

Article

A Multi-Analytical Investigation of Liu Kang's Colour Palette and Painting Technique from the Shanghai Period (1933–1937)

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Abstract: This study presents the analytical characterisation of Liu Kang's paint mixtures and the painting technique used during the important Shanghai artistic phase (1933–1937). Liu Kang (1911–2004) was a Chinese artist who received an academic art education in Shanghai (1926–1928) and Paris (1929–1932). He settled permanently in Singapore in 1945 and became a leading contributor to the national art scene. This study showcases 12 paintings on canvas from the collections of the National Gallery Singapore and the Liu family. An integrated approach combined non- and micro-invasive analytical methods supplemented with archival sources and enabled characterising the investigated paint mixtures and revealing details of the artist's painting technique. The study has proved the artist's ability to produce a variety of hues by utilising a conventional palette of colours. The predilection for ultramarine, viridian, yellow and red iron-rich earth pigments, umber, yellow chromate pigments, as well as lead white, zinc white or Zn-base compounds like lithopone and barium white was recorded. The study emphasises a minor use of Prussian blue, emerald green, cadmium yellow or its variant and bone black. Although it remains unknown what brands of paints Liu Kang used, the available archival sources give insights into the painting materials available in Shanghai that the artist could have had at his disposal during the period under review. The archival information is based on the Chinese and overseas colourmen advertisements printed in Chinese journals and the respective contemporary colourmen catalogues. The artist's painting technique departs from the experimental approach of his Paris phase. In Shanghai, he focused on synthesising the painting principles of the School of Paris with traditional Chinese calligraphy. The outcomes of this research may support future technical studies of works by other artists contemporary to Liu Kang and who were active in pre-war Shanghai.

Keywords: SEM-EDS; FTIR; IRFC; pigments; Liu Kang; Shanghai Art Academycheck for
updates

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1. Introduction

Liu Kang (1911–2004) was a Chinese emigreé to Singapore who began his training in easel painting at the Xinhua Arts Academy in Shanghai (1926–1928). He was admitted to the Académie de la Grande Chaumière in Montparnasse in 1929 [1] and started work at Shanghai Art Academy, the Faculty of Western art in 1933 [2,3]. The outbreak of the Second Sino-Japanese War in 1937 had a profound impact on his prolific artistic activity in Shanghai, resulting in his relocation to Malaya. He eventually settled permanently in Singapore in 1945 and became one of the founders of the modern art movement in the emerging nation-state.

Liu Kang's stay in Shanghai was crucial for formulating his artistic ideas, which accompanied him throughout his professional career. In the late 1920s and early 1930s, Shanghai was the centre of the national art reformation movement, which challenged traditional art practices by introducing artistic ideas from the School of Paris [4–6]. The Shanghai

Art Academy played a pivotal role in these developments and Liu Kang's affiliation with the Academy created many opportunities to develop and professionally contribute to the art reformation movement [4,7]. A teaching position at the Academy meant admission to famous Shanghai artists' circles. Moreover, those affiliated with the Academy enjoyed a local and national reputation through numerous opportunities to present their works to the public through art exhibitions, publications and art societies' activities. In 1933, the Academy hosted a group exhibition of paintings by Liu Kang and fellow artists entitled "Master's art exhibition" [7]. He recalled: "The 30s was the golden age of art in Shanghai, especially of the Academy. There was vision. There was freedom of expression" [8].

As a tutor, Liu Kang promoted outdoor painting as an essential element of fine art education through trips with his students to Suzhou, Hangzhou, Changshu, Qingdao, Wuxi and Nanjing and other scenic locations near Shanghai to study the richness of the natural landscapes (Figure 1) [9]. He recalled: "We left footsteps everywhere in search of ideal subject matter for drawing but would return to our lodging by sunset" [2]. As an artist, he integrated the expression of Chinese identity and a vivid fascination with Post-Impressionism and Fauvism, which he regarded as symbols of universal progress in art. Hence, key modernist visual elements like solid colours, flat surfaces and reduced shading are commonly present in his artworks alongside the local subject matter and expressive lines evoking Chinese calligraphy [4,10].



Figure 1. Archival photograph of Liu Kang during outdoor painting class with students in Shanghai, in 1933. Liu Kang family collection. Images courtesy of Liu family.

The investigation of the artist's paint mixtures and painting technique from the Shanghai phase is of particular interest as, during that time, he consolidated the artistic experience acquired in Paris and expressed new ideas that laid the foundation for his later development. Therefore, the characterisation of his paint mixtures can determine pigment preferences and give insight into Liu Kang's artistic process during this short but important period. The obtained information can aid conservators in treatment of the paint layers and facilitate further investigation into Liu Kang's artistic activity in Shanghai by art historians.

2. Materials and Methods

2.1. Materials

This study showcases 12 paintings created on canvas supports by Liu Kang in Shanghai between 1933 and 1937 from the collections of the National Gallery Singapore (NGS) and the Liu family (Figures 2 and 3). As Liu Kang actively painted outdoors during that period, the predominant genres of his artistic output were landscapes, seascapes and countryside views. This correlation was observed in an earlier technical investigation of the artist's painting supports from the Shanghai phase, indicating that out of 26 examined artworks, 24 were executed outdoors [11]. In-depth analyses of the paint layers were conducted on 42 samples extracted from the NGS paintings. Artworks from the Liu family served as a

complementary source of information for a more thorough understanding of the artist's painting technique. The inventory data of the paintings is contained in Table 1.



Figure 2. Paintings by Liu Kang from the collection of the National Gallery Singapore. (a) *Working at the fields*, 1933, oil on canvas, 49.5 × 64 cm; (b) *Countryside in China*, 1933, oil on canvas, 60.5 × 72 cm; (c) *Backyard*, 1934, oil on canvas, 59.5 × 72.5 cm; (d) *Chinese house*, 1934, oil on canvas, 64.5 × 50.5 cm; (e) *Waterfall*, 1936, oil on canvas, 65 × 50 cm; (f) *Seaside*, 1936, oil on canvas, 45 × 54 cm. Gifts of the artist's family. Collection of the National Gallery Singapore. Images courtesy of the National Heritage Board, Singapore. Arrows indicate sampling areas.



Figure 3. Paintings by Liu Kang from the Liu family collection. (a) *Courtyard, Shanghai*, 1933, oil on canvas, 73 × 60 cm; (b) *Countryside landscape*, 1933, oil on canvas, 45 × 54.5 cm; (c) *Pagoda*, 1936, oil on canvas, 45 × 55 cm; (d) *Rustic landscape*, 1934, oil on canvas, 54 × 46 cm; (e) *Seascape*, 1936, oil on canvas, 50 × 64 cm; (f) *Seaside near Shanghai*, 1936, oil on canvas, 46 × 55 cm. Liu Kang family collection. Images courtesy of the Liu family.

Table 1. Inventory and technical details of the studied paintings.

Title and Inventory Number	Owner	Date	Dimensions H × W (cm)	Primary Support
<i>Working at the fields</i> , 2003-03258	NGS	1933	49.5 × 64	Primed canvas
<i>Countryside in China</i> , 2003-03299	NGS	1933	60.5 × 72	Primed canvas
<i>Courtyard, Shanghai</i>	Liu family	1933	73 × 60	Primed canvas
<i>Countryside landscape</i>	Liu family	1933	45 × 54.5	Primed canvas
<i>Backyard</i> , 2003-03252	NGS	1934	59.5 × 72.5	Primed canvas
<i>Chinese house</i> , 2003-03328	NGS	1934	64.5 × 50.5	Primed canvas
<i>Rustic landscape</i>	Liu family	1934	54 × 46	Primed canvas
<i>Waterfall</i> , 2003-03247	NGS	1936	65 × 50	Primed canvas
<i>Seaside</i> , 2003-03318	NGS	1936	45 × 54	Primed canvas
<i>Seaside near Shanghai</i>	Liu family	1936	46 × 55	Primed canvas
<i>Pagoda</i>	Liu family	1936	45 × 55	Primed canvas
<i>Seascape</i>	Liu family	1936	50 × 64	Primed canvas

2.2. Methods

The research strategy prioritised the NGS paintings and was based on non-invasive imaging techniques, followed by sampling and detailed analyses of the constituents of the paint mixtures. The imaging techniques comprised visible light (VIS), ultraviolet fluorescence (UVF), reflected ultraviolet (UVR), near-infrared (NIR) photography and infrared false-colour (IRFC). The latter was achieved by manipulating VIS and NIR photographs. The imaging techniques enabled a tentative characterisation of the paint mixtures and determined the potential sampling areas. Then, the micro-invasive methods involved the extraction of the paint fragments and their preparation as cross-sections and pigment dispersions for the characterisation of the optical features of the pigments using optical microscopy (OM) and polarised light microscopy (PLM). The tentative visual identification of pigments was combined with spectroscopic techniques, such as field emission scanning electron microscope with energy dispersive spectroscopy (FE-SEM-EDS) followed by attenuated total reflectance-Fourier transform infrared spectroscopy (ATR-FTIR). The information obtained with these techniques enabled the identification of organic and inorganic constituents of the paint mixtures. The information was cross-referenced with local advertisements of the painting materials and contemporary colourmen catalogues such as Reeves & Sons (R&S), Winsor & Newton (W&N) and Lefranc which additionally gave insight into the local market of art materials.

The artist's family preferred to limit the investigation in regards their paintings to in-situ technical descriptions and detailed photography. Hence, due to the nature of the collected information, the Liu family collection supported the study of the artist's painting technique.

2.2.1. Technical Photography

All paintings were photographed by means of a full spectrum (360–1100 nm) Nikon D850 DSLR camera (Tokyo, Japan) with an AF Micro NIKKOR 60 mm focal length and f/2.8D lens (Tokyo, Japan). VIS and UVF photography was conducted by coupling X-Nite CC1 (Carlstadt, NJ, USA) and B+W 415 (Bad Kreuznach, Germany) filters together, whereas UVR required Andrea "U" MK II filter and NIR imaging used Heliopan RG1000 (North White Plains, NY, USA) filter [12–14]. The paintings were illuminated with two Lastolite Ray D8 (500 W tungsten bulb) lamps for VIS and NIR imaging. The light source for UV and UVR photography techniques was a pair of CLE Design (London, UK) lamps equipped with eight 120 cm long, 40 W, UV fluorescence tubes with a peak at 365 nm. The X-Rite ColorChecker Passport (Grand Rapids, MI, USA) was used for camera calibration and the creation of the colour correction profile for VIS photography in Adobe Photoshop CC software (San Jose, CA, USA). The American Institute of Conservation Photo Documentation target (Washington, DC, USA) was used for the adjustment of the white balance and correction of the exposure for VIS and NIR photography [12]. The IRFC images were obtained by

converting NIR images into greyscale, followed by substituting the VIS images' R, G, B channels into IR, R and G using Adobe Photoshop CC software [15].

2.2.2. Preparation of Samples

Pigment mixtures selected for the PLM analyses were dispersed on microscope glass slide, embedded in Melmount (nD = 1.662) from Cargille (Cedar Grove, NJ, USA) and secured with a glass cover. Samples for the cross-section analyses were mounted in acrylic resin—ClaroCit from Struers (Cleveland, OH, USA). The cured resin-casts were ground and polished wet on SiC Foils from Struers down to grade 4000 using grinder-polisher MetaServ 250 from Buehler (Lake Bluff, IL, USA).

2.2.3. OM and PLM

OM of the paint stratigraphy of the cross-sections and PLM of the pigments' scrapings were carried out using a Leica DMRX polarising microscope (Wetzlar, Germany) at magnification range of 100×–400×. The PLM observations were carried out in accordance with the workflow proposed by Peter and Ann Mactaggart [16]. The observations were recorded using a Leica DFC295 3 Mpx digital camera and further processed with Leica Application Suite 4.8 software.

2.2.4. FE-SEM-EDS

The elemental characterization and mapping of the paint cross-sections were performed using Hitachi SU5000 FE-SEM (Tokyo, Japan) equipped with Bruker XFlash[®] 6/60 EDS (Billerica, MA, USA). The SEM was operated with an accelerating voltage of 20 kV, 50–60 intensity spot, 10 mm working distance and 60 Pa vacuum. Acquisition time for the EDS elemental analyses and mapping was 180 s. Data acquisition and processing were conducted with Bruker ESPRIT 2.0 software.

2.2.5. ATR-FTIR

ATR-FTIR measurements were performed on the paint cross-sections using a Bruker Hyperion 3000 FTIR microscope supplied with a mid-band mercury cadmium telluride detector coupled with a Vertex 80 FTIR spectrometer. The ATR objective (20×) equipped with a germanium crystal was used for the compression of the samples. The background spectrum was measured with 64 scans before spectra acquisition of each sample. All spectra, including backgrounds and samples were obtained in a spectral region ranging from 4000 to 600 cm⁻¹ at a 4 cm⁻¹ spectral resolution over 64 scans. Bruker Opus 7.5 software was used to process and interpret the data. The spectra were also compared to references in the material collection of the Institute for Conservation, Restoration and Study of Cultural Heritage, Nicolaus Copernicus University, spectral library of the Infrared and Raman Users Group (IRUG) [17], database of ATR-FT-IR spectra of various materials [18] and reference spectra published in the literature.

3. Results

3.1. Art Materials in Shanghai in the 1930s

Despite the lack of information about the brands of paints preferred by Liu Kang during his artistic activity in Shanghai, the studies of the contemporary colourmen advertisements published in the *Shanghai Art Academy Graduation Yearbook* and Shanghai pictorials, *The Young Companion* and *Arts and Life* gave insight into the local market of art materials. Hence, the archival sources, although limited, turned out to be complementary to the analytical data collected from the paintings and supported the interpretation of certain materials as well as assisted in a determination of the artist-made or commercial pigment mixtures.

Both local brands, such as Marie's and Eagle, and imported ones like R&S and W&N, were available at stationery shops and bookstores. Although local colourmen catalogues from the 1930s were not available to the authors, combining the textual and pictorial information from the 1930s advertisements revealed the most common painting materials offered to the artists at that time. These included watercolours in tubes and cubes, oil

colours in tubes, poster paints, Chinese ink, drying oil, brushes, canvases, pastels and drawing tools.

Interestingly, Marie’s company advertisement from 1934 listed 12 pigments: orpiment, indigo, azurite, yellow ochre, burnt ochre, malachite, organic red (unspecified), vermilion, carmine, white powder (unspecified), gamboge and cinnabar (Figure 4a–m) [19]. The company additionally highlighted rose madder oil paint and watercolour chrome orange in their 1935 and 1937 advertisements (Figure 5a–d) [20,21]. Various advertisements from 1936 by the Eagle company highlighted oil tube paints with ultramarine and olive green as well as watercolour tubes with chrome yellow and carmine tint (Figure 5e–j) [22].



Figure 4. Advertisement by Marie from 1934 with marked listing of 12 pigments (a) and corresponding details of the Chinese characters referring to orpiment (b), indigo (c), azurite (d), yellow ochre (e), burnt ochre (f), malachite (g), organic red (h), vermilion (i), carmine (j), white powder (k), gamboge (l) and cinnabar (m).

Regarding the imported brands, R&S was the sole advertiser of art materials in *The Young Companion* and *Arts & Life* between 1932 and 1935. During that time, the company actively promoted the introduction of 16 watercolour tubes, 48 oil colour tubes and highlighted watercolours in tubes with Prussian blue and vermilion as well as oil paints in tubes with cobalt blue tint and yellow ochre (Figure 6a–c).

Growing recognition of the R&S brand in China resulted in fierce competition from local manufacturers, who found a niche market for imitations of R&S products. To protect the brand’s reputation, R&S released advertisements warning clients of these poor-quality products (Figure 6a–c) [23–26]. Besides R&S painting materials, W&N was another overseas brand available in Shanghai, and their watercolours, drying oil and painting canvas were reported by T. Tsuruta [7].



Figure 5. Advertisements by Marie from 1935 (a), 1937 (c) and by Eagle from 1936 (e,g) with highlighted paint tubes (colour rectangles) and corresponding details showing types of paints (b,d,f,h–j).

Despite the wide range of local and imported painting materials available in Shanghai, Liu Kang also might have used paints purchased during his time in Paris (1929–1932). Although there is no direct evidence of the specific brand(s) that he used in Paris, it is known that he had some interest in Lefranc colours [27]. Moreover, he might have had access to painting materials from other French and overseas manufacturers whose advertisements were presented in the authors' earlier research [11,28].

3.2. Pigments

The colour scheme of the study group paintings is relatively simple, primarily incorporating hues of blue, green, yellow, and brown as well as white and black. For clarity of the discussion, the results are presented based on the frequently occurring colours. Results of the FTIR analyses of paint samples confirmed that pigments were bound in a drying oil detected by absorption peaks at 2920, 2855, 1735, 1161 and 720 cm^{-1} (Appendix A, Table A1) [18].

3.2.1. Blue

Liu Kang seems to have preferred ultramarine (PB29) for depicting sky, water, distant foreground mountains or for strong outlining of shapes. The pigment was assumed based on the IRFC purple imaging of the blue passages and PLM observation of blue, isotropic particles that have a low refractive index and appear red under a Chelsea filter. These outcomes were corroborated by the Na, Al, Si, and S elements detected using SEM-EDS and FTIR measurements exemplified by IR absorption peaks at 984, 693 and 666 cm^{-1} as in sample 6 from *Countryside in China* (1933) (Figure 7) or peak at 990 cm^{-1} detected in sample

1 from *Seaside* (1936). However, despite the positive PLM observation and detection of ultramarine constituting elements, the FTIR confirmation of this pigment in other blue paint mixtures was complicated due to interferences of functional groups related to different compounds. Therefore, FTIR allowed detection of only a single IR absorption peak at ca. 1000 cm^{-1} implying the presence of ultramarine in the sample 11 from *Backyard* (1934), sample 4 from *Countryside in China* (1933), sample 3 from *Chinese house* (1934) and sample 4 from *Waterfall* (1936).

a

利夫氏學生用水彩畫顏色

▲錫管裝式▼

REEVES
COLOURS



利夫氏廠最近加製美麗之學生用水彩顏料十六種，分發各代售處，可隨時索觀。

該廠應美術界之需求，編有詳細圖表說明書，各美術團體函索付郵即寄。

利夫氏之顏料，早經全世界有名之美術教育專家公認為繪畫最佳之顏料，信譽卓著；故習畫者無不樂用。

經售處：
香港德輔道先施公司
永安公司
大新公司

上海棋盤街各文具教育用品商店
及國內各大商店均有代售

b

Reeves' Colours

二百六十八年來
畫家及學生界所
樂用之「利夫氏」
油繪與水彩畫顏色。為英國倫敦「利夫氏」父子有限公司監製，每筒皆附有「獵犬」商標為記。名畫家及習畫之學生於購買本號顏色時，務請認明商標，因市上冒牌之貨色，品質粗劣，用之必致有損作品也。

中國總經理
上海江西路一三二號
公興洋行有限公司
全國各大書坊文具舖均有出售

利夫氏
各種顏色皆用此商標為記



c

利夫氏學生用油畫顏色
共分四十八種

此顏色係英國倫敦利夫氏父子顏料廠監製。本廠創辦已歷一百六十年。聲譽卓著。所製顏料。每瓶皆有「獵犬」商標為記。各畫家及習畫之學生於購買本廠顏色時。務請認明商標。因市上冒牌之貨甚多。此種冒牌貨色。品質粗劣。用之必致有損作品也。

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永安公司
大新公司

及全國各大商店皆有代售



Figure 6. Advertisements by R&S warning of local imitations of their products and highlighting (a) Prussian blue watercolour, (b) vermilion watercolour and (c) cobalt blue and yellow ochre oil colours.

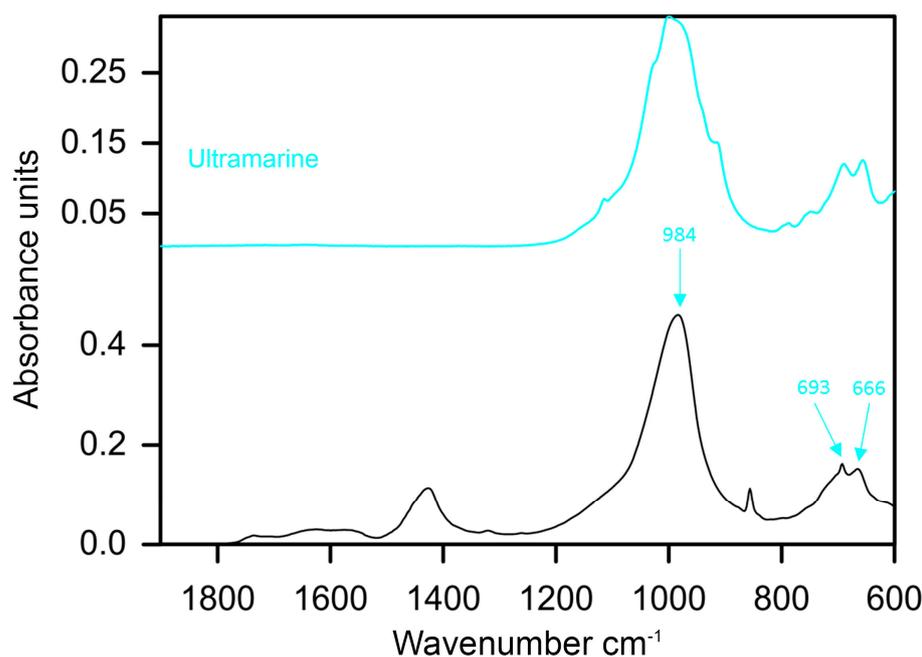


Figure 7. ATR-FTIR spectra derived from the blue paint of sample 6, collected from *Countryside in China*, 1933, with labelled marker peaks of ultramarine and reference spectra of the same pigment.

The blue hue was often modified by combining prevalent ultramarine with other blue, green and yellow pigments. For instance, the addition of Prussian blue (PB27) to ultramarine is assumed in paint sample 4 from *Waterfall* (1936). The pigment was tentatively identified with PLM (observation of dark blue isotropic particles that appear dark green with a Chelsea filter and have a low refractive index), by SEM-EDS detection of iron and an IR absorption peak at 2093 cm^{-1} . The results of the analyses conform with IRFC imaging, as the violet colour of the sampling area is determined by a blue representation of Prussian blue and a purple representation of ultramarine.

The analyses of sample 6 extracted from *Seaside* (1936) implied viridian (PG18) and yellow iron-rich earth pigment mixed with ultramarine (Figure 8). Viridian was assumed based on the combined PLM (observation of green, large and rough anisotropic particles with a high refractive index) and SEM-EDS detection of Cr. Yellow iron-rich earth pigment was considered based on the combined PLM observation (yellow, anisotropic particles with a high refractive index) and detection of Fe-signal. Both ultramarine and yellow ochre were easily available in Shanghai from Eagle and R&S, according to the companies' advertisements (Figures 5i and 6c). The addition of strontium yellow (PY32) to ultramarine was confirmed in the sample 11 from *Backyard* (1934) by FTIR absorption peaks at 907 , 889 , 873 and 843 cm^{-1} and a high concentration of Sr. A trace concentration of emerald green (PG21) found in the sample 6 from *Countryside in China* (1933) may suggest contamination of the paint mixture. Although known for its high toxicity, emerald green was available from major colourmen brands in the 1930s. Both R&S and W&N were operating in China and listed this green pigment in their catalogues from 1934. It was also available from Lefranc under the name vert Véronèse, according to the company's 1934 catalogue (Appendix A, Figures A1–A3). W&N and Lefranc catalogues from 1934 show the availability of strontium yellow (Appendix A, Figures A1 and A3).

Prussian blue was also identified as a principal blue pigment in the sample 3 from *Working in the fields* (1933). The PLM and SEM-EDS outcome was completed with FTIR by absorption peak at 2087 cm^{-1} assigned to $\text{C}\equiv\text{N}$ stretching. It is worth noting that the violet IRFC imaging of the extraction area is determined by a blue representation of Prussian blue and purple representation of viridian in IRFC (Figure 9).

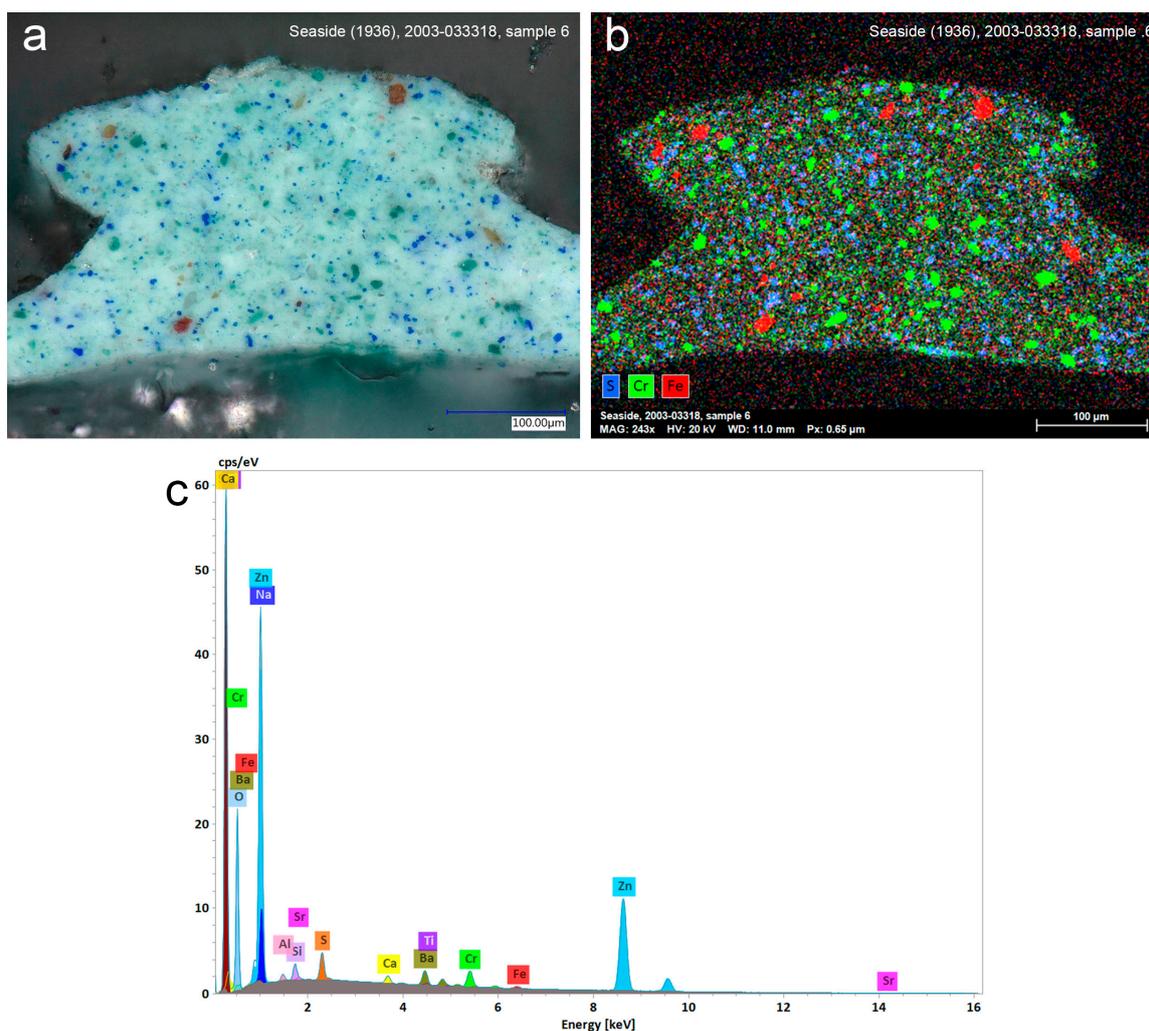


Figure 8. Microscopy image (a), corresponding SEM-EDS elemental map (b) and SEM-EDS spectra (c) of sample 6, extracted from *Seaside*, 1936. The SEM-EDS analyses show the distribution of S elements relating to ultramarine, Cr relating to viridian and Fe attributing to yellow iron-containing earth in the paint sample.

3.2.2. Green

The analyses of green hues revealed a frequent use of viridian, often in combination with ultramarine, Prussian blue, yellow iron-rich earth pigments and yellow chromate pigments.

Sample 4, taken from the green paint of *Countryside in China* (1933) was found to contain a high concentration of viridian. The pigment was confirmed by IR absorption peaks at 3083, 1285, 1252, 1064 and 794 cm^{-1} . The result was consistent with the PLM observation and SEM-EDS analysis. However, an unequivocal declaration of the presence of viridian in other green paint mixtures was challenging due to overlapping bands of other compounds.

Besides viridian, emerald green is another green pigment used. However, it was found only in two investigated green paint mixtures—samples 3 and 4, extracted from *Countryside in China* (1933). This pigment was evidenced by the coincident presence of copper and arsenic elements (Figure 10) as well as IR absorption peaks in the region 1555–1530 cm^{-1} and ca. 680 cm^{-1} and 630 cm^{-1} [29]. Minor use of this green pigment by Liu Kang was already reported in the research of his Paris painting practice (1929–1932) and paintings from the 1950s, suggesting a reluctance to give it a more pronounced role [28,30].

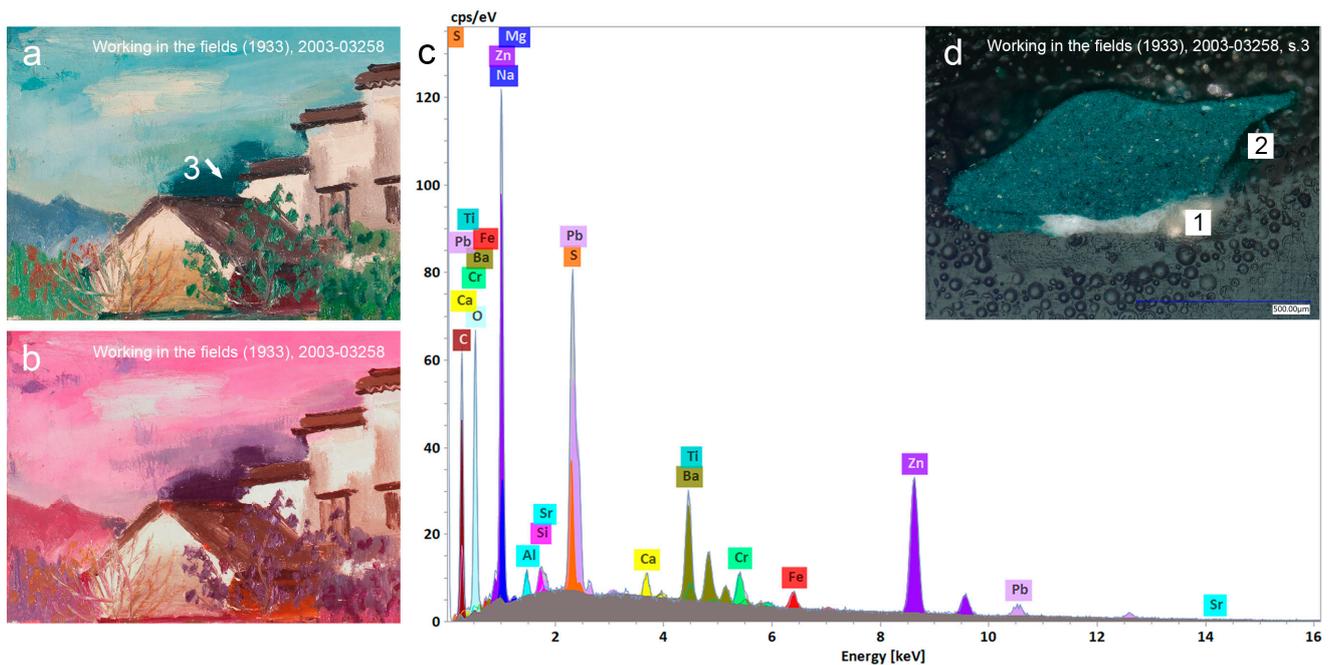


Figure 9. Detail of *Working in the fields*, 1933, photographed in VIS showing the location from which sample 3 was extracted (a) and IRFC image of the same area (b). SEM-EDS spectra of the blue paint, extracted from the sampling spot (c) and corresponding optical microscopy image of the cross-section of sample 3 at 200 \times magnification with the marked area of analysis in layer 2 (d). A blue colour recorded as dark violet in IRFC (b) and the presence of Fe and Cr (c) in layer 2 (d) suggested a mixture composed predominantly of Prussian blue and viridian.

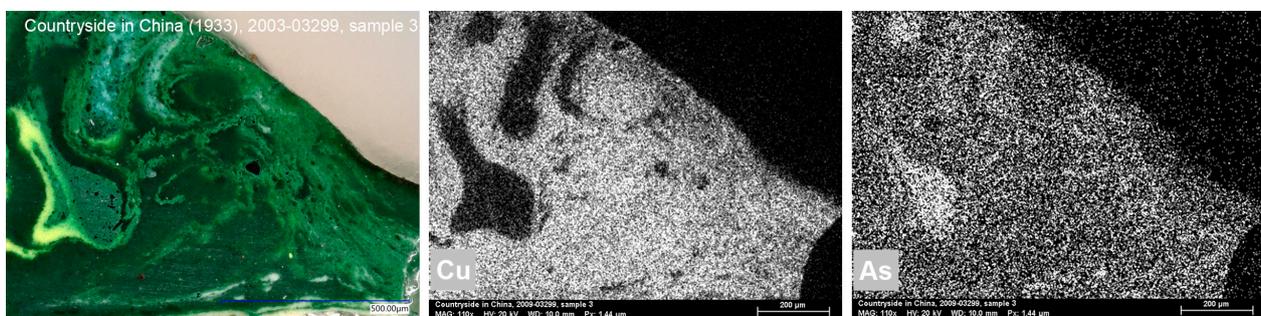


Figure 10. Optical microscopy image of the paint cross-section of sample 3 obtained from *Countryside in China*, 1933 and captured at 100 \times magnification (top-left), followed by SEM-EDS elemental distribution maps. The intensity of the signal of each element is represented by a range of grey tones: white represents high intensity and black represents low intensity. A concomitant presence of highly intensive copper and arsenic signals suggests the use of emerald green.

A green hue of sample 10 extracted from *Backyard* (1934), was achieved by mixing ultramarine, some Prussian blue and strontium yellow. The latter was verified by the SEM-EDS detection of Cr and Sr elements and FTIR absorption peaks at 903, 881, 873 and 840 cm^{-1} (Figure 11). Prussian blue was suspected based on the PLM characterisation of the particles, followed by trace Fe-signal and an IR absorption peak at 2089 cm^{-1} , whereas ultramarine was assumed based on strong S-, Na-, Si- and Al-signals, an IR absorption peak at 1000 cm^{-1} and PLM observation. The microscopic image of the paint cross-section shows partially mixed pigments allowing us to infer that the green was obtained on the palette by the artist (Figure 12).

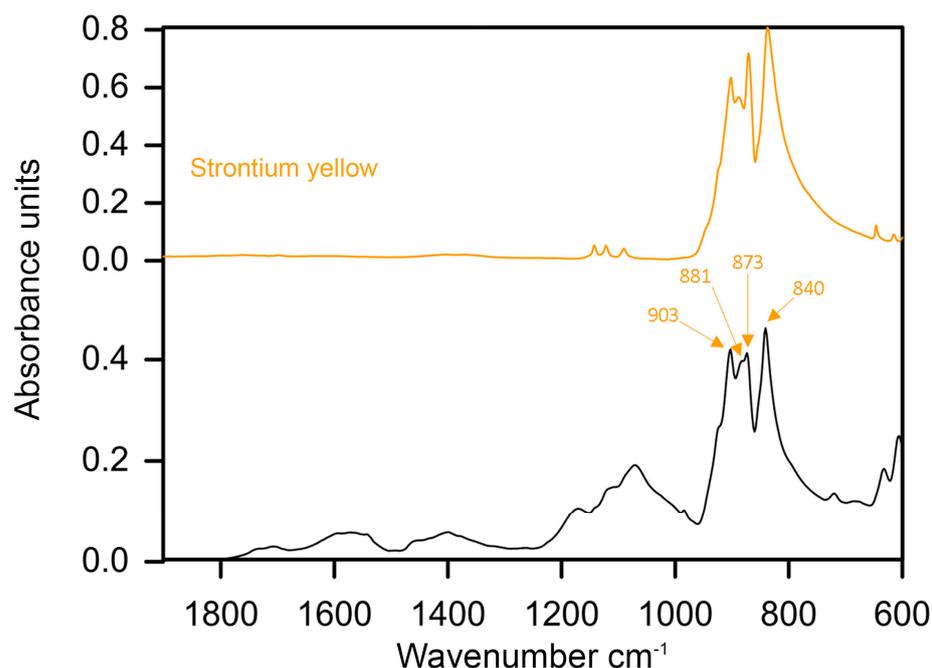


Figure 11. ATR-FTIR spectra obtained from the green paint of sample 10, extracted from *Backyard*, 1934 with labelled marker peaks of strontium yellow and reference spectra of the same pigment.

A combination of Prussian blue and yellow chromate pigment(s) is assumed in some green paint samples. Although Prussian blue was positively identified with FTIR, a precise attribution of yellow chromate pigments was challenging due to their overlapping bands and signal interferences of other compounds. For example, FTIR of the green paint in sample 4 from *Seaside* (1936) implies the presence of zinc yellow (PY36) (937, 872 and 820 cm^{-1}), chrome yellow (PY34) (839 and 820 cm^{-1}), barium yellow (PY31) or strontium yellow (872 and 839 cm^{-1}), chalk (PW18) (872 cm^{-1}) and viridian (797 cm^{-1}). In addition, a single IR absorption peak at 854 cm^{-1} detected in the green paint in the sample 6 from *Chinese house* (1934) and sample 6 from *Waterfall* (1936) as well as an absorption peak at 815 cm^{-1} detected in sample 3, extracted from *Countryside in China* (1933) may imply the use of chrome yellow and/or other yellow chromate pigments based on Zn, Ba and Sr [31,32].

Admixtures of yellow iron-rich earth pigments in the examined green paints were tentatively identified using PLM and SEM-EDS, whereas FTIR spectra could not provide sufficient information to determine the type of the pigment due to overlapping signals of other compounds.

3.2.3. Yellow and Brown

The principal components of yellow and brown brushstrokes were yellow iron-rich earth pigment and yellow chromate pigments. Brown hues were achieved with red iron-rich earth pigments, yellow chromate pigments and umber (PBr7). The latter was evidenced by co-presence of iron and manganese elements and IR absorption peaks at 3693, 3652, 3620, 1027, 1003, 910, 794, 750 and 667 cm^{-1} as in the sample 11 from *Working in the fields* (1933) (Figure 13) [33]. Moreover, the concomitant presence of calcium and phosphorus and the peculiar IR absorption peak at 1027 cm^{-1} are likely associated with bone black (PBk9) added to umber to produce a deeper shade of the brown paint.

Observation of red UV fluorescence of yellow particles in sample 15 from *Backyard* (1934) suggested Cd-based yellow [12]. Further SEM-EDS analyses detected Cd, S, Ba and Zn elements, which implied cadmium yellow (PY35) or cadmopone (co-precipitated cadmium sulfide and barium sulfate) or zinc-modified light cadmium yellow [34]. The pigment was used as an admixture with yellow chromate pigment(s) and red iron-rich earth pigment to obtain a brown hue.

A trace presence of emerald green in sample 8 from *Countryside in China* (1933) was considered as contamination as this green pigment was incorporated in the green passages (samples 3 and 4) and was found in the blue paint (sample 6) of the same composition. However, small concentrations of Prussian blue and viridian found in the brown paint (sample 5) from *Working in the fields* (1933) may be indicative of the intentional enhancement of the hue.

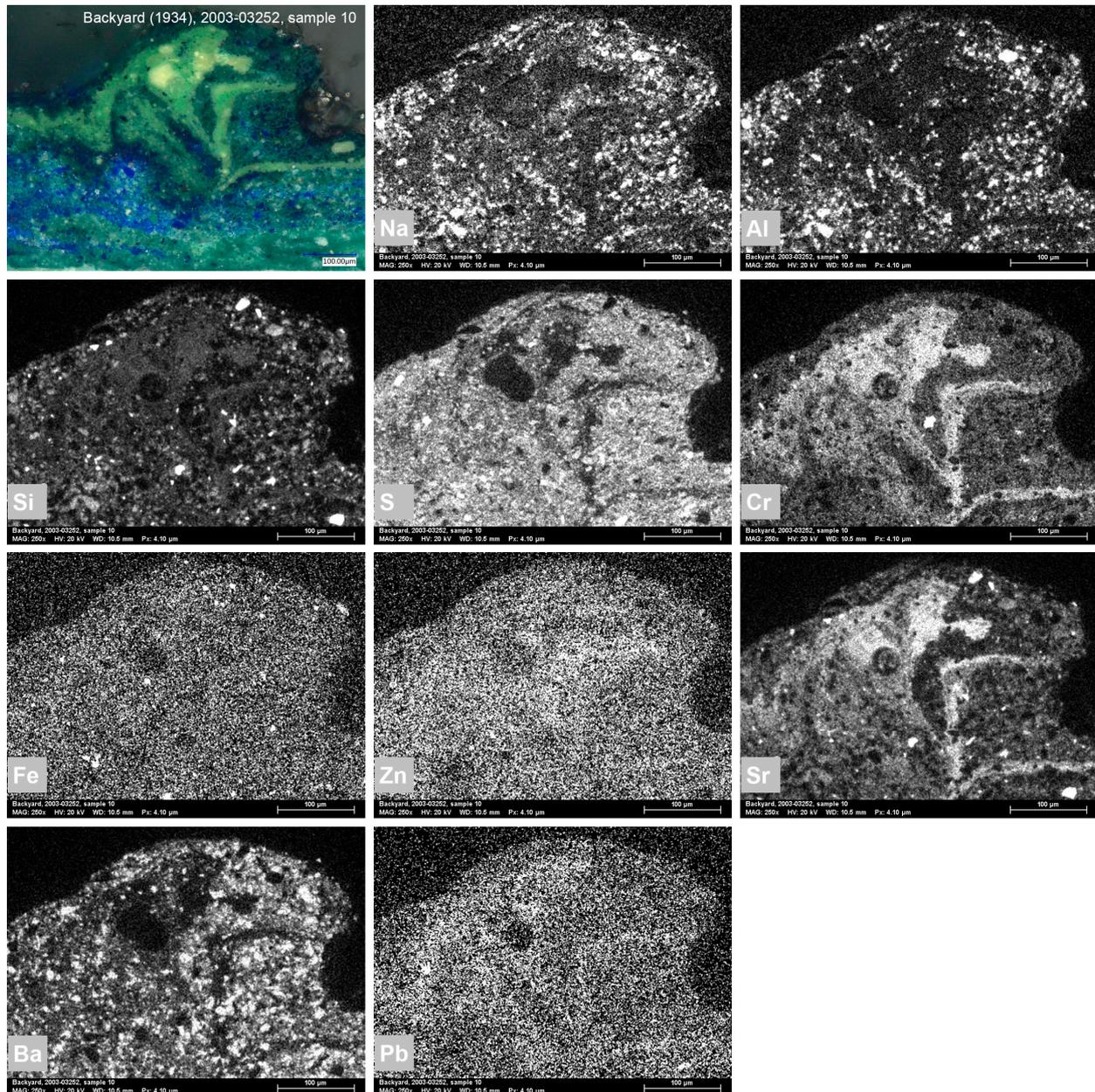


Figure 12. Optical microscopy image of the cross-section of sample 10, extracted from *Backyard*, 1934 and captured at 250 \times magnification (top-left), followed by SEM-EDS elemental distribution maps. The intensity of the signal of each element is represented by a range of grey tones: white represents high intensity and black represents low intensity. A co-presence of highly intensive Cr- and Sr-signals may indicate the use of strontium yellow. Na, Al, Si and S elements may suggest a presence of ultramarine. Fe-signal is attributed to Prussian blue.

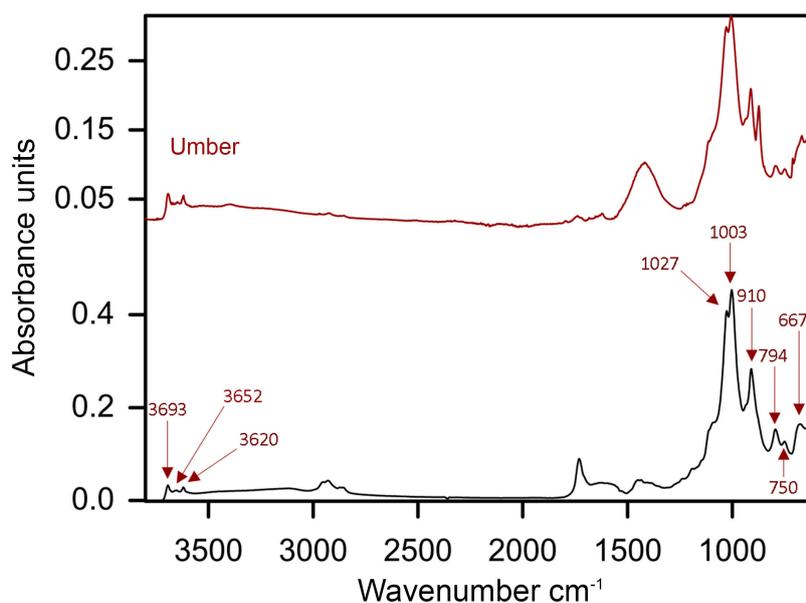


Figure 13. ATR-FTIR spectra of the brown paint of sample 11, extracted from *Working at the fields*, 1933, with labelled marker peaks of umber and reference spectra of the same pigment.

3.2.4. White and Black

The SEM-EDS elemental analyses of white paint samples revealed high concentrations of Zn coexisting with Ba and S elements, suggesting the use of lithopone (PW5) and/or barium white (PW21) and zinc white (PW4). The Zn element is commonly present in other investigated paint mixes; however, it is difficult to ascertain whether zinc white was used or whether zinc was present as part of the lithopone added by the manufacturer as an extender. Interestingly, an exclusive presence of zinc white was recorded in the white paint (sample 3) from *Seaside* (1936).

Low concentrations of Pb found in almost all investigated white paint samples may be indicative of trace presence of lead white (PW1). Frequent admixtures of lead white to zinc-based white paints may relate to the commercial modification of the latter. As zinc white is characterised by poor hiding power in the oil binder, manufacturers often employed lead white or titanium white to improve its properties [35]. Based on the SEM-EDS analyses, lead white features as the main compound only in the white paint (sample 5) from *Countryside in China* (1933). This finding was corroborated with the UVR imaging of the sampling area, which appears white, indicating highly reflective lead white (Figure 14) [12,13,15].

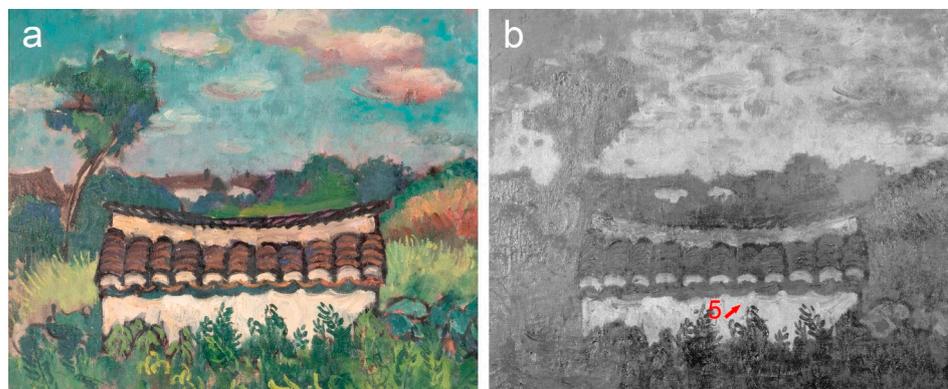


Figure 14. VIS (a) and corresponding UVR detail image (b) of *Countryside in China*, 1933, indicating a strong UV reflectance of white paint from the building (red arrow), suggesting a presence of lead white and/or lithopone.

Frequent occurrences of chalk at low concentrations were suspected based on the detection of Ca element. The presence of chalk may suggest its commercial use as an extender to other white pigments [36]. The detection of Ti only in the white paint (sample 14) from *Waterfall* (1936) seems to point to the minor addition of titanium white (PW6). This white pigment is known to be used as a commercial admixture of zinc white, barium white or lithopone to improve their properties [37]. According to the 1934 W&N catalogue, titanium white was extended with barium white (Appendix A, Figure A1), which is also present in the analysed sample. However, Lefranc listed this white pigment as pure titanium dioxide in the 1934 catalogue (Appendix A, Figure A3), whereas R&S did not sell it in the 1930s (Appendix A, Figure A2) [37]. Although titanium white was found in a single white paint sample, the SEM-EDS analyses lead us to believe that this pigment may be present in small amounts in other investigated colour mixtures. However, it is also known that titanium is a frequent impurity in mineral-based pigments [37].

Black brushstrokes were observed only in *Chinese house* (1934). The analyses of sample 5 from that painting revealed that instead of pure black pigment, the paint was composed of a mixture of Prussian blue, ultramarine, viridian and some bone black. The minimal admixture of bone black was suspected in other paint mixes to modify their shade.

3.3. Painting Technique

Although there is only one watercolour sketch for giving some insights into the artist's development of the composition and colour relationships prior to painting *Pagoda* (1936) (Figure 15), the execution of the remaining investigated artworks shows that the artist began painting with a clear idea of the intended compositions. Hence, the artist's reliance on the sketches is very likely.



Figure 15. (a) Liu Kang, *Pagoda*, 1936, watercolour, 28.5 × 18 cm. (b) Liu Kang, *Pagoda*, 1936, oil on canvas, 45 × 55 cm. Liu Kang family collection. Images courtesy of the Liu family.

Notably, no preparatory underdrawings have been detected in any of the paintings examined with VIS and NIR. Hence, it is assumed that the compositions were initially laid out with painterly contours, which were gradually coloured in, providing the base for further work. Although the compositions were well planned, they reveal spontaneous and rapid execution typical for outdoor painting within a limited time of a single sitting. This observation was confirmed by the OM of the paint layers, revealing partially mixed colours (Figures 10 and 12) and a wet-on-wet paint application. The appearance of immediacy is also reflected by the partially exposed white ground suggesting a lack of time for finishing touches to completely cover the painting support with paint. This can be exemplified by *Countryside landscape* (1933) and *Courtyard, Shanghai* (1933) (Figure 16). The compositions were achieved with washes of highly thinned colours, which were locally overlaid with a thick paint spread with brushes and palette knives in the subsequent stages. Although white ground provides additional contrast between the colours, it seems that this optical effect was not intentional, contrary to the paintings created in Paris [28].

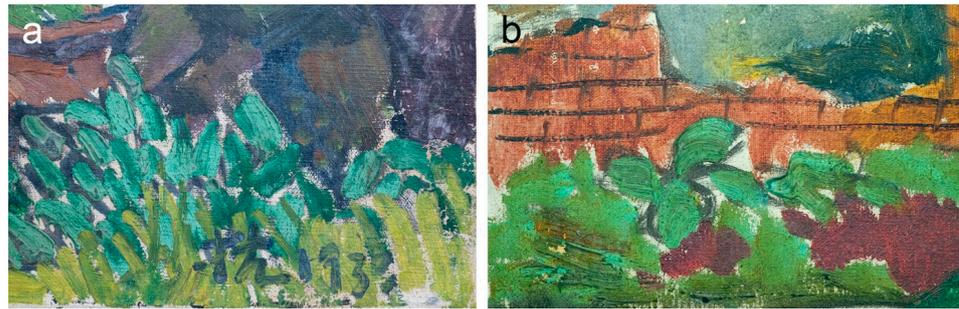


Figure 16. Details showing the intentionally exposed colour of the ground and thin application of colours in the painting process in: (a) *Countryside landscape*, 1933; (b) *Courtyard, Shanghai*, 1933.

Despite prevalent single-session execution of the investigated paintings, *Chinese house* (1934) is a rare example of a composition altered in a distinct stage in a wet-on-dry technique. The alteration concerned replacing the initially painted massive tree with the silhouettes of two young trees on the right side of the composition as reported earlier [38].

All paintings reflect the artist's ability with effortless and synthetic capturing of complex compositions. The painting *Seaside* (1936) is based on three colours—violet, turquoise and brown, whereas *Seascape in China* (1936) is based on a two-colour division—turquoise and yellow (Figures 2f and 3e). The complex composition of *Rustic landscape* (1934) is characterised by simplified colour passages, whereas the lack of painterly details was compensated by an attractive warm-cool interplay between the painted features (Figure 3d). Conversely, other paintings reveal the artist's ability to describe the forms by a combination of bold outlines, moderate impastos and scraping into wet paint (Figure 17). Although Liu Kang did not attempt to further develop the compositions, the paintings *Seaside* and *Seaside near Shanghai*, both from (1936), show his preference for maximising the potential of the subject matter and depict it from two different observation points (Figures 2f and 3f).



Figure 17. Details showing different descriptive painting techniques like calligraphic outlining, scraping into wet paint and building moderate impastos in: (a) *Chinese house*, 1934; (b) *Pagoda*, 1936; (c) *Seaside*, 1936.

4. Conclusions

A comprehensive investigation of Liu Kang's palette of colours and painting technique of his Shanghai artistic phase (1933–1937) was conducted. The analytical methods employed

proved complementary to each other and provided data that led to the characterisation of the artist's pigmentary palette.

Based on the analyses, it can be determined that Liu Kang's palette of colours is conventional and in accord with the materials available in Shanghai from local and imported brands in the 1930s. The colour mixes are straightforward and do not have unexpected complexity. Liu Kang's principal blue pigment was ultramarine; however, it was often admixed with viridian, some yellow iron-rich earth pigment, yellow chromate pigments or Prussian blue. The pigment compositions of green painted areas are based on viridian, which was frequently combined with ultramarine, Prussian blue, iron-containing earths or yellow chromate pigments. Yellow and brown colours were obtained mainly with yellow and red iron-rich earth pigments and yellow chromate pigments. Umber and bone black additionally appear in brown paint mixes. White paints were composed mainly of zinc and barium white, although lithopone is also possible, whereas lead white is considered an admixture. Pure black painted areas were not observed; however, dark brush strokes were achieved by mixing ultramarine with Prussian blue and some bone black. Emerald green and cadmium yellow or its variant were hardly used peculiarities. Red paint was not used in most of the investigated paintings except *Pagoda* (1936); however, the paint was not analysed due to the Liu family's preference for non-invasive techniques. Admixtures of red iron-containing earth pigments were found in brown painted areas. All investigated paint mixtures were bound in a drying oil.

As for Liu Kang's painting technique, the visual evidence allowed identification of some key features. Flat and broad paint application with brushes and palette knives were the most adequate for the outdoor execution of the paintings. Liu Kang worked rapidly within single sitting sessions and did not return to his compositions to apply finishing touches. *Chinese house* (1934) is an exception to this rule. The preferred methods of expression combined the incorporation of dark calligraphic outlines to isolate the forms and scraping into the wet paint to describe details and substitute laborious brushwork. He turned away from shading, which resulted in no identifiable light source falling on depicted forms.

The characterisation of pigment choices and painting technique of Liu Kang's Shanghai phase is an essential step towards expanding the knowledge of the artist's painting practice in the context of his entire artistic output. Furthermore, this study provides information about the art suppliers and the availability of painting materials in Shanghai during the period under review.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Summary of the materials identified or tentatively determined in the paint samples obtained from the investigated paintings.

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
<i>Working at the fields</i> , 2003-03258	1933	Blue	3	Zn, C, O, Pb , Ba, Na, S, Cr, Fe, (Ti, Ca, Al, Si, Sr, Mg)	Lithopone and/or barium white and zinc white, lead white, viridian, yellow chromate pigment(s), Prussian blue, titanium white, chalk	Lithopone and/or barium white and zinc white, lead white, Prussian blue, chalk, viridian and/or zinc yellow or strontium yellow, oil
		Blue	4	Zn, C, O, Na , Si, Al, (S, Cr, Ca, Ba, Pb, Fe, Ti)	Lithopone and/or barium white and zinc white, ultramarine, viridian, lead white, yellow iron-containing earth pigment, titanium white	
		Green	7	Zn, C, O , Cr, Na, Pb, Ba, Ca, S, (Si, Al, Ti)	Lithopone and/or barium white and zinc white, viridian, yellow chromate pigment(s), lead white, ultramarine, chalk, titanium white	Lithopone, and/or barium white and zinc white, chalk, lead white, yellow chromate pigment(s), ultramarine, oil, zinc soap
		Green	8	O, Zn, C, Ba , Pb, Cr, Na, S, Ca, Ti, (Fe, Si, Al, Sr, Cl, K)	Lithopone and/or barium white and zinc white, lead white, viridian, chalk, titanium white, Prussian blue, ultramarine	
		Yellow	10	Zn, C, O , Na, Pb, Ba, Fe, (Ca, S, Si, Cr, Al, Ti, Sr)	Lithopone and/or barium white and zinc white, lead white, chalk, yellow chromate pigment(s), yellow iron-containing earth pigment, titanium white	Lithopone and/or barium white and zinc white, chalk, lead white, yellow chromate pigment(s), iron-containing earth pigment, oil, zinc soap
		Brown	5	Zn, O, C , Na, Ca, Fe, Pb, Ba, Si, (Al, S, P, Sr, Mn, Cr, Mg, K, Ti)	Lithopone and/or barium white and zinc white, chalk, yellow iron-containing earth pigment, umber, lead white, Prussian blue, bone black, viridian, titanium white	Lithopone and/or barium white and zinc white, chalk, lead white, iron-containing earth pigment, viridian, Prussian blue, oil, zinc soap
		Brown	11	O, C, Fe , Si, Al, Zn, Ca, Ti, (Mg, Na, Sr, P, K, Mn)	Umber, bone black	Umber, bone black, oil
		White	2	Zn, C, O, Na , (Pb, Si, S, Ba, Sr, Ca)	Lithopone and/or barium white and zinc white, lead white, chalk	

Table A1. Cont.

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
<i>Countryside in China</i> , 2003-03299	1933	Blue	6	O, C, Ba, Si, Na, Al, S, Cr, Ca, Ti, (K, Pb, Cl, As, Cu)	Barium white, ultramarine, viridian, emerald green, titanium white, lead white	Ultramarine, chalk, oil
		Green	1	C, Zn, O, Na, Pb, Al, Ca, Fe, Ti, (Si, Mg, Cl, Sr, S, P, Cr)	Zinc white, lead white, ultramarine, Prussian blue, yellow chromate pigment(s), titanium white, bone black, viridian	
		Green	3	C, O, Cu, Pb, As, Cr, Ca, (Ba, Fe, S, Al, Si, Zn, Cl)	Emerald green, yellow chromate pigment(s), Prussian blue, chalk, ultramarine	Emerald green, yellow chromate pigment(s), Prussian blue, ultramarine, lithopone and/or barium white and zinc white, chalk, oil
		Green	4	O, C, Cr, Pb, Ba, Zn, Ca, Na, (S, Si, Cu, Al, As, Sr, Ti, Fe, Mg, Cl, K)	Viridian, lead white, lithopone and/or barium white and zinc white, chalk, emerald green, titanium white, yellow iron-containing earth pigment, ultramarine	Viridian, lead white, lithopone and/or barium white and zinc white, chalk, ultramarine, oil
		Yellow	7	Pb, O, C, Ca, Cr, (Ba, Na, Cl, Si, Al)	Yellow chromate pigment(s), chalk, barium white	
		Brown	8	C, Pb, O, Ca, Fe, Ba, Si, Cr, (Al, As, Na, Ti, P, Cu, Mg)	Lead white, red iron-containing earth pigment, barium white, yellow chromate pigment, emerald green, titanium white, bone black	
		White	5	Pb, C, O, Ca, (Si, Mg, Cl, Al)	Lead white, chalk	
<i>Backyard</i> , 2003-03252	1934	Blue	11	Zn, C, O, Na, Ba, Sr, Cr, S, Pb, (Si, Ti, Al, Ca)	Lithopone and/or barium white and zinc white, yellow chromate pigment(s), ultramarine, lead white, titanium white, chalk	Lithopone and/or barium white and zinc white, strontium yellow, ultramarine, oil, zinc soap
		Green	9	O, C, Pb, Sr, Cr, Ba, S, Ca, Si, Fe, Al, Zn, (Na, Mg, K, Ti, Cl, P)	Lead white, yellow chromate pigment(s), lithopone and/or barium white and zinc white, Prussian blue, yellow iron-containing earth pigment, titanium white, bone black	
		Green	10	C, O, Ba, Sr, Cr, S, Si, Na, Pb, Al, Ti, Zn, Ca, Fe, K)	Lithopone and/or barium white and zinc white, yellow chromate pigment(s), ultramarine, lead white, titanium white, chalk, Prussian blue	Lithopone and/or barium white and zinc white, strontium yellow, ultramarine, Prussian blue, chalk, lead white, oil

Table A1. Cont.

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
<i>Backyard, 2003-03252</i>	1934	Brown	6	O, Zn, C , Ba, Pb, Na, Ca, Fe, S, Si, Al, (Mg, Ti, Cr, Sr, P, K, Cl)	Lithopone and/or barium white and zinc white, lead white, chalk, red iron-containing earth pigment, titanium white, yellow chromate pigment(s), bone black	Lithopone and/or barium white and zinc white, lead white, chalk, iron-containing earth pigment, bone black, yellow chromate pigment(s), oil
		Brown	15	O, Ba, C , Fe, S, Pb, Si, Zn, Ca, Cr, Na, Ti, Al, (Cd, P, K)	Lithopone and/or barium white and zinc white, red iron-containing earth pigment, lead white, yellow chromate pigment(s), titanium white, cadmium yellow or its variant, bone black	
		White	14	Zn, C, O, Na , (Ca, Ba, Pb, S, Si)	Lithopone and/or barium white and zinc white, chalk, lead white	
<i>Chinese house, 2003-03328</i>	1934	Blue	3	Zn, C, O , Na, Ba, S, Cr, (Si, Ca, Al, Ti, Sr, Pb, Cl)	Lithopone and/or barium white and zinc white, ultramarine, viridian, yellow chromate pigment(s), chalk, titanium white, lead white, chalk	Lithopone and/or barium white and zinc white, ultramarine, viridian or yellow chromate pigment(s), lead white, chalk, oil, zinc soap
		Green	6	C, Zn, O , Pb, Ba, Na, Cr, S, (Ca, Fe, Al, Si, Ti, Sr, K, Mg)	Lithopone and/or barium white and zinc white, lead white, yellow chromate pigment(s), chalk, Prussian blue, titanium white	Lithopone and/or barium white and zinc white, Prussian blue, yellow chromate pigment(s), oil
		Green	7	C, O, Ba , Cr, Zn, S, Pb, Na, (Sr, Fe, Ti, Si, Al, Ca, Mg)	Lithopone and/or barium white and zinc white, viridian, lead white, yellow iron-containing earth pigment, ultramarine, chalk	
		Green	8	Zn, C, O , Pb, Na, Ba, S, Cr, (Ca, Si, Fe, Al, Ti, Mg)	Lithopone and/or barium white and zinc white, lead white, viridian, chalk, Prussian blue, ultramarine, titanium white	
		Yellow	4	Zn, C, O , Na, Si, Ba, Fe, (Al, S, Sr, Pb, Ti)	Lithopone and/or barium white and zinc white, yellow iron-containing earth pigment, lead white, titanium white	Lithopone and/or barium white and zinc white, iron-containing earth pigment, lead white, oil, zinc soap

Table A1. Cont.

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
Chinese house, 2003-03328	1934	Brown	12	C, O, Zn, Fe, Na, Si, Ba, Ca, S, Al, Cr, (Sr, Pb, Mn, P, Ti, Cl)	Lithopone and/or barium white and zinc white, yellow chromate pigment(s), umber, bone black, titanium white	
		Black	5	C, O, Zn, Na, Ba, Fe, S, Cr, Si, Ca, (Al, Pb, Sr, Ti, P)	Lithopone and/or barium white and zinc white, Prussian blue, viridian, ultramarine, lead white, bone black	
Waterfall, 2003-03247	1936	Blue	3	C, O, Ba, S, Zn, Ca, Ti, Na, (Si, Sr, Pb, Fe, Al, Cl, Cr)	Lithopone and/or barium white and zinc white, chalk, titanium white, ultramarine, yellow iron-containing earth pigment, Prussian blue, viridian	
		Blue	4	C, O, Ba, S, Zn, Ca, Pb, Ti, Na, Si, (Fe, Al)	Lithopone and/or barium white and zinc white, chalk, lead white, titanium white, ultramarine, Prussian blue, yellow iron-containing earth pigment	Lithopone and/or barium white and zinc white, chalk, lead white, ultramarine, Prussian blue, oil
		Blue	5	Zn, C, O, Na, (Ca, Si, Ba, S, Al, Cr, Sr, Pb, Mg, Fe)	Lithopone and/or barium white and zinc white, ultramarine, chalk, viridian, yellow iron-containing earth pigment	
		Green	6	O, C, Ba, Pb, S, Cr, Zn, Ti, Fe, Si, (Ca, Sr, Na, Al, P)	Lithopone and/or barium white and zinc white, lead white, chalk, yellow chromate pigment(s), titanium white, Prussian blue, bone black	Lithopone and/or barium white and zinc white, lead white, chalk, yellow chromate pigment(s), Prussian blue, oil
		Green	11	O, C, Ba, Pb, S, Fe, Cr, Ti, Zn, Al, Si, (Sr, Ca, K)	Lithopone and/or barium white and zinc white, lead white, Prussian blue, viridian, titanium white, chalk	Lithopone and/or barium white and zinc white, lead white, chalk, Prussian blue, oil
		Green	12	O, C, Ba, Cr, S, (Sr, Ca, Ti, Si, Fe, Zn, Na, Pb, Al)	Lithopone and/or barium white and zinc white, viridian, chalk, titanium white, yellow chromate pigment(s), yellow iron-containing earth pigment, lead white	

Table A1. Cont.

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
Waterfall, 2003-03247	1936	Brown	13	C, O, Ba , Zn, S, Ca, Fe, Na, Si, Ti, (Al, P, Pb, Cl)	Lithopone and/or barium white and zinc white, chalk, yellow iron-containing earth pigment, bone black, lead white	Lithopone and/or barium white and zinc white, chalk, iron-containing earth pigment and/or bone black, oil
		White	14	C, O, Ba, Zn , S, Ca, Na, Ti, (Sr, Cl, Si, Al, Fe, Pb, Cr, P)	Lithopone and/or barium white and zinc white, chalk, titanium white, ultramarine, yellow iron-containing earth pigment, lead white, viridian	
Seaside, 2003-03318	1936	Blue	1	Zn, C, O , Na, (Si, S, Al, Ca, Ba)	Lithopone and/or barium white and zinc white, ultramarine, chalk	Lithopone and/or barium white and zinc white, ultramarine, chalk, oil
		Blue	6	C, Zn, O , Na, Ba, Cr, S, (Si, Ca, Al, Fe, Ti, Sr)	Lithopone and/or barium white and zinc white, ultramarine, viridian, yellow iron-containing earth pigment, titanium white	
		Green	2	Zn, C, O , Na, Ba, Cr, S, (Ca, Ti, Fe, Si, Sr, Pb, Mg)	Lithopone and/or barium white and zinc white, ultramarine, viridian, titanium white, yellow iron-containing earth pigment, lead white	
		Green	4	Zn, O, Ba , Pb, Na, S, Cr, C, Fe, Ti, (Si, Al, Sr, Ca, Mg, K)	Lithopone and/or barium white and zinc white, lead white, yellow chromate pigment(s), viridian, Prussian blue, titanium white, chalk, bone black	Lithopone and/or barium white and zinc white, lead white, chalk, yellow chromate pigment(s), viridian, Prussian blue, oil
		Brown	5	C, Zn, O , Na, Fe, Ba, Ca, Si, (S, Al, Pb, Mn, Cr)	Lithopone and/or barium white and zinc white, chalk, umber, lead white	Lithopone and/or barium white and zinc white, iron-containing earth pigment, oil, zinc soap
		White	3	Zn, C, O , (Si)	Zinc white	

* Major elements are presented in bold type, minor elements in plain type and trace elements in brackets.

Winsor & Newton, Ltd.	
<i>Emerald Green</i>	Aceto-Arsenite of Copper.
<i>Strontian Yellow</i>	Chromate of Strontium.
<i>Titanium White</i>	A combination of Titanium Oxide and Barium Sulphate, sometimes sold as Permalba.

Figure A1. Selected pigment compositions, listed in the catalogue of W&N from 1934.

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Alizarin Blue.	Brown Pink.	} SERIES C.			
Alizarin Brown Madder.	Crimson Lake.		Tubes No. 2 each	0	4½
Alizarin Crimson	Emerald Green.		„ „ 4A	0	7½
Alizarin Green Pale.	French Ultramarine.		„ „ 8	1	0
Alizarin Green Mid.	Gamboge Tint.		„ „ 12	1	4
Alizarin Green Deep.	Italian Lake.		„ „ 24	2	6
Alizarin Orange.	Mars Violet.		„ „ 48	5	0
Alizarin Purple Lake.	New Blue.				
Alizarin Purple Madder.	Olive Green.				
Alizarin Scarlet Madder.	Permanent Blue.				
Alizarin Yellow.	Sap Green.				

Figure A2. Selected oil colours, listed in the catalogue of R&S from 1934.

10

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COMPOSITION CHIMIQUE	DÉSIGNATION DES COULEURS	N° 10	N° 6	N° 3	N° 2
		fr. c.	fr. c.	fr. c.	fr. c.

Carbonate de plomb.....	M** Blanc d'argent (1).....				
Oxyde de titane non chimiquement pur.....	M** — — fluide ou épais ** — de titane.....				
Oxyde de zinc.....	M** — de zinc.....				

Chromate de plomb.....	* Jaune de chrome.....				
	clair, moyen, foncé, orangé.				
Chromate de zinc.....	* — citron ou de zinc.....				
Colorant hydrazinique, alumine...	** — indien simili.....				
Oxyde de fer précipité.....	M** — de Mars.....				
Carb. et chrom. plomb, carb. chaux	* — minéral.....				
Antimoniate plomb, sulfate chaux..	M** — de Naples.....				
Carbonate et chromate de plomb...	* — — vert.....				
Col. anthraquinone. sur alumine..	** — permanent clair.....				
Col. azoïque sur alumine.....	** — — moyen.....				
Chromate de strontiane.....	* — de strontiane.....				

Chromate de plomb et cyanure de fer	* Vert anglais (5 nuances).....				
Sulfure de cadm. Oxyde de chrome.	** — de cadmium (vert permanent moyen)				
— — — — —	** — — — clair (vert perm. clair)				
Colorant oxy-azoïque, alumine.....	** — de Chine.....				
Oxyde de chrome.....	M** — de chrome.....				
Combinaison de zinc et de cobalt...	M** — de cobalt.....				
— — — — —	M** — — pâle.....				
Oxyde de chrome hydraté.....	M** — émeraude (vert permanent foncé)..				
— — — — —	M** — — pour glacis....				
Acétate de cuivre.....	— de gris.....				
Malachite naturelle.....	** — malachite..				
Arséniate de cuivre.....	— minéral.....				
— — — — —	* — de Scheele.....				
Acéto-arséniate de cuivre.....	** — Véronèse.....				

Figure A3. Selected oil colours and their pigment compositions, listed in the catalogue of Lefranc from 1934.

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