Art Analysis & Research

ANALYTICAL REPORT

[Ref.: AAR0955.E / 8 May 2018]

Orange Seller, 1916
Natalia Goncharova
Collection Museum Ludwig, Cologne, Inv. ML 1484

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Summary

A painting on canvas by Natalia Goncharova, *Orange Seller*, with a proposed date of creation of 1916 (it is signed but undated), belonging to the Museum Ludwig (ML 1484) was examined and analysed by Art Analysis & Research, Ltd. in cooperation with the Museum, and funded through a grant from the charity The Russian Avant Garde Research Project (RARP). This artwork was assessed as part of a group of fourteen well-provenanced paintings by the Russian artist couple Goncharova and Mikhail Larionov, held in the collection of the Museum Ludwig. The goal set for this research was to investigate these paintings in order to characterise similarities and differences, with the goals of 1) providing detailed studies of specific paintings, 2) providing wider information on the artists' methods, 3) defining a blueprint for promising methodologies to develop further on other works by these artists and applying such information in support of a *catalogue raisonné*, and 4) creating the foundation for applying similar methodologies and techniques to other artists of the genre. To this end, each of the paintings are described in individual reports (as here) accompanied by a summary report under separate cover. The results of the program of examination, material analysis and technical imaging will be set out herein.

Art Analysis & Research

Contents

Tables, Figures and Plates

Art Analysis & Research

A. Introduction

The painting known as *Orange Seller* (**Plate 1**) by the artist Natalia Goncharova (1881-1962), a work on canvas measuring 1300 mm high by 970 mm wide, is now part of the collection of the Museum Ludwig, Cologne (Inv. ML 1484). It is unsigned (lower left) but undated; a date of 1916 has been proposed for its creation. It has been examined as part of a larger technical study of fourteen paintings by Goncharova and Mikhail Larionov in the Museum Ludwig, as part of a project funded through a grant from the charity the Russian Avant Garde Research Project (RARP). The project goal has been to generate detailed technical profiles on authentic paintings by Goncharova and Larionov to expand the data available for art historical study and technical characterization of their work[1]; consequently, fourteen well-provenanced paintings by the Russian artist couple held in the collection of the Museum Ludwig were thoroughly examined and analysed[2]. The short-term goal of the project was to define a blueprint for promising routes of research to develop further on other works by these artists and with a long-term goal of contributing such information to support a technical *catalogue raisonné*; these recommendations are laid out in a summary report[3].

The information in this report therefore provides a detailed technical and material account of the painting. In addition, this material is considered in light of the conservation history and provenance information relating to the painting, held by the Museum Ludwig; the supplementary reports produced by Verena Franken in the course of her work on the RARP project summarises this material[4]. Some of the information concerning examination of the paintings has been included here, as relevant, as are a representative selection of the extensive documentation photographs she made.

The structure of this report is as follows. First, the primary findings of the visual examination and technical imaging will be described in **Section B**.

Materials analysis on micro-samples taken for pigment and binding medium identification and cross-sections is described in **Section C**.

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[1] There is limited specific information available. This includes: Rioux, J.-P.; Aitken, G.; Duval, A. 'Étude en laboratoire des peintures de Gontcharova et Larionov', pp. 220-223. In: *Nathalie Gontcharova, Michel Larionov* [exh. cat.], Éditions du Centre Pompidou : Paris (1995). Rioux, J.-P.; Aitken, G.; Duval, A. 'Matériaux et techniques des peintures de Nathalie S. Gontcharova et Michel F. Larionov du Musée national d'art moderne', *Techne* **8** (1998) 7-32. Gallone, A. 'Œuvres de Michel Larionov et Nathalie Gontcharova: Analyse de la Couleur', *Le dessin sous-jacent la technologie dans la peinture: Colloque XI 14-16 septembre 1995*, R. Van Schoute and H. Verougstraete (eds), Louvain-la-Neuve (1997) pp. 137-141, Pl. 74-76.

[2] These include: Natalia Goncharova: *Paysage de Tiraspol (Tiraspol Landscape)*, 1905, ML 01483; *Rusalka*, 1908, ML 1304; *Still Life with Tiger Skin*, 1908, ML 1305; *The Jewish Family*, 1912, ML 1369; *Orange Seller*, 1916, ML 1484; *Portrait of Larionov*, 1913, ML 1319.
Mikhail Larionov, *Still Life with Coffee Pot*, c. 1906, ML 01486; *Still Life*, c. 1907/1912, ML 1487; *Still Life with Crayfish (Nature morte à l'écrevisse*), c. 1907, ML 1331; *Portrait of a Man (Anton Beswal)*, c. 1910, ML 1306; *Rayonism, Red and Blue (Beach)*, 1911, ML 1333; *Saucissions et maquereau rayonnists (Rayonistic Sausage and Mackerel)*, 1912, ML 1307; *Venus*, 1912, ML 1332; *Rayonistic Composition*, inscribed 1916, ML/Z 211/134.

[3] *Summary Report of the RARP Goncharova/Larionov Project, with the Museum Ludwig,* Art Analysis & Research Inc. (2017).

[4] See reports: *AAR0955.E ML 1484 Conservation*, Franken, V. 'Report on the examination of the painting *Orange Seller* (1916) by Natalia Goncharova' (2017a) and *AAR0955.E ML 1484 Archives*, Franken, V. 'Report on the content of the Museum Ludwig archives, concerning the painting *Orange Seller* (1916) by Natalia Goncharova' (2017b).

Inferences drawn regarding the painting on the basis of these investigations will be discussed in **Section D**.

The methodologies and protocols used in each case may be found described in the general **Protocols** supplement, appended to this series of reports.

B. Examination, imaging and analysis of the images

B.1 Methodology

The painting was initially examined visually under normal lighting conditions and with ultraviolet light (UV), then with a stereo binocular microscope.

A range of technical imaging techniques were also employed (**Appendix 3**), generating a variety of images and imaging datasets[5]. These are presented as follows:

- High-resolution visible colour (**Plates 1, 5**);
- UV luminescence (**Plates 2, 6**);
- Oblique illumination (**Plate 3**);
- 3D laser surface scanning (**Plate 4**);
- Short-wave infrared (SWIR), 1600-2500nm (**Plates 7, 8**);
- X-radiography (**Plate 9**).

Additionally, weave analysis (including thread counting) was conducted on the basis of the X-radiograph (**Plates 10.a-c**). Some exemplar images recorded as part of the surface microscopy and macrophotography are also reproduced here (**Plates 11-16**).

The imaging revealed a range of aspects regarding the use of materials, structure and technique of production of the painting that are complementary to the visual observations made. Consequently, specific observation will be made to each in this section regarding the interpretation of these specific forms of analysis, while a summary overview in the context of the painting technique is presented in **Section D**, below.

B.2 General observations

The painting is executed on a somewhat open weave canvas, industrially prepared canvas. It is unlined and remains on its original wooden strainer support (although it has been restretched). Thus, both recto and verso of the artwork could be studied. Equally, the selvedge edge is preserved along the painting's right edge (as seen from the recto), allowing for the direction of the canvas

[5] Additionally, a visible-NIR multispectral dataset was collected to examine its suitability for study of paintings of Goncharova and Larionov. This has not been otherwise reproduced or further analysed here but is available for study in the future.

weave to be determined. The painting is in generally good condition, with some retouching and consolidation, though this is of a minor, localised nature. It has not been varnished.

B.3 Imaging

Each form of imaging offers different types of insight into the various material aspects of the painting. The most relevant are introduced, in brief, here.

B.3.i Photography with ultraviolet illumination

Excitation by ultraviolet (UV) light can induce luminescence[6] in some materials, commonly seen as a weak re-emission of light in the visible region. Many natural varnishes have this property, emitting a characteristic weak greenish luminescence. While some pigments (notably zinc white and certain 'lake' pigments) are also active in this way, paints otherwise often do not luminesce. Because of the luminescence of varnishes, which are typically applied as a continuous coating across the surface of a painting, this can provide a means of determining if any disturbance has occurred, such as partial cleaning of the surface or addition of later restoration, where the changes show in contrast to the luminescent areas. Consequently, UV light is commonly used to reveal the presence of retouching. When paintings are not varnished, as is the case here, differences between the colour of the luminescence of the different paints and any added retouching paints may also indicate later stages of intervention (as here; **Protocol 3.2** and **Plate 2**).

In the UV image of this work, no evidence for a varnish is visible. No strong luminescence was noted from any of the original paints apart from the zinc white which exhibits bright pale green-white hue. The presence of consolidation material is also revealed by UV, for example in the lower area of brown paint in the figure's skirts, bottom right. Here, the brown paint has been affected by wide, brittle cracks, necessitating consolidation. The white ground, visible in the crack fissures, and the retouching material are therefore thrown in to higher contrast under UV. Otherwise, in this particular work the presence of retouching is seen more effectively in the infrared imaging (see below and **Plate 7**).

B.3.ii Surface conformation

Two techniques for examination of the surface structure of the painting were used: photography under oblique illumination (**Plate 3**) and 3D laser scanning (**Plate 4**). While the former may be the more familiar of the two as a physical examination technique, both essentially provide a means of elucidating paint texture and object deformations, either by recording shadowing, or through direct measurement of surface height. Of the two, 3D laser scanning offers important advantages in terms of being more replicable in the future (to

[6] Commonly referred to as 'UV fluorescence', the word *luminescence* is used here as a broader term that may encompass not only fluorescence phenomena (prompt re-emission of light), but also phosphorescence (slow re-emission of light due to transition via forbidden quantum states). In both cases emission is typically at longer wavelengths than the excitation; here, the excitation is in the UV to blue part of the spectrum (hence 'UV'; in practice, so-called UV-A) and emission in the visible region.

support longer-term conservation assessments for example) and as a numerical dataset that can be studied visually and algorithmically for diagnostic features of technique. Imaging of the painting using oblique illumination, as well as 3D laser surface scanning (see **Protocol 3.3**), served to reveal two kinds of textural features that are particularly evident in this painting.

The 3D imaging is best understood in the context of the conservation treatment of the painting, which has been lined. Consequently, original features relating to stresses in the canvas due to stretching on the original secondary support and subtle differences due to the thickness of the paint layers have been flattened and regularised. A number of features may be specifically highlighted:

- The range of paint handling, stippling, long smooth strokes and textured surfaces used by Goncharova to create surface variation are clearly visible. Areas of textured surface, such as the brown modelling in the centre of the skirt and the blue of the upper background are clearly revealed. The juxtaposition of texture seems to be an aspect particular to her technique.
- Areas of lifting and cracking of paint, such as in the brown of the lower right area quadrant, may also be noted.
- There is notable distortion of the paint film in the green areas around the figure, and in the blue and white are also in the background to the right. It is not fully clear why this has occurred, though it may relate to the level of binding medium, or type of binding medium, used. In contrast, the green areas in the figure itself do not show such buckling of the surface.
- An area of 'rippling' (canvas distortions, cause unknown) near the lower-left corner.

B.3.iii Short-wave infrared (SWIR)

The interest in technologies capable of imaging artworks past the red end of the visible spectrum, in the 'near' ('NIR') or short-wave ('SWIR') infrared regions, has primarily developed out of the long-standing application to reflectography, exploiting the phenomenon of variable transparency of paint films at different wavelengths to enable visualisation of features lying beneath the surface. Imaging of underdrawing has been a major contribution to the study of authorship in paintings, permitting a fuller comprehension of artists' working practices and extending the evidence used in attribution questions. Practical experience (as well as theoretical consideration) has shown that deeper IR cameras can confer additional benefits in terms of penetration to underlying layers; consequently, a system capable of operating in the SWIR region was used here (see **Protocol 3.4**).

In this work, a combination of media seems to have been used to lay in the composition; visual examination suggests the use of a hard drawing medium (**Plates 13.b, 13.c**) as well as under painting (Sample [13]; **Plate 18**), which have been captured in the IR image (**Plates 7, 8**). In particular, the contours of the face seem to have been heavily worked, and lightly adjusted in the painted version (**Plate 8**), suggesting that the painter was concerned to get this element of the composition perfectly balanced. The IR also highlights the brushwork

employed, showing the variance in the different segments of the composition, and which were left in reserve.

Areas of retouching are also visible here as regions that set themselves apart from the fields upon which they sit by their darker tone. The area near the tip of the veil in the lower left region, for example, shows a number of darker areas of this type.

B.3.iv X-radiography and weave analysis

X-radiography shows internal structures in paintings because the transmitted X-rays are blocked to different degrees by virtue of the inherent absorption and thickness variations of the constituent materials. For example, pigments based on lead (such as 'lead white') stop the passage of X-rays more effectively than materials based on organic compounds (such as carbon blacks or the binding medium of the paint), while a thicker application of a material will block more than a thinner one. This allows visualisation of sub-surface features, such as abandoned or altered earlier phases (*pentimenti*), use of techniques such as superimposed forms as opposed to forms left in reserve, characteristic brushwork and so forth.

Here, the prepared surface of the canvas is largely covered by the application of paint, which extends to the tacking margins, although small areas of ground are visible throughout the painting where forms abut. Consequently, the X-ray (**Protocol 3.6**; **Plate 9**) reveals a very direct rendition of form, with areas painted in reserve imaging brightly (where they block the passage of X-ray energy), and areas immediately around many of these forms appearing dark. The dark areas in the X-ray corresponding to the thinly primed areas of canvas that were left visible (i.e. unpainted; these are more X-ray transparent than heavily worked regions). Equally, the variation of paint application is strikingly revealed, as the X-ray provides a graphic depiction of Goncharova's brushwork, from densely stippled forms, to short, overlapping strokes to longer, smoother passages. The degree to which she paints in reserve is also very clear; the boundary lines, rendered in various colours, image darkly here, revealing how she painted the space within their boundaries, leaving the lines free to be painted over with thin, fluid lines of colour at the end of the process to best set off the elements of the composition.

Infilling of the interstices of the threads comprising the canvas support with the priming (ground) and paint also allows the canvas weave to be visualised in the X-ray. Even if a painting is lined, making direct access to the original canvas difficult or impossible, X-ray images can permit the primary weave structure to be examined in detail. A common characterisation of canvases (apart from weave type) is the 'thread count', or number of threads per unit in warp and weft directions. Conventionally determined by hand-measuring a number of representative areas, this is now done by applying an image processing algorithm to the entire X-ray image, which has the benefit of providing both greatly enhanced determination of thread counts as well as density and thread orientation information across the whole painting (see **Protocol 3.7**; **Plates 10.a-.d**).

Here, the canvas was found to be a plain weave. The thread count on this work was determined 15.9 threads per centimetre in the warp (vertical) direction and 9.2 in the weft

(horizontal). However, the weft count seems to have been misrepresented in the automated thread counting, as the canvas is highly irregular (many thicker and thinner threads occur). Subsequently, a hand count from the X-ray suggested that the weft direction count should be more on the order of c. 12 threads per centimetre. Thus, 15.9 threads per centimetre warp and c. 12 weft provides a more accurate measure.

The well-distributed and even cusping distortion at the right edge of the canvas (Plate 10.a) corresponds with the side with the selvedge edge. This may relate to the cusping along this side when this canvas was prepared; it is a factory prepared canvas, not a hand prepared one, so that it would have first been stretched on a much larger support, then cut down and restretched when dry. The fact that the left side is a cut edge, not a selvedge edge, and the width of the canvas measures 97 cm implies that this may be the case; the textile from which the canvas was cut would then likely have been of a width of 2 metres, as halving it would allow for two pieces of 1 metre width (enough to span 97 cm with extra for tacking margin), an effective use of the material, as industry was focused on reduction of waste[7].

C. Sampling and analysis

C.1 Introduction

Samples were taken of the support, ground preparation and paint layers of the work for analysis by different means (**Table App.1.1**) in order to determine the range of materials (canvas, pigments, binders and coatings) used in the painting, the nature of the preparation layer and the sequence of layering employed in building up the painting.

To this end, a series of 13 locations selected over a representative range of the painting were micro-sampled for identification of the pigments (**Table App.2.i, Protocol 1.1**), with six micro-samples of paint taken for analysis of the binding media (**Table App.2.ii, Table App.2.iii**). Two further samples were taken for preparation as cross-sections to study the layering in the selected areas, with the aim of elucidating the development of the painting (**Plates 18, 19, Protocol 1.2**). Finally, canvas threads were taken for fibre identification (**App.2.iv, Protocol 2.7**) and radiocarbon dating (**App.2.v Protocol 2.8**).

Micro-samples for analysis were taken from locations that were adjudged to be original (that is, were clearly contiguous with those below and adjacent to them, and not retouching or repair). Locations were also further selected to represent as wide a range of the colours – and therefore probably pigments and media – as possible. Thus, the materials identified and discussed below therefore represent, as far as can be determined, the full extent of the original palette used by the artist.

[7] 200 cm and 140 cm were standard preindustrial canvas widths; standard canvas formats were based on these measures, in order to keep waste of material to a minimum. Callen, A. *The Art of Impressionism*, Yale University Press: New Haven/London (2000) p. 19.

The micro-samples taken for pigment characterisation were subjected to systematic analysis by polarised light microscopy (PLM) combined with UV-visible-near infrared micro-spectrophotometry, scanning electron microscopy-energy dispersive X-ray spectrometry (SEM-EDX) and Raman microscopy (**App.2.i, Protocols 2.1, 2.2, 2.3**).

Organic components were identified by Fourier Transform Infrared Spectroscopy-Attenuated Total Reflectance (FTIR; **App.2.ii**; **Protocol 2.4**) and subsequently by Gas Chromatography-Mass Spectrometry (GCMS; **App.2.iii**; **Protocol 2.5**).

All of the analytical techniques applied are standard methods within the field, capable of allowing the kinds of differentiation required for this type of work. Comparison was also made between samples from the painting and examples of similar pigments from a large collection of reference standards previously analysed by multiple means[8]. Certain differentiations cannot necessarily be made from this range of techniques, although for present purposes the level of discrimination is thought to be largely or wholly sufficient. All materials were generally identified through a combination of the techniques applied; however, certain key diagnostic features were specifically determined through one or other method.

C.2 Support

The canvas was identified as being based on linen (*Linum usitatissimum* L.) in both warp and weft directions (**App.2.iv**; **Protocol 2.7**).

C.3 Radiocarbon dating

Radiocarbon dating was applied to fibres from the canvas support (**App.2.v; Protocol 2.8**).

The radiocarbon date was determined as 109 years b.p. ±23 years. After calibration, this yielded a date distribution for which the most relevant period for the origin of the canvas lies 1806-1930 at the 95.4% probability level, pre-dating the so-called 'bomb-pulse' period that begins in the mid-1950s.

C.4 Ground

The ground (Sample [1]) was found to be composed primarily of zinc white and calcium carbonate, calcite type, combined with a minor amount of a lead carbonate type white and traces of clay minerals bound in a drying oil-based medium (**Tables App.2.i, App.2.ii**). The ground can be seen to have been thoroughly dry, to the point of forming microcracks, when it was first used (Sample

[8] The pigment reference collection belongs to the Pigmentum Project (see: http://pigmentum.org) and runs to around 3500 samples of both historical and modern origin. Analysis of this collection includes PLM and SEM-EDX as well as other techniques such as X-ray diffraction and Raman microscopy. Access to this research collection is gratefully acknowledged. Reference to specific specimens in the text of this report is to the Pigmentum collection number [Pxxxx]. An organic binding media reference collection is also held by AA&R; samples in this set are cited as [AARxxx].

[13], **Plate 18**). This kind of cracking has been noted to be quite common for grounds on such open weave canvases[9].

C.5 Underdrawing

Underdrawing is present in the painting and a sample (Sample [12]) taken for PLM analysis. This indicated that the drawing material is graphite (**App.2.i**). This was further confirmed by Raman analysis of the black underdrawing in the cross-section, Sample [13] (**Plate 18**), which produced a spectrum consistent with that of graphite.

C.6 Paint layers: Pigments

The following pigments (**Tables App.2.i, App.2.ii**) were identified:

- Zinc oxide ('zinc white')
- Calcium sulfate, gypsum type (as a minor component with other pigments)
- Barium sulfate (as a minor component, with other pigments)
- Magnesium carbonate (as a minor component, with lead chromate)
- Goethite, in yellow and brown toned earth pigments
- Lead chromate ('chrome yellow')
- Lead chromate oxide ('chrome orange')
- Hematite, in red toned earth pigment
- CI Pigment Red 83:1 ('alizarin crimson')
- Ultramarine, synthetic, blue
- Copper acetate arsenite ('emerald green')
- Chromium oxide hydrate type green ('viridian')
- A carbon-based black (bone or ivory black)

The extender barium sulfate was identified as a minor component in several colours: lead chromate (also including magnesium carbonate extender), lead chromate oxide, copper acetate arsenite and ultramarine.

The white paint is principally composed of zinc white, with gypsum-type calcium sulfate as a minor component and traces of clay minerals. Barium sulfate was also identified by FTIR but not picked up by Raman and SEM-EDX analysis in the white sample (Sample [2]), but was identified in other samples (Sample [10]) where white was clearly mixed with a colour, or with emerald green (Sample [8]) or lead chromate (Sample [3]) .

C.7 Paint layers: Binding media

All samples, including both ground and paint layers, indicated the presence of a drying oil (**Table App.2.ii**). Additional analysis using GCMS indicated that poppy oil was present in an area of white paint, with linseed oil in yellow and green-yellow paint samples (**Table App.2.iii**).

[9] Callen, A. *The Art of Impressionism*, New Haven and London: Yale University Press (2000) p. 36.

FTIR also indicated the presence of metal soaps, probably of lead and zinc, assumed to be reaction products between pigments and binding medium.

C.8 Stratigraphy

The preparation of cross-sections allowed for examination of the overall stratigraphy and composition of the priming and paint layers (**Plates 18, 19**). Stratigraphy was found to be quite simple.

Sample [13], a green from the left edge, has a white ground layer followed by a black layer of variable thickness that appears to correspond with underdrawing used to set in the composition (which penetrates into a crack in the ground), and a bright green paint layer, above. A thin dark layer on top of this is visible, particularly at the right-hand side of the sample.

Sample [14], a yellow from the drapery along the bottom edge, includes a white ground layer containing some large translucent particles. The yellow paint also has some large transparent particles and contains a few particles displaying the bright green luminescence that is characteristic of zinc oxide. A few blue particles can be seen in one area towards the top of the yellow layer.

D. Discussion of the findings

The dating proposed for this painting, 1916, suggests that it was executed after Goncharova had left Russia. The following examination of the data gathered shows that the choice of painting supports is consistent with what is known of her practice; it has been observed that post-1915, she began to purchase ready prepared painting supports, as is the case there. Other aspects that may relate to any noted differences in working practice as observed in earlier works produced in Russia will likewise be explored in this context.

D.1 Support, ground and preparatory work

D.1.i The support

The painting has been executed on a rather open, plain-weave, linen canvas (**Table App.2.iv, Plates 11.a, 11.b**) with thread counts of 15.9 per cm in the vertical direction and c. 12 per cm in the horizontal direction (see **Plate 10.d**; see comments regarding weft count). Distinct interstices may be observed between the threads, allowing the ground to be seen between them from the verso (**Plate 11.a**).

The canvas is not of uniform quality; the weave is frequently punctuated by slubby threads, with occasional occurrences of plant husk, suggesting a lower grade artist's canvas. The quality may be identified with what is known as the *étude* or *pouchadé* weights of canvas, which were inexpensive types of canvas supplied in France with a thin layer of ground that allowed the texture of the textile to remain visible[10]. A French origin for the canvas is

[10] Callen (2000) *op. cit*. pp. 31, 32, figures 45-48, 35-37, 57-59.

suggested by the inscription on the strainer bar, which reads '60 F' (this is either stencilled or stamped, in black ink: **Plate 12.b**). This is consistent with the standard size for French canvases known as 'Figure 60', which measured 130 cm high by 97 cm wide (as found here) and is a size in the range known as a 'portrait' canvases[11].

Judging by the cusping (variable tension in the support caused by the pulling during stretching), which is clearly visible only along the right side of the painting (**Plate 10.a**), corresponding with the presence of a selvedge edge (**Plates 11.b, 12.d**), it may be speculated that the canvas was prepared as a large, long piece then cut down to size for mounting onto variously sized wooden supports. As the painting is still mounted on its original wooden strainer (although the tacks and their placement have changed), the inscriptions and labels present on the verso attest to its extensive exhibition history; these are described in detail elsewhere[12].

D.1.ii Priming

The canvas has been prepared with a white ground comprised primarily of zinc white and calcium carbonate, calcite type, combined with a minor amount of a lead carbonate type white and traces of clay minerals bound in a drying oil-based medium (**Tables App.2.i, App.2.ii**). The ground allows the texture of the canvas to remain fully visible and is quite thin, thus probably prepared with a single application of ground, known as the preparation type *à grain*[13] in French (**Plates 11.c, 12.a, 13.a**), again, consistent with a cheaper grade painting support (the double primed canvases were, of course, more expensive).

The ground can be seen to have been thoroughly dry, to the point of forming microcracks, when it was first used (Sample [13], **Plate 18**). This kind of cracking has been noted to be quite common for grounds on such open weave canvases[14].

D.1.iii Underdrawing

Examination of the painting under magnification revealed the presence of an underdrawing in a hard, shiny greyish drawing material (likely a graphitic form such as pencil[15]; **Plates 13.b, 13.c**). Sample [13] (**Plate 18**) shows the green layer of paint along the mid left side of the painting, where it abuts the blue and white background (for location, see **Plate 17**). Both

[11] The designation 'Figure 60' corresponds to the dimensions of 130 x 97 cm stretched canvas known to have been manufactured by the two major suppliers of French supports, Lefranc and Bourgeois Aîné. Labreuche, P. *Paris, capitale de la toile à peindre XVIII^e^-XIX^e^ siècle*, CTHS-INHA: Paris (2011) pp. 298-305, esp. 302. Francone, M. (ed.) *Impressionismus: wie das Licht auf die Leinwand kam* [Ex. Cat. Wallraf-Richartz-Museum & Fondation Corboud, Cologne, 29 February-22 June 2008, and Palazzo Strozzi, Florence, 11 July-28 September 2008], with texts by I. Schaefer, C. von Saint-George and K. Lewerentz, Skira: Milan (2008) p. 50, figure 42.

[12] These are described in more detail in V. Franken, *AAR0955.E 1484 Conservation Report* (2017a).

[13] Callen, A. *The Art of Impressionism*, New Haven and London: Yale University Press (2000) pp. 32, 36.

[14] *Ibid*.

[15] Drawing pencils are typically composed of powdered graphite mixed with clay. For example, a text of 1912 states that: 'German pencil manufacturers have easy access to suitable pencil wood, graphite and to all of the other materials used in the manufacture of lead pencils, especially in the way of a fine clay which is used as a binder for the graphite and which is found nowhere in the United States' (Joseph Dixon Crucible Company, *Graphite*, **14-16** (1912), p. 3599).

in the cross section and by examination of the painting under magnification, a black layer of may be seen under the green of the surface. This underdrawing is also clearly recorded in the infrared image taken of the painting (**Plates 7, 8**), which is unusual in the group of works examined, where often the presence of an underdrawing is noted, but in a form too diffuse to be resolved with IR. Here, perhaps because of the apparent use of a graphitic material, and what appears to be a particularly dense layer of black may be discerned. Unlike the black paint used elsewhere in the painting, which is a bone or ivory black, the black used in the underdrawing is a finely particulate graphitic black (Sample [12]; **Table App.2.i**).

The underdrawing shows very strong resemblance to the drawing in the collection of the Tretyakov Gallery, Moscow (compare **Plates 7.b, 7.c**), which is likewise in graphite[16]. There is no sign of the use of charcoal, as in some of the other paintings observed, which is friable to the point where large particle can be dragged into the paint film and mixed with the colour as the painting is developed. Rather, here, the visible lines are neat and unsmudged when they are visible in small gaps in the paint (**Plates 13.b, 13.c**) though rather thicker and less pristine lines are seen in the IR image (**Plates 7, 8**). Despite the resemblance, the scale and relationships of the forms of one to another have clearly been adjusted and the figure is no longer full length. The lines of the underdrawing are not always neat, suggesting that the artist was working towards developing the right contours, reworking them if they were not perfect, as the shapes were laid in.

D.2 Paint, pigments and binding media

D.2.i General observations

The condition of the painting is generally quite good, although there has been minor loss and flaking that has required retouching (most visible in the IR image: **Plates 7.a**). As noted above, exceptionally, the painting has not been lined and is still mounted on its original strainer in its original dimensions, though it has been restretched.

D.2.ii Paint: pigment and binding medium

Although the canvas weave is visible in many areas where the paint is more thinly applied, it is quite fine, so that it does not form a dominant feature, very much taking second place to the much more prominent, vigorous brushwork that fills the various shapes thoroughly. Only small areas of canvas are occasionally left exposed; as typical of Goncharova's manner of working, in the X-ray image, the various elements of the composition are very distinct, demarcated by dark areas left in reserve and thinly painted (**Plate 9.a**)[17]. The use of an underdrawing facilitates this manner of working, with very few overlaps of colour or form,

[16] Goncharova was known to have explored motif by means of preparatory sketches before painting: 'she would have done two, three, four preparatory drawings, watercolours, or small variants' Chauvelin, J. 'Témoinages/ Encounters', *InCoRM Journal*, vol. 1 Nos. 2-3 (2010) pp. 6-11, esp. p. 8. For the drawing, see: L. Iovleva (ed.) *Natalia Goncharova: between east and west* [exhibition catalogue, 16 October 2013-6 February 2014, Tretyakov Gallery], State Tretyakov Gallery: Moscow (2013) p. 425.

[17] The use of reserves is very common in Goncharova's work. See Rioux, Aitken and Duval (1998) *op. cit.* pp. 19, 25, 26.

each field is developed individually, often with a different type of textured brushwork (for example, see: **Plates 15.a, 15.b**). No evidence for complex layering was observed; areas are worked directly, with mixing both on the palette, and wet-in-wet directly on the canvas. This may be clearly seen in the cross-sections prepared from two paint samples, which show single layers of colour overlying the thin white ground (**Plates 18, 19**). The texture of the paint is well preserved in the cross-section prepared from Sample [14], which exhibits two distinct ridges of paint while a similar effect is seen in the green surface of Sample [13], which overlies a dense layer of underdrawing, with the thin white priming lowermost.

The colours are bright and intense, the paint strongly opaque and used quite thickly (**Plates 15.a, 15.b**) as well as spread thinly in other passages (**Plate 14.b**). The areas that show bright white in the X-ray indicate some of the thickest areas of impasto, which include the eyes (**Plates 8.c, 9.a**).

Outlines, used in some areas and rendered in a variety of colours (such as the brown, of the raised hand, right), formed the final steps in finishing the work. No use of transparent glazes was observed; the colours remain intense, though the surface aspect is generally quite matte, occasionally juxtaposed with areas of gloss (**Plate 15.c**) that relate to the concentration of medium, not to local varnishing (the work is not varnished).

The painting displays a brittle crack pattern consistent with an oil painting of significant age. In addition to this type craquelure, the painting also displays localised drying cracking that is particular to areas of specific colours, namely the green, brown and crimson red (all known to lack siccative properties that might have assisted with the drying of the paint; **Plates 14.a, 14.b**). Here, there is an especially pronounced cracking associated with embrittlement of the paint, which has required consolidation treatment to prevent loss[18]. In addition to the prominent drying crack, on two of the colours – yellow and brown – another process has taken place; the forming of a whitish 'bloom' of crystalline material; this may be the result of a reaction between pigment and binding medium causing the migration of fatty acid components to the surface of the paint (**Plates 14.b, 14.c**)[19]. A final characteristic of this work is the surface deformations apparently related to the green, and to a lesser degree, to the blue and white paint in the background. This deformation (see well in **Plate 4**), does not occur in areas of similar colour in the region of the costume.

[18] See Franken (2017a) *op. cit*.

[19] Although there could be other causes, given the general form of the alteration, this is the most likely; confirmation could be made through (for example) FTIR analysis of samples of the surface exudate. Chrome yellow itself is known to undergo alteration, but this is normally darkening (see notably: Monico, L., Snickt, G. Van der, Janssens, K., Nolf, W. De, Miliani, C., Verbeeck, J., Tian, H., Tan, H., Dik, J., Radepont, M., and Cotte, M., 'Degradation Process of Lead Chromate in Paintings by Vincent van Gogh Studied by Means of Synchrotron X-ray Spectromicroscopy and Related Methods. 1. Artificially Aged Model Samples', *Analytical Chemistry*, **83**(4) (2011) pp. 1214–1223; 'Degradation Process of Lead Chromate in Paintings by Vincent van Gogh Studied by Means of Synchrotron X-ray Spectromicroscopy and Related Methods. 2. Original Paint Layer Samples', *Anal. Chem.*, **83**(4) (2011) pp. 1224–1231; 'Degradation Process of Lead Chromate in Paintings by Vincent van Gogh Studied by Means of Spectromicroscopic Methods. 3. Synthesis, Characterization, and Detection of Different Crystal Forms of the Chrome Yellow Pigment', *Analytical Chemistry*, **85**(2) (2013) pp. 851–859; 'Degradation Process of Lead Chromate in Paintings by Vincent van Gogh Studied by Means of Spectromicroscopic Methods. 4. Artificial Aging of Model Samples of Co-Precipitates of Lead Chromate and Lead Sulfate', *Analytical Chemistry*, **85**(2) (2013) pp. 860–86).

Two yellow tones (yellow earth and lead chromate) have been used in addition to an orange (another form of lead chromate), two reds (an earth with hematite and a red lake, Pigment Red 83:1), two forms of green (emerald green and chromium oxide green), one blue tone (synthetic ultramarine) and a bone or ivory black. The white used was a zinc white, which also forms the main component of the ground. A number of modifying pigments are also noted in minor quantities in various combinations as additives with other colours, including barium sulfate, calcium sulfate and calcium carbonate, as well as magnesium carbonate.

Analysis of the binding media used in the paint layers identified the presence of drying oils: poppy oil (less yellowing than linseed oil) was present in an area of white paint, with linseed oil identified in yellow and green-yellow paint samples (**Tables App.2.ii, 2.iii**).

The painting is signed, 'N Gontcharova', in a darker green on the lighter green of the background, at the lower left of the painting (**Plate 16.a**). The paint of the underlying lighter green field seems to have been substantially dry by the time that the signature was applied, as the darker green does not modify the underlying paint structure. Clearly, Goncharova was interested in a spontaneous effect, but also the right form; the top of the 't' has been retouched, to make the form of the crossing clearer (**Plate 16.b**).

D.2.iii Materials analysis and implications for dating

The painting has been dated to 1916 on the basis of the artist's contact with Diaghilev and a trip to Spain around that time[20], although other dates (including 1910-12 and 1918) have also been proposed for it. It was known to have been exhibited in 1920[21].

The radiocarbon measurement of the canvas gave an origin for it between 1806-1930 at the 95.4% probability level, though pre-dating the so-called 'bomb-pulse' period that begins in the mid-1950s. In addition to this a period of 3-5 years typically needs to be allowed for processing into canvas and use by the artist. This would be compatible with the stylistic date given to it.

The materials identified in the painting are compatible with the supposed date, although they also continued in use after (as well as before) that time and would not preclude a revision of date if deemed necessary. The findings generally agree well with the data collected in the study of 45 paintings by Goncharova and Larionov in the collection of the Musée national d'art modern, Paris[22].

[20] Weiss, E. (ed.) *Von Malewitsch bis Kabakov: Russische Avantgarde im 20. Jahrhundert. Die Sammlung Ludwig* [exhibition catalogue, 16 October 1993 to 2 January 1994, Josef-Haubrich- Kunsthalle], Prestel: Munich (1993) pp. 121, 122. Baudin, K. *Der Kubofuturismus und der Aufbruch der Moderne in Russland*. *Russische Avantgarde im Museum Ludwig*. Wieland: Cologne (2010) p. 72.

[21] *Exposition internationale d'art moderne. Peinture, sculpture, etc.* [exhibition catalogue, 26 December 1920 to 25 January 1921, Geneva], text by E. Faure, Palais Électoral: Geneva (1920), p. 28, cat. no. 25. Online resource, consulted 28 February, 2017: https://fr.wikisource.org/wiki/Exposition_internationale_d%E2%80%99art_moderne

[22] The combination of zinc white ground with lead white paint presents the single exception, in that the authors claim that only zinc white was used throughout the paintings by the two artists. Rioux, Aitken and Duval (1998) *op. cit*. p. 18.

Other technical characteristics arising from the larger review of the works of Goncharova and Larionov may also contribute to a fuller understanding of the relative dating of this painting in the future.

E. Conclusions

The examination of the painting revealed a work that is in exceptional condition. The painting remains on its original strainer, the canvas unlined. The use of a factory prepared canvas is particularly characteristic Goncharova's work executed in Paris. Exceptionally, probably due in part to the use of a graphitic medium (probably in the form of a pencil), a clear indication of the first laying in of the composition is captured in the IR image, which relates to another work on paper by the artist. The varied brushwork, subtle use of matte and gloss in combination with texture is characteristic of Goncharova's masterful handling of paint. The results of the examination have not found any evidence that would speak against the proposed date of the work, 1916 (though this date could equally well be revised slightly earlier or later, should compelling evidence be found).

Art Analysis & Research

F. Acknowledgements

Art Analysis & Research would like to thank the following people for their contributions:

Museum Ludwig

Dr Yilmaz Dziewior	Director, Museum Ludwig	
Rita Kestring	Deputy Director, Museum Ludwig	
Petra Mandt	Deputy Head of Conservation, Museum Ludwig	Project coordinator Paintings conservator

Project Team, AA&R

Dr Jilleen Nadolny	Principal Investigator	Project management
Dr Nicholas Eastaugh	Chief Scientist	Materials and data analysis
Bhavini Vaghji	Senior Scientist	Materials analysis
Francis Eastaugh	Senior Imaging Engineer	Scientific imaging processing
Dr Joanna Russell	Scientist	Materials analysis

Project Subcontractors

Verena Franken	Freelance paintings conservator, Cologne, Germany	Project coordinator, examination, documentation and archival research
Patrick Schwarz	Rheinisches Bildarchiv Köln, Cologne, Germany	Photographic documentation
Prof. Hans Portsteffen, Andreas Krupa	Department of Conservation, Cologne University of Applied Sciences, Germany	Capture of X-ray data
Xavier Aure-Calvet	Freelance imaging specialist, Bristol, UK	3D imaging capture and post processing
Prof Haida Liang and team	Nottingham Trent University, UK	Hyperspectral imaging
Dr Irka Hadjas and team	ETH/ Swiss Federal Institute of Technology, Zurich, Switzerland	Radiocarbon analysis

We would also like to extend our sincere thanks to the Peter and Irene Ludwig Foundation and to the RARP donors and to its board of trustees, without whose generosity and vision this project would not have been possible.

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G. Appendices

Standard protocols used by AA&R in the preparation of this report for sampling, materials analysis and imaging are listed in each subsection below and detailed in the appendices to the global summary report.

App.1 Sampling and sample preparation

Protocols:

[P.1.1] Sampling
[P.1.2] Cross-sectional analysis

App.1.i Sampling

Table App.1.i Samples taken for analysis

#	*Colour*	*Description*	*Location*[23]	*Analysis*
1		Ground	0/1170	PLM, SEM-EDX, Raman, FTIR
2		White	880/1085	PLM, SEM-EDX, Raman, FTIR, GC-MS
3		Yellow	501/795	PLM, SEM-EDX, Raman, FTIR, GC-MS
4		Orange	537/793	PLM, SEM-EDX, Raman, FTIR
5		Red Crimson	501/177	PLM, SEM-EDX, Raman
6		Brown	607/1150	PLM, SEM-EDX, Raman
7		Dark Brown	740/84	PLM, SEM-EDX, Raman
8		Green Yellow	50/468	PLM, SEM-EDX, Raman, FTIR, GC-MS
9		Dark Green	897/192	PLM, SEM-EDX, Raman, FTIR
10		Dark Blue	50/540	PLM, SEM-EDX, Raman

[23] The coordinates in this column are given in millimetres, the measurements taken from the left edge of the picture, and from the lower edge of the picture.

Table App.1.i Samples taken for analysis

#	*Colour*	*Description*	*Location*[23]	*Analysis*
11		Black	353/96	PLM, SEM-EDX, Raman
12		Underdrawing	543/1101	PLM, SEM-EDX, Raman
13		Underdrawing, green	0/438	CSA
14		Yellow	309/0	CSA
15		Black	402/225	PLM, SEM-EDX, Raman
16		Canvas fibre		PLM, FTIR, C14

App.1.ii Cross-sectional analysis

Results are shown in **App.5**, **Plates 18, 19.**

App.2 Materials analysis summary results

Protocols:

[P.2.1] Polarised light microscopy (PLM)
[P.2.2] Scanning electron microscopy and energy dispersive X-ray spectrometry (SEM-EDX)
[P.2.3] Raman microscopy
[P.2.4] Fourier Transform Infrared Spectroscopy-Attenuated Total Reflectance (FTIR-ATR)
[P.2.5] Gas Chromatography Mass Spectrometry (GCMS)
[P.2.7] Fibre Identification
[P.2.8] Radiocarbon dating

App.2.i SEM-EDX, Raman microscopy and PLM analysis

Table App.2.i Analytical results SEM-EDX, Raman Microscopy and PLM

#	Colour	SEM-EDX (elements)			Raman Microscopy (peaks, cm^{-1})	Identification
		Major	Minor	Trace		
1	Ground	**Ca, Zn**	Pb	*Al, Si, S*	**1086 (vw), 1049 (vw), 281 (vw)**	**Calcium carbonate, calcite type (main)** **Lead carbonate type white (minor)** Zinc oxide (main)
2	White	**Zn**	S, Ca	*Al, Si, Fe*	**1008 (vw), 438 (vw)**	**Zinc oxide (main)** **Calcium sulfate, gypsum type (minor)**
3	Yellow	-	Al, S, Cr, Ba, Pb	*Mg, Si, Ca*	**988 (w), 972 (vw), 843 (s), 461 (vw), 452 (vw), 406 (vw), 378 (vw, sh), 361 (m), 338 (vw), 329 (vw, sh), 141 (vw)**	**Lead chromate [P2238]** **Barium sulfate**
4	Orange	**Pb**	S, Cr, Ba	*Al, Si, Ca*	**988 (vw), 848 (s), 838 (s), 825 (vs), 381 (w), 355 (w), 342 (s), 324 (w), 280 (vw), 146 (m), 112 (vw)**	**Lead chromate oxide [P2330] (main)** **Barium sulfate (minor)**
5	Crimson red[24]	**Ca**	P, S	*Mg, Al, Si, K, Fe, Zn, Ba*	**1519 (vw), 1480 (vw), 1355 (vw), 1327 (vw), 1292 (vw), 1221 (vw), 1189 (vw), 1162 (vw), 843 (vw), 484 (vw)**	**CI Pigment Red 83:1 [P1573]** Carbon-based black (bone or ivory black)
6	Brown	**Fe**	Si, S	*Mg, Al, P, K, Ca, Mn, Zn, Ba, Pb*	1258 (w, br), 1166 (w, br), **1008 (vw), 392 (vw)**	**Goethite (main)** **Calcium sulfate, gypsum type (trace)**
7	Dark brown	**Fe**	Si	*Mg, Al, P, S, Cl, K, Ca, Mn, Zn, Ba*	1278 (w, br), 1200 (w, br), **613 (vw), 406 (vw), 294 (vw)**	**Hematite**
8	Green-yellow	**As**	S, Cu, Ba	*Al, Si, P, Ca*	**1440 (vw), 986 (vw), 949 (w), 831 (vw), 759 (vw), 685 (vw), 538 (vw), 488 (vw), 429 (vw), 368 (w), 323 (vw), 292 (vw),** 281 (vw, sh), **242 (m), 217 (s), 172 (w), 153 (m), 120 (m), 107 (w)**	**Copper acetate arsenite [P1302] (main)** **Barium sulfate (minor)**
9	Dark green	**Cr**	-	*Na, Mg, Al, Si, P, S, Ca, Zn, Ba*	-	Chromium oxide hydrate type
10	Blue	-	Na, Al, Si, S, Zn	*Mg, P, Cl, K, Ca, Ba*	**987 (vw), 583 (vw), 547 (m), 380 (vw, br), 258 (vw)**	**Ultramarine** **Barium sulfate (trace)** Zinc oxide

[24] The sample contained black pigments.

Table App.2.i Analytical results SEM-EDX, Raman Microscopy and PLM

#	Colour	SEM-EDX (elements)			Raman Microscopy (peaks, cm^{-1})	Identification
		Major	Minor	Trace		
11	Black	**P, Ca**	-	*Mg, Al, Si, S, K, Zn, Ba*	**1592 (m, br), 1323 (m, br)**	**Carbon-based black (bone or ivory black)**
12	Underdraw -ing	-	S, Ca, Zn	*Mg, Al, Si, Cl, K, Fe, Pb*	**1571 (w, br), 1302 (w, br)**	**Carbon-based black**
15	Black	**P, Ca**	-	*Mg, Al, Si, S, Zn, Pb*	**1578 (w, br), 1300 (w, br)**	**Carbon-based black (bone or ivory black)**

App.2.ii Fourier Transform Infrared Spectroscopy-Attenuated Total Reflectance (FTIR-ATR)

Table App.2.ii Summary results from FTIR

#	Colour	FTIR (peaks, cm^{-1})	Identification
1	Ground	**3524 (vw), 3400 (vw),** 3304 (m, br), 2920 (vw), 2851 (vw), 2514 (vw), 1795 (vw), 1740 (vw), **1586 (w), 1539 (vw),** 1410 (vw, sh), 1396 (vs), **1136 (vw, sh), 1117 (m),** 1061 (vw), 1043 (vw), 1030 (w), 962 (vw), 872 (s), 712 (w), 681 (w), **669 (vw)**	**Calcium carbonate, calcite type**[25] **Lead carbonate type white** **Calcium sulfate, gypsum type** **Oil**[26] **Metal soap formation**
1a	Coating	**3509 (vw), 3403 (vw),** 3336 (m, br), 2950 (vw, sh), 2918 (w), 2849 (w), 2514 (vw), 1794 (vw), 1740 (vw), **1590 (m), 1539 (w), 1454 (vw, sh),** 1410 (vs), 1397 (s), 1322 (w), 1275 (vw), **1143 (vw, sh), 1117 (s),** 1087 (vw), 1043 (vw), 1030 (vw, sh), 963 (vw), 873 (s), 712 (w), 679 (w), **669 (vw)**	**Calcium carbonate, calcite type** **Lead carbonate type white**[27] **Calcium sulfate, gypsum type** **Oil**[28] **Metal soap formation, zinc-based**[29] **Metal soap formation**

[25] The very strong peak present at 1396 cm^{-1} is shared by both lead carbonate type white and calcium carbonate, calcite type.
[26] The characteristic peak of oil occurring at around 1160 cm^{-1} was not observed in the spectrum due to the presence of calcium sulfate, gypsum type whose peaks were masking this characteristic peak of oil however it is assumed that oil is present due to the formation of metal soaps.
[27] The peaks present at 1410 and 1397 cm^{-1} are shared by both lead carbonate type white and calcium carbonate, calcite type.
[28] As noted 26, above.
[29] The peaks present in the sample spectrum matched the reference spectrum of zinc stearate, reference number AAR308. Zinc was identified in the SEM-EDX analysis.

Table App.2.ii Summary results from FTIR

#	Colour	FTIR (peaks, cm^{-1})	Identification
2	White	**3508 (w), 3392 (w), 2919 (w), 2851 (w), 1738 (w), 1682 (vw), 1616 (w), 1583 (vw), 1549 (vw), 1539 (m), 1455 (w), 1415 (w), 1318 (vw), 1111 (vs),** 1072 (vw), 1036 (vw), 1003 (vw), **983 (vw, sh), 743 (vw, sh), 719 (vw), 668 (w),** 636 (vw)	**Calcium sulfate, gypsum type** **Barium sulfate** **Oil**[30] **Metal soap formation, zinc-based**[31] **Metal soap formation**
3	Yellow	**3384 (m, br), 2924 (w), 2854 (w), 1738 (m), 1715 (vw), 1615 (vw),** 1505 (vw), **1482 (vw), 1418 (w), 1377 (vw, sh),** 1322 (vw), **1096 (vw, sh), 1037 (vs), 982 (vw), 965 (vw, sh), 876 (vw, sh), 849 (vw), 822 (s), 722 (vw),** 667 (vw), **625 (m)**	**Lead chromate [P2238]**[32] **Magnesium carbonate** **Barium sulfate** **Oil**[33] **Metal soap formation, presumably lead-based**
4	Orange	**3358 (vw, br), 2916 (w), 2850 (vw), 1731 (w), 1715 (vw), 1557 (w), 1455 (w), 1416 (vw), 1374 (vw, sh),** 1321 (vw), **1177 (s), 1106 (m), 1065 (vs), 984 (s), 828 (vs), 670 (vw), 633 (w), 604 (m)**	**Lead chromate oxide [P2330]** **Barium sulfate** **Lead carbonate type white** **Oil**[34] **Metal soap formation, presumably lead-based**
8	Green-yellow	**3396 (vw, br), 2956 (vw, sh), 2917 (vw), 2851 (vw), 1731 (vw), 1715 (vw), 1556 (s), 1451 (s), 1418 (vw, sh), 1350 (vw), 1192 (m), 1110 (m), 1067 (s), 1025 (vw, sh), 983 (vw),** 870 (vw), **816 (s), 760 (vs), 689 (w), 633 (vs), 606 (vw)**	**Copper acetate arsenite [P1302]** **Barium sulfate** **Binding media component (type unidentified)**[35]
9	Blue (with small amount of green)	**3525 (w), 3395 (vw), 3339 (w, br), 2951 (vw, sh), 2916 (m), 2849 (w), 1739 (w), 1718 (vw), 1684 (vw), 1616 (vw, sh), 1588 (w, sh), 1538 (s), 1456 (w), 1410 (vw), 1398 (w), 1319 (vw), 1108 (vs),** 1065 (vw), **1002 (vw),** 983 (s), 881 (vw, sh), 794 (vw), **744 (vw), 720 (vw),** 698 (vw), **668 (w),** 638 (vw), 604 (w)	**Calcium sulfate, gypsum type** **Barium sulfate** **Oil**[36] **Metal soap formation, zinc-based**[37]
16	Canvas fibre	**3537 (vw, sh), 3403 (vw, sh), 3336 (vw), 3281 (m, br), 2917 (w), 2899 (vw), 2851 (vw), 1732 (w, sh), 1650 (w),** 1622 (w), **1540 (vw),** 1425 (m), **1367 (vw), 1336 (vw), 1315 (vw),**	**Cellulose** **Calcium carbonate, calcite type**

[30] As noted 26, above.
[31] As noted 29, above.
[32] The reference spectrum of lead chromate consists of peaks also corresponding to lead sulfate. These peaks are present in the sample spectrum which could suggests that the lead chromate is likely in the form of lead chromate sulfate or that lead sulfate is present in the reference spectrum. The SEM-EDX data of the sample showed minor amounts of lead, chromium and sulfur.
[33] The characteristic peak of oil occurring at around 1160 cm^{-1} was not observed in the spectrum due to the presence of lead sulfate whose peaks were masking this characteristic peak of oil however it is assumed that oil is present due to the formation of metal soaps.
[34] The characteristic peak of oil occurring at around 1160 cm^{-1} was not observed in the spectrum due to the presence of barium sulfate whose peaks were masking this characteristic peak of oil however it is assumed that oil is present due to the formation of metal soaps.
[35] The six peaks present are peaks assigned to the binding medium however from these six peaks it is unclear what the binding medium is as there are multiple binding media which show these mentioned peaks such as oils, alkyds and natural resins etc.
[36] As noted 26, above.
[37] The peaks present in the sample spectrum matched the reference spectrum of zinc stearate, reference number AAR308.

Table App.2.ii Summary results from FTIR

#	Colour	FTIR (peaks, cm^{-1})	Identification
		1278 (vw), 1199 (vw), 1151 (m), 1105 (m), 1050 (m), 1026 (vw), 1003 (vw), 984 (s), 901 (vw), 876 (w), 712 (vw, sh), **665 (w)**	**Calcium sulfate, gypsum type** **Proteinaceous material** **Possibly oil**[38]

App.2.iii Gas Chromatography Mass Spectrometry (GCMS) Analysis

Table App.2.iii Summary results from GCMS

Sample #	Hexadecanoic acid, methyl ester ($C_{17}H_{34}O_2$)		Octadecanoic acid, methyl ester ($C_{19}H_{38}O_2$)		Ratio
	Retention time, mins	Peak area	Retention time, mins	Peak area	
2	25.663	1.297×10^9	29.583	3.496×10^8	P/S = 3.71
3	25.686	5.674×10^8	29.559	3.705×10^8	P/S = 1.53
8	25.678	3.484×10^8	29.558	1.852×10^8	P/S = 1.88

The P/S value of **Sample [2]**, white paint, was 3.71, consistent with **poppy oil**.

The P/S value of **Sample [3]**, yellow paint, was 1.53, consistent with **linseed oil**.

The P/S value of **Sample [8]**, green-yellow paint, was 1.88, consistent with **linseed oil**.

App.2.iv Fibre Identification of the Canvas

Table App.2.iv Canvas fibre identification, Sample [16]

Sample	*Observations under PLM*	*Interpretation*
Warp (Vertical)[39]	Nodes across fibres, parallel extinction, s-twist Structures with low birefringence, some appearing as broadened ends of fibres – degraded areas?	Bast fibre, probably linen (*Linum usitatissimum* L.)
Weft (Horizontal)[40]	Nodes across fibres, parallel extinction, s-twist A few structures with low birefringence, some appearing as broadened ends of fibres – degraded areas?	Bast fibre, probably linen (*Linum usitatissimum* L.)

App.2.v Radiocarbon measurement

Radiocarbon dating is a method for determining age estimates of formerly living organic materials[41]. Carbon has three naturally occurring isotopes, ^{12}C, ^{13}C and ^{14}C. Both ^{12}C and ^{13}C are

[38] The peaks present are typical of oils and natural resins.
[39] Thread parallel to short dimension of woven fragment; taken running along the upper tacking margin.
[40] Thread parallel to long dimension of woven fragment; taken running along the upper tacking margin.
[41] Based on from the websites of the NDT Resource Center,

stable, but ^{14}C decays by very weak beta decay to nitrogen (^{14}N) with a half-life of approximately 5,730 years. While alive, organic materials continue to exchange carbon with the environment, such that they are in equilibrium. On death, the ^{14}C component begins to decay, such that over time the relative amount decreases. Measuring the level of ^{14}C remaining in the material then allows for a date to be estimated. This must be additionally calibrated against natural historical variation in relative ^{14}C levels in the environment, for which there are accepted standard curves expressing the changes over time[42].

Prior to radiocarbon measurement, fibre identification was undertaken and the canvas sample was pre-tested using FTIR to ascertain the presence of any contaminating material that could influence the outcome. As noted elsewhere, the fibre was identified as a bast type, probably linen (*Linum usitatissimum* L.). FTIR indicated the presence of calcium carbonate (calcite type), calcium sulfate (gypsum type), a proteinaceous material, and possibly an oil, in addition to the cellulose of the fibre[43].

The canvas sample was then submitted to the Laboratory of Ion Beam Physics, ETHZ at the Swiss Federal Institute of Technology (*Eidgenössische Technische Hochschule Zürich*) for radiocarbon dating (see **Protocol 2.7**).

Table App.2.v.i Radiocarbon measurement

Sample-Nr.	Sample Code	Material	C14 age BP	±1σ	F14C	±1σ	δC13 ‰	±1σ	mg C	C/N
ETH-77070	AAR0955.E 16	Textile fibre	109	23	0.9865	0.003	-27.1	1	1	219

The radiocarbon date was determined as 109 years b.p. ±23 years. After calibration, this yielded a date distribution for which the most relevant period for the origin of the canvas lies 1806-1930 at the 95.4% probability level, pre-dating the so-called 'bomb-pulse' period that begins in the mid-1950s.

http://www.ndt-ed.org/EducationResources/CommunityCollege/Radiography/Physics/carbondating.htm and the website of the Oxford Radiocarbon webinfo site: http://c14.arch.ox.ac.uk/embed.php?File=webinfo.html, both consulted on 3 February 2013.

[42] For example, that used here is one known as IntCal13.

[43] Non-cellulosic materials are aimed to be removed by the sample pre-treatment process prior to the radiocarbon measurement.

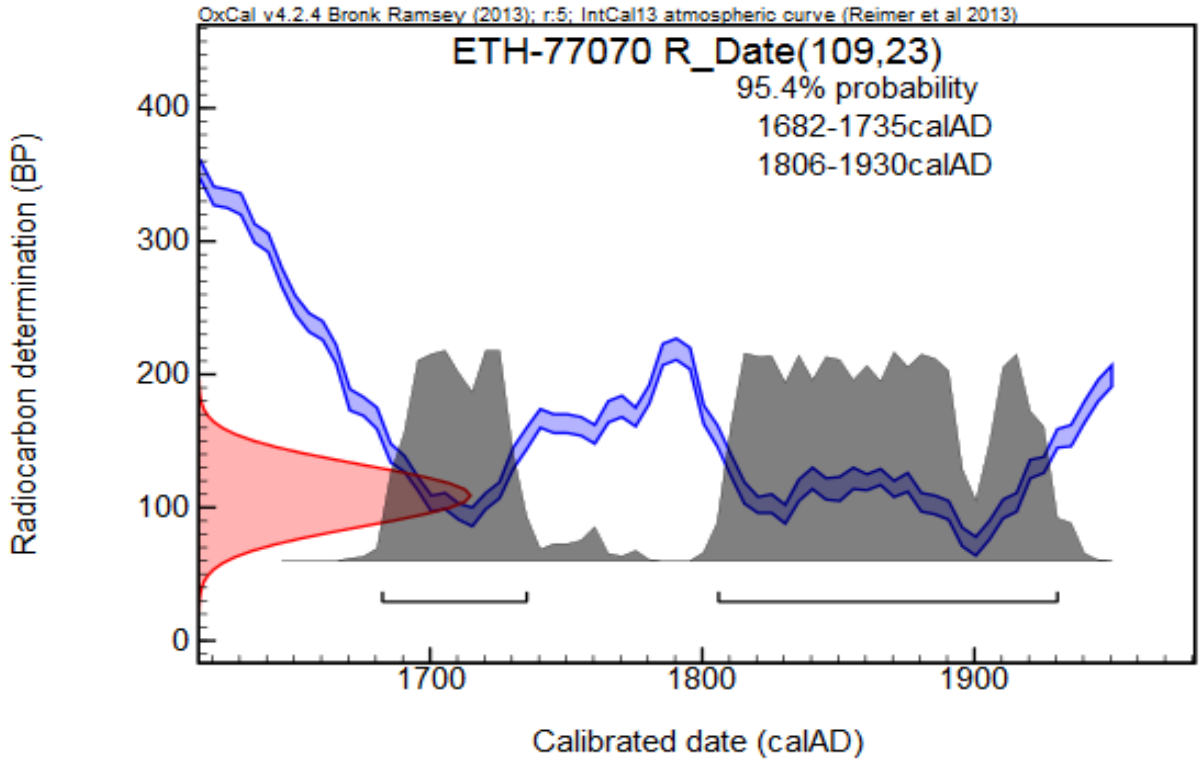


Figure App.2.v.ii Radiocarbon determination

Art Analysis & Research

App.3 Imaging methods

Protocols:

[P.3.1] Photography with visible light
[P.3.2] Photography with ultraviolet illumination
[P.3.3] 3D laser surface mapping
[P.3.4] SWIR infrared imaging
[P.3.6] X-radiography
[P.3.7] Thread counting and weave analysis

App.4 Plates

Plate 1. Natalia Goncharova, *The Orange Seller*, 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **Recto, visible light.**

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050885_09, www.kulturelles-erbe-koeln.de/documents/obj/05021026

Plate 2. Natalia Goncharova, *The Orange Seller,* 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **Recto, UV light**.

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050885_06, www.kulturelles-erbe-koeln.de/documents/obj/05021026

Plate 3. Natalia Goncharova, *The Orange Seller*, 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **Recto, oblique illumination.**

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050885_04, www.kulturelles-erbe-koeln.de/documents/obj/05021026

Plate 4. Natalia Goncharova, *The Orange Seller*, 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **Recto, 3D laser scan**.

Plate 5. Natalia Goncharova, *The Orange Seller,* 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **Verso, visible light.**

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050885_02, www.kulturelles-erbe-koeln.de/documents/obj/05021026
The painting is unlined and on what appears to be its original stretcher.

Plate 6. Natalia Goncharova, *The Orange Seller*, 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **Verso, UV light**.

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050885_08, www.kulturelles-erbe-koeln.de/documents/obj/05021026

Plate 7.a Natalia Goncharova, *The Orange Seller*, 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **Recto, SWIR image**.

Plate 7.b *The Orange Seller*, 1916, collection Museum Ludwig: Inv. Nr. ML 1484. Recto, SWIR image.

Image removed for reasons of copyright

Plate 7.c *Woman Selling Oranges*, 1916, drawing in graphite pencil on paper, 48,8 x 31,5 cm, Tretyakov Gallery, inv. no. P-4572.

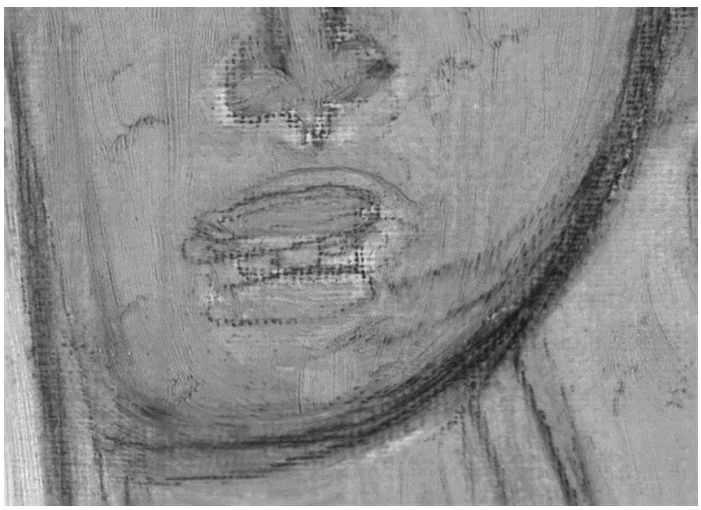
For reproduction see: L. Iovleva (ed.) *Natalia Goncharova: between east and west* [exhibition catalogue, 16 October 2013-6 February 2014, Tretyakov Gallery], State Tretyakov Gallery: Moscow (2013) p. 425. © Tretyakov Gallery.

a.

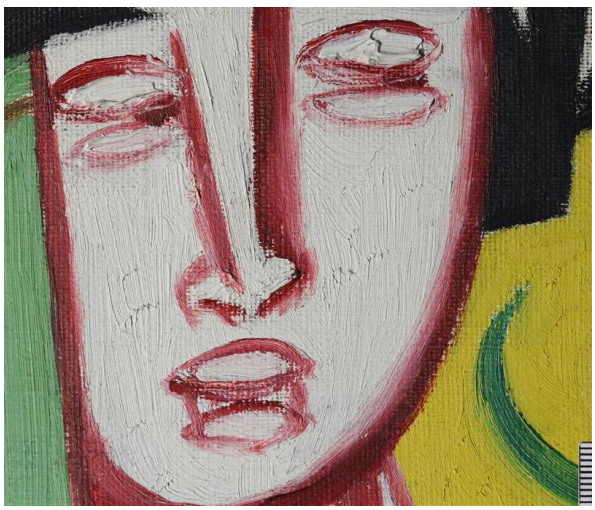
Plate 8.a
Recto, SWIR image, detail, showing the small pentimenti in the face.

Plate 8.b
Recto, SWIR image, detail, showing the quality of the line, lower portion of the face.

Plate 8.c
Recto, Visible light, detail.



b.



c.

Plate 9a. Natalia Goncharova, *The Orange Seller*, 1916, collection Museum Ludwig: Inv. Nr. ML 1484. **X-ray image**.

Plate 9b. The X-ray image before digital compensation for the stretcher bars.

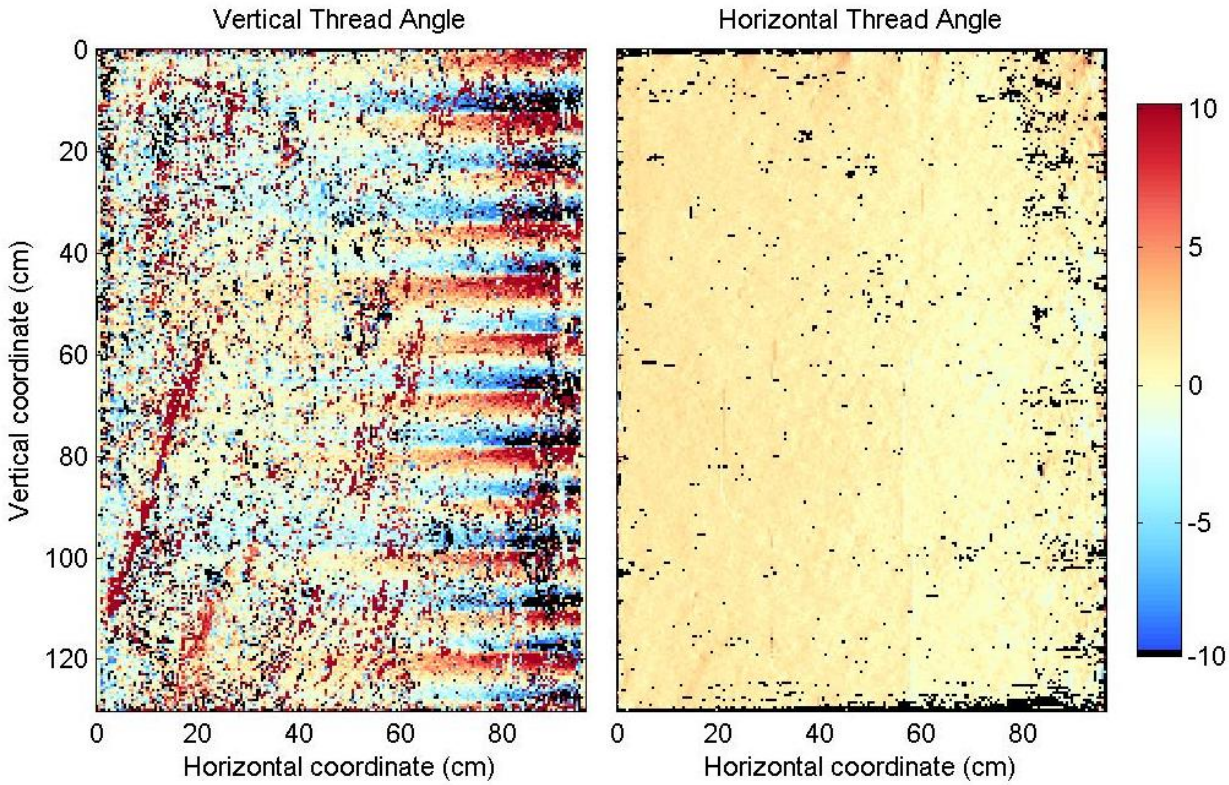


Plate 10.a Maps showing variation in canvas thread angle.

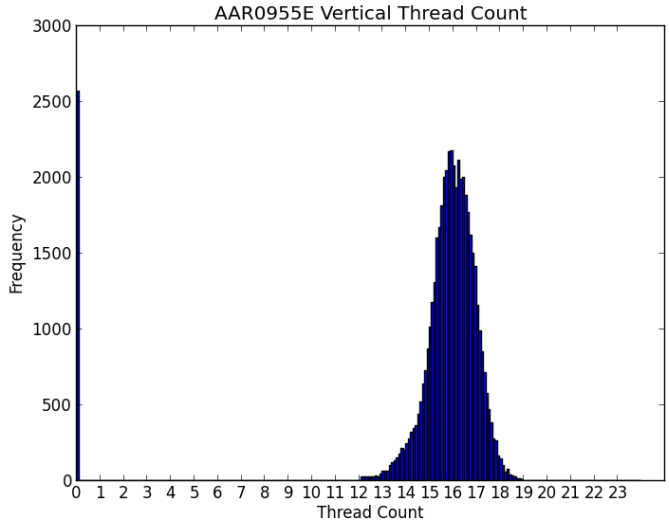


Plate 10.b Histogram of vertical thread count readings.

Showing variation in thread count per centimetre.

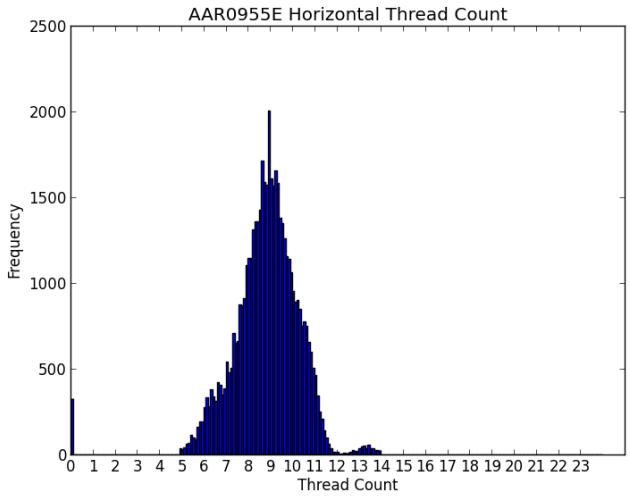


Plate 10.c Histogram of horizontal thread count readings.

Showing variation in thread count per centimetre.

Plate 10.d Table of thread count data (threads per centimetre)

	Mean	Estimated thread count (mode)
Warp (vertical)	15.97	15.9
Weft (horizontal)	9.2	9.2 [12]*

*The weft direction count appears to have come out rather low, due to the irregularity of the canvas (several runs of the program yielded similar results). Subsequently, a hand count from the X-ray suggested that the weft direction count should be more on the order of c. 12 threads per centimetre.

Plate 11.a Detail of canvas, verso.

The weave is a plain weave, quite open, as may be seen where the ground is visible from the recto. The fibre a bast type, probably linen. The weave is quite open, and the ground may be seen between the threads.

Plate 11.b Detail of canvas, verso, showing selvedge, left.

The selvedge runs along the long side of the painting. Along the bottom, the cut edge of the prepared canvas.

Plate 11.c Detail of upper tacking margin.

The ground is thin but opaque. Also visible are nail holes from an earlier stretching, and the slight loss of ground near the nails.

Plate 12.a Detail of right tacking margin.

The paint stops at the turnover edge.

Plate 12.b Detail of right strainer bar.

The bar is stamped ’60 F’.

Plate 12.c Detail (above) of an original tack.

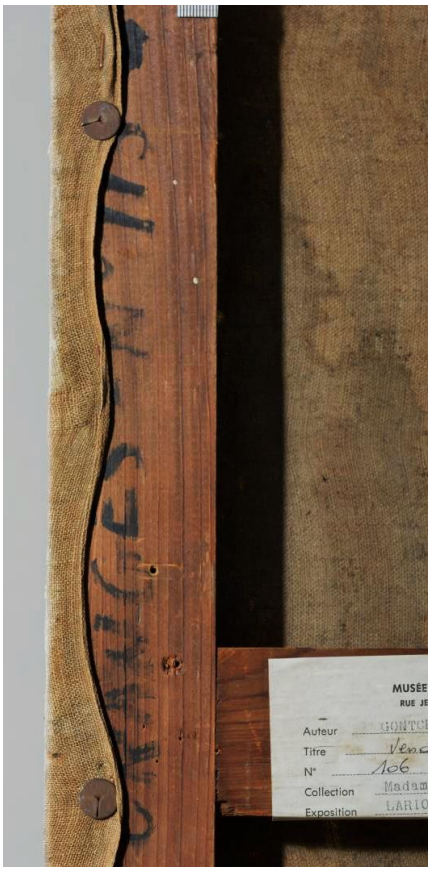


Plate 12.d Detail (right) of the left edge, verso, showing original tacks and selvedge.

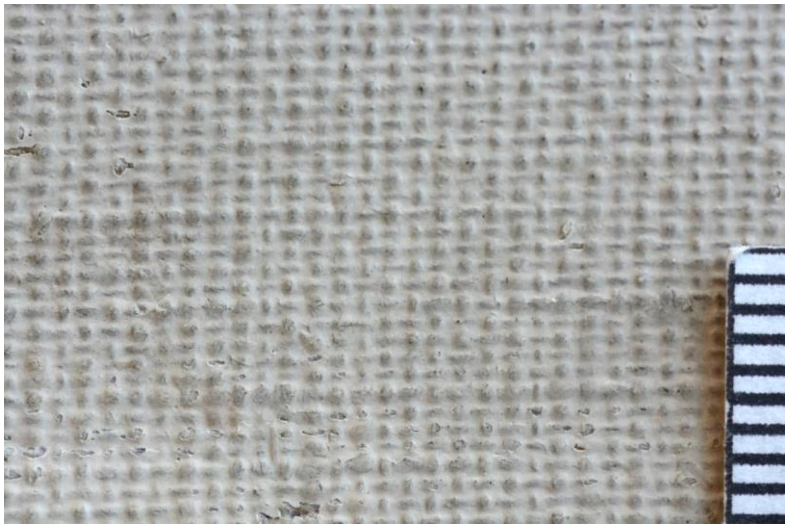


Plate 13.a Detail of the priming, from the bottom tacking margin.

No stress cracking is visible.

Plate 13.b Microscope detail of the priming, with underdrawing in a graphitic medium.

Shows the smooth, solid aspect of this layer, and the small, localised stress cracks occurring in some areas of the priming. The drawn line skims the raised texture of the support.

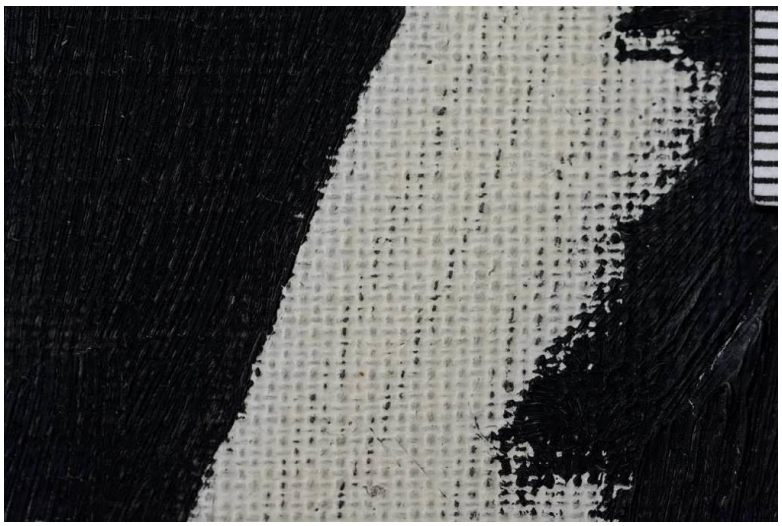


Plate 13.c Detail of the priming, with underdrawing in graphitic medium.

Plate 14.a Detail of drying cracks in the painting, green.

The green is particularly susceptible to drying crack.

Plate 14.b Detail of drying cracks in the painting, brown.

The brown areas also show the formation of a thin, white haze, or 'bloom', probably due to the migration of organic components of the oil binding medium to the paint's surface.

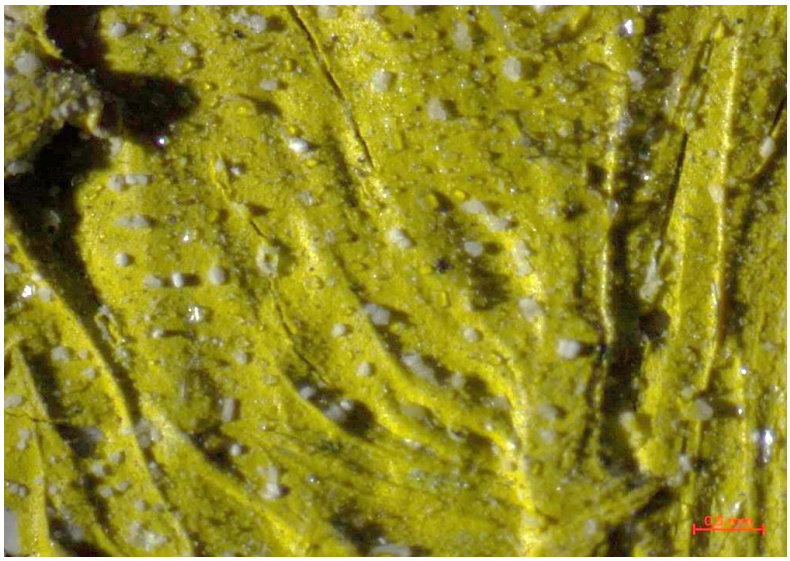


Plate 14.c Microscope detail of crystal formation in the yellow areas of lead chromate.

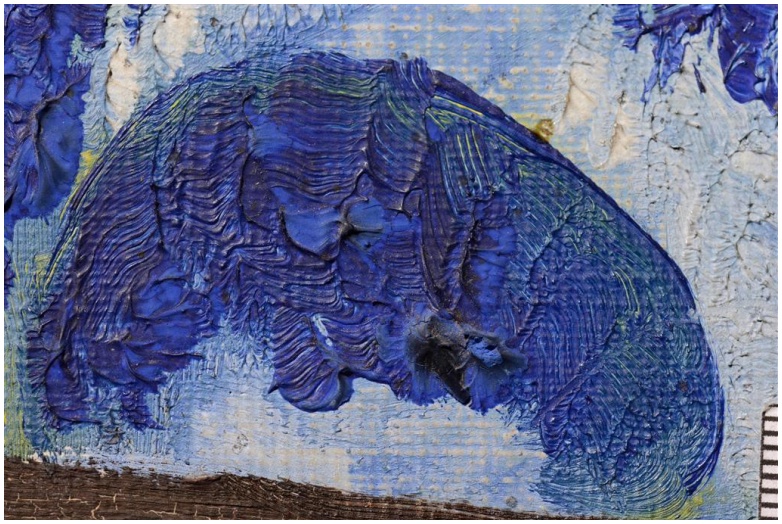


Plate 15.a Detail of the brushwork of the painting.

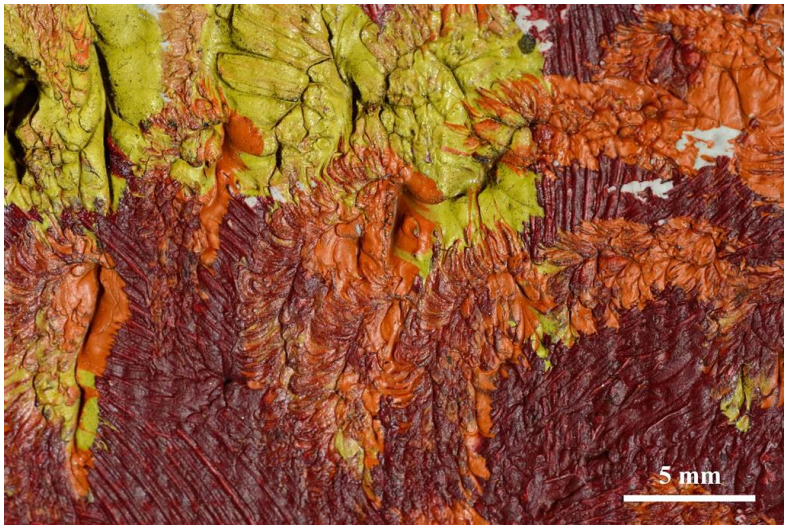


Plate 15.b Detail of the brushwork of the painting.

Various textured features are used – here, stippling in thick applications of paint - in addition to colour to modify the surface and patterning.

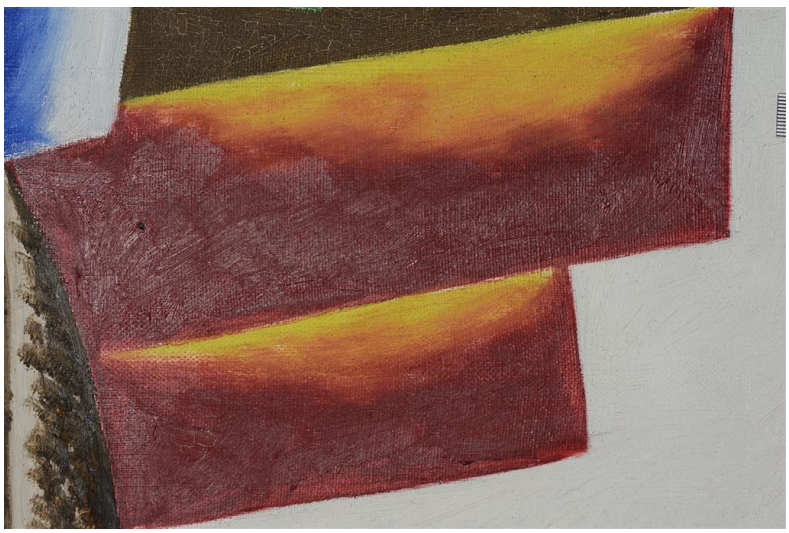


Plate 15.c Detail of the surface, showing variable gloss.

The red is glossy, compared to the adjacent areas.

Plate 16.a Detail of the signature, recto, lower left.

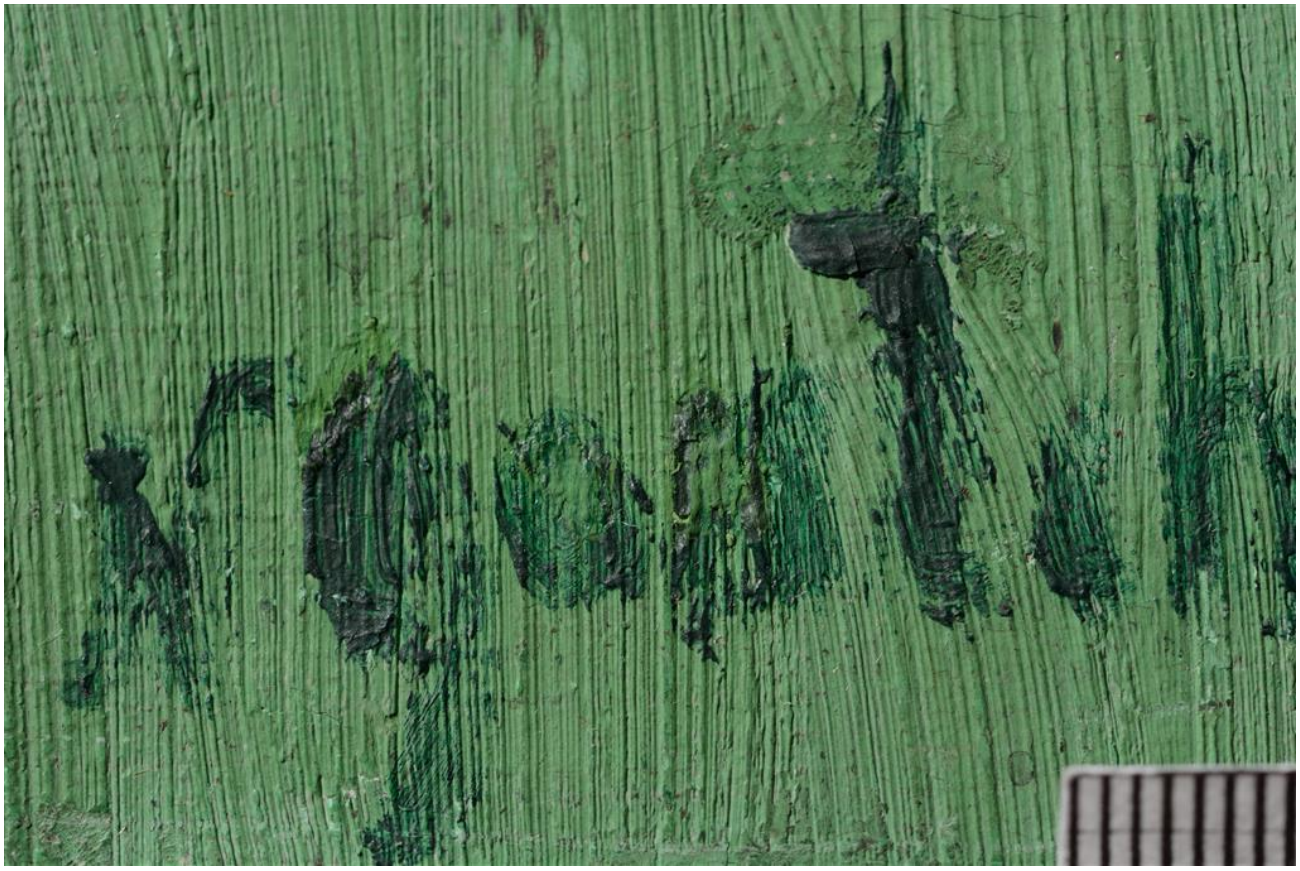
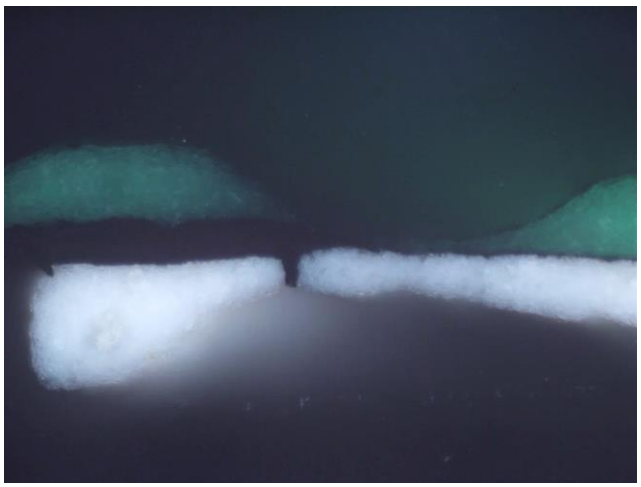


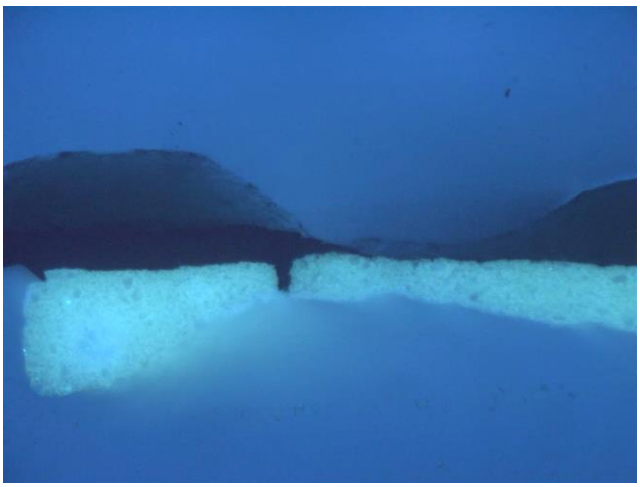
Plate 16.b Macro detail of the signature, recto, lower left.

Plate 17. Image showing approximate location of samples taken for materials analysis.

App.5 Cross-sections[44]



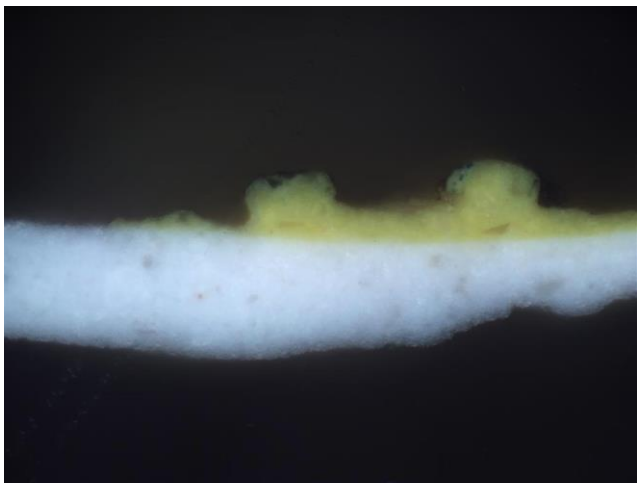
a.



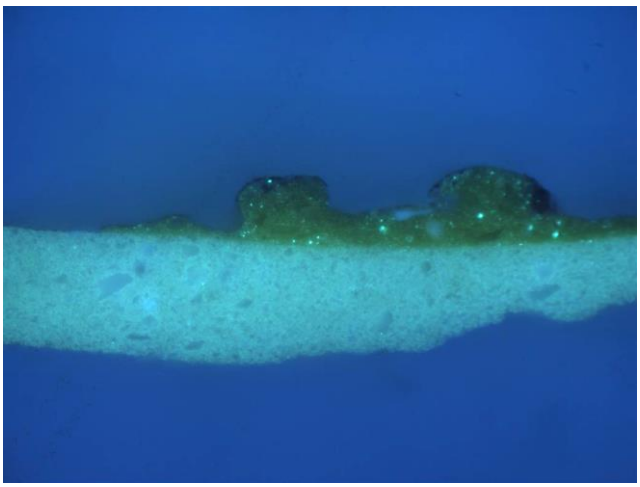
b.

Plate 18. Cross section, Sample [13].

Image ~260µm high. Green from left edge. The sample has a white ground layer followed by a black layer of graphitic underdrawing (confirmed with Raman microscopy) of variable thickness (which has penetrated into a crack in the ground), and a bright green paint layer, above. A thin dark layer on top of this is visible, particularly at the right-hand side of the sample.



a.



b.

Plate 19. Cross section, Sample [14].

Image ~260µm high. Yellow from drapery, bottom edge. The sample includes a white ground layer containing some large translucent particles. The yellow paint also has some large transparent particles and contains a few particles displaying the bright green luminescence that is characteristic of zinc oxide. A few blue particles can be seen in one area towards the top of the yellow layer.

[44] Photographed under visible light, left (**a.**), and with ultraviolet illumination, right (**b.**).