James McNeill Whistler: fluidity, finish and experiment

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ABSTRACT James McNeill Whistler was meticulous in his choice and use of oil painting materials. The late 1870s and early 1880s seem to introduce a period of experimentation, characterised by strongly diluted paints in the full-length portraits of that period, and resulting in a richer language in paint handling in Whistler's later works. Through scientific analyses combined with art-historical research, as well as material from the Whistler correspondence, this paper addresses the process of experimentation as well as the visual impact of Whistler's exploitation of the increased fluidity and transparency of his oil paints, and of his choice of unusual materials to enhance these effects. The research centres on Whistler's full-length portrait *Arrangement in Yellow and Grey: Effie Deans* (Rijksmuseum, Amsterdam) as a key case study.

Introduction

The American painter James McNeill Whistler is acknowledged as one of the most innovative and influential artists of the nineteenth century. Based in London and Paris, he was a central and articulate figure in a wide-ranging circle of artists, including Pre-Raphaelites, French Realists and Impressionists. Whistler developed his own language of art in his roles as public speaker, author, celebrity and teacher. In contemporary literature, he is often portrayed as an arrogant and dandyish character going against academic conventions merely as an act of public relations. Whistler's friend the American painter William Merritt Chase (1849–1916), portrays Whistler rather accurately: 'There were two distinctive sides to Whistler. One was Whistler in public – the fop, the cynic, the brilliant, flippant, vain and careless idler; the other was Whistler in the studio – the earnest, tireless, sombre worker.'[1] And indeed the latter description characterises the highly skilled and innovative draughtsman, painter, etcher and lithographer that was Whistler.

Relatively little is known about Whistler's studio practice, which has so far been studied in focused projects on specific subjects such as Tate Britain's 'Nocturnes', Whistler's use of canvas textures and conservation methods, and his interest in Henri Lecoque de Boisbaudran's method of memory drawing.[2] Yet the full-length portraits of the 1870s–1880s, which signal an important change in Whistler's technique, have received little attention. In this paper we will address a short period of experimentation in the late 1870s, with a technical case study of *Arrangement in Yellow and Grey: Effie Deans* (Rijksmuseum, Amsterdam), which shows Whistler's trials with extremely diluted paints and unusual pigments, resulting in varying states of finish and fluidity, and extending his paint handling repertoire.

The concept of finish

The concept of 'finish' is one that pervades contemporary criticism on Whistler's work, as his use of thin washes and fluid paints often led to an almost ephemeral quality with an emphasis on colour instead of drawing. How this was perceived can be illustrated through the Ruskin vs Whistler trial (25–26 November 1878).[3] During an exhibition at the Grosvenor Gallery in London in 1877, the art critic John Ruskin critiqued Whistler's *Nocturne in Black and Gold: The Falling Rocket* (now at the Detroit Institute of Arts), for sale at the grand price of 200 guineas. It was described in *Punch* as 'Above, all fog, below, all inky flood; For subject – it had none.'[4] Ruskin stated: 'I have seen, and heard, much of Cockney impudence before now; but never expected to hear a coxcomb ask two hundred guineas for flinging a pot of paint in the public's face', after which Whistler sued Ruskin for libel.[5] The rather entertaining court case centred on the relationship between labour and monetary value and the definition of a finished painting. Whistler, never lost for a reply, justified his price of 200 guineas for two days work by stating: 'I ask it for the knowledge I have gained in the work of a lifetime.'[6] Several witnesses and Whistler himself also commented on the concept of finish in the three full-length portraits also included in the exhibition. Tom Taylor, art critic and editor of *Punch*, and witness for Ruskin, noted: 'Mr. Whistler's full-length arrangements suggest to us a choice between materialised spirits and figures in a London fog … All Mr. Whistler's work is unfinished. It is sketchy.'[7] Edward Burne-Jones commented on the *Nocturne in Blue and Silver*: 'I think the picture has many good qualities. It is masterly in some respects, especially in colour. It is a beautiful sketch; but that is not sufficient to make it a good work of art. It is deficient in form, and form is as essential as colour.'[8] When confronted with a

portrait by Titian brought in by the prosecutor for a comparison, Burne-Jones, adding a little twist by using the term arrangement, describes the degree of finish in the Titian as exemplary: 'It is a most perfect specimen of a highly finished work of ancient art … This is an arrangement in flesh and blood.'[9] Whistler himself however, articulated in a letter to Edward Linley Sambourne: 'To be confronted with Titian as … a last means of extermination was … a variation in vanity … flattering even to a Coxcomb.'[10]

Fluidity

Anecdotes talk about Whistler's use of strongly diluted paint, his 'sauce', composed, according to his assistant Walter Greaves, of tube paint with added linseed oil and turpentine. The Pennells, Whistler's biographers, state that Whistler described it as a mixture of copal, mastic resin and turpentine.[11] Whistler's own statement, 'A picture is finished when all trace of the means used to bring about the end has disappeared',[12] supports his use of the 'sauce' as its fluidity would obliterate any trace of the brush. Interestingly, in the early nocturnes, often connected with this technique, clear brushstrokes seem to be used as a compositional device. Scientific analyses of several nocturnes have shown the presence of mastic resin, lead drier and stand oil as the possible composition of this 'sauce', while no copal was identified.[13] Brushstrokes become more difficult to discern in the nocturnes and full-length portraits from the late 1870s and early 1880s. Especially in the full-lengths made around the time of the Ruskin trial, the fluidity of the paint shows in areas of dripping that have not been rubbed or painted out, often leading to the assumption that these works are unfinished. Yet, several were signed, exhibited and sold by Whistler, which suggests otherwise.

Whistler employed or manipulated 'accidental' effects in his works in other media, such as in his use of acid and foul biting in etching copper plates. Leaving such effects and 'drip' marks in order to accentuate a spontaneous freshness is particularly visible in paintings from the 1870s. There is also a strong connection between Whistler's use of diluted paints and his practice as a watercolourist. Instead of the typical Victorian watercolour technique of quite dry, opaque and layered paint application, Whistler used watercolours as transparent washes, the paint often pooling or dripping. Always striving for better ways to achieve the desired effects, he started to use his oils in a similar manner, diluting them so that they almost stained the canvas. Walter Sickert, who met Whistler in 1879 and became his pupil in 1882, was rather negative about this particular technique and stated that Whistler had lost 'the art of oil painting to paint with coat upon coat of paint, considerably thinned with oil and turpentine', calling this technique the 'muffling of the painting in the indecision of universal glaze.'[14] Whistler, however, described his thin paint layers as 'breath on the surface of a pane of glass'.[15] These paintings mark the beginning of a short period of experimentation that led to a very distinct language in paint handling.

Experimentation

The portraits from the late 1870s

The use of fluid and transparent paints occurs especially in the group of full-length portraits made between 1876 and 1880, some of which were exhibited at the Grosvenor Gallery in 1877, including *Arrangement in Black No.3*, *Portrait of Henry Irving as Philip II of Spain*, *Arrangement in Brown: The Fur Jacket* and *Arrangement in Amber and Black*. Several others from that period, including *Arrangement in Yellow and Grey: Effie Deans*, show similar use of fluid paints often with extensive dripping.[16]

Figure 1 James McNeill Whistler, *Arrangement in Yellow and Grey: Effie Deans*, *c.*1876–1878. Oil on canvas, 194 × 93 cm, Rijksmuseum, Amsterdam.

Figure 2 Photograph of James McNeill Whistler, *Arrangement in Yellow and Grey: Effie Deans*, Glasgow University Library, showing the painting in an early state before the signature and inscription were added. Courtesy of Glasgow University Library.

Figure 3 Photograph of James McNeill Whistler, *Arrangement in Yellow and Grey: Effie Deans*, Lucas Collection, Baltimore, showing the picture in a later state than in Figure 2, with some lighter areas in the bodice and more black wash added, dripping extensively on the right-hand side. Courtesy of Lucas Collection, Baltimore.

Anecdotes on Whistler's portrait painting inform us on his methods. Henry Irving describes to Mortimer Menpes how Whistler, 'After twenty sittings … swept the canvas bare'. This contradicts Alan Cole's comment on the same portrait (1876): 'Whistler was madly enthusiastic about his power of painting such full lengths in two sittings or so.'[17] The painting was shown at the Grosvenor Gallery probably in the state seen in a photograph signed by Whistler 'Present state – Unfinished'. During the Ruskin trial Whistler states: 'Is the picture of Irving as Philip II a finished picture? It is a large picture, a sketch, but it was not intended as a finished picture and it was not exhibited for sale.'[18] On *Harmony in Amber and Black* and the *Arrangement in Brown* he says: 'These were impressions of my own. I make them my study. I suppose them to appeal to none but those who may understand the technical matter',[19] and in a letter to Glasgow art dealer Alexander Reid he refers to *Arrangement in Brown: The Fur Jacket* as 'more of an artist's picture'. The interpretation of these statements is crucial as they do not refer to 'finish', but to 'technical matter'; to the 'artist's pictures' as studio experiments.

Effie Deans

Arrangement in Yellow and Grey: Effie Deans (Rijksmuseum, Amsterdam) portrays Whistler's mistress Maud Franklin (Fig. 1). In an early photograph, a series of long narrow drips can be seen at the bottom left, dripping from the dark, shadowy background that surrounds the cloaked figure (Fig. 2). A later photograph shows a lighter tone on the model's bodice and conspicuous black drips on the right side of the figure (Fig. 3). Apparently Whistler was darkening the background with extremely thin washes of paint, to enhance the contrast with the figure while retaining the soft outlines at the edges of the dress. The photographs show several areas, particularly in the folds of the dress, where the shadows have been darkened and the highlights accentuated. Whistler could easily have brushed out the drips if he had wanted – the painting, after all, was rubbed down and changed more than once. This was a method he may have acquired from his friend Henri Fantin-Latour, a pupil of Henri Lecoque de Boisbaudran (1802–1897), who in his *Letters to a Young Professor*, 1877, instructs:

> The usual way to begin is a general 'rub in' of the form and tones. When this 'rub in' is dry, and its surface has been cleaned, or if one wishes, rubbed down, it serves as a preparation for new work, either in solid colour, or with thin opaque colour and glazings.[20]

It is not known exactly when Whistler painted *Arrangement in Yellow and Grey*, but there is a strong likelihood that it was painted in 1876 when Maud was pregnant. Possibly Whistler worked on it up until 1877, but after his bankruptcy in 1878, the painting was out of his hands for many years. In 1889, when it was exhibited and sold to a distinguished Dutch collector, Whistler signed it with a butterfly and added the inscription with the text of Sir Walter Scott.

Scientific analyses

The drips of carbon black-containing paint mixtures seem to make furrows in underlying paint, which are even more prominently visible in infrared images (Fig. 4).[21] Staining tests on cross-sections suggested an oil medium,[22] and the presence of regular linseed oil was confirmed by gas chromatography–mass spectrometry (GC–MS).[23] A small addition of beeswax was also identified. The extreme fluidity must have been achieved by greatly diluting the paint mixture with volatile solvents such as oil of turpentine or spike oil. After evaporation of the solvent the paint surface

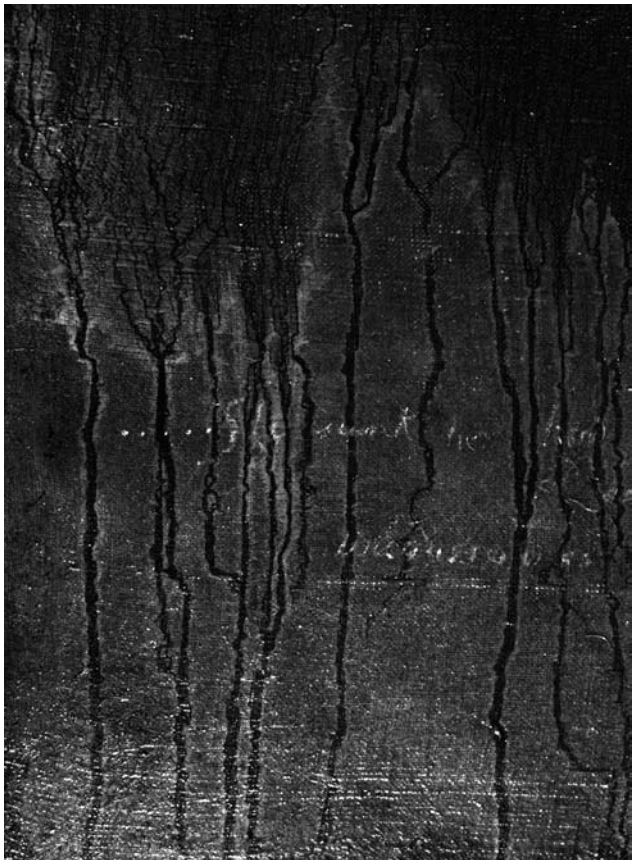


Figure 4 Infrared photograph of the drips on the bottom left of the painting, showing the furrows in underlying paint made by the added black wash.

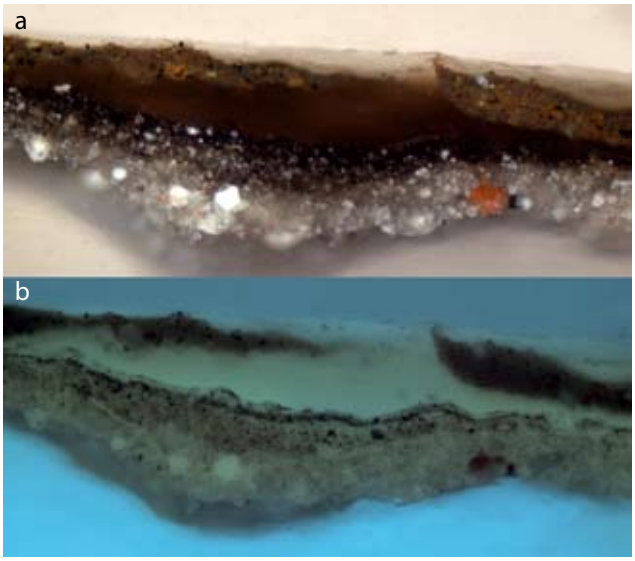


Figure 5 Cross-section of a sample from the signature in normal light (a) and ultraviolet light (b), showing the various stages of paint application. The lightest warm grey layer at the bottom of the layer structure is the ground. This is followed by very dark grey paint, a thin black layer and then an even thinner black wash. These last two layers are more evident under ultraviolet light and were responsible for the dripping. The thick highly fluorescent translucent yellow-brown layer is probably oiling out before applying the opaque brown paint of the signature (visible at the top of the cross-section), added in 1889.

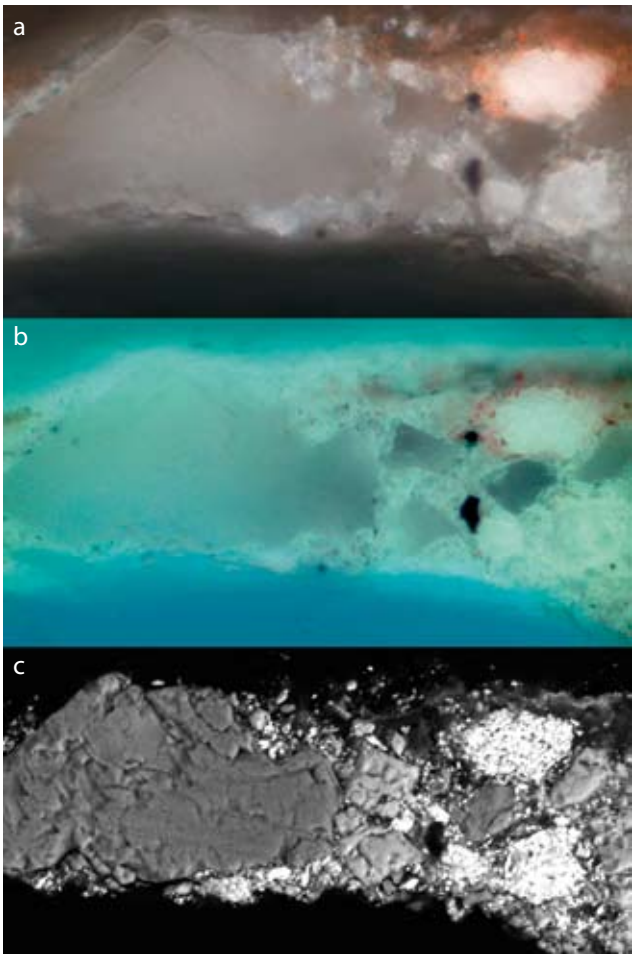


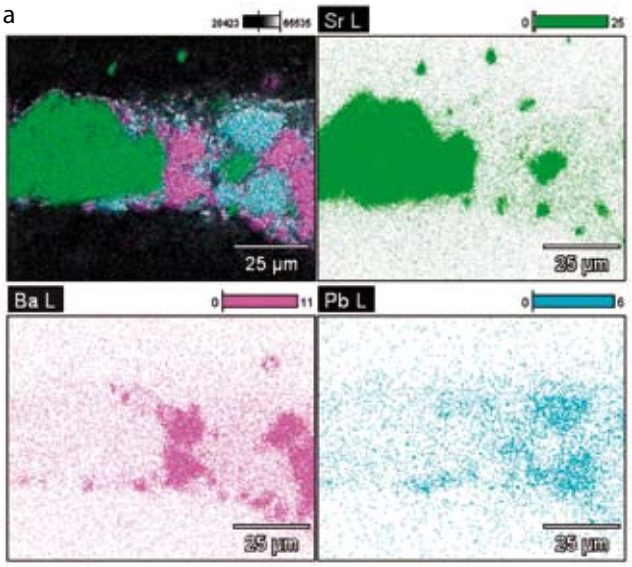
Figure 6 Cross-section of a sample from a light area in the fold of the skirt: (a) normal light; (b) ultraviolet light; (c) backscattered image in the scanning electron microscope. Strontium and barium sulphates, as well as lead and zinc, are present in the ground layer and the light paint layer on top.

would have had a matt velvety appearance, enhanced by the beeswax. Another notable feature of the *Effie Deans* portrait is its remarkable appearance in ultraviolet light, where the painting shows an array of fluorescent tones, indicating a repeated application of partially overlapping thin layers. The cross-section from the signature area (Fig. 5), demonstrates the various campaigns illustrated in Figures 1–4. Elemental analysis of the greyish ground layer confirmed the presence of strontium, barium, zinc, lead and small amounts of iron oxide and ivory black (phosphorus was identified in the black particles by energy dispersive X-ray (EDX) analysis in the scanning electron microscope (SEM)). Three paint layers follow: a dark grey black then a thin blackish layer that caused some dripping, followed by an even thinner black wash which added more dripping especially on the right. On top there is a highly fluorescent transparent layer, probably an oiling out layer, which he applied before adding the signature in 1889. The paint of the latter is much leaner and lower in fluorescence.

In most cases the paint stratigraphy consists of just two or three thin paint layers using a fairly limited palette: white, yellow ochres, red and brown earth pigments and black. X-ray fluorescence (XRF) spectra collected from a cross-section taken from a light area on the fold of the skirt show the presence of lead, iron, barium, strontium, calcium and zinc (Fig. 6). Interestingly, most of the samples showed the presence of barium (Ba) in the XRF spectra.[24] Examination of pigment particles with polarised light microscopy (PLM) gave a strong indication of the presence of natural mineral barites.[25] This was further confirmed with X-ray diffraction (XRD) analysis.[26] The barium sulphate pigment consists of rather large particles and seems to be mixed with conventional lead white. Church mentions permanent white or blanc fixe consisting of lead white and either precipitated barium sulphate, or heavy spar or native barium sulphate, the latter, as seems to be the case here, used in cheaper mixtures.[27] The particulate characteristics of this paint mixture allowed it to be thinned to a very large extent without becoming slick and smooth, and without losing its matt appearance.

Celestine

X-ray fluorescence analysis also indicated the recurrent presence of strontium (Sr), often associated with Ba. Further examination of the cross-sections with SEM–EDX indicated that the strontium was a constituent element, together with sulphur, in surprisingly large angular pigment particles (Figs 7a and b).[28] These particles appeared as tabular, occasionally pyramidal crystals. On the basis



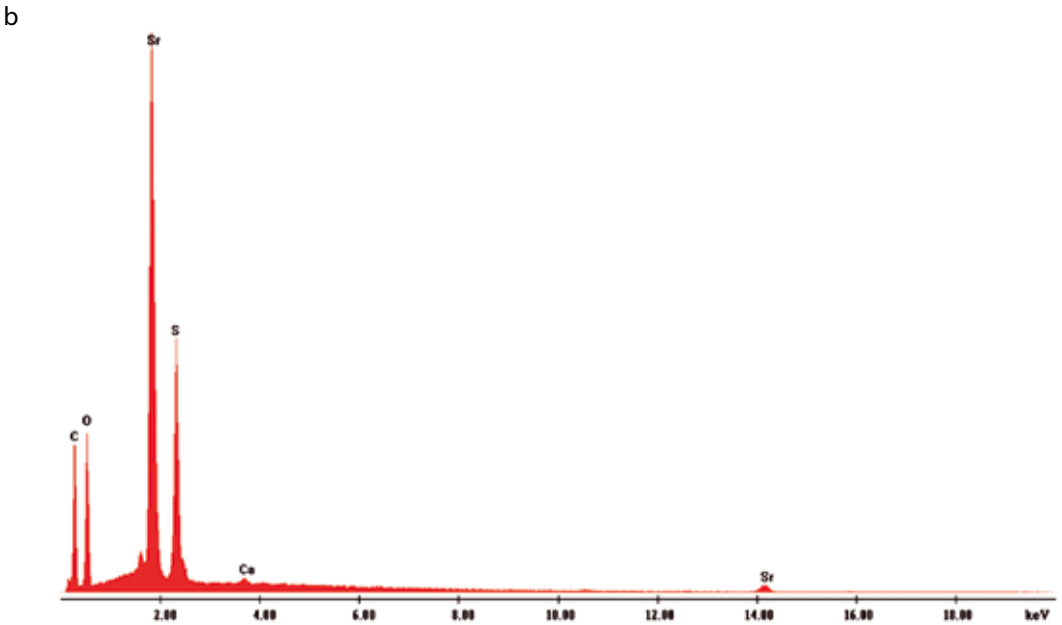


Figure 7 (a) Elemental SEM–EDX maps of the cross-section shown in Figure 6. The image at the top left shows the maps overlaid onto the BSE image; (b) SEM–EDX spectrum indicating the presence of only strontium and sulphur in the large transparent particles present in the ground layer. These transparent particles are also present in the cross-section shown in Figure 5, in the light ground layer.

of their chemical composition (analysed by XRF and SEM–EDX), their optical properties as observed in polarised light microscopy (PLM), and their structural composition as determined by XRD, this pigment could be identified as celestine (strontium sulphate, $SrSO_4$).[29] To our knowledge the use of this mineral as a white pigment on easel painting has not been reported.[30] The presence of strontium has been detected in the ground layers of Van Gogh's paintings, and has been interpreted as an impurity in mineral barite.[31] However, the celestine in the paint of the *Effie Deans* portrait seems to be a mixture of large celestine crystals and smaller amounts of tiny barite particles. The large differences in particle size and their morphology strongly suggest a crushed natural mineral. The glassy transparent, orthorhombic mineral ($SrSO_4$) comes in different colours, its name alluding to the faint sky blue colour (celestial) it often has due to the presence of trace components, primarily K^+ substituting for Sr^{2+} in the celestine lattice.[32] Many of the celestine particles present here are, however, colourless.

Celestine often occurs as a secondary mineral in sedimentary environments in the presence of other sulphate minerals such as barite and anglesite, sharing some mineralogical properties.[33] Large mineral deposits of celestine and barite are found and mined in an area north east of Bristol, Somerset, and Yate in Gloucestershire. The production of English celestine increased following the recovery in the 1870s in Gloucestershire of deposits in residual clays developed over marls of Triassic age.

The increased production of this luminescent and gritty pigment around the 1870s and 1880s, and the appearance of the almost ephemeral, hazy and extremely thinly 'washed' full-length portraits by Whistler at this time can hardly have been coincidental. The low refractive indices ($\alpha = 1.621–1.622$, $\beta = 1.623–1.624$, $\gamma = 1.63–1.632$) of this biaxial (+) crystal must have given the paint mixtures a relatively high transparency which could not have been accomplished by using the most conventional white pigment with roughly the same refractive indices, calcite, since oil paints mixed with calcium carbonate whites tend to result in unattractive, smooth mixtures with a muddy translucency. The fairly large celestine particles, however, would have given his paint mixtures a rather open texture, while its often slightly bluish colour would impart a subtle cool tonality to Whistler's silvery greys used both in the ground layer and the light areas in the skirt of the *Effie Deans* portrait.

Celestine also has fluorescent properties: in both the short and the longer ultraviolet wavelength ranges, it produces a yellowish to whitish blue fluorescence, providing a luminosity that could not have been achieved in any other way.[34] The barite particles, often present in the mixtures, would further increase the luminescence of Whistler's paints.[35] Already in 1603 a lively luminescence in heat-treated barite was observed by the alchemist Vicenzo Cascariolo, who heated a mixture of barium sulphide with charcoal resulting in a powder that showed a temporary bluish glow at night that could be restored by exposure to sunlight; it was called *lapis solaris* (sun stone). As the emission wavelengths of celestine and barite are different under the same conditions of excitation, Whistler could have introduced a subtle play of luminescence in the *Effie Deans* portrait. This trick would not, although quite effective, be consciously notable or detectable by observation of the painting with the unaided eye.

Housepaint or ...?

There may be another explanation for the use of the pigments barite and celestine in the paint. Whistler was not only meticulous when choosing his painting materials, but also in the decoration of his houses and exhibition spaces, which he personally coordinated in every detail. Interestingly, there are similar letters describing the materials to be employed and how he wanted colours to be applied to walls and ceilings to those describing the materials and techniques of his oil paintings. In a letter on the decorative scheme of his brother's house where the yellow had turned out 'crude and glaring', he writes:

> It is just because of the horrid white ground … Also why on earth should the workmen think for themselves that after all <u>two</u> coats of the yellow upon <u>white</u> would do just as well as <u>one</u> coat of yellow on <u>grey</u>! – This was so ordered by me because in my experience the result would have been fair and at the same time soft and sweet – Now listen – See that the man gets a tube of 'Ivory black' from any colorman's and a tube of 'raw Sienna'.[36]

The use of a first layer of grey to tone down bright hues is clearly based on a similar use of grey grounds in Whistler's portraits – for example, the ground layer on the *Effie Deans* portrait consists of a similar mixture.

Whistler participated fully in these decorative schemes as is testified by the builder working on decorating Whistler's new home, The White House in Chelsea, in 1878. He writes: 'also attending Mr. Whistler mixing colours to choice and colouring painting and recolouring walls of Dining Room. Preparing wall and colouring ceilings of Lower Studio and Room adjoining and walls several times to choice'.[37]

In this context it is worth noting that in the 1870s, John Bryson Orr, a paint manufacturer, founded a factory for the production of lithopone, a white paint containing zinc sulphide and barium sulphate, which he patented in 1875, although he had already been producing it for many years. He also developed another white paint by adding celestine to the lithopone mix; this Duresco paint was patented in 1884 but Orr started production in the late 1870s.[38] As all the cross-sections of paint samples from the *Effie Deans* portrait contain small amounts of zinc, barium sulphate and mineral strontium sulphate, it is possible that Whistler used oil-based house paint from Orr containing this mixture, with an addition of some lead white tube paint.

Conclusions

The group of full-length portraits from the late 1870s introduce a period in which Whistler experimented with strongly diluted paints, applied in thin washes. It also seems he used unusual pigment combinations in his white paints either by mixing tube paints such as blanc fixe (lead white and barium sulphate) and zinc white (zinc oxide), and adding mineral strontium sulphate, as its characteristics suited the desired translucent effect. However, it is also possible that he used oil-based house paint such as the Duresco produced by Orr to which he added some lead white tube paint. The experimentation that concerned fluidity and transparency seems connected with his watercolour practice as well as his lithography and etching. In the full-length portraits from the 1880s Whistler is fully exploiting and manipulating his paints to utmost effect. As he stated in 1878: 'These were impressions of my own. I make them my study. I suppose them to appeal to none but those who may understand the technical matter.' In this paper we have tried to understand the technical matter, the 'pot of paint flung into the people's face', and this would surely have amused Whistler.

Acknowledgements

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Notes

1. Metcalf Roof, K., *The Life and Art of William Merritt Chase*, Charles Scribner's Sons, New York (1917).
2. See for example: Hackney, S., 'Colour and tone in Whistler's "nocturnes" and "harmonies" 1871–72', *The Burlington Magazine* **136** (1994) 695–699; Hackney, S., 'Art for art's sake: the materials and techniques of James McNeill Whistler (1834–1903)', in *Historical Painting Techniques, Materials and Studio Practice*, ed. A. Wallert, E. Hermens and M. Peek, Getty Conservation Institute. Los Angeles (1995) 186–190; Townsend, J.H., 'Whistler's oil painting materials', *The Burlington Magazine* **136** (1994) 690–695; Stoner, J.H., 'Whistler's views on the restoration and display of his paintings', *Studies in Conservation* **42** (1997) 107–114; Hermens, E. and MacDonald, M., 'En plein soleil: Whistler, nature and memory', in *Sources and Serendipity: Testimonies of Artists' Practice*, ed. E. Hermens and J.H. Townsend, Archetype Publications, London (2009) 112–118.
3. Merrill, L., *A Pot of Paint: Aesthetics on Trial in 'Whistler v. Ruskin'*, Smithsonian Institution Press and Freer Gallery of Art, Washington, DC and London (1992) 154–158, esp. 41–45 for Whistler's testimony.
4. 'The palace of art (new version)', *Punch*, 7 July 1877, 305, in Merrill 1992 (cited in note 3) 36.
5. Merrill 1992 (cited in note 3) 47.
6. *Ibid*., 148.
7. *Ibid*., 180.
8. *Ibid*., 172.
9. *Ibid*., 174.
10. Whistler correspondence, 05368, 3 December 1878, Glasgow University Library, Ms Whistler S12.
11. Pennell, E.R. and Pennell, J., *The Life of James McNeill Whistler*, Vol. 2, J.B. Lippincott, Philadelphia, PA (1908) 235.
12. Part of Proposition first published in *'Notes' – 'Harmonies' – 'Nocturnes'*, Messrs Dowdeswell, London (1884).
13. Townsend 1994 and Hackney 1994 (cited in note 2).
14. Sickert, W., 'The new English and after', *The New Age*, 2 June 1910.
15. Bacher, O., *With Whistler in Venice*, Century, New York (1908) 31.
16. McLaren Young, A., MacDonald, M., Spencer, R. and Miles, H., *The Paintings of James McNeill Whistler*, Yale University Press, New Haven and London (1980), esp. nos. 187, 182, 183.
17. Quoted in Pennell and Pennell 1908 (cited in note 11) Vol. 1, 199–200.
18. Merrill 1992 (cited in note 3) 143.
19. *Ibid*., 146.
20. Horace Lecoque de Boisbaudran, *Letters to a Young Professor*, 1877, in *Lecoq de Boisbaudran: The Training of the Memory in Art and the Education of the Artist*, trans. L. Luard, MacMillan and Co., London (1911) [first written 1847].
21. Infrared reflectography was carried out with an Osiris scanning InGaAs camera provided with a 16 × 16 tile system based on a 512 × 512 focal plane array, with a sensitivity of slightly beyond 1700 nm. Visible light wavelengths were filtered with an 875 nm infrared filter.
22. Examination of cross-sections was undertaken with a Leica DMLM microscope (magnifications 50×, 100×, 200×, 500×, 1000×). Images in direct incident light (bright field), and ultraviolet light (filter cube BL/VIO C105) were recorded with a digital Leica DFC 420 C camera. We used 2,7 dichlorofluorescein (DCF), Rhodamine B (RHOB), and Sudan black B stains for the assessment of distribution of lipids in the paint layers. Alkanna (a naphthaquinone) stain was used for resins.
23. GC–MS analysis was undertaken by Henk van Keulen, ICN, Amsterdam. The ratios of fatty acid (FA) C16 against FA C18 and presence of FA-2 C9; FA-2 C8; FA C16:1; and 15 hydroxy-FA-C16 would be consistent with a conventional drying oil such as linseed oil. Some beeswax was also detected in the medium. Colophony and dammar resins detected in the chromatogram relate to varnishes. The squalane that was detected is probably a contamination caused by handling of the paint or sample.
24. Bruker Artax μ-XRF spectrometer, 40 kV, 500 μA, 60 s, Mo-anode, 0.090 μm capillary lens, Helium flush (1.7 L/min), over a 50 keV energy range.
25. Pigment dispersions on microscope slides in Meltmount (N_D = 1.662) were examined in normal and polarised transmitted light with a Zeiss Standart 07 microscope. The barite particles showed under the microscope as distinct tabular and prismatic crystals with refractive indices lower than 1.66. Birefringence was low and pleochroism was negligible. The lambda waveplate showed a first order yellow shift. Distinct differences in particle size strongly suggested a ground-up natural mineral product possibly mixed with a more finely and evenly dispersed tube paint such as blanc fixe.
26. XRD was performed with a Siemens GADDS (general area diffraction detector system) instrument, in 2 Φ mode, in 0.100° steps of 11.4° , to 63.7°. Deer, W.A., Howie, R.A. and Zussman, J., *An Introduction to the Rock-Forming Minerals*, 2nd edn, Pearson Education, Harlow (1992) 606–609.
25. Carlyle, L., *The Artist's Assistant*, Archetype Publications, London (2001) 514.
28. SEM–EDX analyses were performed on a JEOL JXA-840A high resolution SEM with a wavelength dispersive (WD) and energy dispersive (ED) combined electron probe microanalyser (EPMA), usually at 10 nA, 25 kV, with a 39 mm working distance. Samples were usually examined in low vacuum mode. EDX analyses were carried out at various points throughout the cross-section by measuring the emitted X-rays with a Noran Vantage EDX system

with Pioneer Norvar detector. In Glasgow the samples were examined by Peter Chung using an ISAAC Quanta 200F field-emission environmental SEM, in low vacuum mode; EDX was performed using an EDAX Genesis system.

29. Due to the presence of lead white in the sample, the diffraction pattern for the celestine was not very clear. The pattern had a better agreement with the diffraction file PDF 5-593 for synthetic celestine (especially the doublet at 2.041 and 2.045, and the strong lines at 2.972 and 3.295), than for the natural mineral specimen from Yate, Gloucestershire: PDF 03-0437. Celestine, $SrSO_4$, orthorhombic – dipyramidal crystals, a:b:c = 1.5618 : 1 : 1.2828, unit cell dimensions: a=8.359, b=5.352, c=6.866, space group Pbnm, Dana Class 28.03.01.02. Brittle, conchoidal fracture, perfect cleavage along [001], good at [210]. Hardness on Moh's scale is 3–3.5.
30. Its occurrence as a pigment has been reported on a nineteenth dynasty Egyptian papyrus: Olsson, A.-M**.,** Calligaro, T., Colinart, S., Dran, J.C., Lövestam, N.E.G., Moignard, B. and Salomon, J., 'Micro-PIXE analysis of an ancient Egyptian papyrus: Identification of pigments used for the "Book of the Dead"', *Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms* **181** (July 2001) 707–714.
31. For Van Gogh see, Marino, B., *Paints Quantified: Image Analytical Studies of Preparatory Grounds used by Van Gogh*, PhD thesis, Amsterdam 2006. Haswell, R., Zeile, U. and Mensch, K., 'Van Gogh's painting grounds: an examination of barium sulphate extender using analytical electron microscopy – SEM/FIB/TEM/EDX,' *Microchimica Acta* **161**(3–4) (June 2008) 363–369; Marino, B., Boon, J.J., Hendriks, E., Horréard, F. and Hillion, F., 'Imaging TOF-SIMS and nano-SIMS studies of barite-celestine particles in grounds from paintings by Van Gogh', *e-Preservation Science* **3** (2006) 41–50.
32. Bernstein, L.R., 'Coloring mechanisms in celestite', *American Mineralogist* **64** (1979) 160–168.
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34. Isetti, G., 'Studio sulla colorazione della celestina', *Doriana* **194** (1970) 1–7. This may explain the remarkable fluorescence and variations therein that we observed over the whole paint surface of the *Effie Deans* portrait. Excitation at 366 nm and 253 nm.
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36. Whistler correspondence, 06695, 16 December 1881, Glasgow University Library, MS Whistler W689.
37. Whistler correspondence, 08930, 26 July 1878, Library of Congress, Manuscript Division, Pennell-Whistler Collection.
38. Schofield, M., 'Rival demands from barium', *Pigment and Resin Technology* **4** (November 1975) 12–14. Celestine became the first mineral entirely produced in Britain and the mineral quality was widely available.

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