Art Analysis & Research

ANALYTICAL REPORT

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Venus, 1912
Mikhail Larionov
Collection Museum Ludwig, Cologne, Inv. ML 1332

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Summary

A painting on a woven support by Mikhail Larionov (faintly inscribed with the artist's name) known as *Venus*, belonging to the Museum Ludwig (reference: ML 1332), was examined and analysed by Art Analysis & Research, Ltd. in cooperation with the Museum Ludwig, and funded through a grant from The Russian Avant Garde Research Project (RARP). It is thought to have been created in 1912 (it is not dated). This artwork formed a part of a group of fourteen well-provenanced paintings by the Russian artist couple Natalia Goncharova and Mikhail Larionov, held in the collection of the Museum Ludwig that comprised the focus of this work. The goal set for this research was to investigate these paintings in order to characterise similarities and differences, with the objectives of 1) providing detailed studies of the specific paintings, 2) obtaining wider information on the artists' methods, 3) defining a blueprint for promising methodologies to develop further on other works by these artists and with an aim of applying such information in support a *catalogue raisonné*, and 4) creating a 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 *Venus* (**Plate 1**) by the artist Mikhail Larionov (1881-1964), a work on a woven support measuring 560 mm high by 735 mm wide, is now part of the collection of the Museum Ludwig, Cologne (Inv. ML 1332). It is faintly inscribed with the artist's name, 'M. L[…]', lower right (**Plates 1.a, 2.a**); a date of 1912 has been proposed for its creation. It has been examined as part of a larger technical study of fourteen paintings by Larionov and Natalia Goncharova 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 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 painting 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; *The 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 a 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; *Saucission 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.A ML 1332 Conservation*, Franken, V. 'Report on the examination of the painting *Venus* (1912) by Mikhail Larionov' (2017a) and *AAR0955.A ML 1332 Archives*, Franken, V. 'Report on the content of the Museum Ludwig archives, concerning the painting *Venus* (1912) by Mikhail Larionov' (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**);
- UV luminescence (**Plates 2**);
- Oblique illumination (**Plate 3**);
- X-radiography (**Plate 5**).

Additionally, weave analysis was conducted on the basis of the X-radiograph (**Plates 6.a-d**). Some exemplar images recorded as part of the surface microscopy and macrophotography are also reproduced here (**Plates 7, 8**).

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 an unusual woven support, which resembles a basket or hat material composed of straw (entire plant stalks) rather than twisted threads spun from fibres as found in conventional canvases. In addition, the support has not been primed and as the painting is undertaken in the linear fashion of a ‘drawing’ with passages of fill thin colour, much of the surface remains exposed (**Plate 1**). It is currently unvarnished.

[5] Additionally, a visible-NIR multispectral dataset was collected to examine its suitability for study of paintings of Goncharova and Larionov. As it did not offer information significantly different or superior to that derived by the SWIR imaging, this has not been otherwise reproduced or further analysed here but is available for extramural studies in the future.

The painting has been lined and mounted on a newer secondary support, so that only the recto of the artwork could be studied. The tacking margins have been removed and the edges of the work covered in paper tape; thus, it is not clear whether the painting retains its original format, nor is it clear how it was originally stretched. The work is in good condition, although there has been some flaking of the paint, which is not well adhered to the unprepared woven substrate. The inscription, lower right (**Plates 1.a, 2.a**), appears to have suffered from abrasion and is difficult to read.

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 - as present here - 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 can also indicate later stages of intervention (**Protocol 3.2** and **Plate 2**).

In the UV image of this work, the original white paint of the composition shows a somewhat bluish white luminescence. A similar characteristic may be observed in the material found in some areas that are likely represent repairs executed in a consolidant (as they do not relate to painted elements) while still other regions, likewise apparently related to repair, exhibit a more yellow tone. This is likely to be associated with a medium rather than a pigment, as this effect is seen in both white and non-white areas of the image (for example, the round yellowish white dot between the folds of the drape upon which the Venus lies, lower left corner. both of white and non-white areas, show a distinctly yellow toned luminescence. The lack of UV luminescence in the reddish paint areas lends the faint inscription, lower right (**Plate 2.a**) more contrast with the support, rendering it more legible. The material exhibiting a whitish fluorescence under UV exposure around the edges of the work is not visible in ordinary light (**Plates 1.a, 2.a**), again suggesting the presence of a consolidation medium or similar.

[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.

B.3.ii 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, unprepared surface of the woven support is largely visible as the paint film consists of primarily of discrete lines or thin, dilute applications (**Plates 8.b, 8.c**). Consequently, the X-ray (**Protocol 3.6**; **Plate 5**) is rather low contrast (which has been heightened somewhat digitally to improve legibility) revealing a very direct rendition of form, with painted areas imaging more brightly (where they block the passage of X-ray energy) and unpainted surface imaging as dark passages (as these are more X-ray transparent than more heavily worked regions).

An advantage of X-ray imaging for thread counting is that even if a painting is lined, as here, 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) cited in the study of paintings is the 'thread count', or number of threads (here fibres) 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 6.a-.d**).

The weave count on this work was determined as 10.3 per centimetre in the vertical direction and 8.6 in the horizontal (**Plate 6.d**). There is no evidence of cusping distortion around the edges of the painting (**Plate 6.a**), but as this is a highly atypical support material, no inferences can be made regarding original format or later adjustment.

C. Sampling and analysis

C.1 Introduction

Samples were taken of the paint for analysis by different means in order to determine the range of materials (canvas, pigments and binding media) used in the painting. As the paint was extremely thin, samples were not taken in order to study stratigraphy.

To this end, a series of four locations selected over a representative range of the painting were micro-sampled for identification of the pigments (**Table App.2.i**), with two of these also used for analysis of the binding media (**Tables App.2.ii-2.iii**).

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.

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), Raman microscopy and some Fourier Transform Infrared Spectroscopy-Attenuated Total Reflectance (FTIR) (**App.2.i-2.ii; Protocols 2.1-.4**).

Organic components were identified by 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[7]. 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 support appears to be based on a woven straw material that was, though sampled, not further identified.

C.3 Radiocarbon dating

It was not possible to remove sufficient material for radiocarbon dating.

[7] 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].

C.4 Ground

No ground appears to be present.

C.5 Underdrawing

No underdrawing was observed.

C.6 Paint layers: Pigments

The following pigments (**Tables App.2.1, App.2.2**) were identified in the paint samples:

- Zinc oxide ('zinc white')[8]
- CI Pigment Red 3
- Earth pigments in red, brown and yellow tones, variously containing silica, baryte, titanium dioxide (anatase type) and kaolinite

C.7 Paint layers: Binding media

Analysis by GCMS on one sample ([1]) indicated the presence of poppy oil[9]. Although it had previously been proposed that the painting was executed in an aqueous medium such as gouache, no evidence for a carbohydrate binder was found. It seems more probable therefore that the matt quality of the paint is due to a low binder content.

C.8 Stratigraphy

No significant stratigraphy was found in the painting; samples for preparation as cross-sections were not taken.

D. Discussion of the findings

D.1 Support and preparatory work

This painting has been executed on an atypical support: a woven material consisting of straw (**Plates 5, 6.a, 6.b**), of variable width from relatively thin to quite broad[10]. Some of the straws have been folded over upon themselves and, due to the brittle nature of this material, there are many edges of these stalks which stand proud of the surface, causing an, irregular appearance (**Plate 3,**

[8] Sample [1] was taken from an area believed to represent original material, though it is near restoration. Thus the result of zinc white is believed to be valid.
[9] In the white sample taken, one side was notably shiny. FTIR analysis identified the material as a polycyclohexanone resin (Laropal K-80 or Ketone Resin N), probably present as a thin layer of localised retouching, as no overall varnished was noted.
[10] The fibre type could not be identified as the painting is lined and sample could not be taken.

8.c). The plant material is of uneven thickness, but an average 'thread' count of c. 10.3 threads per cm in the vertical direction x 8.6 per cm in the horizontal direction was registered.

D.2 Paint and pigments

D.2.i General observations

The condition of the artwork is generally good, although there is minor loss and flaking; some areas have been consolidated (**Plates 2, 8.a**)[11].

D.2.ii Paint: pigment and binding medium

Given the rather matt appearance of the paint surface, the use of a gouache type paint had been surmised in earlier studies, but analysis of the paint binding medium identified an oil, poppy oil, in a white paint sample (**App.2.iii**)[12]. There is some cracking visible in the more thickly applied areas (**Plate 8.a**). The palette is very limited, consisting of white, red, brown tones and black. As noted above, the support is evident throughout the painting acts a unique visual feature. Where the paint is thicker, flaking is evident in some passages while those areas painted in more dilute colour seem to have better adhesion, having penetrated the surface (**Plate**). As poppy oil was identified as the binder of the white sample taken, the transparent passages can be assumed to be quite pigment rich (with little binder) as they would have been quite diluted to achieve such an effect. The use of oil, rather than a water based medium makes a good deal of sense in the context of the support; oil would have had better adhesive properties to such a smooth, relatively non-porous surface. Still, under-bound paint on such a substrate is hardly ideal, and was probably exacerbated by movements of the woven material before lining.

The UV imaging revealed what appears to be an inscription, lower right corner, reading 'M. L….' (**Plates 1.a, 2.a**). Given the stresses present in the support and the clearly poor adhesion of the paint layers, it is likely that this was once more legible, having now suffered from wear and abrasion over time.

D.2.iii Materials analysis and implications for dating

On the basis of its relationship to other works by Larionov, the painting has been dated to 1912. There are however other works that exhibit similarities that are dated to the 1920s[13].

As it was not possible to obtain sufficient sample for radiocarbon dating of the support, no radiocarbon data is available. It is thus necessary to consider the pigments found in the painting.

[11] See Franken (2017a) *op. cit.* for further detail.
[12] It exhibits some sensitivity to water; see *Ibid*. p. 4.
[13] See Franken (2017b).

Of the materials present, that of greatest interest in connection with the dating is CI Pigment Red 3 (PR3). PR3 ('Toluidine Red', an Azo family, β-Naphthol pigment) is a toluidine red which may be produced in a variety of hues ranging from 'light', 'medium' and 'deep'; it becomes bluer in tone as its particle size increases, although bluer shades may be chemically modified.[14] Its colour is a somewhat orangey red to a purer more blue red.[15] It is one of a group of modern organic red pigments synthesised in the late 19th and early 20th centuries; its date of discovery was probably around 1904, with the earliest known patent submitted in 1905[16]. The Bayer Co. noted the production of a modification of PR3 to produce a fast pigment suitable to all but the most severe industrial requirements in 1905[17]. Multiple patents were clearly filed in a number of countries, as a patent submitted in Germany in 1906 was rejected in 1907; clearly on the basis that the patent was already filed for this material[18]. Its chronology of uptake in the colour industry is not clear as the synthetic organic components of early 20th century paintings are poorly studied[19]. It has been identified in paintings dating from 1909 onwards.[20] Thus, a date of 1912, as has been suggested, would not be implausible given the material findings.

The findings are generally consistent with the data collected in the study of 45 paintings by Goncharova and Larionov in the collection of the Musée national d'art moderne, Paris. While the organic red PY3 was not detected in the works studied, this absence is insignificant given that the primary means of testing in that study involved non-destructive elemental analysis). As no works by Larionov from the Paris period – 1915 onwards – were included in the study

[14] Herbst, W. and Hunger, K. *Industrial Organic Pigments: Production, Properties, Applications*, 2nd Completely Revised Edition, Wiley-VCH: Weinheim (1997) p. 279.

[15] In the case of the bluer formulations with coarser particle size, surface hazing may occur during drying, resulting in what is known as 'Toluidine Red haze'. *Ibid*. p. 279. This phenomenon is less pronounced in the smaller particle sized formulations, which are more yellowish in tone. Better dispersion helps reduce this phenomenon.

[16] Lubs, H.A. (ed.) *The Chemistry of Synthetic Dyes and Pigments*, Reinhold Publishing Co.: New York (1955) pp. 632-3 (m-Nitro-p-toluidine Red). Berrie, B. and Lomax, S.Q. 'Azo Pigments: Their History, Synthesis, Properties and Use in Artists' Materials', *Studies in the History of Art*, No. 57, National Gallery of Art: Washington D.C. (1997) pp. 8-33, esp. 20 giving the date as 1905. Patton, T.C. (ed.) *Pigment Handbook, Vol. 1: Properties and Economics*, Wiley-Interscience: New York (1973) p. 467 gives the date as 1907.

[17] Lubs (1955) *op cit.*

[18] Curtis, C.A. *Artificial Organic Pigments and their Applications*, trans. from the original German *Künstliche organische Pigmentfarben* by E. Fyleman, Sir Isaac Pitman & Sons, Ltd.: London (1930) p. 135 (m-Nitro-p-toluidine Red).

[19] On the other hand, a significant decrease in its levels of production was noted in the period 1950-1970, although this was observed for industrial use overall, not specifically for the market in paints *Ibid*. pp. 463-66; Herbst, W. and Hunger, K. *Industrial Organic Pigments: Production, Properties, Applications*, 2nd Completely Revised Edition, Wiley-VCH: Weinheim (1997) pp. 279, 280. The earliest example of an identification of PR3 in use as a paint is in the context of architectural paints: on the Japanese tower (Royal domain, Laeken- Brussels), built in 1902-4 and formally opened on May 1905. The PR3 was found by HPLC very probably in the first overpaint, dating from around 1909, when the Tower became an annex of the Trade Museum of the Ministry of Foreign Affair (see more about history of the Tower on http://www.kmkg-mrah.be/history-0). HPLC analysis indicated the PR3 and the Raman spectroscopy did not confirm its presence. Email correspondence with Dr. Jana Sanyova, IRPA, 4 May, 2013.

[20] Stege, H. Richter, M. and Steuer, C. 'Indanthrenblau, Helioechtrot and Pigmentscharlach: identification of synthetic organic pigments in paintings of Ernst Ludwig Kirchner using Raman microscopy'. *Zeitschrift für Kunsttechnologie und Konservierung* 27/1 (2013) pp. 30 – 42.

no data is available for his later patterns of use of materials[21]. The authors are unaware of Larionov's use of a similar support material in other works.

E. Conclusions

The examination of the painting revealed a work that was created with a limited palette of materials on an unusual support to achieve a unique visual aesthetic. Although the paint has a matt appearance, analysis revealed the use of an oil based binding medium, not a water-based system. No evidence was found that would contradict the suggested date of 1912. The investigation also revealed evidence for what appears to be the remains of an inscription, 'M. L[…]', in the lower right corner of the artwork.

[21] This because upon moving to Paris, Larionov largely turned away from painting to other forms of expression. Rioux, Aitken and Duval (1998) *op. cit.*

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Art Analysis & Research

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

App.1.i Sampling

Table App.1.i Samples taken for analysis

#	*Colour*	*Description*	*Location*[22]	*Analysis*
1		White	176/85	PLM, SEM-EDX, Raman, FTIR, GCMS
2		Red	196/465	PLM, SEM-EDX, Raman, FTIR
3		Brown	595/445	PLM, SEM-EDX, Raman
4		Yellow brown	610/288	PLM, SEM-EDX, Raman
5		Fibre (straw?) of support	619/288	PLM

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)

[22] 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.

Art Analysis & Research

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	White	**Zn**	-	*Al, Si, S*	1447 (vw), **437 (vw), 332 (vw),** 141 (vw)	**Zinc oxide**[23]
2	Red	**Si**	Al, S	*Mg, P, K, Ca, Fe, Zn, Ba*	**1619 (vw), 1605 (vw), 1553 (vw), 1495 (vw), 1445 (vw), 1395 (vw), 1332 (w), 1320 (vw), 1295 (w, sh), 1255 (vw), 1249 (vw), 1224 (vw), 1215 (vw), 1185 (vw), 1158 (vw), 1129 (vw), 1097 (vw), 1082 (vw, sh), 1075 (vw), 985 (vw), 923 (vw), 842 (vw), 796 (vw), 722 (vw), 647 (vw), 616 (vw), 503 (vw), 477 (vw), 454 (vw), 421 (vw), 402 (vw), 383 (vw), 339 (vw), 253 (vw), 196 (vw), 165 (vw)**	**CI Pigment Red 3 [P1531]** Some earth pigment present
3	Brown	**-**	Al, S, K, Ca	*Na, Mg, Si, P, Cl, Fe, Cu, Zn, Ba, Pb*	-	Earth[24]
4	Yellow-brown	**Si**	Al, Fe	*Mg, P, S, K, Ca, Zn, Ba*	**636 (vw), 464 (vw), 394 (vw), 144 (m)**	**Silicon dioxide** **Titanium dioxide, anatase type**[25] Iron containing earth pigments Barium sulfate (trace) Zinc oxide (trace)

[23] Finely particulate.
[24] Possibly a humic earth?
[25] Titanium was not identified in the SEM-EDX analysis.

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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	White (paint)	**3351 (vw, br), 2918 (w), 2850 (vw),** 1605 (vw), 1444 (vw), **1177 (w), 1108 (w), 1060 (w), 983 (vw),** 687 (vw), **638 (vw), 610 (w)**	**Barium sulfate** **Binding media component (type unidentified)**[26]
1	White (coating or consolidant)	**3361 (m, br), 2919 (vs), 2853 (s), 1700 (s), 1446 (s),** 1396 (vw), **1257 (vw),** 1188 (vw), **1138 (vw, sh), 1117 (w), 1054 (m), 1041 (m), 959 (m)**	**Polycyclohexanone resin (Laropal K-80 or Ketone resin N)**[27]
2	Red	**3690 (vw), 3649 (vw), 3620 (vw), 3240 (vw, br), 2918 (vw), 2849 (vw), 1619 (vw), 1605 (vw), 1562 (w), 1524 (vw), 1499 (w), 1472 (w), 1448 (w), 1401 (vw), 1342 (vw), 1333 (vw), 1321 (vw), 1303 (vw), 1255 (vw), 1189 (m), 1129 (vw, sh),** 1114 (vw, sh), **1061 (s),** 1030 (vw), 1006 (w), **986 (m),** 935 (vw), 912 (m), **870 (vw), 849 (vw), 826 (vw), 811 (vw), 797 (vw), 779 (vw), 753 (w), 745 (w), 723 (vw),** 691 (w), **636 (w), 608 (m)**	**CI Pigment Red 3 [P1531]**[28] **Aluminosilicate clay mineral, kaolinite type** **Barium sulfate** **Binding media component (type unidentified)**[29]

[26] There are three peaks of weak to very weak intensity which are thought to be due to the presence of the binding medium. It is unclear what the binding medium is as there are several binding media that would produce such peaks such as oils, alkyds and natural resins. However, the GCMS results indicate that the material is to be interpreted as oil.

[27] Polycyclohexanone are among a group of resins known as ketones. Within this group there are three main types: resins based on cyclohexanone (Laropal K-80 and Ketone Resin N); resins based on cyclohexanone and methyl cyclohexanone (AW2) and those based on modified methyl cyclohexanone (MS2A). There are six reference samples of ketone resins in the AA&R reference collection as follows: 100% MS2A [AAR208], Laropal K-80 [AAR209], AW2 [AAR210], MS2A [AAR211], Ketone N [AAR212] and Laropal K-80 [AAR250]. The infrared spectra's of reference samples 100% MS2A [AAR208] and MS2A [AAR211] did not match and therefore this ketone resin was excluded. The infrared spectrum of reference sample AW2 [AAR210] on close examination the reference sample showed an additional peak of a weak intensity at 1375 cm^{-1} which was not present in sample 1 and therefore this ketone resin was also excluded. The infrared spectrum of sample 1 matched closely to the reference spectra's of Laropal K-80 [AAR209], Ketone N [AAR212] and Laropal K-80 [AAR250]. The infrared spectra's of Laropal K-80 and Ketone Resin N were almost identical; it was therefore not possible to differentiate between the two to determine the exact type present.

[28] The peaks assigned to Pigment Red 3 were a good match to the reference spectrum. CI Pigment Red 3 was identified by Raman analysis.

[29] See note 26, above.

A.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	
1	25.686	7.784×10^8	29.590	2.109×10^8	P/S = 3.69

The P/S value of **Sample [1]**, white paint, was 3.69, consistent with **poppy oil**.

App.3 Imaging methods

Protocols:

[P.3.1] Photography with visible light
[P.3.2] Photography with ultraviolet illumination
[P.3.6] X-radiography (X-ray)
[P.3.7] Thread counting and weave analysis

App.4 Plates

Plate 1. Mikhail Larionov, Venus, 1912, collection Museum Ludwig: Inv. Nr. ML 1332. **Recto, visible light.**

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050874_07, www.kulturelles-erbe-koeln.de/documents/obj/05020021

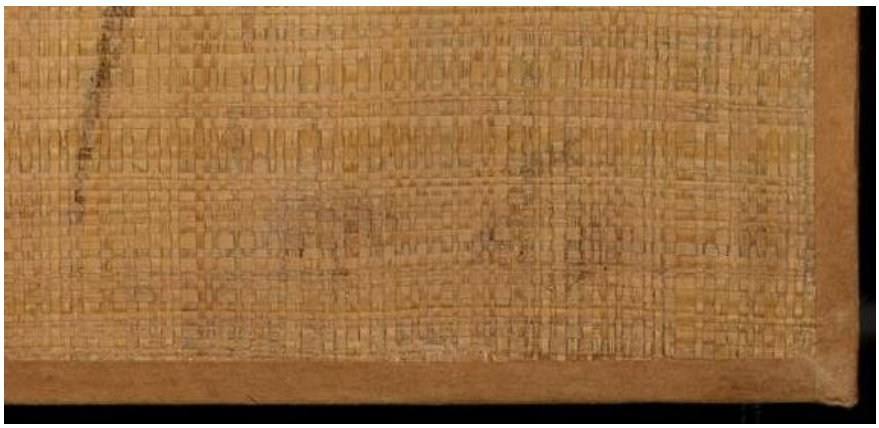

Plate 1.a Detail of the inscription, lower right corner, as above.

Plate 2. Mikhail Larionov, *Venus*, 1912, collection Museum Ludwig: Inv. Nr. ML 1332. **Recto, UV light**.

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050874_06, www.kulturelles-erbe-koeln.de/documents/obj/05020021

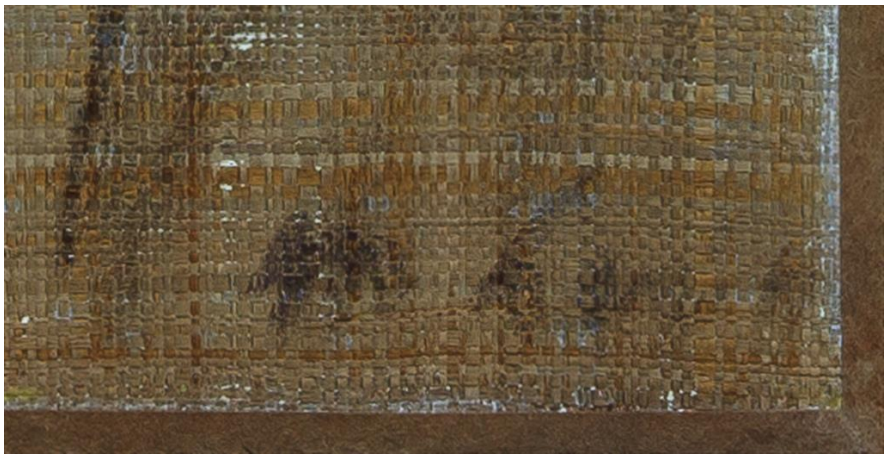

Plate 2.a Detail of the inscription, lower right corner, as above.

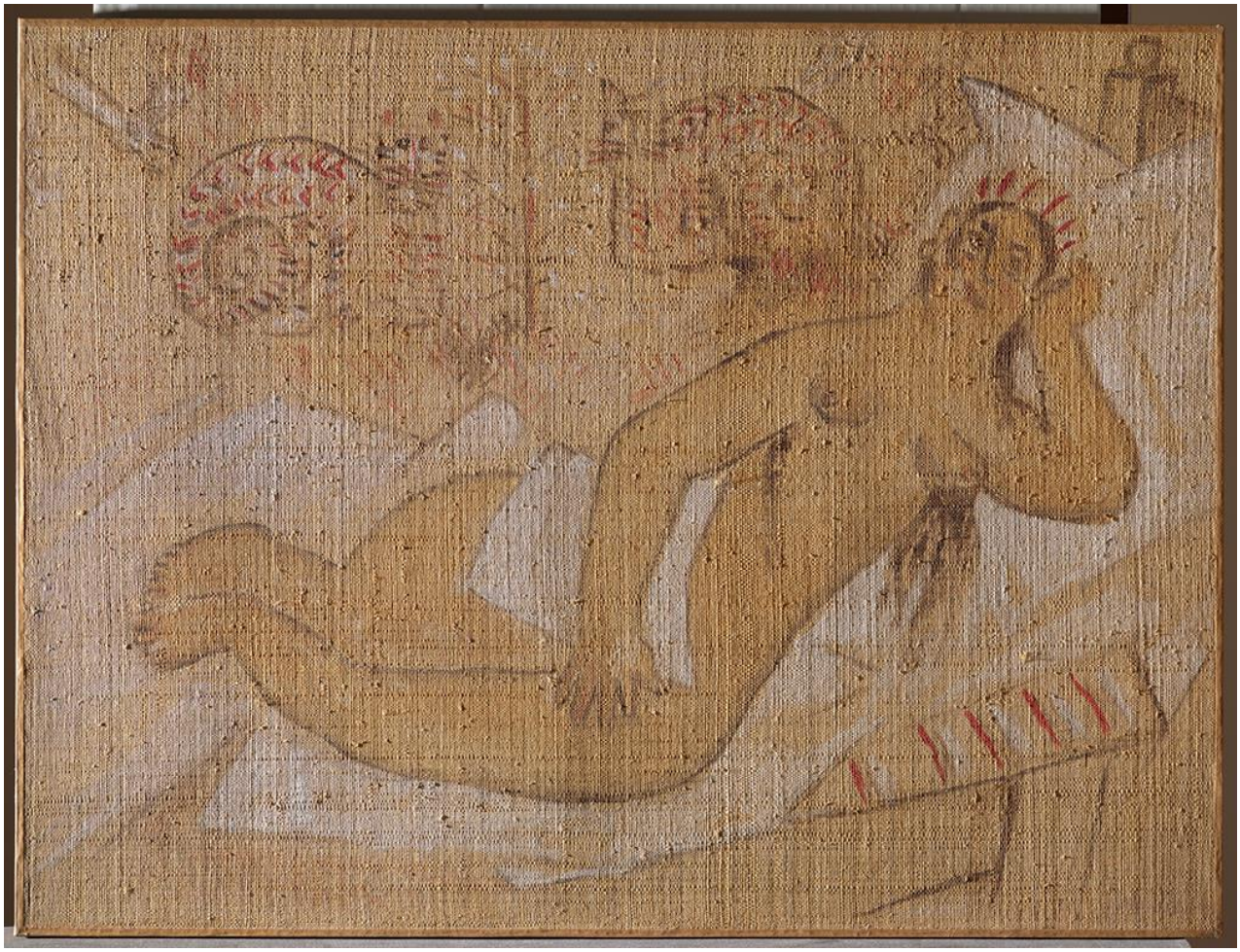

Plate 3. Mikhail Larionov, Venus, 1912, collection Museum Ludwig: Inv. Nr. ML 1332. **Recto, raking light**.

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050874_04, www.kulturelles-erbe-koeln.de/documents/obj/05020021

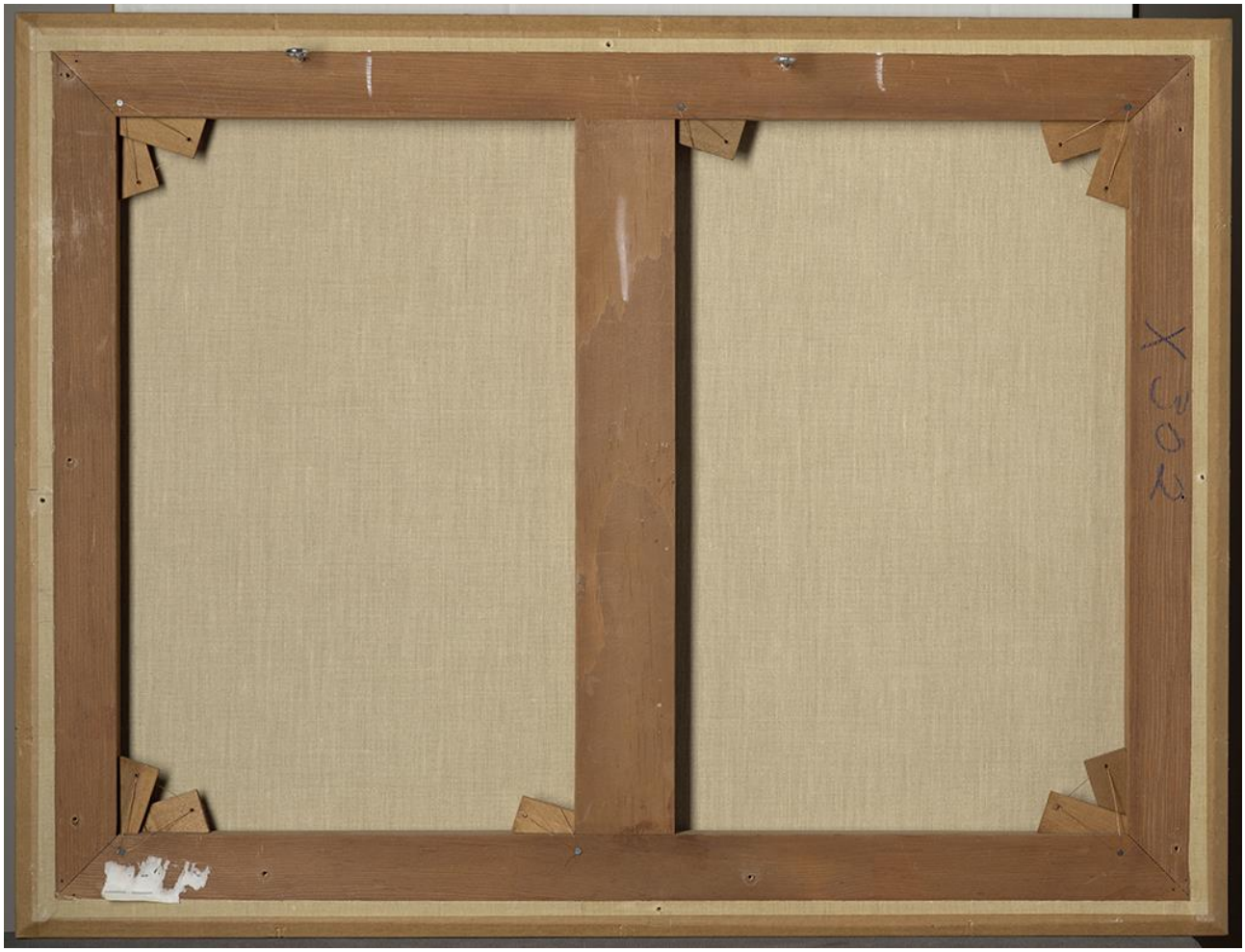

Plate 4. Mikhail Larionov, Venus, 1912, collection Museum Ludwig: Inv. Nr. ML 1332. **Verso, visible light.**

Rheinisches Bildarchiv Köln, Patrick Schwarz, rba_d050874_02, www.kulturelles-erbe-koeln.de/documents/obj/05020021
The painting has been lined (no original material is visible).

Plate 5. Mikhail Larionov, Venus, 1912, collection Museum Ludwig: Inv. Nr. ML 1332. **X-ray image**.

Plate 5.a The X-ray image before digital compensation for the stretcher bars.

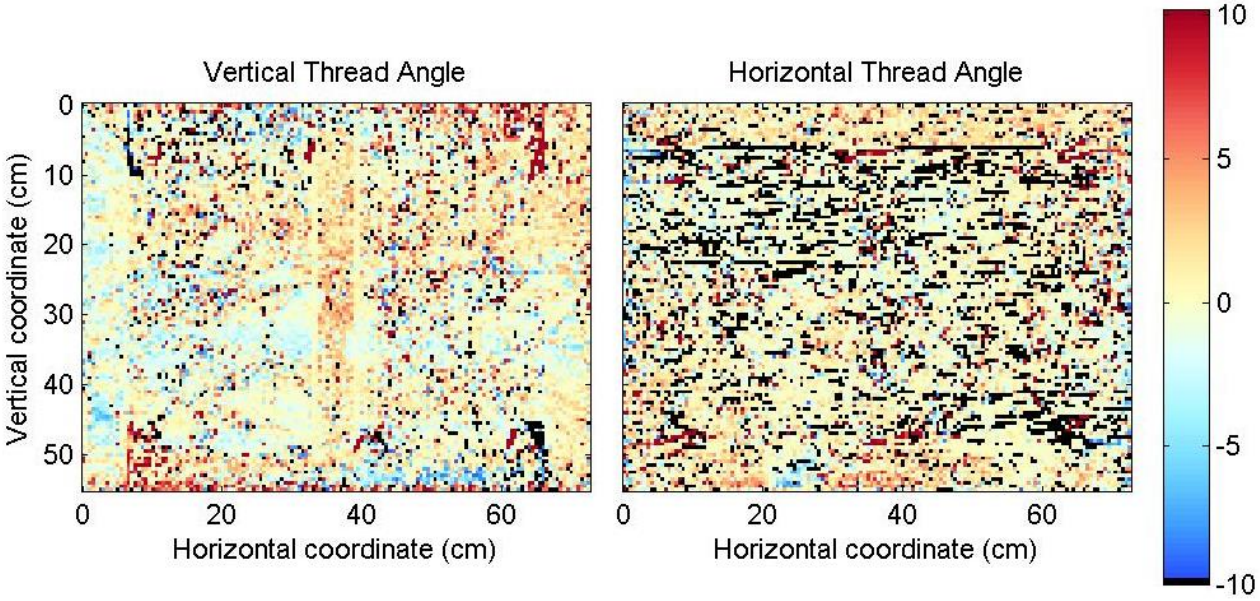

Plate 6.a Maps showing variation in canvas thread angle.

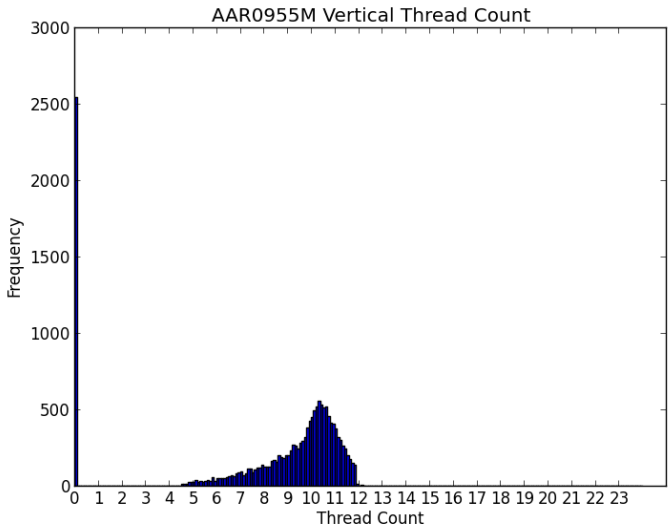

Plate 6.b Histogram of vertical thread count readings.

Showing variation in thread count per centimetre.

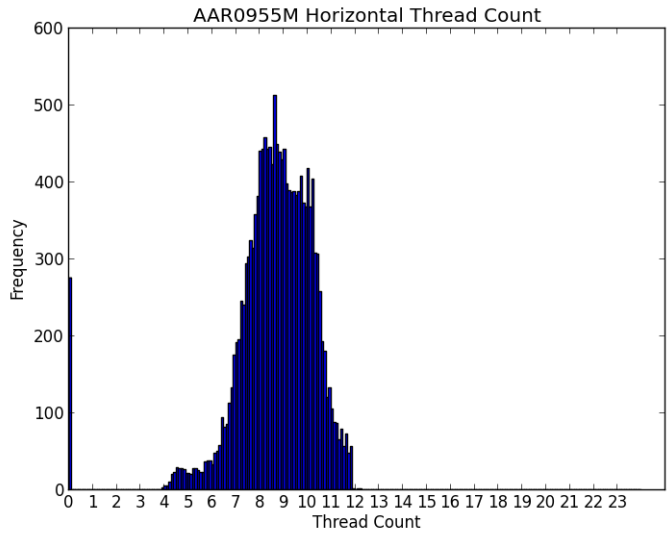

Plate 6.c Histogram of horizontal thread count readings.

Showing variation in thread count per centimetre.

Plate 6.d Table of thread count data (threads per centimetre)

	Mean	Estimated thread count (mode)
Vertical	9.6	10.3
Horizontal	8.8	8.6

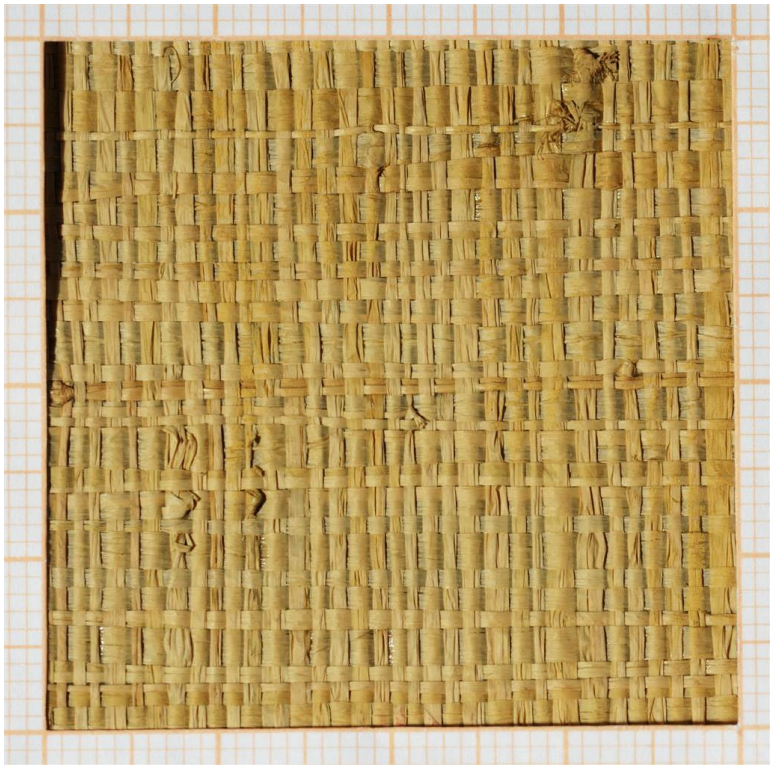

Plate 7.a Detail of the support, recto.

The thick, flat aspect of the woven material is evident. No priming has been used.

Plate 7.b Macro detail of the support.

The weave elements consist of individual strands of plant husks, which have not been macerated or twisted, rather than threads.

Plate 8.a Detail of support, recto, showing the poor adhesion between paint layers and the unprimed surface.

Plate 8.b Detail of support, showing the 'staining' effect achieved by more dilute applications of paint.

Plate 8.c Detail of support and paint.

Splintered plant strands showing broken fragments standing proud of the surface and the rough lines and shapes created by application of paint to the textured surface.

Plate 9. Image showing approximate location of samples taken for materials analysis.