artists' Pigments: A Handbook of their History and Characteristics*, vol. 1, edited by Robert L. Feller (Washington: National Gallery of Art), pp. 169-186.

43. Mount Riga Painting Notes 10, Orchard and Brown Valley, November 1, 1921, Milne Family Papers.

44. Letter to James Clarke, 1925, Milne Family Papers.