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Journal of the Canadian Association for Conservation (J. CAC), Volume 24.

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

Journal de l'Association canadienne pour la conservation et la restauration (J. ACCR), Volume 24.

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

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Technical examination of an oil painting on canvas attributed to Louis Dulongpré has provided insight into the nature of the ground layer responsible for the poor condition of the work. The paint and ground layers exhibited extensive cracking, cleavage, cupping, and loss throughout. Cross-sections from several areas of the painting were examined and components were identified using a combination of x-ray microanalysis, x-ray diffraction, Fourier transform infrared spectroscopy, and polarized light microscopy. The examination showed that three distinct ground layers were applied to the canvas before the portrait was painted. Cross-sections and x-radiographs provided evidence that these ground layers had cracked even before the application of the paint layers. The first ground layer applied to the canvas was found to be composed of starch, protein, gypsum, and a red iron oxide pigment. The presence of a high concentration of starch granules in this layer indicated that the material was not heated sufficiently to form a paste. This explains the lack of cohesion within the ground layer and the ensuing cracking and cleavage. Although the use of pigmented, starch-based preparatory layers is mentioned in documentary sources, this type of ground has rarely been identified in a painting.

L'examen scientifique d'une huile sur toile attribuée à Louis Dulongpré a permis de déterminer la nature de la couche de préparation responsable du piètre état du tableau. On pouvait observer dans la couche picturale et les couches de préparation des craquelures, des clivages, des soulèvements en cuvette et des lacunes. Des coupes transversales prélevées à plusieurs endroits ont été examinées et leurs composantes identifiées en ayant recours à la micro-analyse, à la diffraction des rayons X, à la spectroscopie infrarouge à transformée de Fourier et à la microscopie en lumière polarisée. L'examen a révélé la présence de trois couches de préparation appliquées sur la toile avant que le portrait soit peint. L'examen des coupes transversales et des radiographies du tableau indique que ces couches de préparation avaient déjà craquelé avant que la couche picturale ne soit appliquée. La première couche de préparation contenait de l'amidon, du gypse, une protéine et un pigment rouge à base d'oxyde de fer. La présence de granules d'amidon en grande quantité dans cette couche indique que ce matériau n'avait pas été suffisamment chauffé pour obtenir une pâte. Ceci explique le manque de cohésion de la couche de préparation et le craquèlement et le clivage qui se sont produits subséquemment. Bien que l'utilisation de couches de préparation pigmentées à base d'amidon soit mentionnée dans la littérature, ce type de préparation a rarement été identifié dans un tableau.

Manuscript received April 1999; revised manuscript received August 1999

Introduction

The *Portrait of Jean Dessaulles* (**Figure 1**), from the collection of the Séminaire de Saint-Hyacinthe, was recently treated at the Canadian Conservation Institute (CCI). This oil painting on canvas depicts Jean Dessaulles, seigneur of Saint-Hyacinthe and benefactor of the local seminary, seated beside a table on which rests a plan of his seigneury. Although the painting is neither signed nor dated, it has been attributed to early Québec artist Louis Dulongpré (1754-1843) and is thought to date from about 1825.[1] However, attributions to Dulongpré, who rarely signed or dated his works, are often problematic. According to his obituary, Dulongpré was a prolific painter thought to have created more than 4,000 works in oil and pastel. Today, less than 200 of his works are known and only a fraction of these, perhaps 50, have been officially attributed to him. Adding to the complexity of the attribution is the fact that Dulongpré made multiple versions of some of his portraits.[2]

The *Portrait of Jean Dessaulles* was in very poor condition upon its arrival at CCI. It exhibited extensive cracking, cleavage, cupping, as well as loss of paint and ground layers. Similar types of deterioration have been noted in other paintings attributed to Dulongpré.[3] During its conservation treatment, the work was carefully examined and analysed in order to gain information about the original materials and techniques of the artist and to determine the reasons for its poor condition. Although a detailed examination of the paint and surface coatings was carried out prior to treatment as part of a larger study of paintings attributed to the artist,[4,5] this paper describes only the results of the analysis of the ground layers. These results proved to be the most significant in terms of the condition of the work.

Analytical Methods

X-radiography of the painting was carried out using a Philips industrial x-ray tube with a tube current of 4 mA and a tube potential of 30 kV. The film-to-focus distance was 125 cm and the exposure time was 35 seconds.

Cross-section samples were taken from several areas of the painting in order to elucidate the layer structure of the paint. The cross-sections were embedded in polyester casting resin, ground and polished using cushioned abrasive papers, and examined by incident light and fluorescence microscopy with a Leica DMRX polarizing light microscope. For fluorescence microscopy, autofluorescence of the samples was excited using a mercury vapour lamp and a blue or ultraviolet excitation filter. Certain

cross-sections were stained with a potassium iodide/iodine reagent to test for the presence of starch.[6]

To identify materials in layers of interest, a combination of analytical techniques was employed. X-ray microanalysis was undertaken using an Hitachi S-530 scanning electron microscope equipped with a Tracor x-ray detector and a Noran Instruments Voyager II x-ray microanalysis system. Using this technique, elemental analysis of small volumes can be obtained for chemical elements from sodium (Na) to uranium (U) with a sensitivity on the order of 1%. X-ray diffraction, using a Rigaku RTP 300 RC rotating anode generator with a cobalt target, was utilized to identify crystalline components. Fourier transform infrared (FTIR) spectroscopy was carried out using a Bomem MB-100 spectrometer with a diamond anvil microsample cell and a microbeam sample compartment. Binding media, as well as certain inorganic pigments and extenders, were identified using this technique. Selected samples were mounted in Cargille Meltmount medium (n = 1.66) and examined by polarized light microscopy using a Leica DMRX polarizing light microscope. Polarized light microscopy allows the identification of materials based on their optical and morphological properties.

Composition of the Ground Layers

Visual observations and the examination of cross-sections showed that three distinct ground layers were applied to the canvas before the portrait was painted (**Figure 2**). The first ground layer, present directly on the canvas, is dark pink in colour and has a coarse, friable, and finely cracked texture. It is followed by a second ground layer, lighter pink in colour and with a smoother texture. A third ground application, a thin, pale pink layer, lies on top of the second ground. Cleavage has occurred predominantly within the first ground layer and in a few areas between the paint and the third ground layer. Using a stereomicroscope, a white, granular substance could be seen on the exposed surfaces of the first ground layer.

Analysis using FTIR spectroscopy showed that the white, granular substance on the exposed surfaces was gypsum (hydrated calcium sulfate). Using FTIR spectroscopy, x-ray microanalysis, and polarized light microscopy, the first ground layer, applied directly on the canvas, was found to contain starch, protein, and a red iron oxide pigment, in addition to gypsum. In some regions, the infrared spectrum also showed traces of carbonyl of unknown

Figure 1. *Portrait of Jean Dessaulles*, attributed to Louis Dulongpré, oil on canvas, 90 cm x 70.4 cm (collection of the Séminaire de Saint-Hyacinthe), (a) before treatment, and (b) after treatment.

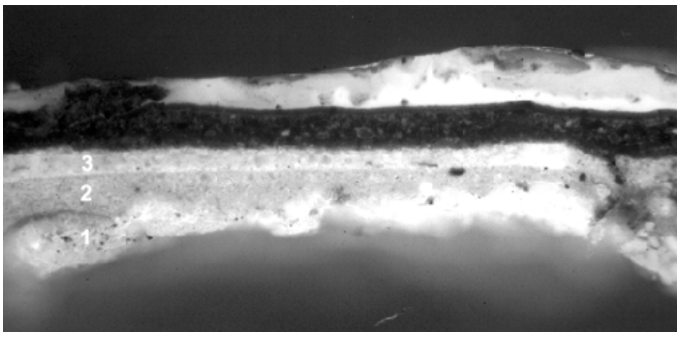

Figure 2. Cross-section, in autofluorescence, showing the three ground layers. The first, second, and third ground layers are labelled 1, 2, and 3 respectively (full image width 700 μm).

origin, possibly from the presence of a small amount of oil or resin. An infrared spectrum of the ground, showing the characteristic bands for starch and protein, is given in **Figure 3**. The high concentration of starch and protein corresponds either to the use of flour paste, which contains both compounds, or a mixture of starch with a proteinaceous material such as animal glue.

Figure 4 shows a cross-section of the starch-based ground layer after staining with potassium iodide/iodine. The cross-section contains many starch grains that were not dissolved during the formulation of this material; the individual granules, which appear dark blue to black after staining, are clearly visible in the sample. Examination of a dispersion of the first ground layer using polarized light microscopy showed that the round to oval starch grains are present as agglomerates, with individual grains varying in size from approximately 5 to 25 μm. In cross-polarized light, the smaller grains showed a distinct cross, while the larger grains showed a fainter black cross. The optical and morphological characteristics of the grains are consistent with wheat starch.[7]

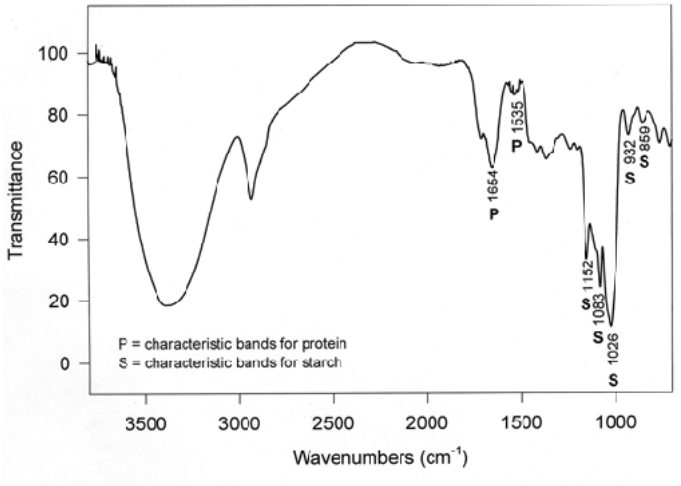

Figure 3. Fourier transform infrared spectrum of the first ground layer showing characteristic bands for starch and protein.

Analysis of the second ground layer using FTIR spectroscopy, x-ray diffraction, and polarized light microscopy, indicated that it has a drying oil binding medium and is pigmented with calcium carbonate, lead white, a small amount of red iron oxide, and probably barium sulfate. Based on x-ray microanalysis, the third ground layer, a thin, pale pink application, has a similar composition to the layer beneath.

Effect of the Ground on the Condition of the Painting

The cracking of the paint and ground layers and the cleavage within the ground layers resulted from the characteristics of the starch-based preparation applied directly to the canvas. This thickly applied layer is granular and very friable. Starch develops its adhesive properties when it is heated to the gelatinization temperature (55-80 ºC) and the granules break open and partially dissolve.[8] The presence of a high concentration of undissolved starch granules in this layer indicates that the material was not heated sufficiently to form a paste and explains the layer's lack of cohesion.

It is apparent that environmental fluctuations exacerbated the poor condition of the paint and ground layers. The central area of the painting, unprotected from temperature and humidity fluctuations, showed the extensive deterioration described above whereas the area buffered by the wooden stretcher showed less cracking and only slight cupping along the more prominent cracks.

Examination of the x-radiograph revealed that the ground layers had begun to crack even before the portrait was painted. **Figure 5** shows a fine network of unusual white (radio-opaque) cracks juxtaposed against the black (radio-transparent) craquelure through paint and ground normally seen in x-radiographs of cracked paintings. The white craquelure in the x-radiograph occurs where paint has penetrated cracks in the ground layers, producing regions of thicker, and thus more radio-opaque paint. Paint that had flowed into cracks in the ground layers was also visible in areas of loss using a stereomicroscope. **Figure 6** is a cross-section showing the penetration of the blue paint from the sitter's jacket into a fissure in the ground layers.

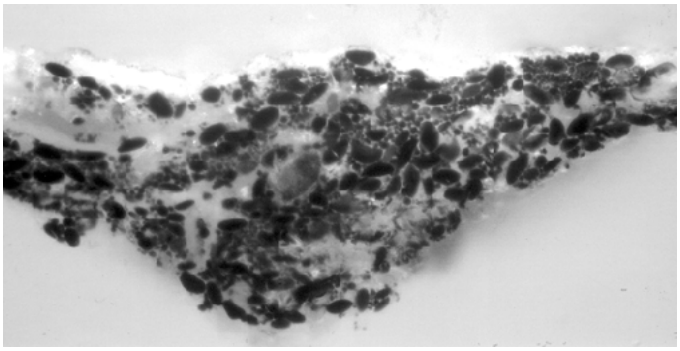

Figure 4. Cross-section of a fragment of the first ground layer after staining for starch using potassium iodide/iodine reagent. The starch granules appear black in the photomicrograph (full image width 545 μm).

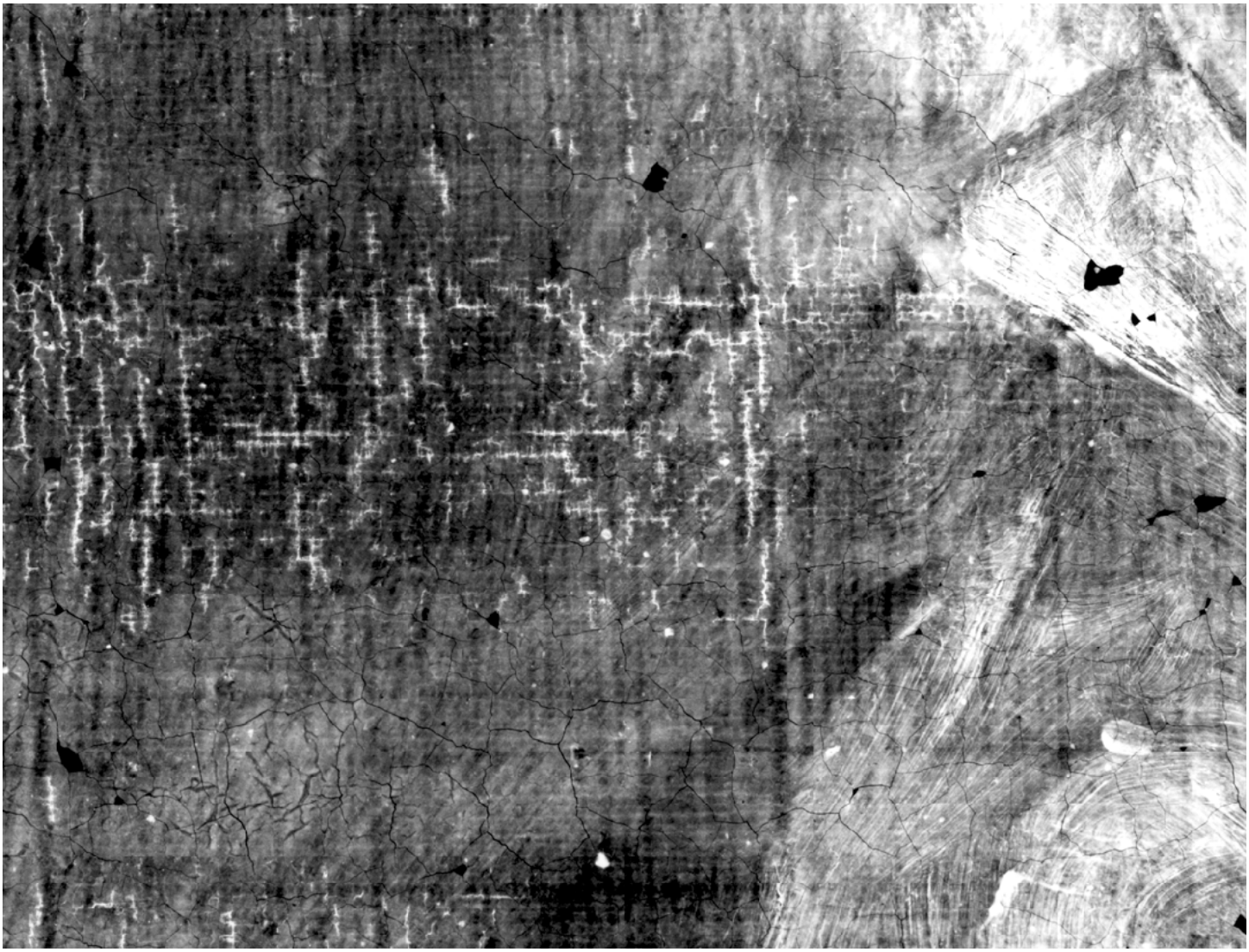

Figure 5. Detail of the x-radiograph showing a fine, unusual network of white (radio-opaque) cracks above the proper right shoulder. The white (radio-opaque) cracks are juxtaposed against the typical, black (radio-transparent) craquelure through the paint and ground. The radio-opaque craquelure occurs where paint from the image layers has flowed into cracks already present in the ground when the portrait was painted.

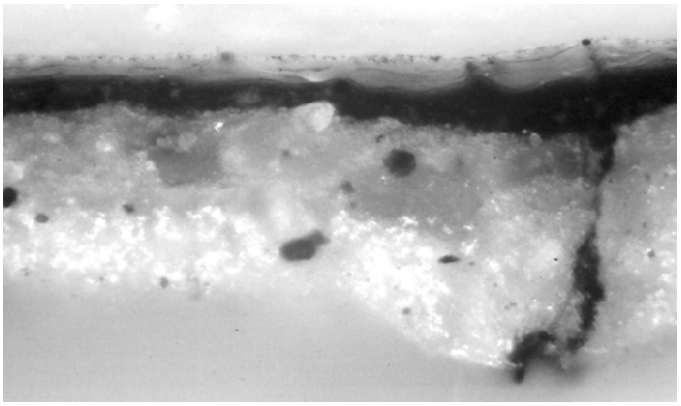

Figure 6. Cross-section showing the penetration of the dark blue paint from the sitter's jacket into a crack in the ground layers (full image width 350 μm).

Examination of the overall, composite x-radiograph, shown in **Figure 7**, suggests a horizontal pattern to the major areas of paint loss, giving the impression that the canvas with its friable ground layer might have been rolled prior to painting, thereby initiating much of the cracking and cleavage.

Conclusions

The *Portrait of Jean Dessaulles* has an unusual, starch-based ground layer applied directly on the canvas. The thickly applied layer is dark pink and has a granular, friable texture. It was found to be composed of starch, protein, gypsum, and a red iron oxide pigment. Although preparatory layers based on starch or flour paste mixed with pigments and other ingredients are mentioned in nineteenth-century documentary sources, as well as in earlier treatises,[9,10] such grounds have not often been identified on paintings.[11]

The presence of a high concentration of starch granules in the first ground layer indicates that it was not heated sufficiently to form a paste. This explains the lack of cohesion within the layer and the ensuing cracking and cleavage. Examination showed that cracking of the starch-based ground and the subsequent oil-based ground layers began to occur even before the image layers were applied.

Further analyses may allow us to determine if similar cracking and cleavage are associated with the use of a defective starch ground in other paintings attributed to the artist. If this unusual ground layer is found to be characteristic of authenticated works by Dulongpré, its presence or absence in other paintings could assist with future attribution studies.

Acknowledgements

The authors would like to thank several colleagues at the Canadian Conservation Institute for their assistance: Leslie Carlyle for alerting them to the possible presence of a starch ground layer and for providing references to the use of such preparations; James Bourdeau for sharing his knowledge regarding the condition and treatment of other paintings attributed to Dulongpré; Peter Vogel for helpful discussions about the painting; and Jeremy Powell who skillfully carried out the x-radiography and technical photography. The authors would also like to acknowledge the contribution to the treatment of the painting made by Barbara Ramsay, Ramsay Conservation Services, who was hired on contract to undertake the extensive relaxation, flattening, and local consolidation of the lifting paint and ground.

Figure 7. Composite x-radiograph of the portrait, showing a slight horizontal pattern to the cracking and areas of paint loss.

Notes and References

1. An article by Jean-Noël Dion, "Les œuvres de Dulongpré au Séminaire (3)," *Le Courrier de Saint-Hyacinthe*, May 6, 1987, states that the portrait owned by the Centre d'archives du séminaire de Saint-Hyacinthe has been dated to 1825 in the inventory of the collection of the seminary undertaken by the Ministère des affaires culturelles du Québec in 1974, based on the fact that Dessaulles is known to have had his portrait painted by Dulongpré around this time. Dion's article also describes a second portrait of Dessaulles attributed to Dulongpré and owned by the National Gallery of Canada. In the National Gallery's portrait, Dessaulles is facing a table on which rests a letter addressed to F. Burton. Sir Francis Nathaniel Burton, lieutenant-governor of Lower Canada in 1824-1825, passed a popular bill in September, 1825 and Dion suggests that the letter could perhaps be a clue to the date of execution of this version of the portrait.

2. Derome, R., Bourassa, P., and Chagnon, J., *Dulongpré, De plus près, A Closer Look* (Montréal: McCord Museum of Canadian History, 1988), p. 11.

3. Treatment records and discussion with conservators responsible for treating other portraits attributed to Dulongpré in the collections of the National Gallery of Canada and the National Archives of Canada revealed that extensive consolidation of paint and ground was often required.

4. The following pigments and fillers were identified in the paint layers: lead white, gypsum, calcium carbonate, Prussian blue, iron oxide pigments, vermilion/cinnabar, a red lake, and charcoal black. Under a thin, uneven varnish layer there is a brown surface coating which, in many areas, has dried into an unusual pattern of long strings on the surface of the paint. Analysis revealed this brown layer to be a pigmented glaze and it has been noted over most of the painting. In a few cross-sections the glaze is directly on the surface of the paint, in others it appears to have been lifted by the varnish; the varnish flows under and over the glaze. This intermixing makes it impossible to remove the varnish without removing the glaze. Furthermore, as there is nothing that indicates the painting has ever been cleaned or treated, it is assumed that these layers were the first surface coatings applied to the painting. Further information on the examination and treatment of the painting can be found in: Daly Hartin, D., "Condition Report, Treatment Proposal & Treatment Record; Portrait of Jean Dessaulles," CCI No. 68478, April-July 1998.

5. Daly Hartin, D., "Revealing Dulongpré and his *Portrait of Jean Dessaulles*," *CCI Newsletter*, no. 22, November 1998, p. 11.

6. Browning, B.L., *Analysis of Paper*, second edition (New York: M. Dekker, 1977), pp. 83-85.

7 McCrone, W. C. and Delly, J. G., *The Particle Atlas*, volume II, second edition (Ann Arbor: Ann Arbor Science Publishers, Inc., 1973), pp. 457-462.

8. Horie, C.V., *Materials for Conservation* (London: Butterworth-Heinemann, 1990), pp. 135-141. This reference provides scanning electron micrographs showing that by 65ºC, most of the granules in a sample of wheat starch have broken open and partially dissolved.

9. Carlyle, L.A., *A Critical Analysis of Artists' Handbooks, Manuals, and Treatises on Oil Painting Published in Britain between 1800-1900: With Reference to Selected Eighteenth Century Sources*, Ph.D. dissertation (London: Courtauld Institute of Art, University of London, 1991), p. 236.

10. Merrifield, M.P., *Original Treatises on the Arts of Painting*, volume 1 (New York: Dover, 1967), pp. cclxxxiv-cclxxxv.

11. For another published identification of a starch ground, see: Bochwicz, Z., "The identification of starch and proteins on cross-sections of paint and ground layers" (in Polish), *Materialy Zachodnio-Pomorskie*, vol. 6, 1960, pp. 539-63, referenced by J. Mills and R. White in *The Organic Chemistry of Museum Objects* (London: Butterworths, 1987), p. 71.