

The Painting Materials and Techniques of Cornelius Krieghoff

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The Painting Materials and Techniques of Cornelius Krieghoff

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A study of the painting materials and techniques of Cornelius Krieghoff, a 19th-century Canadian artist (1815-1872), was undertaken. The project was initiated in 1999 at the time of the exhibition "Kriehoff: Images of Canada," which was curated and organized by Dennis Reid at the Art Gallery of Ontario. As part of the preliminary examination of the paintings, nine unlined canvases were examined and the signatures on 130 dated paintings were documented. In the second phase, 55 paintings were chosen that spanned Krieghoff's career and that were representative of his major subject areas: autumn and winter landscapes, Aboriginal people, Québec country scenes and portraits. Over 300 minute samples of paint and ground layers were taken from these paintings and were subjected to instrumental analysis. Samples were analysed by x-ray microanalysis, Fourier transform infrared spectroscopy (FTIR), polarized light microscopy (PLM) and, to a limited extent, x-ray diffraction (XRD) and gas chromatography-mass spectrometry (GC-MS). Pigment mixtures were present in many paint samples. Pigments identified include lead white, vermilion/cinnabar, red lakes, iron oxides, Prussian blue, ultramarine blue, cobalt blue, bone black, cadmium yellow, chrome yellow, Naples yellow, barium yellow and zinc yellow. Some pigments were used throughout his career; others appeared to be used during specific time periods. Also investigated were certain problems inherent in Krieghoff's materials and their uses, such as colour fading due to fugitive pigments, wrinkled paint surfaces and drying cracks.

Une étude des matériaux picturaux et des techniques de Cornelius Krieghoff, un peintre canadien du dix-neuvième siècle (1815-1872), a été entreprise en 1999 à l'occasion de l'exposition rétrospective "Kriehoff: Images du Canada," qui a été organisée et préparée par Dennis Reid au Musée des beaux-arts de l'Ontario. Lors de l'examen préliminaire des tableaux, neuf toiles non rentoilées ont été examinées et les signatures de 130 tableaux datés ont été documentées. Dans la deuxième partie, 55 tableaux ont été choisis afin d'obtenir une sélection représentative de chaque période de la carrière de Krieghoff et des divers sujets qu'il a peints comme des paysages d'automne et d'hiver, des Autochtones, des scènes rurales au Québec et des portraits. Plus de 300 petits échantillons de peinture et de préparation ont été prélevés sur ces tableaux et ont été soumis à l'analyse instrumentale. Les échantillons ont été analysés par microscopie électronique à balayage couplée à la spectrométrie des rayons X, spectroscopie infrarouge à transformée de Fourier (SIRTF), microscopie en lumière polarisée (MLP) et, dans une moindre mesure, par diffraction des rayons X (DRX) et chromatographie en phase gazeuse-spectrométrie de masse (CG-SM). Des mélanges de pigments étaient présents dans un grand nombre d'échantillons de peinture. Les pigments identifiés comprennent du blanc de plomb, du vermillon/cinabre, des laques rouges, des oxydes de fer, du bleu de Prusse, de l'outremer, du bleu de cobalt, du noir d'os, du jaune de cadmium, du jaune de chrome, du jaune de Naples, du jaune de baryum et du jaune de zinc. Krieghoff a utilisé certains de ces pigments pendant toute sa carrière alors que d'autres sont associés uniquement à des périodes précises. Certains problèmes inhérents liés aux matériaux de Krieghoff et la façon dont ils ont été utilisés, comme des couleurs décolorées à cause de pigments fugaces, des plissements à la surface de la peinture et des craquelures de séchage, ont aussi été examinés.

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Introduction

Cornelius David Krieghoff (1815-1872) was a prolific 19th-century Canadian artist, whose well-known subjects include autumn and winter landscapes, portrayals of Aboriginal people and depictions of life in rural Québec. His paintings are found in many Canadian public and private collections and were much copied and imitated, even in his own day. This study of his painting materials and techniques was initiated in 1999 when the exhibition *Kriehoff: Images of Canada* was curated and organized by Dennis Reid at the Art Gallery of Ontario.¹ The assembly of over 150 well-documented works by Krieghoff for the exhibition provided an excellent opportunity to conduct a technical study in the context of the Canadian Artists' Materials Research Project at the Canadian Conservation Institute. Similar studies have been undertaken on the work of several 20th-century

Canadian artists including Alfred Pellon, Tom Thomson, Jean Dallaire and Jean-Paul Riopelle.²⁻⁵

The analysis of samples from Krieghoff's paintings is intended to provide comparative data that can be consulted when paintings of uncertain attribution are being examined. The project also provides information that will assist conservators in devising treatments and selecting appropriate display and storage conditions for Krieghoff's works.

Cornelius Krieghoff was born in Amsterdam in 1815. He moved to the United States in 1837 and joined the American army. His career as a painter began in Boucherville, Québec around 1840, following his marriage to Emilie Gauthier. The five distinct periods of Krieghoff's career, based mainly on where he was residing, and their approximate dates, are as follows:

I. The Early Years: 1840-1844

The earliest phase of Kriehhoff's career as an artist includes time spent in Boucherville, Québec, and in Rochester, New York. It also includes a stay in Toronto, where he received a major commission to paint the portraits *William Williamson and His Son Alexander* and *Margaret Erskine Williamson and Her Daughter Jessie*, now in the collection of the Royal Ontario Museum (Accession No. 978.289.1 and 978.289.2, respectively).¹ This was followed by a trip to Paris in 1844, during which he registered as a copyist at the Louvre to develop his artistic technique. While there, he developed his skill in the handling of light, which remained of enduring interest to him.

II. The Montréal Period: 1845-1853

Kriehhoff moved to Montréal in late 1845 or early 1846, and established himself as a professional artist. This period produced works that were shown in the Montréal Society of Artists Exhibition of 1847, and included copies of known works as well as original compositions comprising paintings commissioned by friends, patrons and business partners, and early paintings of Québec country life and of Aboriginal people.

III. The Québec Period: 1853-1863

This period encompasses 10 years when Kriehhoff lived in Québec City. The many sites of natural splendour around Québec City, such as lakes, waterfalls and mountains, became the subject of many paintings and dominated the human figures in others. Kriehhoff also painted portraits of patron-friends, Aboriginal people (primarily French-speaking Hurons from the community of Lorette near Québec City), and people from unpopulated areas north and south of Québec City who settled there during the government colonization program. He also created many single-figure compositions for tourists as souvenirs.

IV. The European Period: 1864-1870

In 1864, Kriehhoff returned to Europe for an extended period. He continued to paint romantic scenes of Canada for sale in Europe, the United States and Canada. In 1867, he exhibited paintings of Canadian landscapes and of Aboriginal themes at the Exposition Universelle in Paris to help promote the prosperity of the newly-formed nation.

V. The Late Québec Period: 1870-1872

Kriehhoff returned to Québec City in 1870 and exhibited in the Québec Provincial Exhibition which celebrated industrial, economic and cultural growth. Eighteen months later, Kriehhoff moved to Chicago to live with his daughter and he died there in 1872.

Preparations for the exhibition *Kriehhoff: Images of Canada* involved a systematic examination by curator Dennis Reid and conservator Sandra Webster-Cook of 283 Kriehhoff works in public and private collections. This preliminary process helped to establish the framework for a technical study. Paintings for inclusion in the subsequent analytical study were chosen to

provide a representative selection from each of the five major stages of Kriehhoff's career. Paintings chosen highlighted his themes and subject matter, were particularly representative of his oil painting techniques, and demonstrated the inherent problems encountered in his work. Twelve lenders to the exhibition, including both public institutions and corporate collections, agreed to participate in the project.

The first part of this study, which was undertaken prior to the exhibition, included an examination of the 283 paintings. The original supports and the signatures on 130 dated paintings were documented. The second part of the study focused on the instrumental analysis of samples of paint from 55 selected paintings as well as analysis of the ground layers and the determination of the stratigraphy, where possible. Several inherent problems that were noted in Kriehhoff's choice of materials during the examination of the paintings were investigated, including faded colours, wrinkled paint surfaces and drying cracks in glazes. A complete list of the 55 oil paintings that were sampled is given in **Table I**.

Methods of Analysis

A technical examination of the 283 paintings was conducted by Sandra Webster-Cook. Two hundred and sixty-three of the paintings, from several collections, were examined at the Art Gallery of Ontario, including the collection of Kriehhoff paintings belonging to the late Ken Thomson. The remaining paintings were examined at their respective institutions (11 at the Royal Ontario Museum and 9 at the McCord Museum). The condition of the paintings that were examined ranged from almost pristine to severely damaged and heavily restored, frequently by several generations of treatment. Only retouchings that were recently applied could be identified using ultraviolet illumination. Examination of the paintings under the high magnification of a stereomicroscope allowed the majority of old over-painting, now covered by one or more layers of fluorescent varnish, to be identified.

Thread counts were taken from the nine unlined paintings using a 6x Linen Tester W/Scale. The type of canvas was identified by examination at high magnification using a stereomicroscope.

For the instrumental analysis, microscopic paint samples were removed from original areas in the subset of 55 paintings by Elizabeth Moffatt and Marie-Claude Corbeil. Since many of the works had been extensively treated, sample sites were chosen in consultation with Sandra Webster-Cook, following careful examination of the paintings with the aid of a stereomicroscope. The paint samples, which were taken using a sharp scalpel, were very small so that the locations would not be visible to the naked eye.

The results obtained from the various analytical techniques that are described below were considered together in determining the composition of a sample. For Fourier transform infrared spectroscopy (FTIR), the sample was positioned on a diamond

Table I: Paintings Included in the Study Organized by Period and Themes.

| Period | Title of Painting | Date | Accession Number |
|--|--|-------------|-------------------------|
| I. The Early Years: 1840-1844 | | | |
| Toronto 1844 | <i>William Williamson and His Son Alexander</i> | 1844 | ROM 978.289.1 |
| | <i>Margaret Erskine Williamson and Her Daughter Jessie</i> | 1844 | ROM 978.289.2 |
| Paris trip 1844, copy of known work | <i>Still Life with Flowers, Fruit and Corn</i> | 1846 | MMFA 1967.1549 |
| II. The Montréal Period: 1845-1853 | | | |
| The Montréal Society of Artists Exhibition 1847 | <i>The Artist's Studio</i> | c. 1845 | NGC 128 |
| | <i>The Plains of Babylon (after Staunton)</i> | 1846 | PCC |
| | <i>An Officer's Room in Montréal</i> | 1846 | ROM 954.188.2 |
| | <i>The Winetasters (after Hasenclever)</i> | c.1846 | TC P-C-65 |
| | <i>Breaking Lent (A Friday's Surprise)</i> | c. 1847 | TC P-C-672 |
| Commission for patrons and friends, Montréal | <i>King's Walden, Hertfordshire</i> | 1846 | MMCH 990.758.1.1 |
| | <i>Seigneurie at Sainte-Anne-de-la-Pérade</i> | 1846 | MMCH 990.758.1.3 |
| | <i>Charles Theophilus Metcalfe, Baron Metcalfe</i> | 1847 | MCR 1998.1865 |
| Québec rural life | <i>Habitant Sleigh, View Near the Canada Line</i> | c. 1847 | TC P-C-669 |
| | <i>A Game of Cards</i> | 1848 | LAC C-011003 |
| | <i>Cottage, St. Anne</i> | c. 1850 | MNBAQ 34.257 |
| | <i>Canadian Interior</i> | 1850 | MNBAQ 59.629 |
| | <i>White Horse Inn by Moonlight</i> | 1851 | NGC 16702 |
| | <i>Fiddler and Boy Doing Jig</i> | 1852 | TC P-C-777 |
| Aboriginal people | <i>Caughnawaga Indian Encampment at a Portage</i> | 1844? | ROM 949.39.20 |
| | <i>A Caughnawaga Indian Encampment</i> | c. 1848 | ROM 949.39.17 |
| | <i>Huron Indians at Portage</i> | 1850 | ROM 954.188.3 |
| III. The Québec Period: 1853-1863 | | | |
| Commissions for patrons and friends, Québec City | <i>Elizabeth Bickell</i> | c. 1854 | NGC 6107 |
| | <i>John Palmer Bickell</i> | 1854 | NGC 6106 |
| | <i>Lt. Alfred Torrens and His Wife in Front of the Citadel</i> | c. 1854 | TC P-C-715 |
| | <i>Self-portrait</i> | 1855 | NGC 1657 |
| | <i>Andrew John Maxham</i> | 1856 | MNBAQ 34.268 |
| | <i>The Narrows on Lake St. Charles</i> | 1859 | TC P-C-703 |
| | <i>Death of the Moose at Sunset. Lake Famine South of Québec</i> | 1859 | GM 81.7.1 |
| | <i>Sportsmen at Jacques Cartier Falls</i> | 1861 | TC P-C-575 |

| | | | |
|---|--|---------|------------------|
| Landscapes | <i>Québec from Pointe-Lévis</i> | 1853 | ROM 955.84 |
| | <i>In the Jardin de Caribou, below Québec</i> | 1856 | MMCH M967.100.13 |
| | <i>The Artist at Niagara</i> | 1858 | AGO 98/20 |
| | <i>The Chaudière</i> | 1858 | NGC 2037 |
| | <i>In the Jardin de Caribou, 50 Miles below Québec</i> | 1861 | TC P-C-574 |
| | <i>Lac Laurent: Autumn</i> | 1862 | TC P-C-168 |
| Aboriginal people | <i>Indian Encampment at Big Rock</i> | 1853 | TC KRT-C-5 |
| | <i>Portage Near Falls of Grand'Mère, St. Maurice River</i> | 1855 | PCC |
| | <i>Taking Shelter from the Storm</i> | 1857 | TC P-C-616 |
| | <i>On Lake Laurent</i> | 1863 | TC P-C-746 |
| Québec rural life | <i>Midday Rest</i> | 1854 | AGO 2532 |
| | <i>Habitants Sleighing</i> | c. 1855 | AGO 2531 |
| | <i>Settler's Log House</i> | 1856 | AGO 2413 |
| | <i>After the Ball, Chez Jolifou</i> | 1856 | TC P-C-671 |
| | <i>A Winter Incident</i> | c. 1860 | TC P-C-933 |
| | <i>Winter in Laval Mountains near Québec</i> | 1863 | TC P-C-633 |
| Single figures | <i>Head of a Habitant</i> | c. 1855 | MMFA 1910.308 |
| | <i>The Indian Moccasin Seller</i> | c. 1855 | TC P-C-499b |
| | <i>"Pour le Bon Dieu?"</i> | 1859 | KG |
| | <i>"Va au Diable"</i> | 1859 | KG |
| | <i>The Old Poacher</i> | c. 1860 | TC P-C-291 |
| | <i>Sillery Cove, Québec</i> | c. 1864 | TC P-C-585 |
| IV. The European Period: 1864-1870 | <i>Chippewa Indians at Lake Huron</i> | 1864 | PCC |
| | <i>Spill My Milk</i> | 1865 | TC P-C-115 |
| | <i>Winter Scene in the Laurentians - The Laval River</i> | 1867 | TC P-C-108 |
| V. The Late Québec Period: 1870-1872 | <i>J.B. Jolifou, Aubergiste</i> | 1871 | TC P-C-431 |
| | <i>The Blacksmith's Shop</i> | 1871 | AGO 50/13 |

AGO - Art Gallery of Ontario, GM - Glenbow Museum, KG - Kastel Gallery, LAC - Library and Archives Canada, MMCH - McCord Museum of Canadian History, MMFA - Montréal Museum of Fine Arts, MCR - Musée du Château Ramezay, MNBAQ - Musée national des beaux-arts du Québec, NGC - National Gallery of Canada, PCC - Power Corporation of Canada, ROM - Royal Ontario Museum, TC - Thomson Collection

anvil microsample cell and was analysed using a Spectra-Tech IR-Plan microscope interfaced to a Bomem Michelson MB-120 spectrometer. X-ray microanalysis was undertaken using an Hitachi S-530 scanning electron microscope (SEM) equipped with a Noran Instruments x-ray detector and Voyager II x-ray microanalysis system. Most samples were dispersed in Cargille Meltmount®, a mounting medium with refractive index (n) of 1.66, for examination by polarized light microscopy (PLM) using a Leica DMRX microscope. X-ray diffraction (XRD) was undertaken on several samples, using a Rigaku RTP 300 RC rotating anode generator with a cobalt target and a microdiffractometer. Due to the limited amount of sample material available, most samples could not be analysed by this technique. For analysis by gas chromatography-mass spectrometry (GC-MS), two samples were methylated in trimethyl(α,α,α -trifluoro-tolyl)ammonium hydroxide (TMTFTH) (5% in methanol) and toluene and analysed using an Agilent 6890 gas chromatograph interfaced to an Agilent 5973 mass spectrometer.

Results

Part 1: Preliminary Examination

Supports

The supports of 283 of Kriehoff's oil paintings were documented. The majority (269) were painted on fine canvas. Thread counts were made of the nine unlined paintings. All were plain weave, linen canvas with 19, 20 and 22 threads per cm². Four of the lined canvases presented patterns of damage that suggest shrinkage along the canvas threads in response to a high moisture treatment (e.g. glue lining).

Thirteen small works were painted on paperboard, including multi-ply paperboard and pulpboards, measuring between 0.2 and 0.3 cm in thickness (**Figure 1**). One painting was on a wood panel, thought to be oak, in a tilt-top table from a private collection.

Signatures

Of the 283 paintings that were examined, eight were unsigned. The placement, colour, form and slant of Kriehoff's signatures were documented on 130 paintings that were dated either by the artist on the work of art or by art historians.

A "model" of Kriehoff's signature is composed of a sequence of the following typical elements: "C. Kriehoff. Québec. 1846." In his signature, the artist never used his given name but rather the capitalized initial, "C" (often followed by a period or joined to the "K") that represented the artist's given name, Cornelius. The initial "C" is followed by the full spelling of his surname: "Kriehoff" (often followed by a period). This was sometimes followed by the place name, "Quebec." or, as in the case of the copies, "after artist name" and there is an example of his surname followed by "pinx" (not followed by a period).

This is sometimes followed with either the full or partial date of the year of execution (often followed by a period). This basic format varies, with inclusions or omissions at times of either or both the place name and date. Throughout his career, however, the signature consistently begins with the initial of his given name followed by his surname (see **Figures 2 to 12**). The single exception encountered was the monogrammed signature from 1846 described below.

The paintings were usually signed in oil paint with the tip of a fine brush in the lower left or lower right corner on one or two straight lines, rarely three. Where appropriate, the signature was integrated into the composition of the image, sometimes on a diagonal (see **Figure 2**). Kriehoff used a wide range of colours in his signatures, including black, shades of brown, blue (permanent and fugitive), yellow, red (ranging from bright orange-red to rust-toned red), pink, cream, and coral, shown in **Figure 3**.

Although a person's signature varies from day to day and over a lifetime, characteristic details are often consistent. Kriehoff's printed and cursive signatures show remarkable consistency over time.

The Early Years and the Montréal Period

The 10 early Kriehoff signatures that were studied, dated prior to 1853, are inscribed with letters in printed form, which appear vertical. The early signature shown in **Figure 4** illustrates the typical form of his letters, which persists to the end of his life - e.g., the capital letter "K" and the letter "g", although he occasionally used the more traditional "g" form. **Figure 5** shows another early signature, from 1846, in which his use of this particular form of the letter "g" is clearer. Only one monogrammed signature (from around 1847) was encountered where the capital letter "C" overlies the capital letter "K" (**Figure 6**).

The Québec Period

Of the signatures studied on 94 paintings dating from the Québec Period (1853-1863), signatures with letters in cursive form appear in approximately equal proportion to those with letters in printed form. The signatures shown in **Figures 7 to 9** are from 1858, 1859 and 1863, respectively. The letters are mainly vertical, but increasingly the angle of the letters leans to the left. Only seven signatures with the angle of the letters leaning slightly to the right were observed in the paintings of the Québec Period.

The European Period

No examples of signatures with letters in printed form were seen on the seven paintings from the European Period (1864-1870) that were examined. All signatures were inscribed with letters in cursive form and consisted of two vertical and five leaning to the left. **Figures 10 and 11** show signatures from 1864 and 1867, respectively.

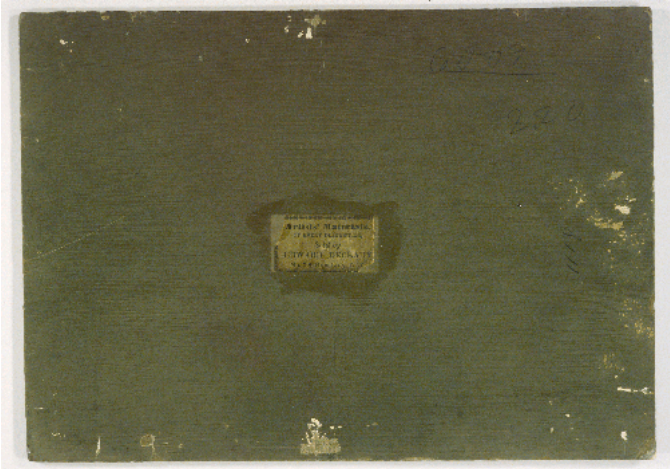


Figure 1. Verso of paperboard support, *The Card Players*, c. 1848, collection of the Art Gallery of Ontario, Toronto, Canada (74/387). Photograph courtesy of the Art Gallery of Ontario.



Figure 2. Signature integrated into the image, *Death of the Moose at Sunset, Lake Famine South of Québec*, 1859, collection of the Glenbow Museum, Calgary, Canada (81.7.1). Photograph courtesy of the Art Gallery of Ontario.



Figure 3. Coral signature, *Indian Woman Carrying Baskets*, c. 1860, Private Collection. Photograph courtesy of the Art Gallery of Ontario.

The Late Québec Period

In the paintings examined from the later years (1870-72), there are two examples of signatures where the angle of the letters, in



Figure 4. Early printed signature, *Still Life with Flowers, Fruit and Corn*, 1846, collection of the Montréal Museum of Fine Arts (MMFA), Montréal, Canada (1967.1549). Photograph courtesy of the MMFA.

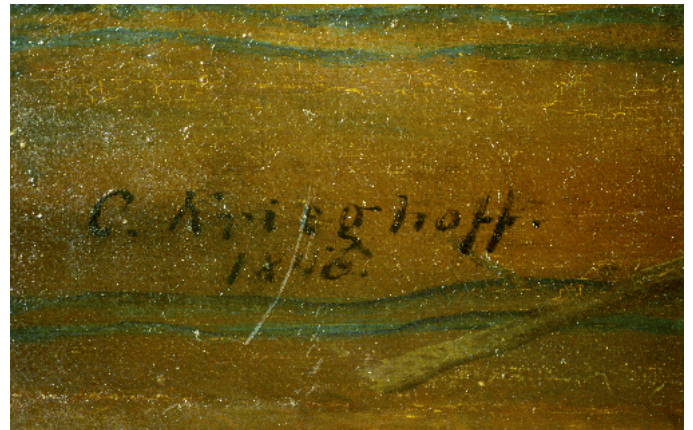


Figure 5. Early printed signature, *An Officer's Room in Montreal*, 1846, collection of the Royal Ontario Museum, Toronto, Canada (954.188.2). Photograph courtesy of the Art Gallery of Ontario.



Figure 6. Monogrammed signature, *Habitant Sleigh, View Near the Canada Line*, c. 1847, Thomson Collection (P-C-669). Photograph courtesy of the Art Gallery of Ontario.

cursive form, leans to the left, as illustrated in the signature from 1871 shown in **Figure 12**. There are also three printed signatures with vertical letters.



Figure 7. Printed signature from the Québec Period, *Tubular Bridge, St. Henry's Falls*, 1858, C. Kreighoff, collection of the McCord Museum, Montréal, Canada (M967.100.1). Photograph courtesy of the Art Gallery of Ontario.



Figure 10. Cursive signature from the European Period, *Sillery Cove, Québec*, c. 1864, Thomson Collection (P-C-585). Photograph courtesy of the Art Gallery of Ontario.

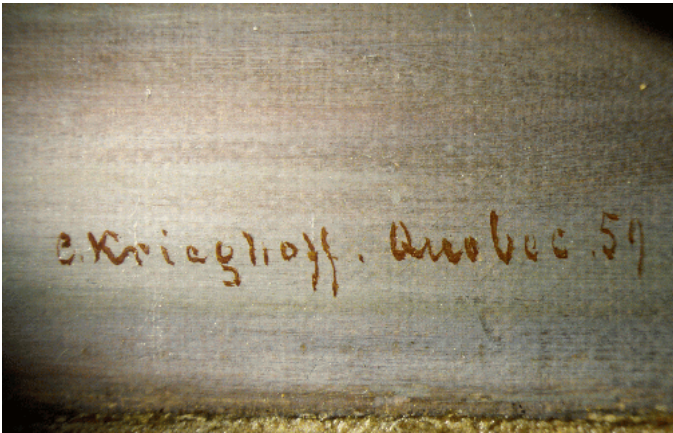


Figure 8. Signature from the Québec Period, *The Narrows on Lake St. Charles*, 1859, Thomson Collection (P-C-703). Photograph courtesy of the Art Gallery of Ontario.



Figure 11. Cursive signature from the European Period, 1867, *Winter Scene in the Laurentians - The Laval River*, 1867, Thomson Collection (P-C-108). Photograph courtesy of the Art Gallery of Ontario.



Figure 9. Cursive signature from the Québec Period, *On Lake Laurent*, 1863, Thomson Collection (P-C-746). Photograph courtesy of the Art Gallery of Ontario.

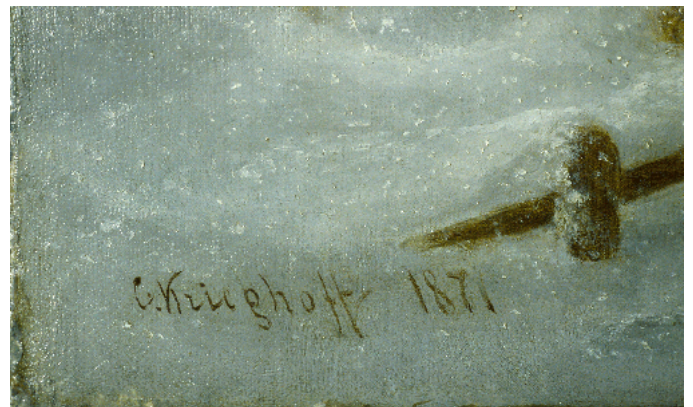


Figure 12. Cursive signature from the Late Québec Period, *The Blacksmith's Shop*, 1871, collection of the Art Gallery of Ontario (50/13). Photograph courtesy of the Art Gallery of Ontario.

Part 2: Instrumental Analysis

The second part of the study involved the analysis of 323 samples of paints and grounds from 55 oil paintings. Varnishes were not analysed since most were likely not original.

Grounds

Samples of the ground layers were obtained from 35 of the 55 oil on canvas paintings included in the study. All samples contained lead white and often neutral lead carbonate, which can occur as an impurity in lead white.⁶ As shown in **Table II**, there were three



Figure 13a. *Habitants Sleighing*, c.1855, collection of the Art Gallery of Ontario (2531). Photograph courtesy of the Art Gallery of Ontario.



Figure 13b. Detail showing granular ground, *Habitants Sleighing*. Photograph courtesy of the Art Gallery of Ontario.

Table II: Number of Paintings with Each Type of Ground Layer.

| Composition | Group | | | | |
|---|-------|----|-----|----|---|
| | I | II | III | IV | V |
| lead white, drying oil | 2 | 6 | 1 | - | - |
| lead white, calcium carbonate, drying oil | - | 3 | 6 | 1 | 2 |
| lead white, calcium carbonate, barium sulfate, drying oil | 1 | 6 | 7 | - | - |

Granular grounds were observed in a number of paintings, including *Habitants Sleighing*, c. 1855 (**Figure 13a** and **13b**). Granular grounds from six paintings dating from 1846 to 1871 were analysed. Three, including that of *Habitants Sleighing*, were composed of lead white, calcium carbonate, a trace of barium sulfate and a drying oil medium. Two consisted of lead white and calcium carbonate in drying oil while one contained only lead white and drying oil. In summary, the granular grounds were not all identical and they were similar in composition to the other grounds that did not display the granular texture. It has been suggested in the literature that development of discoloration

main types of ground layer identified, all with a drying oil medium: lead white; lead white with calcium carbonate; and lead white, calcium carbonate and barium sulfate. All three types were used during the first three periods of Krieghoff's career. The choice of ground did not appear to be related to a specific time period or location. So few ground layers from paintings in Groups IV and V were sampled that it is not possible to draw conclusions regarding the type of ground layer prevalent in the paintings in the later years.

Table III: Pigments Identified in Paintings from Each Period of Kriehoff's Career.^a

| | | Group I | Group II | Group III | Group IV | Group V |
|--|--------------------------------|-----------|-----------|-----------|-----------|-----------|
| | | 1840-1844 | 1845-1853 | 1853-1863 | 1864-1870 | 1870-1872 |
| Total Number of Paintings Sampled | | 3 | 17 | 29 | 4 | 2 |
| Blue: | Prussian blue | 3 | 14 | 20 | 4 | 2 |
| | ultramarine | 1 | 13 | 19 | - | 1 |
| | cobalt blue | - | - | 2 | 2 | - |
| Green: | green earth | - | 1 | - | - | - |
| | copper-arsenic green | - | 1 | 3 | - | - |
| Yellow and orange: | iron oxide(s) | 3 | 17 | 26 | 3 | 2 |
| | cadmium yellow | - | 5 | 6 | 3 | 2 |
| | Naples yellow | - | 3 | - | - | 1 |
| | chrome yellow | 1 | 4 | 2 | - | - |
| | barium yellow | - | - | 5 | 1 | - |
| | zinc yellow | - | - | - | 1 | - |
| Red: | cinnabar/dry process vermilion | 2 | 3 | 12 | 2 | 2 |
| | wet process vermilion | 1 | 11 | 9 | 1 | 2 |
| | iron oxide | 2 | 11 | 9 | 3 | - |
| | red lake | 1 | 8 | 2 | 1 | 1 |
| Black: | bone black | 1 | 5 | 10 | 3 | 2 |
| | charcoal black | - | 6 | 6 | - | 1 |
| Brown: | van Dyck brown | - | 2 | 6 | - | - |
| White and extender:^b | lead white | 3 | 17 | 28 | 4 | 2 |
| | calcium carbonate | 3 | 10 | 11 | 3 | 2 |
| | barium sulfate | 1 | 2 | 10 | 1 | 1 |

^aFigures within the table indicate the number of paintings in which a particular pigment was identified.

^bZinc white may also have been used but its presence could not be confirmed due to instrumental constraints.

and granular texture in 19th- and 20th-century lead white-based oil grounds is attributable to the use of oil driers.⁷ However, in this case, no evidence was found to support this hypothesis.

Paint Layers

Paint layers were, in general, thinly applied with fine brushes and meticulous attention to detail, most notable in the figures and vegetation. The pigments identified, which are listed in **Table III**, are summarized by colour, and the manner in which the pigment selection changed over time will be examined.

Blue

While three blue pigments were identified in the Kriehoff paintings analysed, only two were used extensively, Prussian blue and ultramarine blue. Cobalt blue was rarely used. There were 126 confirmed occurrences of Prussian blue ($\text{Fe}_4[\text{Fe}(\text{CN})_6]_3 \cdot x\text{H}_2\text{O}$), including some at trace levels in pigment mixtures. Prussian blue was present in 43 of the 55 paintings, from all time periods.

Ultramarine blue, a complex sulfur-containing sodium aluminum silicate, was identified in 80 samples and in 30 of these it was mixed with Prussian blue. Ultramarine blue was not identified in the samples from the four paintings of Group IV but it was used extensively in works from other periods.

There was limited use of cobalt blue ($\text{CoO} \cdot \text{Al}_2\text{O}_3$). This pigment was identified in only two paintings from Group III and two from Group IV, dating from c. 1854 to 1867.

Green

There was very limited use of green pigments in the paintings studied. There was one occurrence of green earth (a complex silicate) in a sample from a painting dating from 1846 (Group II), where it was mixed with several other pigments.

A green pigment containing copper and arsenic was identified in samples from four paintings, one in Group II and the rest in Group III. The exact structure of this green pigment was not determined. Its infrared spectrum (**Figure 14**) showed a major

absorption at 807 cm^{-1} , which may be indicative of a copper arsenite or arsenate.^{8,9} Microscopical examination revealed that the pigment consisted of isotropic, pale green gel-like particles ($n \geq 1.66$), some of which exhibited undulose extinction. The pigment may be a form of Scheele's green, a copper arsenite of variable composition that was introduced in 1778.¹⁰

Shades of green in Kriehoff's paintings were typically obtained from pigment mixtures, including Prussian blue and/or ultramarine blue with yellow and orange iron oxides (**Figure 15**). Chrome yellow, barium yellow and cadmium yellow were also detected in various green paints.

Yellow

Yellow and orange iron oxides were identified in almost every painting in a wide variety of colours, ranging from yellow to red, brown and green.

Cadmium yellow (CdS) was indicated in 67 samples from 15 paintings, in yellow, green, brown and orange paints from all groups except Group I. In general, due to sample size restrictions, the identification was based on the detection of cadmium by x-ray microanalysis, along with the presence of a finely divided yellow pigment observed by polarized light microscopy. Cadmium sulfide was first prepared in 1818 but did not become commercially available as a pigment until the 1840s.¹¹ The early history of its use as a pigment is not well documented. The earliest occurrences of cadmium yellow in the Kriehoff study were in five paintings in Group II attributed to the middle to late 1840s.

Naples yellow (lead antimonate yellow, $\text{Pb}_2\text{Sb}_2\text{O}_7$) was identified in yellow or yellow-green samples from four paintings. Three of the occurrences were in paintings from Group II, dating

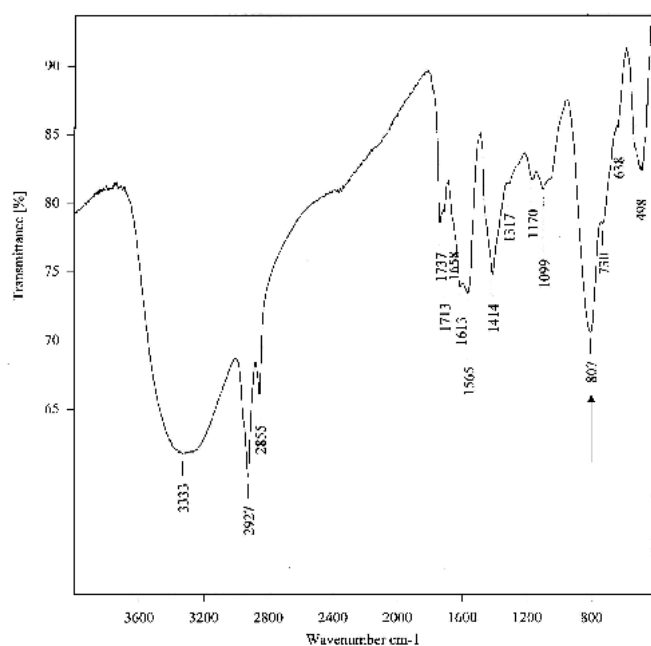


Figure 14. Infrared spectrum of a green paint containing a pigment in which copper and arsenic were identified. The absorption at 807 cm^{-1} is attributable to an arsenite or arsenate compound.

from c. 1847 to 1850. The fourth occurrence was in a Group V painting dating from 1871. In Europe, the most extensive use of Naples yellow was between 1750 and 1850.¹²

Chrome yellow, composed of lead chromate (PbCrO_4) or lead chromate-sulfate ($\text{PbCrO}_4 \cdot \text{PbSO}_4$), was identified in nine samples from seven paintings in Groups I, II and III. The earliest occurrence of chrome yellow in the Kriehoff works in the study was in a painting dating from 1844.

Barium yellow (BaCrO_4) was identified in five paintings from Group III, dating from c. 1855 to 1863 and one from Group IV (1865). Barium yellow was generally found in pigment mixtures used for green.

There were three occurrences of zinc yellow ($\text{K}_2\text{O} \cdot 4\text{ZnCrO}_4 \cdot 3\text{H}_2\text{O}$) in one Group IV painting from the mid 1860s. Zinc yellow was present in various shades of green, where it was mixed with Prussian blue.

Red

The principal red pigment found in the Kriehoff paintings was mercuric sulfide (HgS , vermilion/cinnabar). This pigment can be either the natural mineral cinnabar or one of two synthetic types, dry process vermilion, which has been prepared since antiquity by a sublimation process, or wet process vermilion, which was first discovered in 1687.¹³ The microscopical characteristics of cinnabar and dry process vermilion are very similar, making it difficult to differentiate the two, while wet process vermilion is readily distinguished. There were 61 occurrences of cinnabar/dry process vermilion and 29 of wet process vermilion in the samples. Both types of this pigment were identified in paintings from each time period.

Red iron oxide was used in a variety of colours and mixtures throughout Kriehoff's career. It was identified in samples from

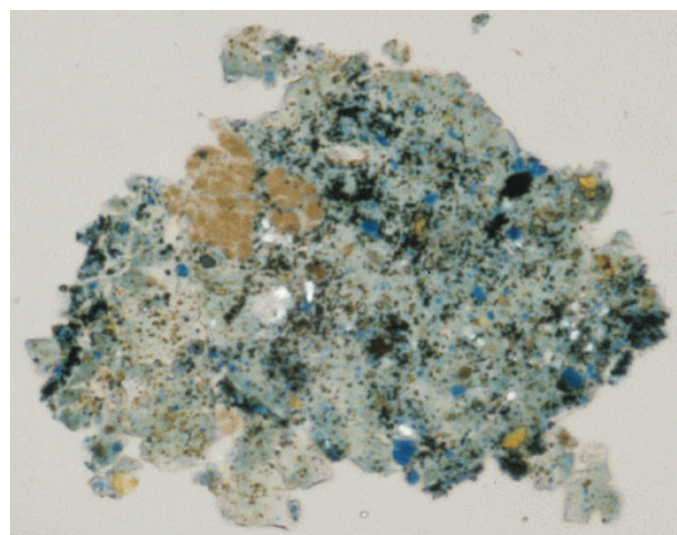


Figure 15. Photomicrograph of a typical dark green paint. Particles of Prussian blue, yellow iron oxide and bone black are visible. Transmitted light, full image width $140\text{ }\mu\text{m}$.

25 paintings. Red lakes were detected in 25 samples from 13 paintings, but the exact nature of these lakes was not determined due to sample size restrictions.

Black

Black pigments identified include bone black and charcoal black. However, in a number of black paint samples, bone black was mixed with Prussian blue and a trace of orange or red iron oxide. Other mixtures identified include bone black with traces of orange iron oxide and van Dyck brown; charcoal black with ultramarine blue and orange iron oxide; and bone black with Prussian blue and cinnabar/dry process vermilion.

Brown

A variety of pigment mixtures was identified in samples of brown paint. Brown paints were usually based on orange iron oxide, often mixed with either bone black or charcoal black, Prussian blue, other colours of iron oxide and sometimes additional pigments such as van Dyck brown.

White Pigments and Extenders

As well as being used as a white paint pigment, lead white ($\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$) was used throughout as an extender in other paint colours. Other extenders include calcium carbonate (CaCO_3), identified in samples from 29 paintings, and barium sulfate (BaSO_4), identified in samples from 15 paintings. Significant quantities of zinc were detected by x-ray microanalysis in seven Group III paintings, indicating a zinc-containing pigment, possibly zinc white. The presence of zinc white could not be confirmed in the samples by XRD or FTIR - the sample size precluded analysis by x-ray diffraction and zinc white could not be identified by infrared spectroscopy since its characteristic absorption is outside the detection range of the FTIR microscope system.

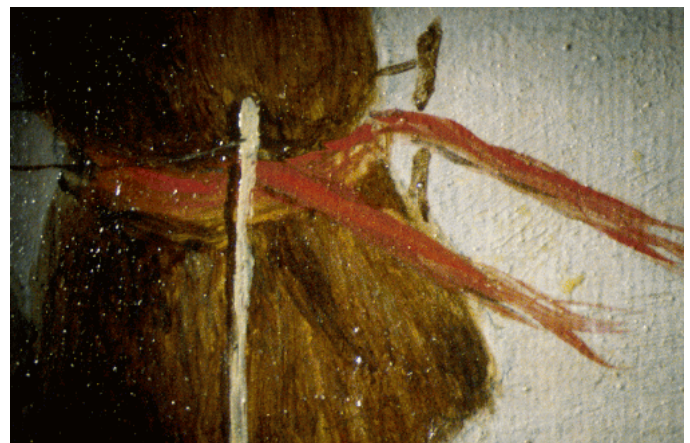
Analysis Related to Inherent Problems

Fugitive Pigments

One of the inherent problems observed in Krieghoff's paintings was the use of fugitive pigments. Many of the subdued colours have been strengthened by restoration overlay. Faded blue, violet, red and coral pink paints were encountered (**Figure 16a** and **16b**). Mixtures of Prussian blue, lead white and traces of other pigments were identified in several faded blue and violet samples. The fading of Prussian blue, particularly when it is used highly diluted in lead white mixtures, has been described in the literature.¹⁴ Red lakes, which are known to be light sensitive,¹⁵ were detected in several samples that had noticeably faded, and in 25 samples overall. In several other lead white-based paints that had faded (a red, a coral pink and a violet that also contained Prussian blue), vermilion was identified but no red lake was detected.



(a)



(b)

Figure 16. Details showing faded red and blue pigments, *Habitants Sleighing*, c.1855, collection of the Art Gallery of Ontario (**Figure 13a**). Photographs courtesy of the Art Gallery of Ontario.

Wrinkling in Upper Paint Layer

While Krieghoff's paintings, throughout his life, largely present smooth- to low-textured surfaces, fine wrinkling in the upper paint layers was observed in several paintings. This phenomenon was especially visible in the blue and coral pink in the sky of the 1858 painting *The Artist at Niagara* (**Figures 17a** and **17b**). The blue paint was composed primarily of cobalt blue, lead white and drying oil, while the coral pink was composed mainly of cinnabar/dry process vermilion, barium yellow, lead white and drying oil.

Relatively high levels of zinc soaps were detected by FTIR in both samples. Zinc soaps were likely formed in the paints from the reaction of zinc white pigment (which, as previously mentioned, would not be detected due to instrumental constraints) and free fatty acids in the drying oil medium. The high level of zinc soaps in these samples was the unusual feature of these samples, but it is not conclusive that their presence would explain the wrinkling phenomenon. Varying levels of zinc soaps were also detected in samples from six other Group III paintings that did not show wrinkling.

Drying Cracks

Drying cracks were observed in many Kriehoff paintings, especially in the rich dark green and brown glazes, as in the painting *Sillery Cove, Québec* (c. 1864) shown in **Figures 18a to 18c**. Due to sample size restrictions, only two samples of these glazes were analysed by GC-MS. The drying oil of the brown glaze of the painting *Sillery Cove, Québec* was identified as walnut oil, which had a high diacid content. A high diacid content is related to poor cross-linking of the oil.¹⁶ The second example that was investigated was a resinous green toning layer from the 1854 painting *Midday Rest*. The green was composed of a *Pinaceae* resin, linseed oil, Prussian blue, ultramarine blue, yellow iron oxide and silicates. *Pinaceae* resins include pine and European larch resins. The GC-MS analysis showed that there was a high ratio of resin to oil in the medium, which is likely responsible for the cracking of the paint.



Figure 17a. *The Artist at Niagara*, 1858, collection of the Art Gallery of Ontario (98/20). Photograph courtesy of the Art Gallery of Ontario.

Conclusions

The study has yielded much information about Kriehoff's materials and insights into his techniques. This information will assist conservators, curators and scientists by providing comparative data that will be useful both in attribution studies and in evaluating the conservation requirements of his works.

The documentation of the artist's signatures will provide a useful reference in the consideration of works of questionable attribution. Distinctive features have been identified and recorded.

Kriehoff's favoured support was fine linen canvas, although he occasionally used a variety of paperboards and, in at least one instance, wood. Three main types of ground layer were identified, all with a drying oil medium - lead white, lead white and calcium carbonate, and lead white, calcium carbonate and barium sulfate.

Analysis of over 300 paint samples from 55 paintings spanning Kriehoff's career allowed his rich palette and its chronology to be documented. Many pigments were used throughout his career, such as lead white, Prussian blue, ultramarine blue, vermilion/cinnabar, bone black, and orange, yellow and red iron oxides, and extenders such as calcium carbonate and barium sulfate. There was also extensive use of cadmium yellow and more limited use of cobalt blue, Naples yellow, chrome yellow, barium yellow, zinc yellow, van Dyck brown and charcoal black. A characteristic of Kriehoff's paintings is the use of complex pigment mixtures, with the addition to many colours of small amounts of pigments such as Prussian blue and yellow or orange iron oxide. Due to the sensitivity to light of some of Kriehoff's pigments (in particular Prussian blue and red

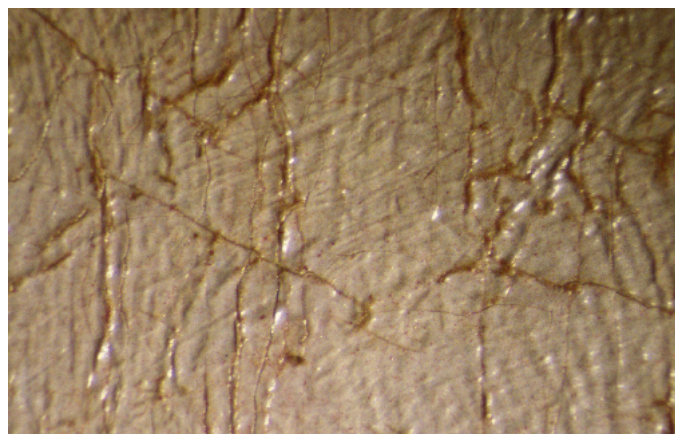


Figure 17b. Detail of wrinkled paint in the sky, *The Artist at Niagara*. Photograph courtesy of the Art Gallery of Ontario.

lakes), it is recommended that his paintings, especially those in pristine condition, be exhibited at light levels below 100 lux.

Many of Kriehoff's paintings have suffered loss from insensitive cleaning, most notably the thinning of the dark glazes. The high points of the wrinkled paint surfaces are particularly fragile; extensive abrasion and loss were frequently observed in these areas. The textured surface of paintings with an underlying granular ground is also vulnerable to abrasion. Conservation treatment of such delicate surfaces should be undertaken with caution, under high magnification using a stereomicroscope.

It is hoped that this analytical project will enhance the understanding and preservation of paintings by this important 19th-century Canadian artist.



Figure 18a. *Sillery Cove, Quebec*, c. 1864, Thomson Collection (P-C-585). Photograph courtesy of Thomson Works of Art Ltd.

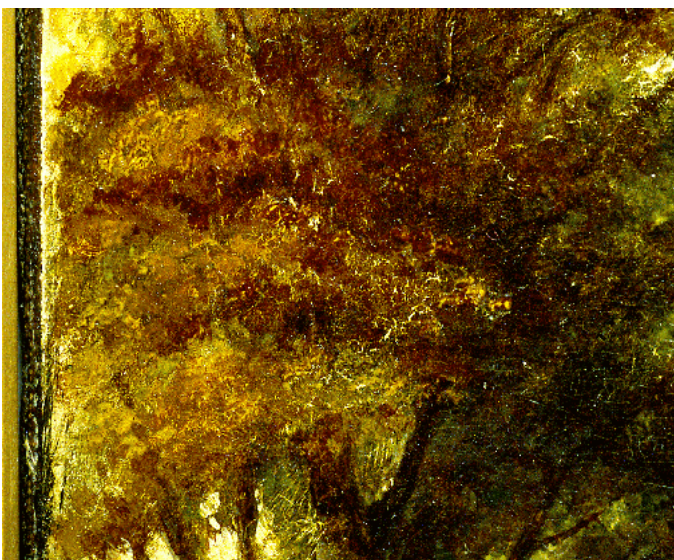


Figure 18b. Detail showing drying cracks in brown glazes, *Sillery Cove, Quebec*. Photograph courtesy of the Art Gallery of Ontario.



Figure 18c. Detail showing drying cracks in green glazes, *Sillery Cove, Quebec*. Photograph courtesy of the Art Gallery of Ontario.

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