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Series editor **Ashok Roy**

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FRONT COVER

Georges Seurat, *Bathers at Asnières* (NG 3908),
detail of PLATE 4, page 7

TITLE PAGE

Giulio Romano, *The Birth of Jupiter* (NG 624),
detail of PLATE 1, page 38

Seurat's Painting Practice: Theory, Development and Technology

JO KIRBY, KATE STONOR, ASHOK ROY, AVIVA BURNSTOCK, RACHEL GROUT AND RAYMOND WHITE

SEURAT IS EXTREMELY WELL REPRESENTED in London. Holdings of his work in the National Gallery and the Courtauld Institute allow the development of his career to be studied here as nowhere else. Furthermore, the majority of Seurat's works in the two collections – all the large paintings and a considerable number of oil sketches – have recently been examined and analysed. The National Gallery's *Bathers at Asnières* (NG 3908) and the related small oil sketches in the collection were examined by a variety of analytical techniques for the exhibition *Seurat and The Bathers*, held at the Gallery in 1997, but only a limited amount of technical information was included in the catalogue.¹ Following a technical study of Seurat's paintings in the Courtauld Institute collection carried out

between 2000 and 2001,² it was decided to combine and publish here the results acquired by the two institutions as together they provide an unusually full survey of the painter's development in the course of his short career. In spite of the very large art-historical literature devoted to the painter, there is surprisingly little on his methods and materials, apart from the 1989 study of *A Sunday on La Grande Jatte*, published by the Art Institute of Chicago,³ and the brief account of the *Bathers* in the 1997 exhibition catalogue. This is unexpected in view of Seurat's well-documented interest in colour theory: it is inconceivable that this would not have influenced, for example, his choice of pigments. The materials available to him were in turn dictated by the state of development of the paint industry, the

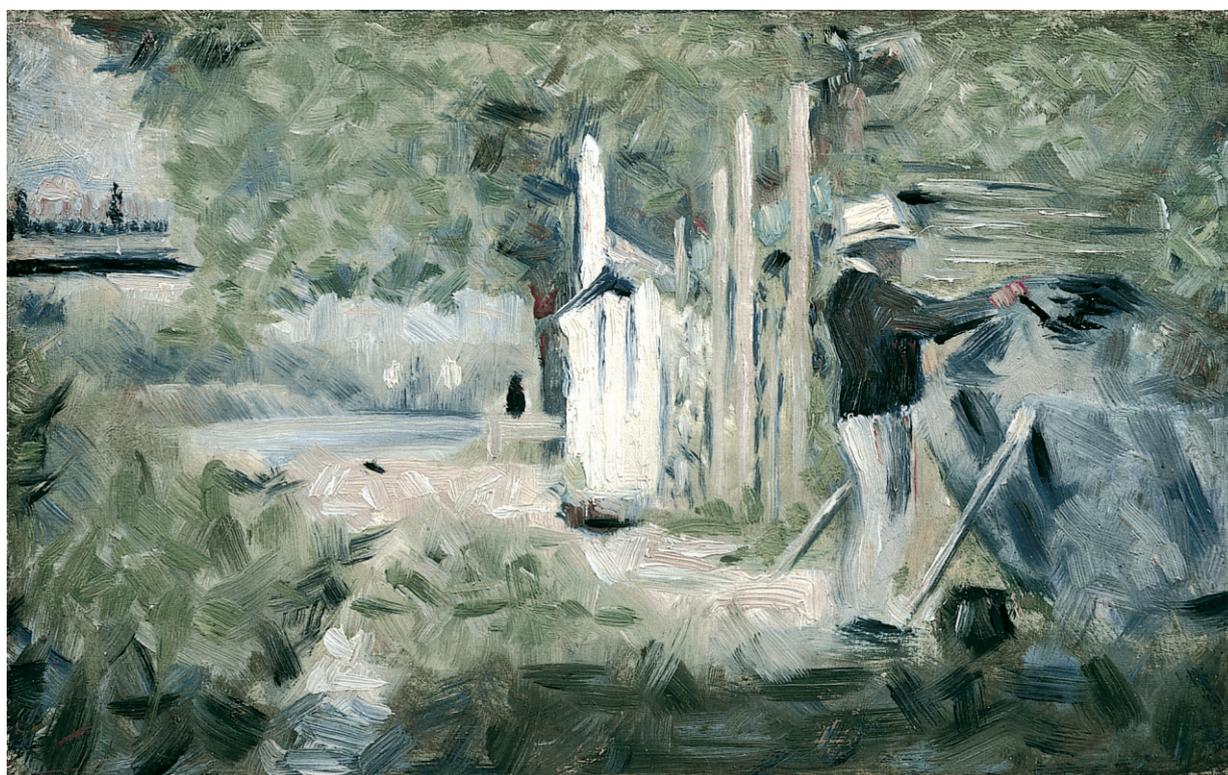


PLATE I Georges Seurat, *Man painting a Boat*, 1883. Panel, 15.9 × 25 cm.
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TABLE 1 Paintings examined in the survey, their supports and grounds

	Dimensions (h × w)	Support; canvas weave and thread count	Sizing	Priming
FINISHED PAINTINGS				
<i>Bathers at Asnières</i> , 1883–4, reworked 1886–7 (NG 3908)	201 × 300 cm (single piece of canvas)	Linen, plain weave (coarse)	Probably sized	Commercially applied greyish-white ground (lead white with some carbon black)
<i>Le Bec du Hoc, Grandcamp</i> , 1885, reworked 1888, Tate Modern, on loan to the National Gallery (L 728)	65 × 81 cm (size No. 25, <i>figure</i>)	Linen, plain weave; 33 × 34 per sq. cm	Probably sized	Commercially applied white ground (single layer?)
<i>The Bridge at Courbevoie</i> , 1886–7, Courtauld Collection (P.1948.SC.394)	46.3 × 55.1 cm (size No. 10, <i>figure</i>)	Linen, plain weave; 28 × 24 per sq. cm	No	None
<i>Young Woman powdering Herself</i> , 1889–90, Courtauld Collection (P.1932.SC.396)	95.5 × 79.5 cm (originally size No. 30, <i>figure</i> ; stretcher altered)	Linen, plain weave; 22 × 20 per sq. cm	Animal glue size	Double priming: lower ground: commercial application, greyish (lead white, chalk, some carbon black in heat-bodied linseed oil) upper ground: artist's application (lead white and chalk in heat-bodied linseed oil)
<i>The Channel of Gravelines, Grand Fort-Philippe</i> , 1890 (NG 6554)	65 × 81 cm (size No. 25, <i>figure</i>)	Linen?, plain weave (fine)	No size layer apparent but absorbent oil-bound first priming layer	Double priming (artist's application): lower ground: chalk in oil upper ground (two applications): lead white in oil
STUDIES				
<i>Fisherman in a Moored Boat</i> , c.1882, Private Collection on extended loan to the Courtauld Gallery (LP.1997.XX.16)	15.8 × 25.1 cm	Hardwood (mahogany?)	–	None
<i>A Boat near a Riverbank, Asnières</i> , c.1883, Courtauld Collection (P.2000.XX.2)	15.4 × 24.8 cm	Hardwood (mahogany?)	Possibly sized	None
<i>Man in a Boat</i> , c.1883, Private Collection on extended loan to the Courtauld Gallery (LP.1997.XX.2)	25 × 16.1 cm	Hardwood (mahogany?)	–	Single layer, white pigment in oil (lead white?)
<i>Man painting a Boat</i> , 1883, Courtauld Collection (P.1948.SC.393)	15.9 × 25 cm	Hardwood (mahogany?)	–	Single layer, white pigment in oil (lead white + some silica)
<i>Horses in the Water: Study for 'Bathers at Asnières'</i> , 1883–4, Private Collection on extended loan to the Courtauld Gallery (LP.1997.XX.17)	c.15.8 × 24.7 cm	Hardwood (mahogany?)	–	None
<i>A River Bank (The Seine at Asnières)</i> , c.1883 (NG 6559)	15.8 × 24.7 cm	Hardwood	–	None
<i>The Rainbow: Study for 'Bathers at Asnières'</i> , 1883–4 (NG 6555)	15.5 × 24.5 cm	Hardwood	–	None
<i>Study for 'Bathers at Asnières'</i> , 1883–4 (NG 6561)	16 × 25 cm	Hardwood	–	None
<i>The Angler</i> , c.1884, Private Collection on extended loan to the Courtauld Gallery (LP.1997.XX.15)	24.9 × 15.9 cm	Hardwood (mahogany?)	–	None
<i>Study for 'La Grande Jatte'</i> , c.1884–5 (NG 6556)	15.2 × 24.8 cm	Hardwood	–	None
<i>Study for 'La Grande Jatte'</i> , c.1884–5 (NG 6560)	16 × 25 cm	Hardwood	–	None
<i>The Morning Walk</i> , 1885 (NG 6557)	24.9 × 15.7 cm	Hardwood	–	None
<i>The Seine seen from La Grande Jatte</i> , 1888 (NG 6558)	15.7 × 25.7 cm	Hardwood	–	Thin lead white priming
<i>Study for 'Le Chabut'</i> , c.1889, Courtauld Collection (P.1948.SC.395)	c.22 × c.15.8 cm	Mahogany? (cut down from larger piece)	–	Single layer, white pigment in oil
<i>At Gravelines</i> , 1890, Courtauld Collection (P.1948.SC.397)	c.15.9 × c.25.2 cm	Hardwood (mahogany?)	–	Single layer, white pigment in oil (lead white + some silica)



PLATE 2 Georges Seurat, *Study for 'Bathers at Asnières'* (NG 6561), 1883–4. Panel, 15.2 × 25 cm.

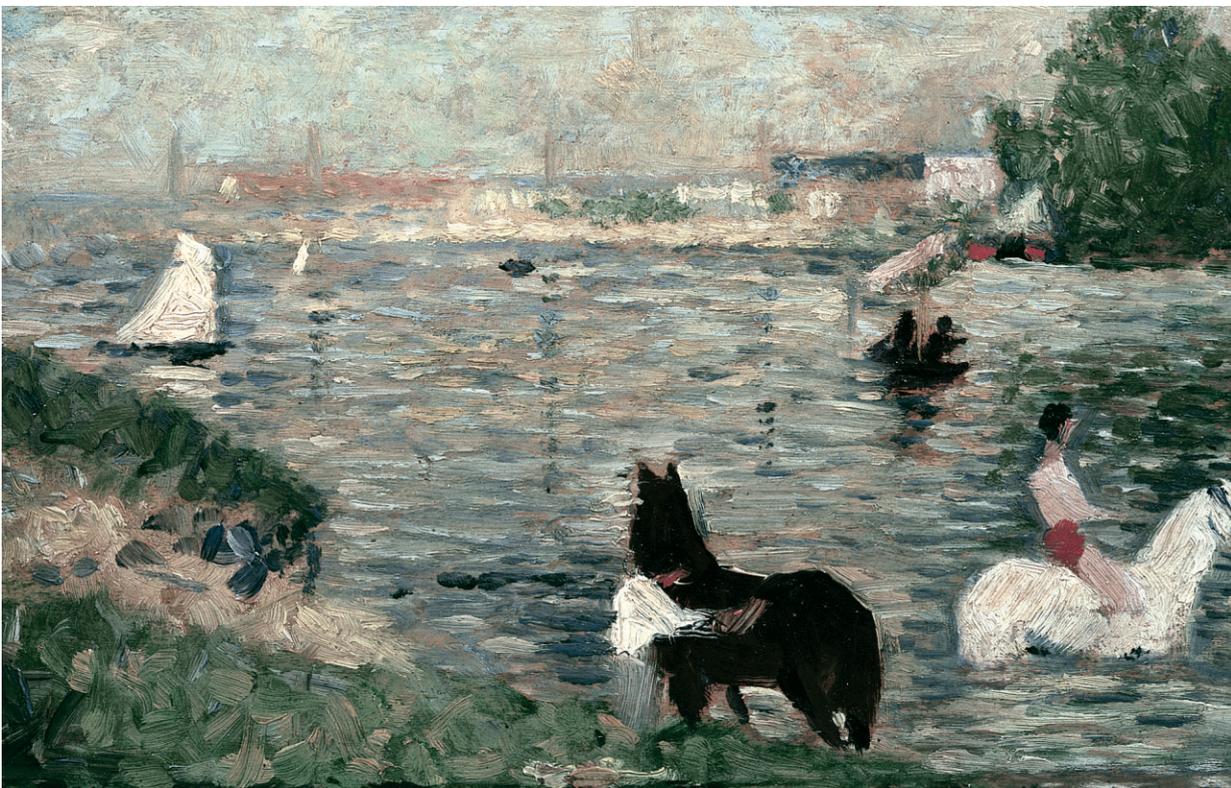


PLATE 3 Georges Seurat, *Horses in the Water: Study for 'Bathers at Asnières'*, 1883–4. Panel, 15.2 × 24.8 cm. Private collection on extended loan to the Courtauld Institute Gallery, Somerset House, London.



PLATE 4 Georges Seurat, *Bathers at Asnières* (NG 3908), 1883-4, reworked 1886-7. Canvas, 201 x 300 cm.

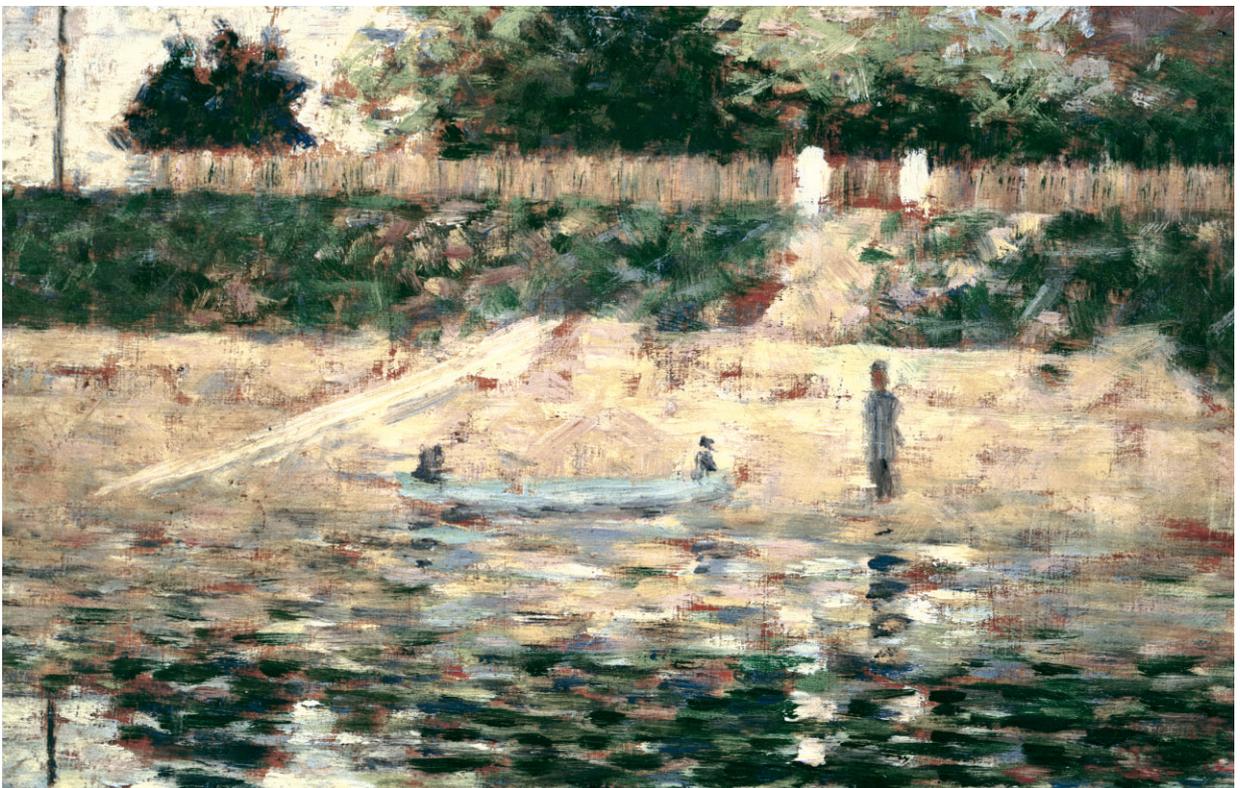


PLATE 5 Georges Seurat, *A Boat near a Riverbank, Asnières*, c.1883. Panel, 15 x 24 cm.
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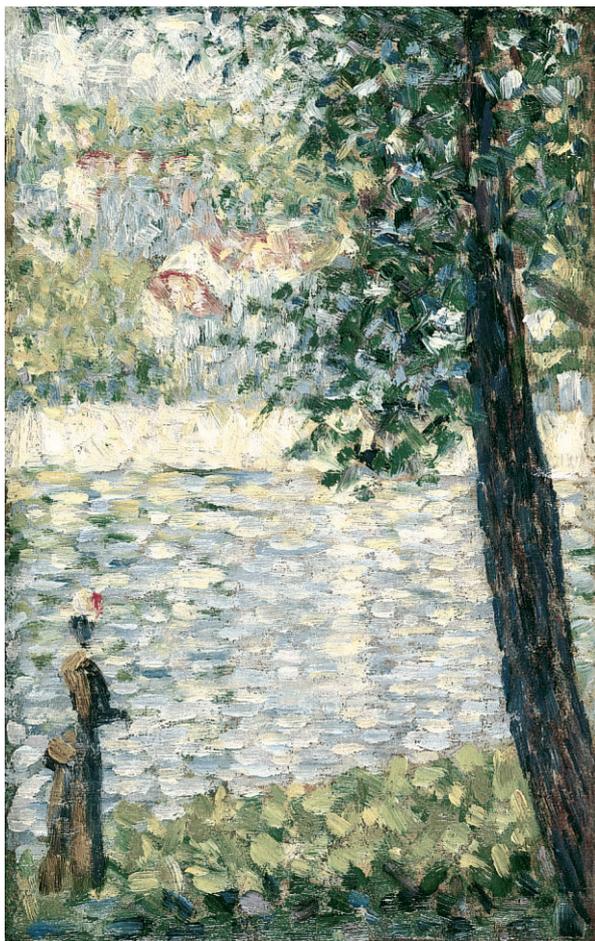


PLATE 6 Georges Seurat, *The Morning Walk* (NG 6557), 1885. Panel, 24.9 × 15.7 cm.

manufacture of artists' materials and the extent to which these were manipulated by suppliers and *marchands du couleurs*.

The paintings examined comprise fifteen oil sketches (see Table 1; PLATES 1–3, 5, 6, 21), including several for the *Bathers* and for the *Grande Jatte*, and four finished, fully realised paintings dating from between 1883 and 1890. These are: *Bathers at Asnières* (NG 3908; PLATE 4), *The Bridge at Courbevoie* (Courtauld Institute Gallery; PLATE 8), *Young Woman powdering Herself* (Courtauld Institute Gallery; PLATE 9), and *The Channel of Gravelines, Grand Fort-Philippe* (NG 6554; PLATE 11). *Le Bec du Hoc, Grandcamp* (London, Tate Modern, on loan to the National Gallery; PLATE 7), was also examined visually for this survey, but no samples were taken.⁴

As well as showing changes that took place in the artist's choice of materials as his style and technique developed in the ten or so years of his career, this survey enables a comparison to be made between those materials used for the sketches and

those used in the more finished pictures, where the choice of, for example, one particular green pigment might be significant for the very precise optical effects Seurat sought. It is important to realise that nothing in Seurat's art seems to have been unconsidered – even the most cursory drawing or painted sketch appears to have had a very precise function in the production of the finished work. This may be one of the reasons why Seurat's work is so recognisable, because he consistently chose a particular range of materials for each purpose. In effect, by always using a fixed set of materials – for example the habitual use of charcoal and conté crayon in the drawings – an element of unpredictability, a variable in scientific terms, was removed: the artist could concentrate on what he was aiming to express rather than on the means of expression.

Georges Seurat was born in Paris in 1859 into a wealthy middle-class family who supported him during his formal artistic training and, after his military service (1879–80), during his independent studies.⁵ This freed him from any need to sell his work or seek commissions. From 1876 to 1878, he took drawing lessons at the *Ecole Municipale de Sculpture et de Dessin* in Paris, run by the sculptor Justin Lequien *fils*, where students were encouraged to simplify forms and to avoid unnecessary detail. Most of those attending the school were destined to work in the applied and industrial arts; for them such a drawing education was eminently suitable. It seems also to have had a lasting influence on Seurat's painting style, as well as on his characteristic tonal drawings in soft materials such as charcoal, pastel and conté.

In 1878 he was admitted to the *Ecole des Beaux-Arts* and entered the studio of Henri Lehmann, a former pupil of Ingres. Here he followed a conventional academic programme, including drawing from plaster casts of antique sculptures and from life; he also made drawings from the works of old masters such as Raphael, Holbein and Poussin. It is easy to imagine that Seurat would have been attracted to the work of Ingres and it is clear that he did respond to the working methods of this archetypal academic painter, distilled through the teaching of Lehmann. However, it seems that even at this early stage of his career he was also interested in the work of other very different painters. It is reported, for example, that he visited the fourth Impressionist exhibition in 1879, where he would have seen works by Caillebotte, Degas, Monet and Pissarro, among others, and that of the American painter Mary Cassatt, who exhibited two paintings

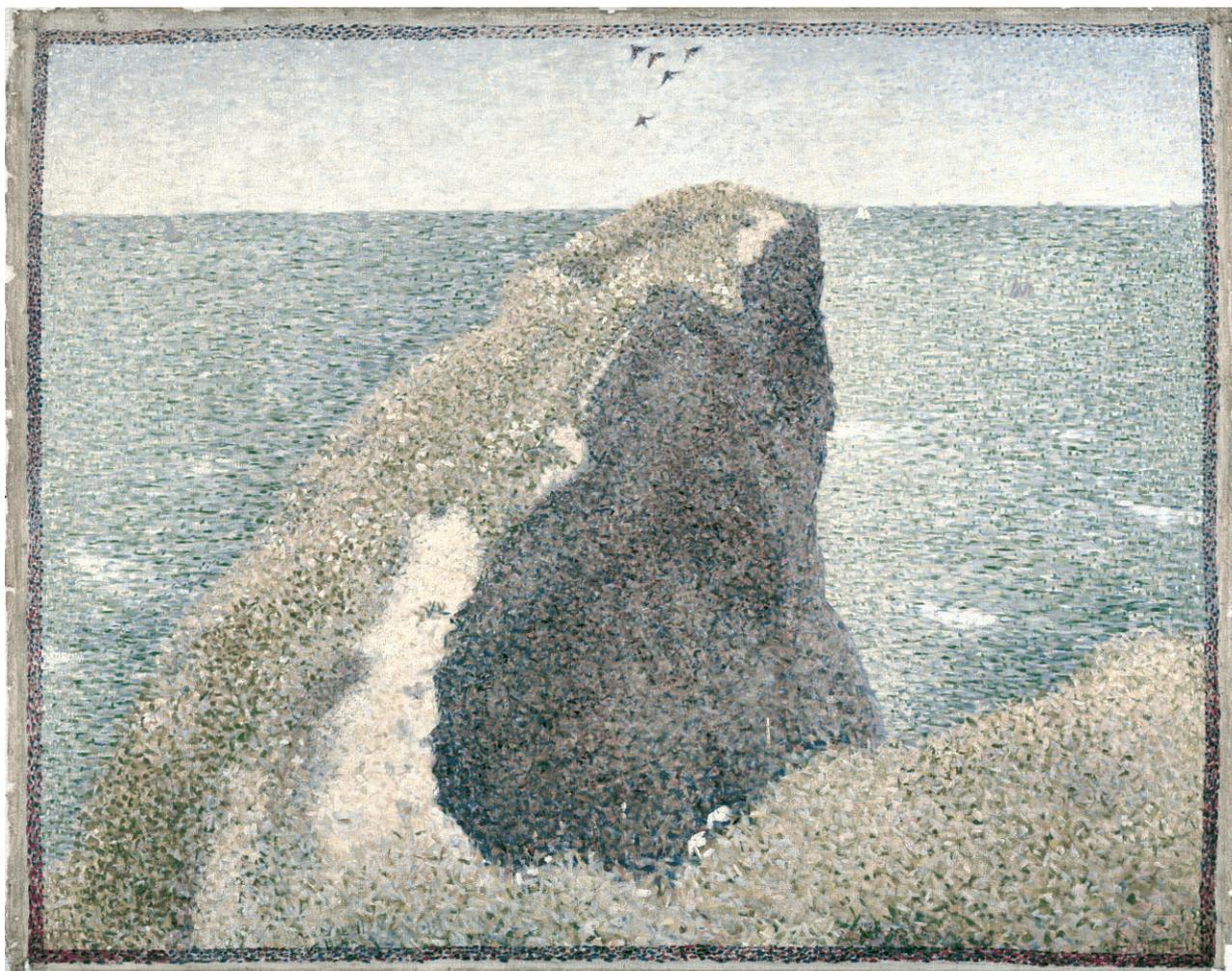


PLATE 7 Georges Seurat, *Le Bec du Hoc, Grandcamp* (L728), 1885, reworked 1888. Canvas, 64.8 × 81.6 cm. On loan from Tate Modern, London.

in coloured frames.⁶ Renoir, whose work Seurat admired particularly, had work accepted at the Salon that year and so did not participate in this Impressionist exhibition. On completing his military service, Seurat did not return to the Ecole des Beaux-Arts but concentrated on developing a theoretical foundation for his art by reading, and pursued his own independent researches in the Louvre and in the Salon exhibitions. He is known, for example, to have made a free copy of *The Poor Fisherman* (Paris, Musée d'Orsay) by Pierre Puvis de Chavannes,⁷ shown in the Salon exhibition of 1881, and he looked seriously at the works of Eugène Delacroix, including the wall paintings in the church of St-Sulpice. Delacroix's paintings influenced Seurat deeply, much as they had the Impressionists some twenty years before. During 1881 he made notes on Delacroix's palettes and on his use of red and green in conjunction, and on where he allowed tones of blue and orange, yellow and violet to play against one another.⁸ In view of his later discussions

with the mathematician and aesthete Charles Henry, it is interesting that even at this stage in his career Seurat seems to have been more impressed by the harmonies arising from such pairs of complementary colours rather than the contrasts.

Although a drawing of his – a portrait of his close friend Aman-Jean (Amand-Edmond Jean) – was accepted for the Salon exhibition of 1883, Seurat did not otherwise have much success with this official venue: *Bathers at Asnières*, for example, was rejected the following year.⁹ The Salon was no longer under State control by this time, however, and its annual exhibitions gradually declined in importance. The political climate was also different from that of the early 1870s when the Impressionists had so signally failed to achieve official recognition. Dealer exhibitions became more influential and smaller groups, often founded by artists, came into being. The *Bathers* was shown in the summer of 1884 at the first exhibition of one such group, the Groupe des Artistes Indépendants, of which Seurat



PLATE 8 Georges Seurat, *The Bridge at Courbevoie*, 1886–7. Canvas, 45.4 × 55.3.
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was a founder member, and which, like the first Impressionist exhibition in 1874, contained works by artists who had been rejected by the Salon jury. It was at this time that he met Paul Signac. As a result of this exhibition the Société des Artistes Indépendants was established and Seurat contributed regularly to their exhibitions until his death. In fact, most of Seurat's finished paintings were exhibited to the public at independent exhibitions of this type during his lifetime. *A Sunday on La Grande Jatte* and *Le Bec du Hoc, Grandcamp* were shown at the last Impressionist exhibition in 1886, at the exhibition of 'Les Vingt' in Brussels in 1887 (both by invitation), and at the second exhibition of the Société des Artistes Indépendants,¹⁰ also in 1886, while *The Channel of Gravelines, Grand Fort-Philippe* was on display at the Society's seventh exhibition at the time of Seurat's death in March 1891.¹¹

The results of Seurat's constant researches into optical and aesthetic theory, with the attendant

modifications to his handling of paint and developments like the use of coloured borders and frames, were frequently the subject of criticism and analysis by artists and critics alike, but Seurat himself said little about the theory of his painting techniques – he left such explanations to others such as Felix Fénéon. A letter written to Maurice Beaubourg in August 1890 gives a brief statement summarising his views on the harmonious use of tone, colour and line.¹² It is clear that Seurat relied very much on the written word in developing his ideas, to an unusually large extent compared with other painters at that time. From the beginning of his career he sought an 'optical formula' for the proper construction of his paintings and he turned for assistance to the theories of scientists, partly as interpreted by other authors. He read Charles Blanc's article on Delacroix in the *Gazette des Beaux-Arts* (1864) during his student days and, more significantly, his *Grammaire des arts du dessin* (1867).¹³ Through this



PLATE 9 Georges Seurat, *Young Woman powdering Herself*, 1889–90. Canvas, 95.5 × 79.5 cm. Reproduced by kind permission of the Courtauld Institute Gallery, Somerset House, London.

book he was first introduced to the essential elements of Michel-Eugène Chevreul's work, along with the conventionally accepted notion of primary colours and colour mixing, with complementary colours illustrated in a star-shaped diagram (PLATE 10).

Chevreul became Director of Dyeing at the Gobelins tapestry workshops in 1824. One of his tasks was to investigate the apparent dullness of certain textile dyestuffs. This had been assumed to be a technical problem relating to the dyestuffs, but Chevreul found that the lack of brightness was a phenomenon arising from the optical mixture of the hues of adjacent threads. It is worth noting that the primary colours as generally understood by most painters during the nineteenth century were red, yellow and blue; the complementary secondary colours produced by mixing pairs of these primaries are thus green (blue + yellow), violet (red + blue) and orange (red + yellow). Chevreul found that where neighbouring threads were of complementary

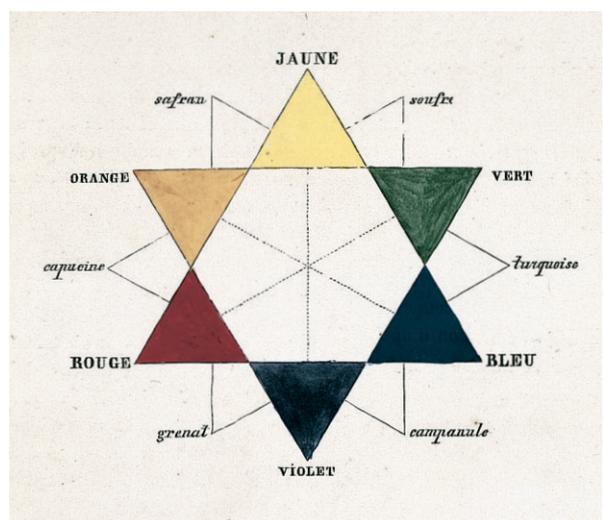


PLATE 10 Diagram of complementary colours from Charles Blanc, *Grammaire des arts du dessin* (2nd edn Paris 1870).



PLATE 11 Georges Seurat, *The Channel of Gravelines, Grand Fort-Philippe* (NG 6554), 1890. Canvas, 65 x 81 cm.

colours – blue and orange, for example – the resulting appearance to the eye was greyish. Chevreul formulated his observations as the law of simultaneous contrast of colours, which stated that when the eye saw two contiguous colours at the same time, they would appear as dissimilar as possible, both in hue and in tone. In the case of two different colours, the hue of each is modified by the effect of the complementary colour of the other, for example, if red is placed next to blue, its colour will appear a more orange-red than it would if used alone or placed next to yellow. The blue, meanwhile, appears more green than if used alone. Another optical effect Chevreul described was ‘the phenomena of the duration of a light impression on the retina’, as Seurat summarised it in the letter to Beaubourg – in other words, successive contrast. If the eye looks at a coloured area, say red, intensively for a while, and then looks away, for a moment the ‘fatigued’ eye perceives a green after-image, that is, the complementary colour. If the eye then looks at another colour, say yellow, the colour actually registered will



PLATE 12 Detail of shadow on the riverbank in *Bathers at Asnières* (PLATE 4) showing the use of simultaneous contrast of colour.

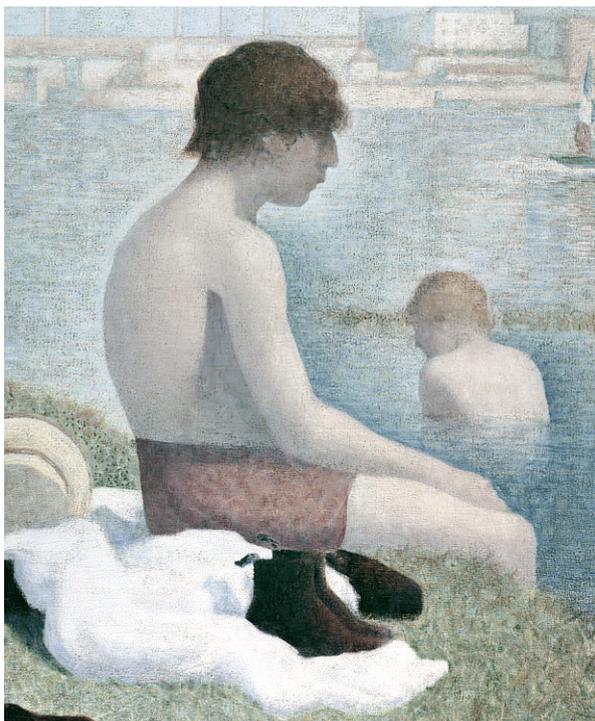


PLATE 13 Detail of central figure from *Bathers at Asnières* (PLATE 4) showing the thick, smooth brushwork of the flesh paint, the dark blue band of water outlining the front of the figure and light-coloured paint outlining his back. Note the paler colour contrasts of pink and pale mauve with cream and pale yellow, and the late application of orange and blue dots in the shadow of the lower back.

be a lime or apple green – the combination of the yellow and the induced green. Chevreul first reported these and related findings in a lecture in 1829, but the work was only published ten years later in the much reprinted *De la loi du contraste simultané des couleurs, et de l'assortiment des objets colorés* (1839).¹⁴ A large part of the book was

concerned with examples of colour contrast in different contexts, including the framing of pictures, effects which Seurat came to exploit in the coloured borders and frames in some of his later works.

Whether or not Seurat read Chevreul's book in its entirety, he did note down several paragraphs from the section on painting, including those on the raising and lowering of tones of different colours by their juxtaposition to achieve harmony, and the attainment of chiaroscuro by the juxtaposition of different tones of the same colour, an effect Seurat came to exploit with great subtlety.¹⁵ The simultaneous contrast between areas of two complementary colours (PLATE 12) is particularly marked along the boundary between them, a feature that may be observed on many of his paintings, for example in the National Gallery *Bathers*, where the pale, heavily reinforced outline of the shoulder and upper arm of the boy seated on the bank stands out against the strong blue of the water (PLATE 13). A similar technique is used in the Courtauld Institute Gallery's *Young Woman powdering Herself* where the blue colour of the background has been intensified to bring out the palest tones of the sitter's arms and the white lace of her shoulder straps (PLATE 14).

Seurat regularly used simultaneous contrast to emphasise chiaroscuro, the sculptural quality of an object, and to isolate the subject from its background; clearly this effect was an important device in the tonal construction of his compositions and also, it should be said, in his drawings. In this his reading of Blanc and Chevreul was perhaps reinforced by a short paragraph on 'irradiation' in one of a series of articles by the Swiss aesthetician David Sutter, which appeared in the journal *L'Art* in 1880.¹⁶ Sutter's 'irradiation' could be described as



PLATE 14 Detail from *Young Woman powdering Herself* (PLATE 9), showing intensification of the colour of the background adjoining the flesh paint and bodice.

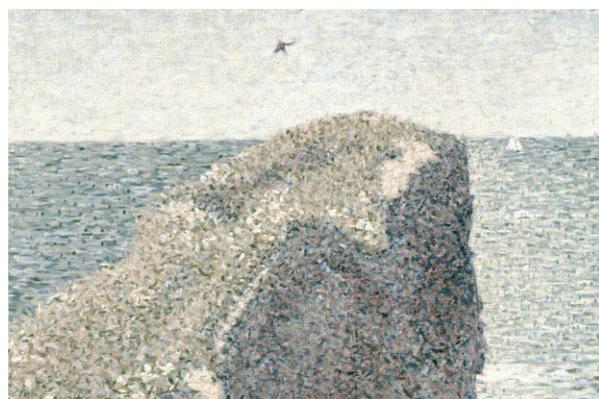


PLATE 15 Detail from *Le Bec du Hoc, Grandcamp* (PLATE 7), showing the band of lighter paint of the sea outlining the promontory to the right, and darker paint at the left, exploiting the 'irradiation' effect.



PLATE 16 Detail of the woman's hair in *Young Woman powdering Herself* (PLATE 9).

an effect seen at the boundary between a very light object against a darker background (or vice versa), giving the object high relief as well as separating it from the background.¹⁷ This increase in the definition of the form certainly describes very well the characteristic 'detached' appearance of the bathing figures in the *Bathers*, and of the figures in the small version of *Les Poseuses* (c.1888; Private Collection), and in several of the sketches and drawings for this composition, for example *Seated Model in Profile* (1887; Paris, Musée d'Orsay). However, the effect is also employed in his landscapes, notably to outline the spectacular rocky promontory in *Le Bec du Hoc, Grandcamp* (PLATE 15). In the later *Young Woman powdering Herself* the technique is used in a very much more subtle and indeed more decorative way. The woman's dark hair is constructed in dots largely of red, blue and green which in some places give an overall blackish appearance (PLATE 16). This is surrounded by a halo of light-coloured paint made up of touches of pale blue, light creamy yellow and white, while the areas inside her right elbow and above her left forearm, both very pale flesh tones, are painted in a moderately dark blue-

green colour, giving a marked light and dark contrast. In addition, however, the areas of light and dark greenish-blue paint of the background wall-covering create a pattern of decorative swirls, as well as depicting the irradiation effect around the figure. The effects of simultaneous contrast have here been exploited – on the scale of individual dots of paint, and on the larger scale of broader areas of colour – to provide tonal contrast and even to create a lively pattern within the painting.

The way colour was actually perceived by the eye was, by Seurat's time, quite well understood. Research done by Thomas Young at the beginning of the nineteenth century and developed by Hermann von Helmholtz had revealed that white light consisted of three primary colours: an orange-red, green and a blue-violet (the colours to which the cones in the retina of the human eye respond).¹⁸ If light of these colours is mixed in the correct proportions, white light is obtained; yellow light results from mixing red light and green light. This is additive mixing. When pigments and dyestuffs are combined, however, the mixing is subtractive: a yellow pigment, for example, appears yellow because it absorbs light from the blue and violet regions of the spectrum, reflecting the remainder; and a mixture of red, yellow and blue, the three subtractive primaries, should yield black, or a greyish colour; mixing a primary (red) with its complementary secondary colour (green) will also give grey or, ideally, black. (This was the problematic effect that Chevreul in fact observed in the dyed textiles.)

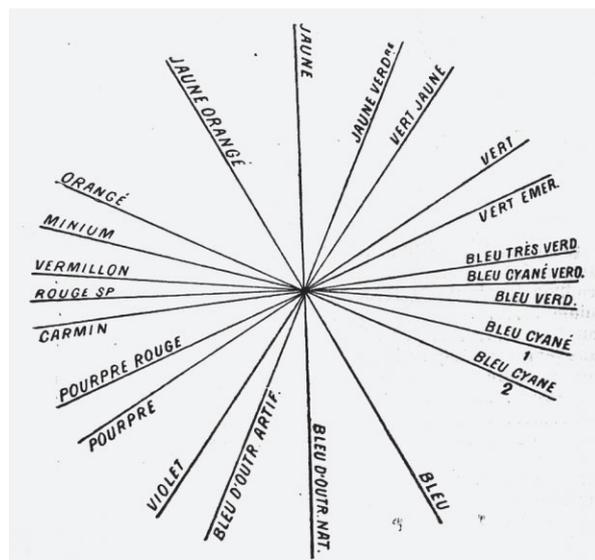


Fig. 120. — Diagramme des contrastes d'après O. Rood.

FIG. 1 Diagram of colour contrasts from Ogden Rood, *Théorie scientifique des couleurs* (Paris 1881).

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PLATE 17 Detail of the brushwork and colour of the skirt in *Young Woman powdering Herself* (PLATE 9).

How the principles of additive mixing might be represented on the canvas had also been the subject of study. The clearest and most relevant explanations of the theory and its practical applications were given in Ogden Rood's *Modern Chromatics, with Applications to Art and Industry* (New York 1879) which Seurat read in its first French translation in 1881.¹⁹ Rood carried out colour matching experiments, many based on spinning discs of papers painted in different colours, others using coloured glass filters, under different lighting conditions. The spinning disc experiments were based on earlier work of the 1850s by the Scottish physicist James Clerk Maxwell, who experimented with discs of red, green and blue paper in which the sizes of sectors of each colour illuminated could be varied. Using algebraic colour matching equations, the precise quantity of the illumination of each of the three colours needed to match any spectral colour could then be specified. Rood used red, green and blue papers (painted using vermilion, emerald green and artificial ultramarine), together with smaller black and white papers to make a neutral grey, but he also allowed for the fact that the three colours were not equal in luminosity. He was able to construct an accurate diagram of contrasting colours (FIG. 1), from which it can be seen that, for example, vermilion is complementary to a greenish blue and emerald green is complementary to purplish red.²⁰

The same diagram could be used to produce harmonious effects based on the angle between one colour and another on the colour wheel. Angles of

less than 80° or 90° between colours gave rise to effects of contrast that were unsatisfactory or even discordant. Sets of three colours, separated by angles of about 120° , were often particularly appealing in Rood's opinion; the examples he gave of the use of such 'triads' of colour by artists suggested that two of the three should be 'warm' colours, such as red and yellow, which took precedence over ideals of contrast. The association of colours separated only by a small interval (red and orange-red) was very effective when, for example, it was necessary to represent small gradations in colour.²¹ This effect bears some relation to Chevreul's simultaneous contrast of tones; it can be seen in Seurat's work in the flesh painting and skirt of *the Young Woman powdering Herself* (PLATE 17). The placing of small dots of colour side by side so that, when viewed from certain distances, 'the blending is more or less accomplished by the eye of the beholder', was a method of achieving such gradation and the tints observed were, according to Rood, identical to those obtained by the method of spinning discs of coloured paper, rather than by mixing pigments on the palette. Rood described this method as giving 'true mixtures of coloured light', the nearest the artist could get to the additive mixture of colour explained by Helmholtz.²²

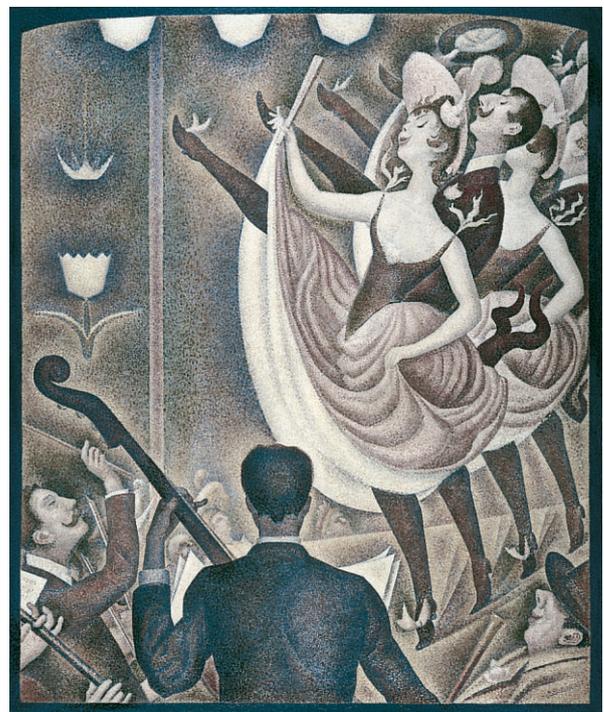


PLATE 18 Georges Seurat, *Le Chahut*, 1889–90. Canvas, 171.5 × 140.5 cm. Collection Kröller-Müller Museum, Otterlo, The Netherlands. Photo: Indien van Toepassing, Amsterdam.

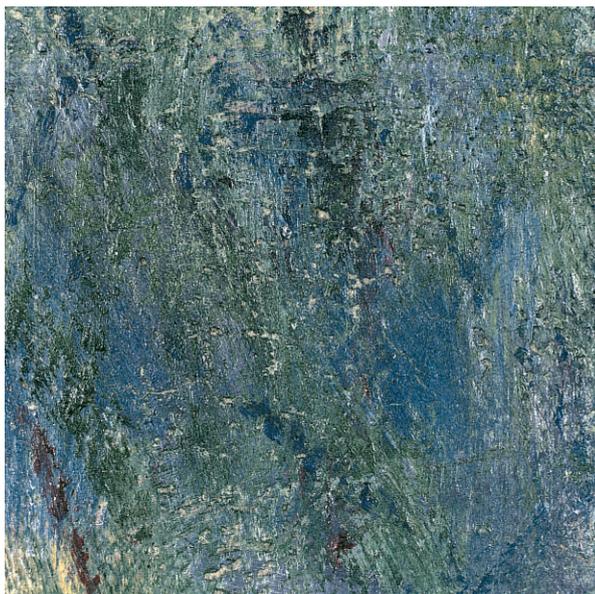


PLATE 19 Detail of purple shadow on grass from *Bathers at Asnières* (PLATE 4), showing contrast between viridian green and mixed purple paint.

It is clear that Seurat wished to explore harmony of colour over and above effects of simple contrast. As well as the information he gained from Rood's book, his meeting and subsequent friendship with the mathematician Charles Henry encouraged him in this. Henry developed theories concerned with the symbolic values and associations of colours. Warm colours were more or less pleasant, whereas cold colours such as green, violet and blue were somewhat sad or inhibiting. He too constructed a chromatic circle where colours were associated with a particular emotional direction; thus pleasant (dynamogenous, that is, physiologically stimulating) colours correspond to agreeable directions: upwards and left to right. In his desire for a logical and scientific basis for the construction of his paintings, Seurat was particularly indebted to Henry's theories on the combination, direction and relationships of the linear elements of his compositions to control harmony and mood. Seurat's preoccupation with colour harmony can be seen in his earliest works and after 1886, when he first met Henry,²³ he also began to incorporate Henry's ideas on the perceptual effects of geometry and spatial arrangement on his compositions. Seurat's development in this regard can be seen clearly from a comparison of the *Bathers* and the rather later landscapes, for example *The Bridge at Courbevoie*, where so many vertical features are stressed, and the *Channel of Gravelines*, *Grand Fort-Philippe*, in which the idea is more subtly demonstrated by the slight upward rise

in the line of the horizon from left to right, emphasised by painted borders. The symbolic use of line and also colour were perhaps explored to a greater extent in the interior scenes, all painted after 1886, such as *Le Chabut* (PLATE 18) and the *Young Woman powdering Herself*.

At some time Seurat copied out Rood's colour wheel and made notes on one of the experimental sections of the book. He may well have used the colour wheel to construct some of the contrasts and harmonies visible in the *Bathers*, as it was exhibited in 1884 – there are, for example, many based on cold viridian green and purple (PLATE 19), which are complementary colours according to Rood's system – but at this stage he had yet to investigate the effects of 'optical mixture' opened up for him by Rood and Henry and to develop the dotted brushwork so characteristic of his later paintings. In fact, his interest in and exploitation of contemporary colour theories are clearly evident in his earlier works, where the brushwork, although broadly directional, was more conventional. For Seurat, the purpose of this type of brushwork was both to optimise the optical mixture by juxtaposing the desired complementary colours in adjacent dots of paint, and also, on a larger scale, to construct areas of tonal contrast. It is, however, important to emphasise that Seurat's colour harmonies and contrasts whether constructed on the basis of Chevreul's work, or on Delacroix's, Blanc's, Rood's or Henry's, are in no way naturalistic. His earliest outdoor sketches, and indeed his studies of a model posed in the studio, may have been painted from what he observed; but the colour in the later studies and in the final painting has been ordered and contrived as part of the intellectual process of the construction of the picture.

Seurat's working practice

The five fully realised exhibition pictures examined here cover the whole development of Seurat's style, from the earlier controlled and directional brushwork seen in the *Bathers* in its first phase, and when first exhibited, to his adoption first of divisionist brushwork (that is, individual small touches of paint) and, slightly later, of subtly constructed harmonies and contrasts of colour in the *Channel of Gravelines* and the *Young Woman powdering Herself*. This apparently straightforward description of Seurat's development is complicated by the fact that he reworked many of his earlier pictures, including the *Bathers* and the *Grande Jatte*, in his



PLATE 20 Detail from *Horses in the Water* (PLATE 3) showing the colour of the support (panel) showing through the paint.

later, divisionist style, in some cases adding a toning painted border.²⁴ Seurat's most elaborate use of his own theories can be seen in his indoor compositions such as the *Young Woman powdering Herself* and *Les Poseuses*, in which he was free to define imaginary colour combinations and contrasts. These seem to have been painted under artificial light, unlike the outdoor scenes, such as *The Bridge at Courbevoie* and *Gravelines*, where the parameters of shifting natural light imposed constraints on his invention by the sheer number of possible

harmonies and contrasts generated in the scene in front of him. Because Seurat reworked so many of his pictures, the use of materials typical of his later divisionist technique is evident even on the earlier compositions in the reworked areas.

Examination of the sketches for these and other compositions has revealed a great deal about the painting materials Seurat used throughout his life. On the whole these are consistent with those found in the finished pictures. The small sketches were primarily compositional works, in which considerations of colour theory were of subsidiary importance, which is why perhaps their palettes were relatively restricted in comparison with the large-scale works based on them and do not change very much over time – apart from Seurat's abandonment of earth pigments some time after he painted the *Bathers*. Another consistent feature of Seurat's small compositional studies is his use of thin wood panels as supports, while his finished paintings are all on canvas with light-coloured or white grounds.

Supports and grounds

There were a number of possible supports that could be used for small preparatory sketches. Contemporary artists' suppliers list papers, mill-

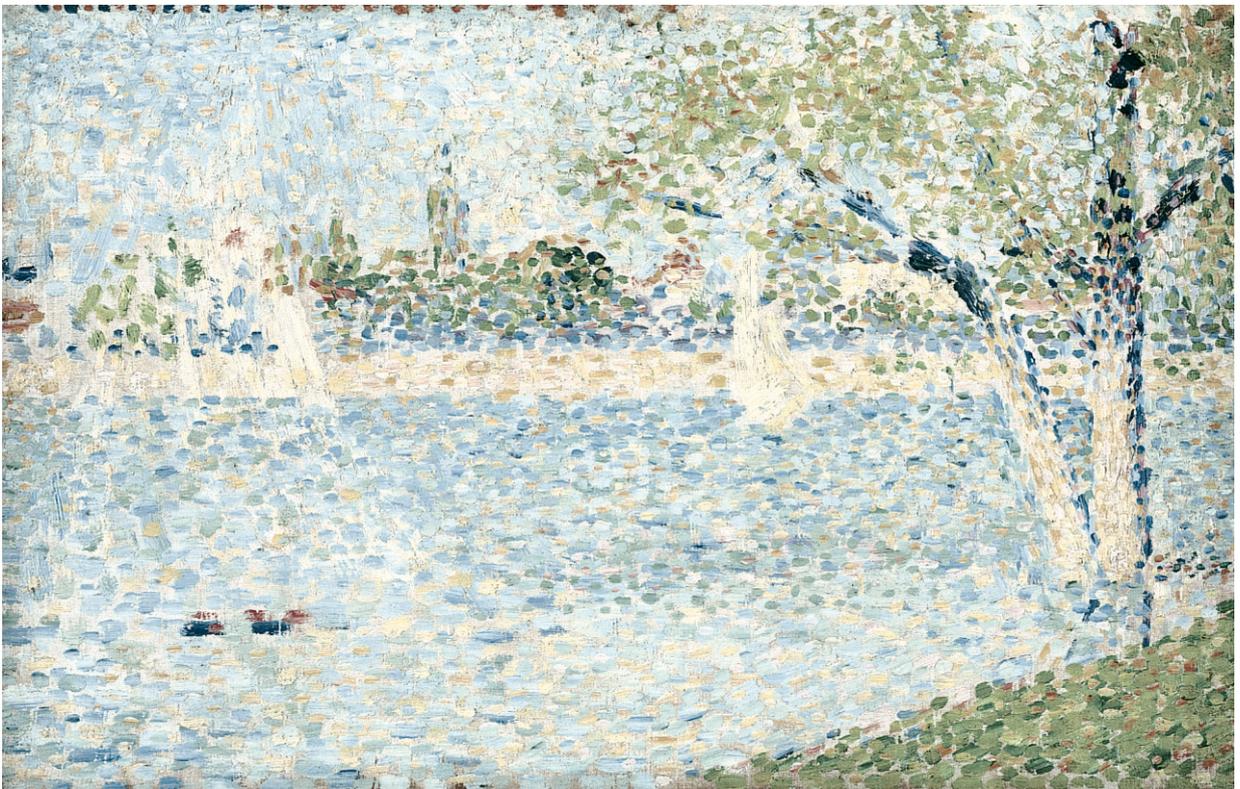


PLATE 21 Georges Seurat, *The Seine seen from La Grande Jatte* (NG 6558), 1888. Panel, 15.7 × 25 cm.

board, wood panels and canvases in a range of formats and sizes. The Impressionists preferred to employ canvas for all their works, but the Barbizon painters, such as Camille Corot, Théodore Rousseau and Charles-François Daubigny, used all types of support both for landscapes and for other subjects, and even for the most informal of their works.²⁵ Where works by these painters have been examined, the support usually carries some kind of ground. Seurat, on the other hand, habitually worked on small unprimed (PLATE 20) or simply filled wood panels.²⁶ In catalogues such as those produced by Lefranc & Cie smaller sizes of panel similar to those used by Seurat were advertised as *panneaux d'étude*. These, like other panels, were available with or without a priming or *rebouchés* (with the grain simply filled) and could be bought in sizes that would fit into a paint box, convenient to use out of doors. One standard size, listed as a No.2 landscape format by major Parisian suppliers such as Lefranc or Bourgeois *ainé*, was nominally 24–5 cm by 16 cm, and most of Seurat's small panels fall within this size range (PLATE 21). Panels were available as *mince* (thin) or *fort* (strong, or thicker); the actual thicknesses were not stated. Seurat's panels, which are about 0.4 cm thick, must be the 'thin' variety.²⁷ The painting boxes are listed in catalogues under names such as *boîtes de poche*, *boîtes au pouce*, *boîtes d'étude*, *boîtes paysage* and *boîtes d'étude à coulisses* (sliding), *rallongées* (extended leaf) and *crémaillères* (racked). Some painting boxes could hold several tiny *panneaux d'étude* suitable for outdoor work.²⁸ If Seurat used such a box to transport his studies for the *Bathers*, for example, this may explain the flattening of the impasto seen in some of the sketches: many of his panels display marks or grooves at the edges from being held in place within the lid of the box.

The *panneaux d'étude* were available in *bois blanc* (softwood, probably pine) and the more expensive *acajou* (mahogany): these are typical of



PLATE 22 Detail from *The Channel of Gravelines* (PLATE 11) showing the exposed white priming on the canvas.

the selection sold by most colourmen. Seurat's panels in the Courtauld Institute and the National Gallery have mostly been identified tentatively as mahogany. The support for the *Study for Le Chahut* appears rather different in format and has been cut down from a larger piece of wood.²⁹ Walnut panels were also available, and also, at the very end of the nineteenth century, more expensive woods such as tulip wood. In a few of the National Gallery sketches, the grain of the panel suggests the use of walnut rather than mahogany.

Ready-stretched canvases were widely available in a similarly standardised but more extensive range of sizes and with a considerable choice, in both colour and thickness, of primings.³⁰ Examination of *The Bridge at Courbevoie* failed to reveal a priming on the canvas, although this is very unusual. The canvas is close in size to a so-called No.10 portrait canvas measuring 55 by 46 cm. *Le Bec du Hoc*, *Grandcamp* and the *Channel of Gravelines*, *Grand Fort-Philippe* were both painted on No.25 portrait-format canvases (81 cm by 65 cm). In these cases, the canvases have been turned on their sides and used in landscape format. *Couple walking: Study for the 'Grande Jatte'* (c.1884–5; Cambridge, Fitzwilliam Museum) is also painted on a No.25 canvas, in this case in the upright 'portrait' orientation.³¹ Evidently, Seurat's preference was for the squarer 'portrait' shape, rather than the slightly narrower 'landscape' or 'marine' formats also available in standard sizes. *Young Woman powdering Herself* appears also to have been painted on a standard size portrait-format canvas, but later alterations to the stretcher mean that its present dimensions (about 94 cm by 78 cm) no longer correspond with any standard size.

The monumental scale of the finished paintings of *Bathers at Asnières* and *A Sunday on La Grande Jatte* suggests that the canvases must have been stretched to order. This would explain the coarseness of the linen used. Both works were painted on a single piece of canvas, and it is likely that they were of identical size before the *Grande Jatte* was enlarged by Seurat, who re-covered the tacking margin to accommodate a painted border.³²

A plain-weave canvas was used for *The Bridge at Courbevoie* and *Young Woman powdering Herself*. Both canvases are of a tightly woven, fine weave and similar canvases were used for *Le Bec du Hoc* and *Gravelines*. Canvases of this type were favoured in academic circles for finished works and exhibition pictures and it is probable that Seurat's particular preoccupations with brushwork and optical effects

were better achieved on a relatively smooth surface. A considerable variety of weaves was available for ready-stretched canvases, from a simple plain, relatively coarse weave for *pochades et études* through *toile demi-fine* to *toile très-fine* and *extra fine* in, for example, the Bourgeois catalogue of 1888. The *Study for 'A Sunday on La Grande Jatte'* (1884–5; New York, Metropolitan Museum of Art)³³ has a thread count of 30 by 29 threads per centimetre and *Le Bec du Hoc* 33 by 34 threads per centimetre, both extremely fine canvases which would probably come under one of these last categories.

Apart from the few occasions where Seurat appears to have used unprimed canvas (in this survey, *The Bridge at Courbevoie* and also the *Study for 'A Sunday on La Grande Jatte'*), his canvas paintings have light-coloured or white grounds. Most were commercially primed: the ground can be seen covering the tacking edges, as in, for example, the lower pale grey ground layer of the *Young Woman powdering Herself*. This is similar in colour to the ground on the large canvas of the *Bathers* which consists largely of lead white in oil lightly tinted with carbon black. In some paintings another ground layer has been applied over the commercial ground, as in the *Young Woman powdering Herself* where a very thin lead white ground has been applied on top of the commercial one. The canvas for the *Channel of Gravelines* also has a double-layered white ground, but in this case it appears to have been primed by the artist since neither layer extends onto the tacking edges. The lower layer consists of calcium carbonate, while the upper layer is lead white, both bound in oil. It is conceivable that, later in his career, Seurat desired a pure white ground for its optical effect, particularly as it was allowed to show in some areas of the composition

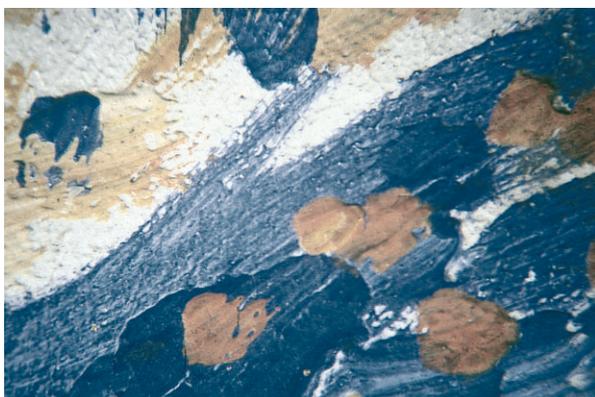


PLATE 23 Macro detail from *Study for Le Chahut* (London, Courtauld Institute Gallery) showing preliminary outline in blue paint of foreground figure. Photographed at 2×.

(PLATE 22). This could have represented a wish for a smoother surface texture, except that the artist's rather textured application was less smooth than that produced by the blades, similar to large palette knives, used by commercial canvas primers. The commercial *lisse* priming (generally at least two layers) was in fact very smooth. All the grounds examined analytically proved to be bound in oil. Canvases with absorbent grounds of calcium carbonate in aqueous (glue) media were available and Seurat experimented with such a *toile à plâtre* for *Les Poseuses* in 1887, but was displeased with the results. Paul Signac, who tried a similar ground, commented in a letter to Lucien Pissarro that the medium-rich paint stained the ground and sank on drying.³⁴

Painting structure and development

Examination by infrared reflectography of the *Study for 'A Sunday on La Grande Jatte'* in the Metropolitan Museum of Art has shown that two overlapping drawn grids divided the canvas first into regular quarters and then into square sixths. A similar, although not identical, grid related to a drawing of the subject and visible with the naked eye, has also been found on the Fitzwilliam Museum canvas study, *The Couple walking, Sketch for the 'Grande Jatte'* (Cambridge, Fitzwilliam Museum). The grid appears to have been done in black conté crayon. On the other hand, examination of the *Bathers* failed to reveal any squaring up, although, in cross-sections, some evidence was found for preliminary drawing in charcoal or conté over the light-coloured ground. Certain of the later sketches, for example *Study for 'Le Chahut'* and *Gravelines*, show long continuous strokes of cobalt blue outlining the design (PLATE 23). This is also clearly visible in the *Study for 'Le Cirque'* (Paris, Musée du Louvre), in *Poseuse debout* (1887; Paris, Musée d'Orsay) and in the preparatory sketch (Houston, Museum of Fine Arts) for the *Young Woman powdering Herself*. While these features can be seen in the studies, it is not possible to say whether he used a similar method for the completed paintings.

The majority of Seurat's works have preparatory drawings and painted studies, indicating the meticulous academic planning that went into his finished paintings. The *plein air croquetons* show the sense of immediacy and spontaneity commonly associated with certain types of Impressionist sketch, but their function was entirely subsidiary to the overall concept of the finished work. *Horses in the Water:*



FIG. 2 X-ray detail of boy seated on the bank from *Bathers at Asnières* (PLATE 4). The thinner paint outlining the reserve left for the figure registers as a dark band in the X-ray image, and is particularly evident below the boy's thigh.

Study for 'Bathers at Asnières' (1883–4; London, Courtauld Institute; PLATE 3), for example, is a very freely painted sketch of the banks of the Seine, closely similar to the view depicted in the *Bathers*, but it includes two horses and figures which do not appear in the finished, large painting.

It is known from X-ray study of the *Bathers* that Seurat left reserves for the principal elements of his

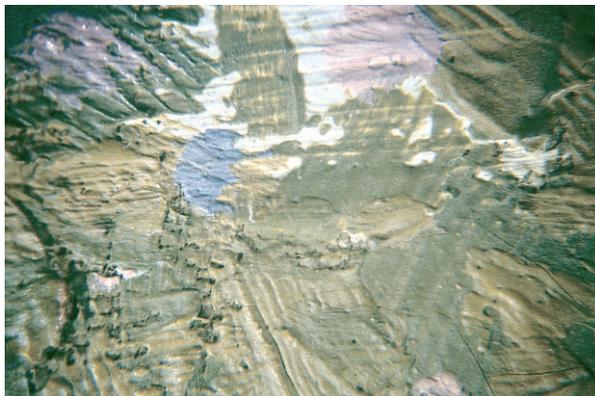


PLATE 24 Macro detail from *The Bridge at Courbevoie* (PLATE 8) showing yellow-green lay-in of the riverbank over white paint of the water. Photographed at 1.5x.

large composition, particularly the figures (FIG. 2),³⁵ and it seems likely that he followed much the same method in the execution of the *Grande Jatte*, which is even more complex in design. The principle of leaving reserves for the main elements of the composition seems to have been followed throughout his career in his finished paintings and in a few of the studies. Simple blocking-in of areas of the composition, leaving reserves revealing the ground or support, is apparent in *The Angler* (London, Courtauld Institute of Art), a study for the *Grande Jatte*; the orange-coloured support is visible around the figure to the right. Reserves have been observed in *The Bridge at Courbevoie* (visible in the X-radiograph), *Le Bec du Hoc* at the top of the rocky outcrop, where the ground is exposed, and in the *Young Woman powdering Herself* (also detectable in the X-radiograph). In the *Channel of Gravelines*, the paint is so densely applied that it is impossible to judge whether or not reserves were left for any parts of the composition, and the X-ray image, for the same reason, is not revealing in this respect.

In both the *Bathers* and the *Grande Jatte*, the broad features of the landscape – the riverbank, the

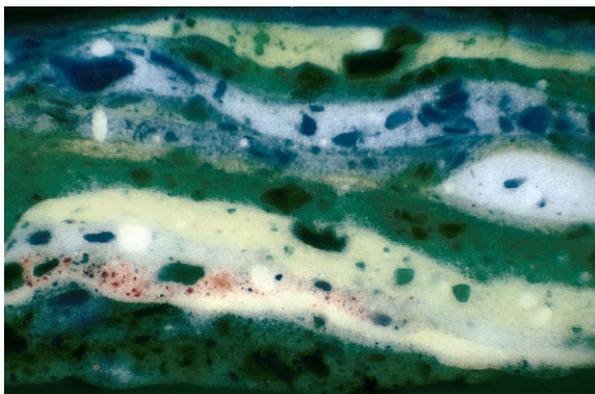


PLATE 25 Cross-section of paint from shadow behind seated figure in *Bathers at Asnières*, showing the multi-layered structure; at least three of the layers contain viridian (transparent chromium oxide). Photographed at 450x; actual magnification 360x.



PLATE 27 Detail from the painted border of *The Channel of Gravelines* (PLATE 11) containing cobalt violet and cadmium orange.

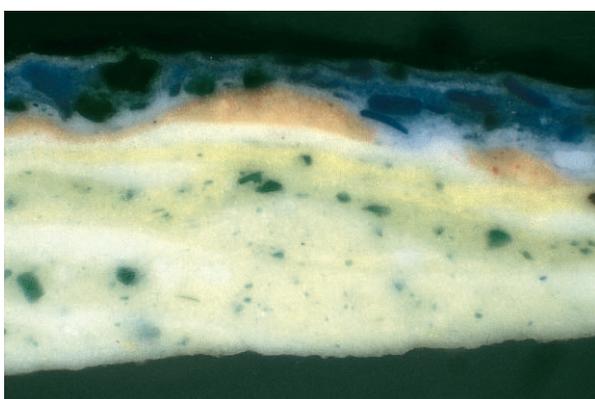


PLATE 26 Cross-section of deep blue-green surface paint over bright orange from the foreground riverbank in *Bathers at Asnières*. The underlayers contain chrome yellow and viridian, representing perhaps a commercially mixed paint. Photographed at 320x; actual magnification 250x.

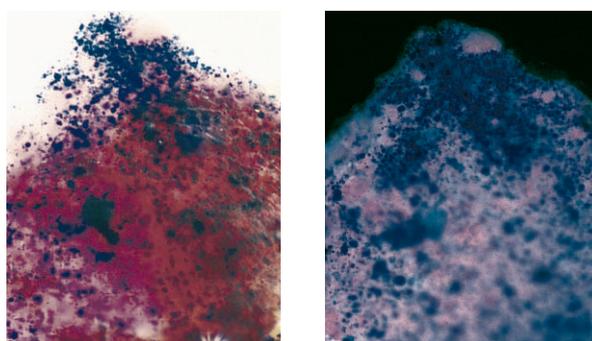


PLATE 28A (LEFT); PLATE 28B (RIGHT) Unmounted fragment of paint from the trousers of the reclining man, foreground left, from *Bathers at Asnières*, containing a mixture of French ultramarine with madder and cochineal lakes. A. photographed in reflected light at 250x. B. photographed by ultraviolet illumination showing fluorescence of the lakes; 200x.

water, the sky and so on – were brushed in with a thin layer of appropriately coloured lean paint. Thin dry paint was similarly used to lay in the compositions of *The Bridge at Courbevoie* and *Le Bec du Hoc*. The initial blocking-in in *The Bridge at Courbevoie* is much simpler than the same stage in the *Bathers* (PLATE 24). It is a smaller and less elaborate composition and Seurat's preoccupations with colour, and particularly brushwork, were rather more developed by this time; also, the very large scale of the *Bathers* dictates a broader and less time-consuming application of paint in the initial stages.

Seurat's selection of pigments, as identified from the analysis of paint samples, for the pictures covered by this survey are recorded in Table 3. It is clear that from an early stage in his career Seurat fixed on a core palette, composed largely of strong, spectrally pure colours:³⁶ cobalt blue and French

(synthetic) ultramarine; red lake and vermilion; chrome and cadmium yellows; viridian (PLATE 25) and emerald green, and lead white. Mixtures of these pigments are also found to give other reds, oranges, greens, purples and occasionally browns and blacks. Certain of these combinations may have been supplied ready mixed by the colourman, for example the green based on viridian with a little chrome yellow and lead white (PLATE 26). The Table shows the more restricted use, in addition, of other pigments such as red and yellow ochres, cadmium orange, manganese violet and the occasional use of carbon and bone black. It is the earlier pictures that show the widest range of palette, whereas the manganese violet and cadmium orange occur only in the late *Channel of Gravelines*, in the painted border (PLATE 27). Depending on the subject, a similar restriction in the range of pigments can be seen

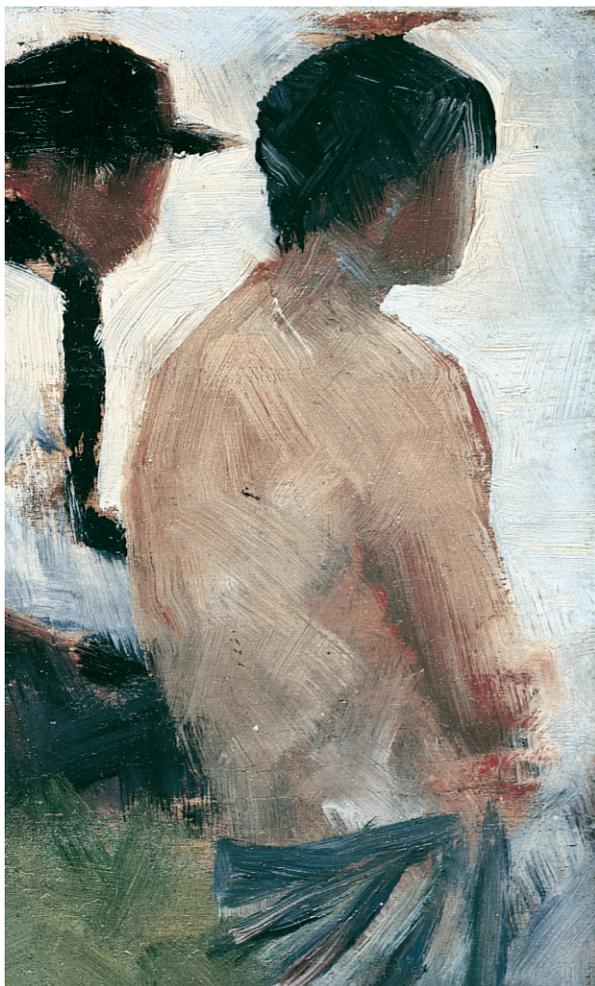


PLATE 29 Detail from *Study for 'Bathers at Asnières'* (PLATE 2) showing Seurat's use of earth pigments.

in the works of the Impressionists from the mid-1870s into the 1880s.³⁷ The motivation was perhaps the same: to obtain the most effective and vibrant colour contrasts, and, initially at least, it seems likely that Seurat was influenced by the Impressionists in this respect as much as by anything he may have read.

It is significant, perhaps, that neither chrome green (a pigment manufactured by the co-precipitation of Prussian blue with chrome yellow, and often described as *vert anglais*) nor Prussian blue itself feature in any of Seurat's pictures studied; both were widely available, inexpensive, useful colours and commonly employed in later nineteenth-century painting. These two colours, although of very strong intensity, lack the spectral purity of the core colours chosen by Seurat. Prussian blue tends to be rather green in tone and therefore less useful for the construction of essentially simple colour contrasts of the type that he, and the Impressionists, sought. Chrome green, which is already a mixture of

pigments, lacks the force of the pure pigment greens, viridian and emerald green, and is less effective in forming successful colour contrasts. The greenish cast of cerulean blue, another colour widely available, seems also not to have appealed to painters concerned with the application of simultaneous contrast and similar optical effects in their pictures, including Seurat.

It can be seen from the Table that Seurat's purples and violets were most frequently mixed from red lakes and French ultramarine, occasionally with the use of a red earth pigment rather than red lake, and sometimes with cobalt blue replacing, or in addition to, the ultramarine. In one case only in this survey, the *Channel of Gravelines*, an actual mauve pigment – manganese violet – was detected. At first sight it might appear surprising that the artist chose not to use a pure unmixed colour (cobalt violet was also available after 1859) as he did for the greens; however, the pigments in his mixed purple paints, that is, red lake and French ultramarine, have particularly high tinting strengths, and this quality, unusually, is retained in their mixture (PLATE 28). The mixture is also relatively transparent and can be used to create the saturated dark tones frequently found in areas of shadow in Seurat's work, as well as to create the lighter, more opaque mauves by the addition of lead white. Cobalt and manganese violets are less versatile.

Red and yellow earth pigments, whether these were natural earths or Mars (synthetic) colours, occur in his works until about 1884. In this survey these include both small studies on panel (PLATE 29) and *Bathers at Asnières*. Earths are also reported to be present in the first (1884–5) stage of the *Grande Jatte*.³⁸ All, of course, are essentially landscape compositions for which earth pigments are actually very useful and convenient. The use of these relatively muted pigments is more marked in the small sketches, where the artist was recording a particular scene or motif, but not exploring colour effects in detail. In the *Bathers*, the earth pigments tend to have been used in the lower layers, when the first stage of the design was being developed. At the surface, their colours are produced by mixtures of the more optically pure pigments noted above. In the later works, some time after Paul Signac's injunction to Seurat in 1884 to abandon earth pigments in favour of the 'prismatic colours' favoured by the Impressionists, Seurat does indeed seem to have relinquished them, with the possible exception of yellow ochre.³⁹

It is not unusual to find a relatively large number

of yellow pigments present in an otherwise rather limited palette. This is because the colour of a yellow pigment is difficult to modify by mixing other than by the addition of white to lighten it. It is possible, with care, to obtain a warmer shade by the addition of a little red, but mixture with other pigments will change the yellow colour to a green or a brown. The yellow pigments identified here in Seurat's work cover the whole range from pale primrose, through the lemon of strontium yellow, to more golden hues of cadmium and chrome yellows.

It may also be significant that although fairly few pigments are used, Seurat consistently worked with two blues (cobalt blue and French ultramarine), two greens (viridian and emerald green) and at least two reds (vermilion and red lake). In practical terms this generally proves necessary not only for reasons of intrinsic hue – that is, in the case of the blue pigments, the quality of the blue, whether it is purplish or greenish – but also for the way in which the pigments behave when mixed to give another colour (purple, for example) or when required for areas of the deepest shadow. The ultramarine is used in areas of shadow and often mixed with red lake to form deep, translucent purples, whereas cobalt blue is seldom used for mixed purples, but occurs regularly in sky paint. These considerations also apply to the greens: viridian is used to represent deep shadows, for which emerald green, with its rather unnatural grass green colour, would be entirely ineffective. In the case of the reds, vermilion is a markedly more opaque pigment than are red lakes and, in conventional painting, a rather dominant colour. The difference in transparency, which

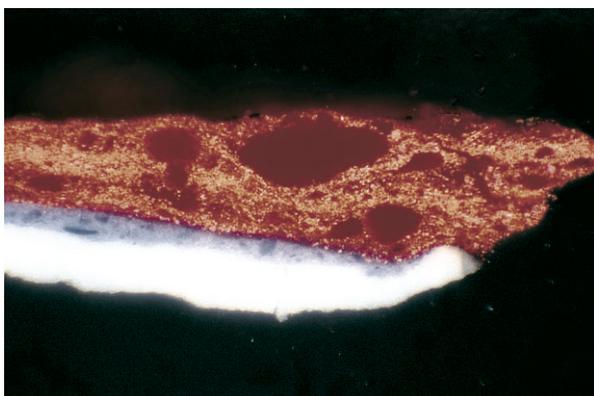


PLATE 30 Cross-section of bright red paint composed of a mixture of red lake with vermilion from the border of *The Channel of Gravelines*. The combination of pigments may be a colour-maker's mixture. Cobalt blue and the white ground lie beneath. Photographed at 280x; actual magnification 225x.

was widely exploited in earlier centuries for the painting of draperies, seems not to have been relevant to Seurat's technique. It is notable, however, that vermilion is frequently combined with some red lake in such a way that its tendency to dominate in a composition is mitigated (PLATE 30), and thus it contributes towards the more integrated surface that Seurat aimed to achieve with his broken brushwork.

Developments in paint technology

By Seurat's time, the pigments heralded as new in the early decades of the nineteenth century had established themselves as standard materials on the palette, particularly cobalt blue, a range of chrome yellows, emerald green, French ultramarine and viridian.⁴⁰ The cadmium yellows and cobalt and manganese violets became more widely used a little later, certainly by the 1880s. A surprisingly large number of traditional artists' pigments continued to be available throughout the nineteenth century, although in some cases their method of manufacture had been improved by innovations in chemical technology; these included Naples yellow (lead antimonate yellows), madder lakes, Prussian blue, vermilion and lead white. In addition, a range of synthetic dyestuffs that could be used as the basis of pigments were introduced during the latter part of the century. Some, such as alizarin, had a naturally occurring equivalent in the madder plant, others, such as mauveine and the coal-tar dyes, eosin colours and related products, had no counterpart in nature.⁴¹ There is no evidence so far to suggest that any of these purely synthetic dyestuff-based colours feature in Seurat's palette, either as pigments in their own right or as additives or as adulterants to other pigments.⁴²

The table of pigment occurrences (Table 3) indicates Seurat's consistent and widespread use of chrome yellow, which was available in several varieties. The 1888 *Bourgeois aîné* catalogue of artists' materials, for example, listed at least four shades of chrome yellow, presumably all lead chromates produced under differing conditions of precipitation, particularly temperature, alkalinity and dilution.⁴³ Other chromate yellows containing barium, zinc and strontium gave rather different more transparent lemon shades, listed under names such as *jaune citron* in suppliers' catalogues. In addition to these chromes, Seurat used yellow ochre, cadmium yellow and a pigment which may have consisted of a yellow organic dyestuff on a lead white substrate.⁴⁴ Although yellow ochre is found in

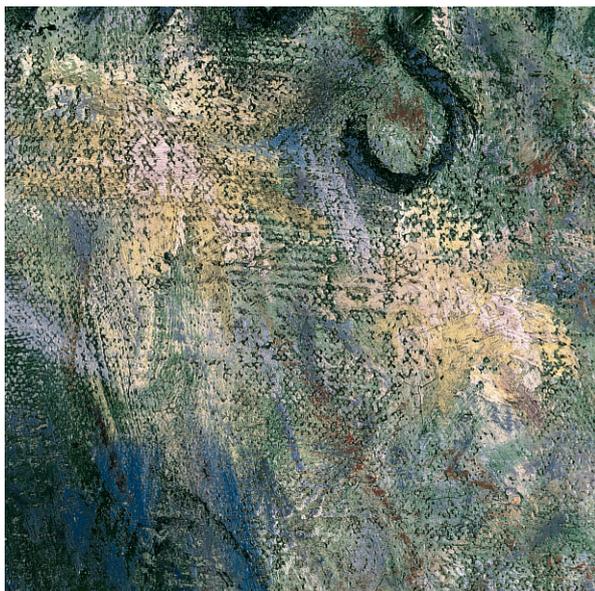


PLATE 31 Detail of yellow flowers near the signature, lower left, in *Bathers at Asnières* (PLATE 4), painted in cadmium yellow.

Seurat's paintings throughout his career, he tended to use it less frequently after about 1884. Cadmium yellow and the organic yellow pigment both appear in the *Bathers* (PLATE 31), apparently for the first time, and are used sporadically thereafter for the particular quality of yellow they provided. Cadmium yellows were made in almost as wide a range of hues as the chromes: the Bourgeois catalogue of 1888 lists four (*citron, clair, moyen* and *foncé*).⁴⁵ It would therefore have been possible for Seurat to obtain the range of yellow he needed largely from stable cadmium pigments, as indeed Monet had chosen to do after experiencing some problems with the chromes he had been using.⁴⁶ The fact that the cadmium yellows were four times the price of the chromes must have discouraged their wider use. Similarly, stable mid-priced yellows composed of lead and antimony (true Naples yellow) had enjoyed a revival in the second half of the nineteenth century, probably as a result of dissatisfaction with certain chrome yellows. Renoir, for example, used Naples yellow in the 1880s, rather than chrome;⁴⁷ Seurat, however, seems not to have used this pigment, perhaps because its particular, slightly pinkish tone was not useful to him.

Analysis of all these chromate yellows frequently reveals the presence of barium sulphate, lead sulphate, calcium sulphate and zinc oxide, which modify the colour, transparency and handling properties.⁴⁸ These are examples of extenders, although it is difficult to be sure whether they were co-precipitated with the yellow chromate, deliberately ground



PLATE 32 Detail of the application of dots of paint around the straw hat on the riverbank in *Bathers at Asnières* (PLATE 4), probably applied by Seurat in 1887. The olive green is a discoloured mixture of emerald green (copper acetoarsenite) and zinc yellow (zinc potassium chromate), while the brownish-orange colour is based on zinc yellow. These paints contain starch as an extender or modifier of paint working properties.



PLATE 33 Macro detail from *The Bridge at Courbevoie* (PLATE 8), bottom right corner of the riverbank, revealing undiscoloured yellow paint in a flake loss. Photographed at 3.5×.

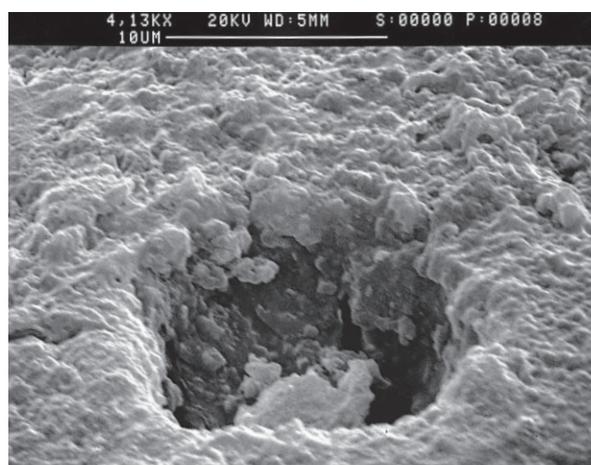
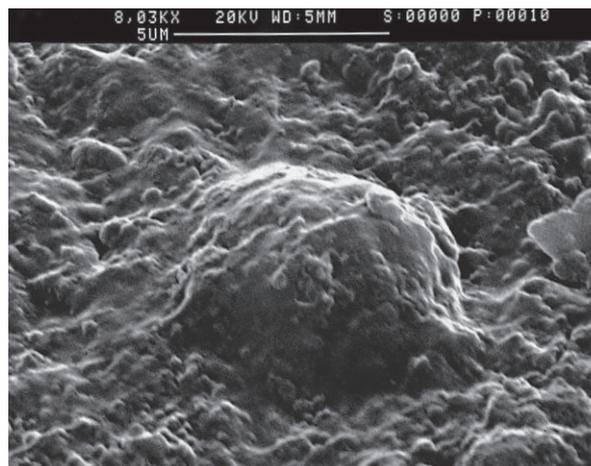
together with it by the manufacturer, or both.

In spite of the reputation that chrome yellow and its congeners had for instability to light – a tendency noted by Mérimée as early as 1830⁴⁹ – this seems not to have been a problem in Seurat's pictures. All the areas of chrome yellow paint appear to have remained in good condition, apart from those areas in which a particular zinc-yellow-containing paint was used. Zinc yellow (zinc potassium chromate) is known to be one of the less light-stable forms of yellow chromate pigments, turning from a bright lemon yellow to grey-green due to the formation of green chromic oxide.⁵⁰ Seurat had purchased this pigment from the Maison Edouard for the reworking of the *Grande Jatte* on

the recommendation of Camille Pissarro in October 1885;⁵¹ no zinc yellow has been found on the preparatory studies. The same unstable material was identified in discoloured greenish-brown spots applied by Seurat in 1887 in his reworking of the *Bathers* (PLATE 32). This was described by Signac, who also noted the darkening and the fact that the pigment had been bought from Edouard.⁵² This is about the same time that Seurat painted *The Bridge at Courbevoie* (that is, the winter of 1886/7) where the pure yellows have taken on a distinctly ochreous tone and caused darkening of the pigment mixtures in the light greens and oranges (PLATE 33). It is perhaps significant that, in each of these pictures, the zinc yellow paint has been shown to contain a starch-based extender (FIG. 3) which may play a part in the mechanism of discoloration, but this is difficult to elucidate because of the complexity of the inorganic phases present. It is also worth pointing out that the manufacture of all chromate yellow pigments required a careful post-treatment following the precipitation reaction giving the pigment. If this was not sufficiently thorough, an unstable product was the result.⁵³

Red lakes were an important part of the palette for their intensity of hue and colour saturation. The most common sources of red dyestuff throughout most of the nineteenth century were the madder root and the cochineal insect, and lakes prepared from both of these sources have been identified in the works of many nineteenth-century painters. Towards the end of the century, after the elucidation of the structure of the alizarin molecule and its subsequent synthesis in 1868 by Graebe and Liebermann, the manufacture of synthetic 'madder' lakes became feasible.⁵⁴ In addition, other synthetic coal-tar dyestuffs, including reds, such as eosin, were made into lakes, although not necessarily for use as *couleurs fines*. It is known that an eosin-based lake was listed under names such as 'Geranium red', but there is no evidence from this survey that Seurat used this particular fugitive pigment.

During the nineteenth century considerable progress was made in the understanding of the colouring principles present in the madder root. Alizarin was extracted and identified by Robiquet and Colin in 1826; similarly purpurin,⁵⁵ although this is not itself present in the root in large quantity – the compound found in the root is pseudopurpurin, a purpurin carboxylic acid derivative. On the basis of this research considerable improvements were made in the preparation of madder lakes, resulting in a large variety of shades available to the



FIGS 3A and B SEM micrographs of discoloured yellow paint containing zinc yellow from *Bathers at Asnières*. A. Starch grain (extender or paint property modifying agent) protruding from surface; magnification 8,030 \times . B. Pit in paint surface caused by loss of starch grain. These pits fill with dirt and varnish, leading to increased discoloration of the paint layer; magnification 4,130 \times .

painter as recorded in the colourmen's catalogues. A process first devised by Robiquet and Colin in 1828 was the treatment of the madder root with aqueous sulphuric acid to give a brown material known as 'garancine'. Alizarin and the other anthraquinones are present in the fresh root largely in the form of glucosides (with sugar moiety attached); as a result of this acid hydrolysis treatment, the free anthraquinones are liberated. In addition, the pseudopurpurin is largely converted to purpurin. The end result is a product that is very much richer in dyestuff than the original root, rendering lake making and dyeing considerably more efficient and economical.

Slightly later in the century, other methods of processing the fresh root were devised. Kopp's



PLATE 34 Detail of reclining figure, left, on the riverbank in *Bathers at Asnières* (PLATE 4) in which the trousers are painted in a mixture of French ultramarine and red lake pigments based on madder and cochineal.

purpurin (1861), for example, was prepared from ground madder root soaked in water, saturated in sulphurous acid (H_2SO_3). After further treatment the resulting product contained pseudo-purpurin, purpurin, and other anthraquinones. Garancine, Kopp's purpurin and the other similar derivatives available at the time could then be used for lake making in a conventional way by precipitating the dyestuff on to a substrate of hydrated alumina, or other materials.⁵⁶

Analysis has shown that some late nineteenth-century madder lakes are rich in sulphur; one explanation for this could be the use of a madder derivative of this kind as the source of the dyestuff, although the presence of a sulphur-rich substrate is perhaps more likely.⁵⁷ This has been shown to be so for a number of lakes found in Seurat's paintings, for example *Young Woman powdering Herself* and the *Channel of Gravelines*. Under the microscope, the lakes are generally an orange-red, with a marked pale orange fluorescence under ultraviolet illumination (see PLATE 28). Chromatographic examination of the dyestuff (HPLC) has revealed the presence of a madder dyestuff with a very high content of pseudopurpurin and some purpurin, but very little alizarin; this is a common pattern for late nineteenth-century madder lakes, however, and not all show such a marked fluorescence or sulphur content. They can usually be described as being of the *laque de garance rose* type.⁵⁸ Seurat also used a lake containing cochineal dyestuff, for example in the brownish-purple trousers of the figure in the foreground of the *Bathers* (PLATE 34), where it is mixed with a madder lake and French ultramarine. It is not possible to say, however, whether Seurat mixed the two lakes himself, or if the mixture was

sold as a tube colour (it was available under the name *carmin de garance*).

Developments in the technology of pigments in the nineteenth century were paralleled to some extent by improvements to paint binding media, especially following Chevreul's research into the drying behaviour of the oils used, the effects of different methods of processing and the addition of metal salts as siccatives.⁵⁹ This paved the way for a greater understanding of the factors involved in the drying of oil paint and thus for efficient manufacture of the oils themselves. It also coincided with the development of collapsible metal tubes, generally of tin, which were a considerable improvement over the earlier storage method of bladders. Bladders, once punctured to release the contents, could only be imperfectly resealed with a tack; inevitably the paint tended to dry. This would have been particularly true of lead white and other fast-drying pigments. The screw cap of the metal tubes permitted effective sealing; furthermore, because the tube could be rolled up as the contents were used, the air was efficiently excluded. The shelf life of tube colours was also much greater. When the manufacturer could not rely on the container preventing premature drying, indeed setting, of the paint, it was not feasible to modify the siccative properties and consistency of the oil medium to any great extent other than, perhaps, to use the better drying linseed oil for poorly drying pigments such as lakes, ultramarine and blacks. These properties could be adjusted by the artist by the addition of oils, proprietary media, siccatives and so on. The use of metal tubes allowed the manufacturer to use modified oil media to improve drying where required, or to modify handling properties. This is

demonstrated by the finding of heat-bodied (that is, heat-thickened) oils in some of Seurat's paintings, whether they were bound in linseed or poppyseed oils (Table 2).

Examination of the binding medium in a number of samples from Seurat's paintings reveals certain trends, but no very consistent pattern, other than the fact that the lead white paint he bought usually seems to have been prepared with poppyseed oil. It also appears probable that he used more than one supplier for his tubes of paint: for example, the constitution of the paints used for the retouchings on the *Bathers*, bought from the Maison Edouard, show some similarities with those examined from *The Bridge at Courbevoie* and it is possible these came from the same supplier.⁶⁰ The results suggest a greater use of paint containing heat-bodied oil, mainly linseed oil, in the later paintings, and this type of paint may have been chosen because Seurat found that its handling properties suited his pointillist technique. Linseed oil appears to be the predominant binder for the poorly drying red lakes and for vermilion, while the blues were sometimes bound in the less yellowing poppyseed oil. In this the manufacturer of the finished paints was following what had become established practice by this date. The greens and yellows were usually bound in linseed oil.

It is known that a variety of materials were added both to the pigment, before mixture with any medium, and to the tube paint itself for a number of reasons, including the prevention of settling out in the tube of heavy pigments such as vermilion and to alter the consistency or flow properties of the paint. Certain pigments, for example Prussian blue, benefited from the incorporation of colourless extenders, which both lightened an otherwise extremely dark colour and improved working properties. Pigments with a high tinting strength could be extended in this way without any loss of colour saturation, and the product would be cheaper, but not necessarily of poor quality. Materials used as extenders might include barium sulphate, chalk, silica, calcium sulphate, and starch in one form or another. At a later stage in the preparation of the paint, before it was put into tubes, materials might be added to modify its handling properties or to extend its shelf life. The addition of wax might be made primarily to prevent separation of pigment and medium, although it would also alter the consistency of the paint, increasing its paste-like quality; water might be added for the same reason. During examination of French paintings dating from the late nineteenth

century in the National Gallery collection, however, wax, apparently used for such a purpose, has been found on only two occasions, in both cases in vermilion paint.⁶¹

Other ingredients might be added to the paint for rather different reasons. These include the addition of driers and the incorporation of substances (including water) to improve the 'wetting' of the pigment by the oil binder. This was particularly necessary for hydrophilic pigments such as French ultramarine; the surfactants used by the paint manufacturers for this purpose included soaps such as aluminium stearate.⁶² There is some analytical evidence to indicate that this practice was followed for certain of the tube paints Seurat used.

The analysis of Seurat's paintings in this survey indicates that on the whole the pigments were of high quality; there is little evidence for the presence of excessive amounts of extender and none for the use of pigments which had been adulterated or modified during manufacture by the addition of cheaper materials or brightly coloured but fugitive synthetic dyestuffs.

The pictures

'If you consider a few square inches of uniform tone in Monsieur Seurat's *Grande Jatte*, you will find on each inch of this surface, in a whirling host of tiny spots, all the elements which make up the tone.'⁶³ This was Fénéon's response to *A Sunday on La Grande Jatte* in his review of the eighth Impressionist exhibition of 1886, written for the new journal *Vogue* – the brushwork by this stage in Seurat's career embodies the logical outcome of the practical application of his researches into optical theory. This evolution can be summarised by comparing the surface paint of the foreground in the *Bathers* with the brushwork in the *Young Woman powdering Herself*, which changes from curving, criss-cross strokes of vibrating colour to small discrete dots and strokes of paint in which form is defined not only by the colour of the dots but also by their density (PLATES 35 and 36). In terms of the brushwork, pictures such as the *Grande Jatte* and *The Bridge at Courbevoie* could be described as transitional in their different ways.

The influence of Delacroix and certain Impressionist works can be seen in the brushwork of Seurat's earliest works and also in the small studies. However, although directional strokes are very obvious in studies such as *A Boat near a Riverbank, Asnières* (1883; Courtauld Institute Gallery; PLATES

5 and 37), it should be remembered that the function of these small paintings was more to experiment with the motif than with the brushwork and the handling of the paint. It is self-evident that horizontal features are conveniently represented by horizontal strokes of the brush, particularly for speed and economy of effort. Seurat's sketches are notably successful in their simplicity, conveying the essential features of a scene or motif efficiently and with concentrated focus – he may paint figures in just two or three strokes, but all that he requires for the further development of his projected composition is there.

The *Bathers* is a monumental composition in both conception and scale. No one form of brush-



PLATE 35 Detail of the brushwork in *Bathers at Asnières* (PLATE 4).

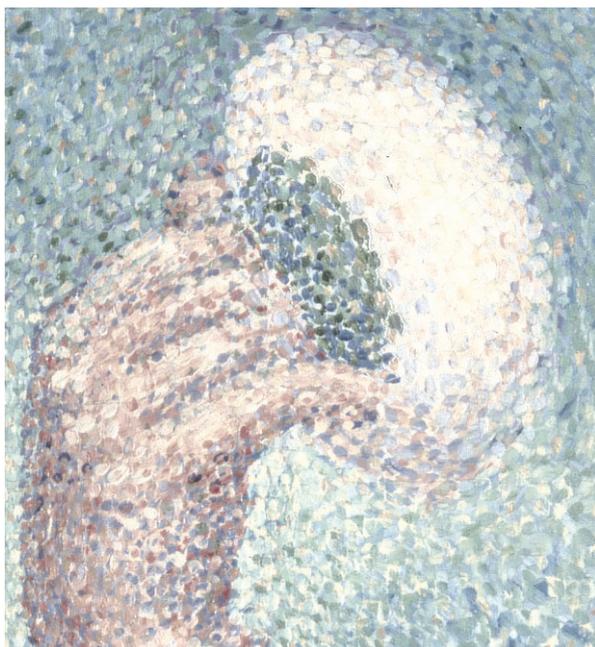


PLATE 36 Detail of the brushwork in *Young Woman powdering Herself* (PLATE 9).

work is used consistently throughout. The foreground has been constructed with an interlaced network of coloured *balayé* (sweeping) brushwork over a more solid underpaint, to create the flickering effect of the play of light over grass. It is a method Seurat often used to render similar features such as cornfields and broad masses of foliage. Elsewhere, smooth horizontal brushstrokes have been used for the water and an even smoother effect has been sought in the painting of the flesh of the bathers themselves. Here, and in the water, the paint has been heavily worked as it was built up in many layers, resulting in a somewhat dry and pasty texture. Soft, irregular blotches of paint were used for the dog, the figures' clothing and hair, the sky and other features, producing a mottled, indefinite effect. A curious detail is the febrile network of light blue brushwork around the dog's hindquarters and tail, which is very reminiscent of Seurat's drawing style at this time. Around 1886 or 1887, over two years after the painting was completed and first exhibited, Seurat revisited his composition and applied small dots of colour, principally to the bathers and their immediate surroundings, based on the type of brushstroke he used in his final reworking of the *Grande Jatte*, in which it first appears. The 'orderly, elongated, parallel dashes' as defined by Henri Dorra and John Rewald, used to construct the forms of the tree trunks, clothing, parasols, and other features in the *Grande Jatte*, are absent from the *Bathers*, although they do occur in a few others of his works of about this date.⁶⁴

The composition of *The Bridge at Courbevoie* has been laid in using directional and criss-cross brushstrokes, worked wet-in-wet over a preliminary underpainting. It was then finished with a series of superimposed dots, applied with a small brush (PLATE 38). *Le Bec du Hoc* was begun, and also worked up, with a similar technique of horizontal and *balayé* strokes; the dots were not applied until some time later, when the painting was being lent for exhibition: the pale-coloured criss-cross strokes are still visible in the sky under the dotted application. In this painting, the dots are far from circular. Short horizontal lines and tiny vertical strokes in the water suggest its shimmer (PLATE 39); dots around the periphery of the composition follow the direction of those in the adjacent painted border. The painting of the promontory itself is rather reminiscent of the manner of painting of the foreground in the *Bathers*, although the scale of the brushstrokes is smaller and diminishes in general size and spacing towards the point of the cliff, suggesting recession.



PLATE 37 Detail showing the brushwork in *A Boat near a Riverbank, Asnières* (PLATE 5).



PLATE 39 Detail from *Le Bec du Hoc* (PLATE 7) showing the variety of brushwork.

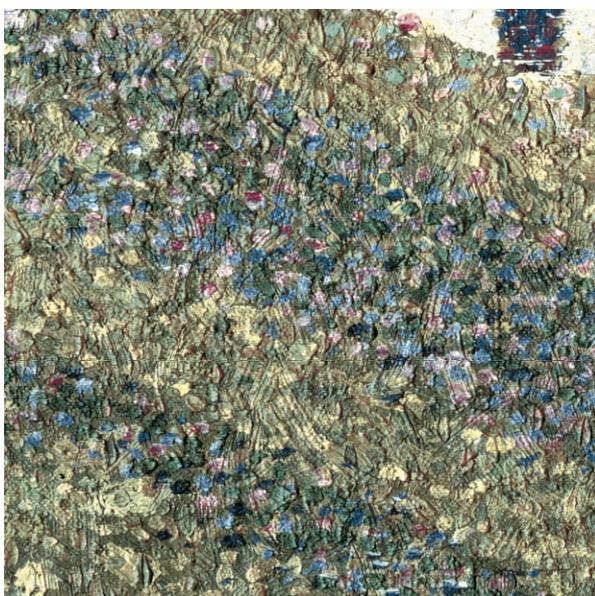


PLATE 38 Detail from *The Bridge at Courbevoie* (PLATE 8) showing the variety of brushwork.

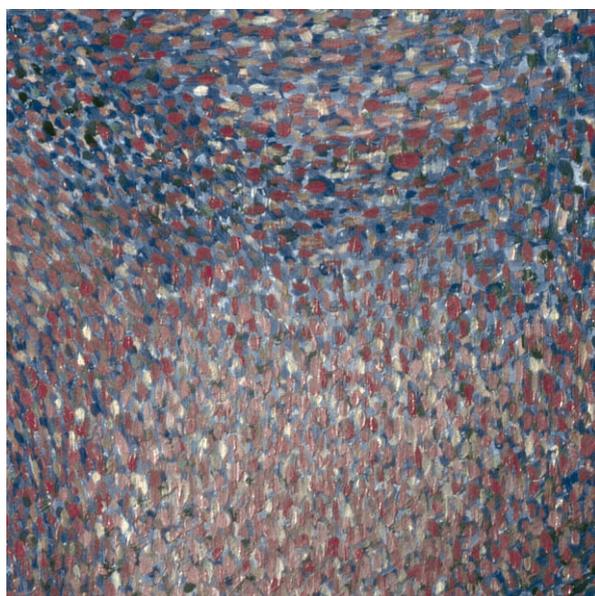


PLATE 40 Detail of the brushwork in *Young Woman powdering Herself* (PLATE 9).

Even in Seurat's later works, such as *Young Woman powdering Herself* and the *Channel of Gravelines*, the dots cannot be described as a single type of brushstroke and were certainly not applied in a mechanical and unthinking manner. Seurat used his brushes to form strokes of many different sizes and shapes, oriented in varied directions to delineate form and create movement. In both these paintings, and particularly in *Young Woman powdering Herself*, Seurat seems to change his brushstrokes according to the amount of detail desired, or the prominence of the motif (PLATE 40). The brushwork in the skirt of the young woman is much broader and more directional than the tiny dots used to build up the features of her face. Similarly, the dashes used to paint the beach in the foreground of *Gravelines* are fatter and freer than those used in the

middle ground and distance, creating the effect of aerial perspective (PLATE 41).

In the large earlier version of *Les Poseuses* (1886–8; Merion, Barnes Foundation), the background is depicted using dots of a very small scale, which Paul Signac considered too small to be effective. He described the resulting overall tonality as grey, whereas 'other parts, which are treated more broadly, are of a much more beautiful colour'.⁶⁵ A second smaller version of the composition, Private Collection, formerly in the Berggruen Collection, was painted in 1888, in a looser, broader style of brushwork; although less readable at close range, this version appears much fresher in colour and a livelier work from a natural viewing distance. In spite of Ogden Rood's theoretical assertion that paint of complementary colours applied in adjacent



PLATE 41 Detail from *The Channel of Gravelines* (PLATE 11), centre of beach, showing the brushwork of the foreground.

small dots produced the most vibrant effects and the most realistic representation of the effects of light, in practice small brushstrokes, however highly coloured, tend to produce a greyed overall appearance when viewed from a distance so that the constructed forms emerge from the maze of brushwork, and the strokes themselves appear to blend into one another. On the other hand, in their works of the 1870s, painters such as Renoir and Monet achieved a far more striking and effective use of complementary colour in the depiction of everyday landscape scenes by using similarly vivid pigments, but using larger strokes and blocks of colour.

The five finished paintings examined during this survey provide examples of the complete range of Seurat's oeuvre, from the point of view of subject matter: landscapes, compositions involving groups

of figures and portraits. The only category that seems to have been of little interest to him was still life. Each of these types of painting imposes its own technical discipline on the painter: thus painting a landscape necessarily dictates a particular range of colours and choice of palette, and the painter will have to take into account changing patterns of light and weather. Painting an indoor scene allows painters to control and determine light and shade, to place the subject, and even to devise a totally imaginary setting, entirely to their own requirements. For Seurat, the particular appeal of indoor scenes was that his interests in the expression of mood and optical effects could be integrated and were under his full imaginative and practical control. At the same time, he maintained his interest in the effects of changing natural light on landscape and water, painting many views at Gravelines and elsewhere on the coast. Even in his later landscapes, however, Seurat creates a level of artificiality, a static quality, which is a product of the divisionist technique. It is noticeable that in none of the paintings examined here – *Bathers*, *Bridge at Courbevoie*, *Le Bec du Hoc*, *Young Woman powdering Herself* and the *Channel of Gravelines* – is there much sense of depth or recession, and this is also largely the result of the particular manner in which Seurat applied the divisionist technique. When the eye can resolve individual dots and brushstrokes, these are inevitably perceived to lie in the same plane, but it seems likely that this phenomenon was of subsidiary importance to Seurat.

Throughout his career, Seurat constructed his compositions around the principles of simultaneous and complementary contrast of colour, although not entirely in the ways suggested by the theories of Chevreul and Rood. For example, incidences of a simple red–green textbook combination are very infrequent and similarly the stark use of yellow against purple is also rarely seen, whereas the orange–blue juxtaposition was a favourite of Seurat's (PLATE 42). The other consistently used combinations involve an orange-red with blue, and various greens, including a light yellow-green, with purple.

Many of these ideas of colour, brushwork and composition had already reached fruition in the *Bathers*, the earliest of the group of works examined. This can be seen in the use of broken and directional brushstrokes discussed above, but also in the complex layering and juxtaposition of colour both in terms of contrast and in terms of lightness and darkness of tone. Contrasts are set up between



PLATE 42 Detail of the middle distance, left, in *The Channel of Gravelines* (PLATE 11) showing Seurat's use of complementary contrast of orange and blue.

individual brushstrokes, working up to broader areas of neighbouring colour in the painting. The complexity of execution is at its greatest in the colour and structure of the sunlight grass in the foreground compared with those areas of the bank cast in shadow. A similar, more subtle, effect can be seen in the pale blues, oranges, yellows and greens of the water. It is generally the case that when Seurat mixed a desired colour the number of pigments used was as few as possible to retain the purity of tone. In the *Bathers*, for example, cobalt blue, which is found in both sky and water, was used in pure form or mixed only with white, while greyer blue tints, containing French ultramarine, were applied as separate brushstrokes. The most intense green colours of the bank are composed of viridian or simple mixtures of the pigment with white or cadmium or chrome yellow. Cobalt blue combined with viridian provided a dark green. Almost all the applications of paint incorporate a proportion of lead white, giving the painting a light and opaque appearance. This is a general feature of Seurat's works and it is notable that he did not incorporate proprietary resin-containing painting media into any of his paints to increase their gloss or transparency. Within the overall green colour of the grass are touches of intense blue (cobalt blue), a greyer blue (French ultramarine with white), mauves and purples (cobalt blue, French ultramarine and red lake), yellow (cadmium and chrome yellows), pink and red (vermilion, red lake and white), and orange (vermilion and chrome yellow).⁶⁶

In the later *Channel of Gravelines* simultaneous contrast of colour has to some extent become subordinate to simultaneous contrast of tone, that is, the contrast between light and dark shades of the

same colour. The painting is constructed largely in shades of yellow in the foreground and gradations of blue and lilac in the sky. At the same time there is the overall complementary contrast of colour between the sky and the beach; the effect achieved is quite subtle because of the blonde colour. In this painting the consistent use of a divisionist technique throughout the whole composition unifies the surface and creates a calm effect.

Conclusion

In assessing Seurat's career it is clear that the guiding principles underlying his paintings were theory and technique and the connection between the two. This resulted in an unusual clarity of purpose in the planning and execution of his paintings, so much so that he seems never to have had any doubts about what he was trying to achieve (FIG. 4). This certainty in turn impressed others so that he attracted a number of followers, among them Paul Signac, and a considerable degree of public interest in his work. The paintings surveyed here reveal unambiguous trends in his technical development as far as the expression of theoretical concepts and the handling of paint are concerned. The *Bathers*, however, does not quite fit comfortably into this pattern of development and appears to be a point at which Seurat changed direction. The *Bathers* was intended as an Academic piece on a monumental scale constructed on the basis of many studies. Unlike their surroundings, the unclothed figures, particularly that of the central bather, are conventionally and smoothly painted. One may speculate that the rejection of this painting by the Salon may have been a factor in Seurat's reconsideration of the direction his painting



FIG. 4 Georges Seurat, *The Artist in his Studio*, c.1884. Conté crayon on paper, 31.5 × 22.5 cm. © Philadelphia Museum of Art (A.E. Gallatin Collection).

should follow. *A Sunday on La Grande Jatte* has a similar subject, and is also a large-scale work based on many studies, but the use of more formulaic systems of brushwork throughout the whole painting suppresses the importance of the figures in such a way that they become part of a patterned surface. Having decided that the real subject of his art was the exploration of optical and aesthetic theories of colour and design, Seurat carried his researches through to their logical conclusion. The 'painterly' quality of painting – the individualistic touches of impasto, the idiosyncratic use of line, wash and handling of paint – was eliminated by the use of standardised brushwork: colour, light and shade became the means of expression. At the same time forms became even more simplified and here we may see the influence of his earliest drawing lesson at the Ecole Municipale de Sculpture et de Dessin. The fact that Seurat was able to crystallise the principles behind his art in the letter to Maurice Beaubourg in 1890 suggests that he felt he had achieved his aims. 'Art is harmony. Harmony is the analogy of contrary and of similar elements of tone, of colour and of line considered according to their dominants and under the influence of light, in gay, calm or sad combinations.'⁶⁷

Acknowledgements

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Aviva Burnstock is Senior Lecturer in the Department of Conservation and Technology, Courtauld Institute. Kate Stonor is presently Intern in Paintings Conservation at the Hamilton Kerr Institute, University of Cambridge.

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- 7 Leighton et al. 1997 (cited in note 1), p. 93; Herbert 1991 (cited in note 5), pp. 109, 111.
- 8 Herbert 1991 (cited in note 5), pp. 394–6; M.L. Zimmermann, *Seurat and the Art Theory of his Time*, Antwerp 1991, pp. 45–7.
- 9 Herbert 1991 (cited in note 5), p. 147; J. Rewald, *Post-Impressionism*:

- From van Gogh to Gauguin*, 2nd edn, New York 1962, p. 80.
- 10 Herbert 1991 (cited in note 5), p. 411.
 - 11 Rewald 1962 (cited in note 9), pp. 100–2.
 - 12 There were four versions of this letter: see Herbert 1991 (cited in note 5), pp. 372–3, 381–3; see also Dorra and Rewald 1959 (cited in note 6), pp. lxxii, xcix (fig. 37). For a general summary of the scientific and psychological theories underlying Seurat's work see W.I. Homer, *Seurat and the Science of Painting*, Cambridge, Mass. 1964 (1978 reprint), pp. 20–48; 112–79. For further discussion of how far Seurat's approach was, in fact, scientific see also J. Gage, 'The Technique of Seurat: A Reappraisal', *Art Bulletin*, LXIX, 1987, pp. 448–54; A. Lee, 'Seurat and Science', *Art History*, 10, 1987, pp. 203–26; P. Smith, 'Seurat: The Natural Scientist?', *Apollo*, CXXXII, no. 346, 1990, pp. 381–5.
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 - 15 Chevreul 1839 (cited in note 14), paragraphs 335–40, pp. 197–201. See also Herbert 1991 (cited in note 5), pp. 388–91.
 - 16 D. Sutter, 'Les phénomènes de la vision', *L'Art*, VI, I, 1880, pp. 74–6, 124–5, 147–9, 195–7, 216–20, 268–9; for irradiation and chiaroscuro see paragraphs vlv–vlii, p. 216. See also Herbert 1991 (cited in note 5), pp. 387–8; Zimmermann 1991 (cited in note 8), pp. 52–3.
 - 17 The optical effect to which the name of irradiation is usually given is defined as the apparent enlargement of the edges of a strongly illuminated object when seen against a dark background. It was so described by Hermann von Helmholtz in an article entitled 'L'optique et la peinture', published in Ernst von Brücke's *Principes scientifiques des beaux-arts*, Paris 1878: see esp. pp. 207–9 (Brücke's own work on colour physiology, published in Leipzig in 1866, became available in French translation in 1881). Helmholtz thought the explanation lay in the fact that the cornea and lens of the eye are a little cloudy, thus causing some refraction, and therefore scattering, of a proportion of the light received. The effect has its maximum intensity near the object, diminishing strongly at a greater distance, giving the appearance of a halo and it can still be seen if the object – Helmholtz used a lighted match as an example – is blocked out by holding a finger between it and the eye of the observer. This effect is quite close to that seen in some of Seurat's drawings.
 - 18 H. von Helmholtz, *Physiological Optics*, English trans. of 3rd German edn (Hamburg 1911, 1st edn 1866), New York 1924; the French translation, *Optique physiologique*, was published in 1867. For nineteenth-century colour theory in general see P.D. Sherman, *Colour Vision in the Nineteenth Century: The Young-Helmholtz-Maxwell Theory*, Bristol 1981; the theories are summarised in C.A. Padgham and J.E. Saunders, *The Perception of Light and Colour*, London 1975, pp. 67–74, and K. McLaren, *The Colour Science of Dyes and Pigments*, Bristol 1983, pp. 63–73. For the importance and applications of colour theory to painting see J. Gage, *Colour and Culture: Practice and Meaning from Antiquity to Abstraction*, London 1993, esp. pp. 171–6; M. Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*, New Haven and London 1990, pp. 306–22.
 - 19 O.N. Rood, *Théorie scientifique des couleurs et leurs applications à l'art et à l'industrie*, Paris 1881; French edn of *Modern Chromatics, with Applications to Art and Industry*, New York and London 1879. See also Herbert 1991 (cited in note 5), pp. 390–1; Zimmermann 1991 (cited in note 8), pp. 54–5.
 - 20 For the diagram in the context of colour contrast see Rood 1881 (cited in note 19), p. 213; it is repeated in the section on combination of colours, p. 252. In the English edn, Rood 1879 (cited in note 19), see pp. 250, 293. For Seurat's copy see Homer 1964 (cited in note 12), pp. 40–1; the diagram, which is in the Signac archives, was first published by J. Rewald, 'Seurat – The Meaning of the Dots', *Art News*, 48, April 1949, pp. 24–7, 61–3, reprinted in J. Rewald, *Studies in Post-Impressionism*, New York 1986, pp. 157–67. It is important to note that 'emerald green' (copper acetoarsenite, *vert Véronèse* in French) in the English edition has been translated by *vert émeraude*, the common name for viridian (hydrated chromium oxide), which is a bluer green. This may have been the source of some slight misinterpretation by Seurat (depending on how much use he made of the circle in practice) and others.
 - 21 For 'trials' of colours see Rood 1881, pp. 246–62, esp. pp. 257–60; Rood 1879, pp. 286–304, esp. pp. 299–301 (both cited in note 19); for small intervals and gradations of colour see Rood 1881, pp. 235–45, Rood 1879, pp. 273–85.
 - 22 Rood 1881, pp. 117–19, 241–2; Rood 1879, pp. 139–41, 279–80 (both cited in note 19).
 - 23 For Rood's discussion of warm or pleasant colours see Rood 1881, pp. 254–7; Rood 1879, pp. 295–9. Emerald green (*vert émeraude* in the French edition) and violet gave particularly hard, cold combinations: p. 249 (1881 edn), p. 289 (1879 edn). For Charles Henry see Herbert 1991 (cited in note 5), pp. 391–3; Zimmermann 1991 (cited in note 8), pp. 227–46, 249–75, 279–300, esp. pp. 295–300. The notion that the direction of the slope of lines within a picture could influence its mood had already been proposed by David Humbert de Superville in the 1830s and was recapitulated by Charles Blanc, where Seurat could first have come across the idea: see Herbert 1991, p. 386.
 - 24 The borders were applied from 1888 onwards: see Herbert 1991 (cited in note 5), pp. 376–7. For the *Bathers* see Leighton et al. 1997 (cited in note 1), pp. 81–2; for the *Grande Jatte* see Fiedler 1989 (cited in note 3), pp. 172, 178–9.
 - 25 A. Roy, 'Barbizon Painters: Tradition and Innovation in Artists' Materials', in A. Burmester, C. Heilmann and M.F. Zimmermann (eds), *Barbizon: Malerei der Natur – Natur der Malerei*, Munich 1999, pp. 330–42.
 - 26 In the present study of the small oil sketches on panel, no evidence was found for Seurat's use of cigar-box lids as supports.
 - 27 Bourgeois *ainé*, *Catalogue général illustré. Fabrique de couleurs fines et matériel pour l'aquarelle, la gouache, le dessin, le modelage, la peinture à huile et la peinture sur porcelaine*, Paris (January) 1888, p. 88.
 - 28 Bourgeois *ainé* 1888 (cited in note 27), p. 89.
 - 29 Stonor 2001 (cited in note 2), pp. 14–15.
 - 30 Lefranc et Cie, *Fabrique de couleurs et vernis, toiles à peindre* [catalogue], Paris 1883, p. 27; Bourgeois *ainé* 1888 (cited in note 27), p. 87.
 - 31 The Fitzwilliam Museum painting was examined by K. Stonor in a subsequent study.
 - 32 Fiedler 1989 (cited in note 3), pp. 175, 178–9. Prepared canvases of all grades could be supplied in lengths of 10m at a width of 2m; the *demi-fine* and *fine forte* grades were also available in widths of 2m 35cm, 2m 75cm and 3m: Bourgeois *ainé* 1888 (cited in note 27), p. 88.
 - 33 Private communication to K. Stonor from Charlotte Hale, Department of Paintings Conservation, Metropolitan Museum of Art, New York.
 - 34 Signac to Lucien Pissarro, Collioure, 29 August 1887: Rewald 1962 (cited in note 9), p. 105, quoting an unpublished letter then in the collection of the late Mrs Ester Pissarro, London.
 - 35 The radiograph is printed in Leighton et al. 1997 (cited in note 1), p. 68.
 - 36 D. Bomford, J. Kirby, J. Leighton and A. Roy, *Art in the Making: Impressionism*, London 1990, pp. 51–72: 'Impressionism and the Modern Palette'. A palette belonging to Seurat, presumably dating from 1891, was found in his studio at his death and is now in the Musée d'Orsay, Paris. The pigments on it have not been examined, although their arrangement has been discussed at length. For a colour illustration see Smith 1997 (cited in note 13), p. 32; see also W.I. Homer, 'Notes on Seurat's Palette', *The Burlington Magazine*, CI, May 1959, pp. 192–3; Stonor 2001 (cited in note 2), pp. 21–3 and notes 119–23.
 - 37 Bomford et al. 1990 (cited in note 36), pp. 200–1, 'The Artists' Palettes'.
 - 38 Fiedler 1989 (cited in note 3), p. 176.
 - 39 Rewald 1962 (cited in note 9), p. 82; see also P. Signac, *D'Eugène Delacroix au Néoimpressionnisme*, 4th edn, Paris 1939 (first published 1899), pp. 83–5. In so-called version B of the letter Seurat wrote to Félix Fénéon in June 1890, found in his studio at his death so presumably never sent, Seurat claimed to have given up earth colours in 1882–4 and, on Pissarro's advice, viridian in 1885: 'Sur le conseil de Pissarro je lâche le vert émeraude 1885' (Herbert 1991 (cited in note 5), pp. 383–4; *vert émeraude* is mistranslated as emerald green). Both these statements are demonstrably untrue.
 - 40 Examination of samples of viridian in Seurat's paints indicated that at least two forms of the pigment, differing very slightly in their infrared spectra, were present. When samples were examined by wavelength dispersive X-ray analysis traces of boron were identified in some, indicating that the method of manufacture was probably that devised by Guignet in 1859, which involved calcining a mixture of boric acid and potassium bichromate. Depending on the method of manufacture, the composition of the pigment is likely to have varied slightly, which probably explains the differences observed in the infrared spectra. See R.

- Newman, 'Chromium oxide greens: Chromium Oxide and Hydrated Chromium Oxide', in *Artists' Pigments: A Handbook of their History and Characteristics*, Vol. 3, ed. E. West FitzHugh, Washington DC and Oxford 1997, pp. 273–93, esp. pp. 279–81.
- 41 S. Garfield, *Mauve: How One Man Invented a Colour that Changed the World*, London 2000. For pigments prepared from synthetic dyes see, for example, G.H. Hurst, *Painters' Colours, Oils and Varnishes: A Practical Manual*, 2nd edn, London 1896, pp. 272–91; G. Halphen, *Couleurs et vernis*, Paris 1895, pp. 18–29. The Lefranc et Cie catalogue for 1890 (see note 30) lists four *laques d'aniline* among the *couleurs extra-fines en tubes*, including a *laque géranium*. These were among the more expensive paints, although cheaper than the madder lakes or carmine.
- 42 An eosin-containing colour has been identified in works by Vincent van Gogh: see J.H. Hofenk de Graaff, M.F.S. Karreman, M. de Keijzer and W.G.T. Roelofs, 'Scientific Investigation', in C. Peres, M. Hoyle and L. van Tilborgh (eds), *A Closer Look: Technical and Art-Historical Studies on Works by Van Gogh and Gauguin*, (Cahiers Vincent no. 3), Zwolle 1991, pp. 75–85, esp. pp. 76–8; J.-P. Rioux, 'Caractérisation de pigments décolorés dans les tableaux de Van Gogh peints à Auvers-sur-Oise', in J. Bridgland (ed.), *ICOM Committee for Conservation, 12th Triennial Meeting, Lyon, 29 August–3 September 1999: Preprints*, London 1999, Vol. I, pp. 402–8.
- 43 J.-F.-D. Riffault Deshêtres, A.-D. Vergnaud and C.-J. Toussaint, *Nouveau manuel complet du fabricant de couleurs et de vernis*, new edn revised by F. Malepeyre and E. Winckler, 2 vols (Encyclopédie Roret – Manuels Roret), Paris 1884, Vol. 2, pp. 16–44.
- 44 The pigment is an intense bright yellow, with no tendency towards green or orange. Examination of a sample of the pigment by EDX and FTIR has indicated the presence of lead white only, suggesting that it may consist of an organic dyestuff with a lead white substrate or extender. If this is so, it is likely to be synthetic as no flavonoid dyes could be detected by HPLC and the presence of a carotenoid dye is unlikely. An unknown synthetic yellow dyestuff was present in one of Van Gogh's paints: see Hofenk de Graaff et al. 1991 (cited in note 42).
- 45 Bourgeois *aimé* 1888 (cited in note 27), p. 82.
- 46 I. Fiedler and M.A. Bayard, 'Cadmium Yellows, Oranges, and Reds', in *Artists' Pigments: A Handbook of their History and Characteristics*, Vol. 1, ed. R.L. Feller, Cambridge 1985, pp. 65–108, esp. pp. 102–4.
- 47 Bomford et al. 1990 (cited in note 36), pp. 188–95.
- 48 Hurst 1896 (cited in note 41), pp. 123–41 (chrome yellows), 57–94 (extenders); Halphen 1895 (cited in note 41), pp. 15–17.
- 49 J.-F.-L. Mérimée, *De la peinture à l'huile*, Paris 1830, p. 106.
- 50 Leighton et al. 1997 (cited in note 1), pp. 82–3; H. Kühn and M. Curran, 'Zinc Yellow', in Feller 1985 (cited in note 46), pp. 201–4, esp. p. 202.
- 51 Fiedler 1989 (cited in note 3), p. 178.
- 52 J. Rewald (ed.), 'Extraits du journal inédit de Paul Signac, I, 1894–1895', *Gazette des Beaux-Arts*, 6th period, XXXVI, 1949, pp. 97–128 (English trans., pp. 166–74): entry for 29 December 1894, pp. 114, 170–1.
- 53 J.S. Remington, and W. Francis, *Pigments: Their Manufacture, Properties and Use*, London 1954, pp. 102–14; the modern zinc-containing chrome yellow is described as more permanent than the lead chromes, pp. 111–14.
- 54 C. Graebe and C. Liebermann, 'Über künstliches Alizarin', *Dingler's Polytechnisches Journal*, 193, 1869, pp. 321–3.
- 55 'Sur un nouveau principe immédiat des végétaux (l'alizarin) obtenu de la garance. Note extraite d'un travail de MM. Colin et Robiquet' (article initialled A.B.), *Journal de Pharmacie et de Chimie*, 12, 1826, pp. 407–12.
- 56 H. Schweppe, *Handbuch der Naturfarbstoffe: Vorkommen; Verwendung; Nachweis*, Landsberg/Lech 1993, pp. 242–3; H. Schweppe and J. Winter, 'Madder and Alizarin', in FitzHugh 1997 (cited in note 40), pp. 109–42, esp. pp. 119–23. On garancine see 'Mémoire de MM. Robiquet et Colin sur la question, "Séparer la matière colorante de garance, et déterminer la quantité qu'un poids donné de garance peut en contenir"', *Bulletin de la Société industrielle de Mulhouse*, 1828, pp. 126–45. For Kopp's purpurin see E. Kopp, 'Recherches sur la garance d'Alsace', *Répertoire de Chimie appliquée*, III, 1861, pp. 85–95.
- 57 An unexpectedly large amount of sulphur was detected in samples by EDX analysis, together with aluminium from the substrate. It is possible that the substrate contains basic aluminium sulphate, mentioned in nineteenth-century French paint technology literature; see, for example, Halphen 1895 (cited in note 41), pp. 178–9. Its advantage over a substrate containing hydrated alumina alone was that it formed a non-gelatinous precipitate that was easier to filter and wash. The sulphur cannot be ascribed to, for example, the presence of a barium sulphate extender. Sulphur was present in a sample of Kopp's purpurin prepared in the laboratory, but not much.
- 58 A sulphur-rich madder lake with a similarly strong fluorescence was identified in Monet's *Irises* (1914–17; NG 6383). As with the Seurat lakes, the principal constituent was pseudopurpurin, 1,2,4-trihydroxyanthraquinone-3-carboxylic acid (seen, after derivatisation, in its methylated form), purpurin and a little alizarin. On the other hand, a madder lake containing a similar pattern of dyestuffs, but showing only a faint fluorescence and no sulphur, was identified in Monet's *The Water-Lily Pond* (1899; NG 4240). In all cases the substrate was otherwise essentially aluminium-containing only. It is possible that slightly different forms of madder root, or root derivative, were used as the starting material; the method of preparation may also have varied. A wide range of madder lakes were available which may well have included the *laques Robert* and *laques de Smyrne*: see Bourgeois *aimé* 1888 (cited in note 27), p. 83.
- 59 R. White, J. Pilc and J. Kirby, 'Analyses of Paint Media', *National Gallery Technical Bulletin*, 19, 1998, pp. 74–95, esp. pp. 79–83, 90–4.
- 60 Maison Edouard's paints were hand ground and had a good reputation. At this time the establishment was run by the brothers Mulard, with the workshop at the rue Clauzel and the retail shop in rue Pigalle: see A. Callen, *The Art of Impressionism: Painting Technique and the Making of Modernity*, New Haven and London 2000, pp. 103–5, esp. p. 104; Bomford et al. 1990 (cited in note 36), pp. 41–2. The ingredients would have been bought from specialist manufacturers, however, and it is not possible to say with certainty if, for example, barium-containing or starch extenders were added to the pigment by the manufacturer, before the colourman bought it, or by the colourman at the grinding stage. Other shops sold Edouard's colours so Seurat need not necessarily have bought them in the rue Pigalle. For the range available from Lechertier, Barbe & Co. in 1885 see J. Bouvier, *A Handbook for Oil Painting*, London 1885, p. 56. Stamps on the back of the *Young Woman powdering Herself* (1889–90) and *Le Bec du Hoc, Grandcamp* (1885, reworked in 1888) give the name of the supplier as Chabod, who seems also to have supplied colours: see Stonor 2001 (cited in note 2), p. 12. His address was listed as 20 rue Jacob, near the Ecole des Beaux-Arts, but not near any of Seurat's known addresses (all in the general area of the place Pigalle). This part of Paris, Montmartre, was the home of many artists and, unsurprisingly, colour merchants, so there was no obvious need for Seurat to travel to the rue Jacob, unless, having used Chabod in his student days, he preferred to remain with a supplier whose products he trusted.
- 61 In Van Gogh's *A Cornfield with Cypresses* (NG 3861): see J. Leighton, A. Reeve, A. Roy and R. White, 'Vincent Van Gogh's "A Cornfield with Cypresses"', *National Gallery Technical Bulletin*, 11, 1987, pp. 42–59, esp. p. 59; and in Pissarro's 'The Côte de Boeufs at L'Hermitage' (NG 4197): see Bomford et al. 1990 (cited in note 36), pp. 74–5.
- 62 A description of the addition of soaps and other materials to improve dispersion of certain pigments, including ultramarine, in the oil medium is given in N. Heaton, *Outlines of Paint Technology*, 3rd edn, London 1948, pp. 382–3. The possible additives are perhaps rather more numerous than anything mentioned in late nineteenth-century literature, although unfortunately this particular topic is not one that is much discussed.
- 63 F. Fénéon, *Les impressionnistes en 1886*, Paris 1886, reprinted in F. Fénéon, *Oeuvres*, Paris 1948, pp. 79–80. The translation quoted is taken from Rewald 1962 (cited in note 9), p. 98; a slightly different version appears in Herbert 1991 (cited in note 5), p. 173. See also J.U. Halperin, *Félix Fénéon: Aesthete and Anarchist in Fin-de-Siècle Paris*, New Haven and London 1988, pp. 77–85, esp. p. 81.
- 64 Dorra and Rewald 1959 (cited in note 6), p. lxxxv.
- 65 J. Rewald (ed.), 'Extraits du journal inédit de Paul Signac, II, 1897–1898', *Gazette des Beaux-Arts*, 6th period, XXXIX, 1952, pp. 265–84 (English trans., pp. 298–304): entry for 28 December 1897, pp. 270–1, 300.
- 66 Leighton et al. 1997 (cited in note 1), pp. 76–81.
- 67 Herbert 1991 (cited in note 5), pp. 372–3, 381–3.

TABLE 2 Seurat's tube paints and their binding media

Date	Painting(s)	Pigment or mixture	Medium ¹	Other ingredients
1883–4	<i>Studies for the Bathers at Asnières: A River Bank (The Seine at Asnières)</i> , NG 6559; <i>The Rainbow: Study for 'Bathers at Asnières'</i> , NG 6555; <i>Study for 'Bathers at Asnières'</i> , 1883–4, NG 6561	red lake viridian viridian + traces of lead white, chrome yellow (probably colourman's or manufacturer's mixture) French ultramarine cobalt blue: i) <i>A River Bank</i> ii) <i>The Rainbow</i> lead white	probably linseed oil probably poppy oil heat-bodied linseed oil (possibly + some poppy?) probably poppy oil linseed oil poppy oil poppy oil	extender including barium sulphate or lithopone
1884	<i>Bathers at Asnières</i> , NG 3908, first campaign	madder, cochineal lakes vermilion, often + red lake cadmium yellow viridian viridian + traces of lead white, chrome yellow French ultramarine cobalt blue lead white (paint) lead white (ground)	linseed oil linseed oil linseed oil, possibly heat-bodied probably linseed oil linseed oil poppy oil, probably heat-bodied probably linseed oil, possibly heat-bodied poppy oil linseed oil	
1884–5	<i>Studies (Study for 'La Grande Jatte')</i> , NG 6556; <i>Study for 'La Grande Jatte'</i> , NG 6560; <i>The Morning Walk</i> , NG 6557)	chrome yellow viridian viridian + traces of lead white, chrome yellow French ultramarine lead white lead white (in cream-coloured reeds, NG 6556)	linseed oil linseed oil, heat-bodied in one case linseed oil linseed oil, possibly heat-bodied poppy oil linseed oil	extender including barium sulphate or lithopone; some soap formation or a soap added, possibly a palmitate ²
1886–7	<i>Bathers at Asnières</i> , NG 3908, reworking; <i>The Bridge at Courbevoie</i> , Courtauld Collection, P.1948.SC.394	zinc yellow + other chromate yellows emerald green emerald green + lead white + traces of zinc yellow, cadmium yellow, possibly chrome yellow? French ultramarine cobalt blue lead white	linseed oil poppy oil, heat-bodied linseed oil, heat-bodied linseed oil, heat-bodied linseed oil, heat-bodied i) heat-bodied linseed oil, ii) linseed + poppy oils, heat-bodied	extender including barium sulphate, starch; some soap formation or a soap added, possibly a palmitate extender, possibly barium sulphate extender including barium sulphate or lithopone, starch some soap formation or a soap added, possibly a palmitate some soap formation or a soap added, possibly a palmitate, in the <i>Bridge at Courbevoie</i> sample
1888	<i>The Seine seen from La Grande Jatte</i> , NG 6558	emerald green lead white (paint) lead white (ground)	probably linseed oil poppy oil, heat-bodied linseed + poppy oils, partially heat-bodied	extender of siliceous material
1889–90	<i>Young Woman powdering Herself</i> , Courtauld Collection, P.1932.SC.396; <i>The Channel of Gravelines, Grand Fort-Philippe</i> , NG 6554; all samples from borders unless otherwise stated	madder lake + vermilion (either artist's or colourman's mixture) cadmium orange French ultramarine cobalt blue manganese violet lead white (border, <i>Young Woman</i>) lead white (white on beach, perhaps intensified during painting of border, <i>Gravelines</i>) lead white (ground, <i>Young Woman</i>)	linseed oil, heat-bodied linseed oil, heat-bodied linseed oil, heat-bodied linseed oil, heat-bodied linseed oil, heat-bodied linseed oil, heat-bodied linseed oil, heat-bodied	
	<i>The Channel of Gravelines</i> , main body of painting ³	'red' 'blue'	poppy oil, perhaps + some linseed, lightly heat-bodied poppy oil	

Notes

¹ Many of the samples examined contained mixtures of pigments. In some cases the palmitate/stearate ratios obtained were intermediate between those expected for linseed oil and those for poppy oil, so within the region for walnut oil. It would therefore be possible to interpret these results as suggesting the presence of walnut oil in the paint. However, examination of the pigment content suggested that these were better interpreted as mixtures of linseed and poppy: most contained lead white which was usually bound in poppy oil, while the other pigments, where a pure sample could be examined, usually contained linseed oil. It should also be remembered that Seurat could have added a little extra oil to his paint to adjust its working properties, which was not necessarily the same as that in the tube.

² An indicator for the presence of soaps, probably of lead, in several samples,

most notably from *The Bridge at Courbevoie*, is an apparent increase in the proportion of palmitate in the paint. Soap formation might be expected over time and might be encouraged by the presence of certain pigments or additives, or even water, but it seems unlikely that this would affect the oil fatty acid proportions so unevenly. The effect observed may be due to the deliberate addition of a palmitate soap at some stage during the manufacture or packing of the paint, possibly to improve wetting of the pigment by the oil medium. French ultramarine, for example, is a hydrophilic pigment and, without some effort or the assistance of a wetting agent, is poorly wetted by the oil. In one or two cases the raised palmitate content meant that the analytical results could not be interpreted.

³ Unfortunately the pigment content of these samples was not examined.

TABLE 3 Pigment occurrences in Seurat's works examined

	Red	Orange	Yellow	Green
FINISHED PAINTINGS				
<i>Bathers at Asnières</i> , 1883–4 (NG 3908)	red lake; (pink) red lake, tr. French ultramarine + lead white; (red-brown) earth pigments + vermilion; vermilion, red lake + little lead white	(bright orange) vermilion + chrome yellow (also + lead white and/or red lake); (discoloured addition, 1886 modification) zinc yellow, tr. vermilion + barium sulphate ²	cadmium yellow + a little lead white; organic yellow (not characterised) ⁵	range of mixed greens based on viridian, ⁶ cobalt blue, chrome yellow, lead white and French ultramarine; (lime green) viridian, cadmium yellow + (possibly) chrome yellow; (discoloured addition, 1886 modification) emerald green and lead white + tr. cadmium yellow + zinc yellow + barium sulphate (starch) ³
<i>The Bridge at Courbevoie</i> , 1886–7, Courtauld Collection	red lake; vermilion	vermilion + zinc yellow (starch) ³	zinc yellow (+ starch) ³ + chrome yellow; barium chromate + tr. yellow earth; calcium chromate + yellow dyestuff	viridian + emerald green; emerald green + zinc yellow
<i>Young Woman powdering Herself</i> , 1889–90, Courtauld Collection	red lake; vermilion; vermilion + red lake ¹	vermilion + chrome yellow	chrome yellow; cadmium yellow	viridian; emerald green; emerald green + chrome yellow
<i>The Channel of Gravelines, Grand Fort-Philippe</i> , 1890 (NG 6554)	vermilion + madder lake	cadmium orange	organic yellow (not characterised); ³ strontium chromate + chrome yellow	(bright, cool green) emerald green + a little cobalt blue + lead white; (yellow-green) emerald green + strontium yellow + chrome yellow
STUDIES				
<i>Fisherman in a Moored Boat</i> , c.1882, Courtauld Gallery	red lake, vermilion; semi-transparent red earth	red earth + yellow ochre + chrome yellow	chrome yellow; yellow ochre; chrome yellow + yellow ochre	viridian; emerald green; viridian + emerald green + chrome yellow
<i>A Boat near a Riverbank, Asnières</i> , c.1883, Courtauld Gallery	red lake; vermilion; red lake + vermilion	red earth; yellow ochre + chrome yellow	chrome yellow; yellow ochre; chrome yellow + yellow ochre	viridian; emerald green; viridian + emerald green + cobalt blue
<i>Man in a Boat</i> , c.1883, Courtauld Gallery	red lake; vermilion; red earth	red + yellow ochre	chrome yellow; yellow ochre	viridian; French ultramarine + chrome yellow + yellow ochre
<i>Man painting a Boat</i> , 1883, Courtauld Collection	red lake; vermilion; red earth; red lake + vermilion	vermilion + chrome yellow	chrome yellow; zinc yellow; yellow ochre	viridian + chrome yellow; emerald green + chrome yellow; French ultramarine + chrome yellow
<i>Horses in the Water: Study for 'Bathers at Asnières'</i> , 1883–4, Courtauld Gallery	red lake; vermilion; red earth; red lake + vermilion	red + yellow ochre	chrome yellow; yellow ochre	viridian + emerald green; viridian + emerald green + chrome yellow
<i>A River Bank (The Seine at Asnières)</i> , c.1883 (NG 6559)	not examined	not examined	chrome yellow	viridian
<i>The Rainbow: Study for 'Bathers at Asnières'</i> , 1883–4 (NG 6555)	not examined	not examined	not examined	viridian
<i>Study for 'Bathers at Asnières'</i> , 1883–4 (NG 6561)	not examined	red lake + unidentified yellow	not examined	(yellow-green) viridian + chrome yellow + French ultramarine
<i>The Angler</i> , c.1884, Courtauld Gallery	red lake; vermilion; vermilion + red lake	vermilion + chrome yellow	chrome yellow; yellow ochre	viridian; emerald green; viridian or emerald green + chrome yellow
<i>Study for 'La Grande Jatte'</i> , c.1884–5 (NG 6556)	pinkish-red lake + white	not examined	(yellow-brown) chrome yellow + vermilion + tr. cadmium pigment	viridian + chrome yellow in varying proportions
<i>Study for 'La Grande Jatte'</i> , c.1884–5 (NG 6560)	red lake	not examined	organic yellow (not characterised) + tr. viridian + tr. vermilion	viridian; unidentified, intense yellow pigment + viridian
<i>The Morning Walk</i> , 1885 (NG 6557)	not examined	(orange-brown) chrome yellow + tr. emerald green ⁴ and tr. vermilion	organic yellow (not characterised) + some emerald green	emerald green; (lime green) emerald green + chrome yellow
<i>The Seine seen from La Grande Jatte</i> , 1888 (NG 6558)	red lake	(orange-brown) chrome yellow + vermilion	not examined	(lime green) chrome yellow + tr. emerald green; (green-blue): emerald green + white + a little cobalt blue
<i>Study for 'Le Chahut'</i> , c.1889, Courtauld Collection	red lake; vermilion; vermilion + red lake	vermilion + chrome yellow	chrome yellow; yellow ochre	viridian; emerald green; emerald green + chrome yellow
<i>At Gravelines</i> , 1890, Courtauld Collection	red lake; vermilion; vermilion + red lake	vermilion + chrome yellow	chrome yellow	viridian + emerald green; emerald green and chrome yellow

Notes:

tr. = trace

¹ Mixtures of vermilion and red lake are common in the works examined. It is not certain whether these represent colourmen's mixtures or are a part of Seurat's practice.

² Lithopone could be present in these samples.

³ Starch, probably added by the manufacturer as an extender or to modify paint handling properties, was detected microscopically, by SEM and FTIR. It is found particularly in zinc yellow containing paint, which has discoloured in a number of cases.

⁴ Emerald green is copper acetoarsenite; *vert Véronèse* in the contemporary French colour lists (see note 6 below).

Blue	Purple	White	Black	Brown/Earths
cobalt blue; French ultramarine; cobalt blue and/or French ultramarine + small additions of red lake + viridian; cobalt blue, viridian + lead white	(reddish-mauve) pinkish-red lake, French ultramarine, cobalt blue + lead white; (glaze) French ultramarine + red lake	lead white	not examined	(orange-brown) lead white + natural red-brown earths; (mid-brown) yellow-brown earth + red lake
French ultramarine; cobalt blue; French ultramarine + cobalt blue	red lake or vermilion + French ultramarine or cobalt blue	lead white	red lake + French ultramarine	not examined
French ultramarine; cobalt blue	red lake + French ultramarine	lead white (chalk extender)	French ultramarine + viridian	not examined
French ultramarine, cobalt blue	(deep purple) manganese violet ⁷ + some madder lake + a little lead white	lead white	not examined	not examined
French ultramarine; cobalt blue	red earth + French ultramarine	lead white ⁸	carbon black; red earth or red lake, emerald green or viridian + French ultramarine	sienna type earth
French ultramarine; cobalt blue	red lake, French ultramarine + lead white	lead white ⁸	not examined	tr. sienna type earth
French ultramarine; cobalt blue	not examined	lead white ⁸	carbon black	dark ochre/sienna type earth
French ultramarine	not examined	lead white	bone black	sienna type earth
French ultramarine	possibly cobalt violet	lead white ⁸	carbon black (tr.); vermilion, French ultramarine + red lake or red earth	dark ochre/sienna type earth
cobalt blue; cobalt blue + a little French ultramarine	(pinkish-mauve) white, red lake + French ultramarine	lead white ⁹	not examined	not examined
French ultramarine; cobalt blue, French ultramarine, white + viridian	(dark purple-brown) French ultramarine + brownish-red lake	lead white	not examined	not examined
French ultramarine	(dark purple) French ultramarine + red lake	not examined	not examined	not examined
French ultramarine; cobalt blue	red lake + French ultramarine	lead white ⁸	carbon black (trace); red lake + French ultramarine	not examined
French ultramarine + cobalt blue	not examined	not examined	not examined	red lake, yellow ochre + French ultramarine; (orange-brown) orange-brown earth + viridian
French ultramarine	not examined	lead white	not examined	not examined
French ultramarine (possibly with a little cobalt blue)	(mauve) French ultramarine, red lake + white	lead white	not examined	not examined
cobalt blue	not examined	lead white	not examined	not examined
cobalt blue; cobalt blue, viridian + emerald green	not examined	lead white (chalk extender)	carbon black; ¹⁰ cobalt blue + viridian	not examined
cobalt blue + a little French ultramarine	not examined	lead white	not examined	not examined

⁵ The organic yellow is associated with lead white as a substrate or extender.

⁶ Viridian is transparent (hydrated) chromium (III) oxide; *vert émeraude* in the contemporary French colour lists.

⁷ Manganese violet is one or other form of manganese phosphate pigment.

⁸ Lead white presumed to be the white pigment used; not analysed.

⁹ Sample contains some silica.

¹⁰ Black pigment is present in the surface design.