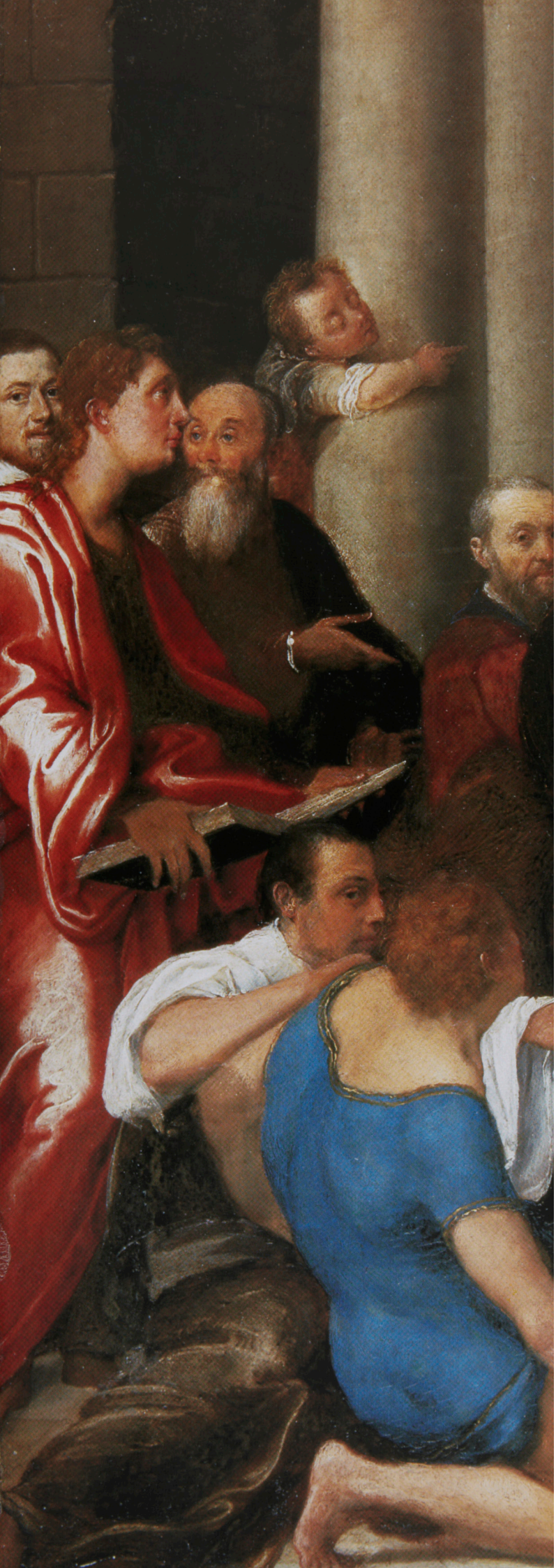

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FRONT COVER
Vincenzo Foppa, *The Adoration of the Kings*
(NG 729) (detail of Plate 1, p. 19)

TITLE PAGE
Attributed to Pedro Campaña, *The Conversion of the Magdalen*
(NG 1241) (detail of Plate 1, p. 55)

Colour change in *The Conversion of the Magdalen* attributed to Pedro Campaña

MARIKA SPRING, NICHOLAS PENNY, RAYMOND WHITE AND MARTIN WYLD

Introduction

The small *Conversion of the Magdalen* in the National Gallery, attributed to Pedro Campaña (NG 1241; PLATE 1)[1] is derived from a composition by Federico Zuccaro, known from drawings for a fresco on the side wall of Cardinal Giovanni Grimani's chapel in S. Francesco della Vigna, Venice.[2] Federico Zuccaro (*c.*1540–1609) came from Rome to Venice to work for Cardinal Giovanni Grimani in 1562.[3] The altarpiece which he painted for the cardinal's chapel is dated 1564, and the frescoes on the side walls must have been painted at the same period. One of these, representing the Raising of Lazarus, survives, but the other, showing the Conversion of the Magdalen, is now lost and known only from the painter's drawings.[4]

In his will, dated 29 August 1592, Grimani mentions some small pictures framed in ebony, two of which were by 'Pietro di Fiandra' (Peter from Flanders). One of these was after the altarpiece of the chapel in S. Francesco della Vigna. In the other 'the story is of Christ seated and preaching to the people and to the Magdalen' (*la historia è Jesu Christo che siede et predica al populo et alla Madalena*). This painting, which he bequeathed to 'Signor Commendatore Lippomani', can be identified as the picture now in the National Gallery.[5] It does not look like a straightforward copy of the fresco by Zuccaro; there are numerous minor pentimenti and additions to the composition when compared with Zuccaro's surviving drawings. These are most evident in the 'people' who seem to consist in large part of portraits. There are over a dozen of these, among them no doubt Grimani, certainly many members of his family, and perhaps the artist.

The picture came to the National Gallery from the famous collection of Philip Miles at Leigh Court near Bristol. Miles had acquired it from Richard Hart Davis who bought it from Thomas Moore Slade, who acquired it with the Vetturi collection in Venice in the 1770s.[6] The painting already had an attribution to Pedro Campaña, and since this artist was not at all famous (certainly not in Italy), there must have been a reason for this attribution (perhaps because of some reference to Campaña in a manuscript catalogue or in an inscription on a frame).[7]

Pedro Campaña could have been styled 'Pietro di Fiandra' by the Italians, but the question remains, was he the artist of the National Gallery painting? The attribution has, in fact, been doubted and does present problems.[8] Pedro Campaña (Peeter de Kempeneer) was born in Brussels in 1503. He went to Spain (in some accounts from Italy) and was active in Seville between 1537 and 1539 and then again between 1546 and 1561. He returned to Brussels in 1563, when he became a tapestry designer for the city, and he died there in 1580.[9] His talent as a portraitist is apparent from the donors included in his Spanish altarpieces, and he also had a reputation for precious work on a small scale. Allowing for the hybrid character of a copy (or partial copy) there seems no obstacle to this painting being by his hand, although it would have to date from around 1562 (at the very date the fresco was being planned) during a brief, and undocumented, visit to Italy prior to his return to Brussels – unless, as seems unlikely, he travelled again in his last years.

Bert W. Meijer has recently proposed, however, that Grimani's 'Pietro di Fiandra' is in fact Pieter Cornelisz. van Rijck and this is supported by the fact that he was a pupil of Huybrecht or Hubertus Jacobsz., who must be the 'Uberto Fiandrese' also mentioned in Grimani's will as executing a small picture after Federico Zuccaro.[10] Stylistic comparisons with other works by this Pieter are not conclusive and the matter cannot at present be settled. What cannot be doubted is that the National Gallery's panel is the one painted for Cardinal Grimani in Venice – either shortly before he made his will in 1592 or soon after the fresco by Zuccaro was completed in the early 1560s.

That the painting enjoyed a certain reputation is suggested by the existence of an early modified copy in the Borghese Collection (PLATE 2) in which some heads have been made less portrait-like, while other

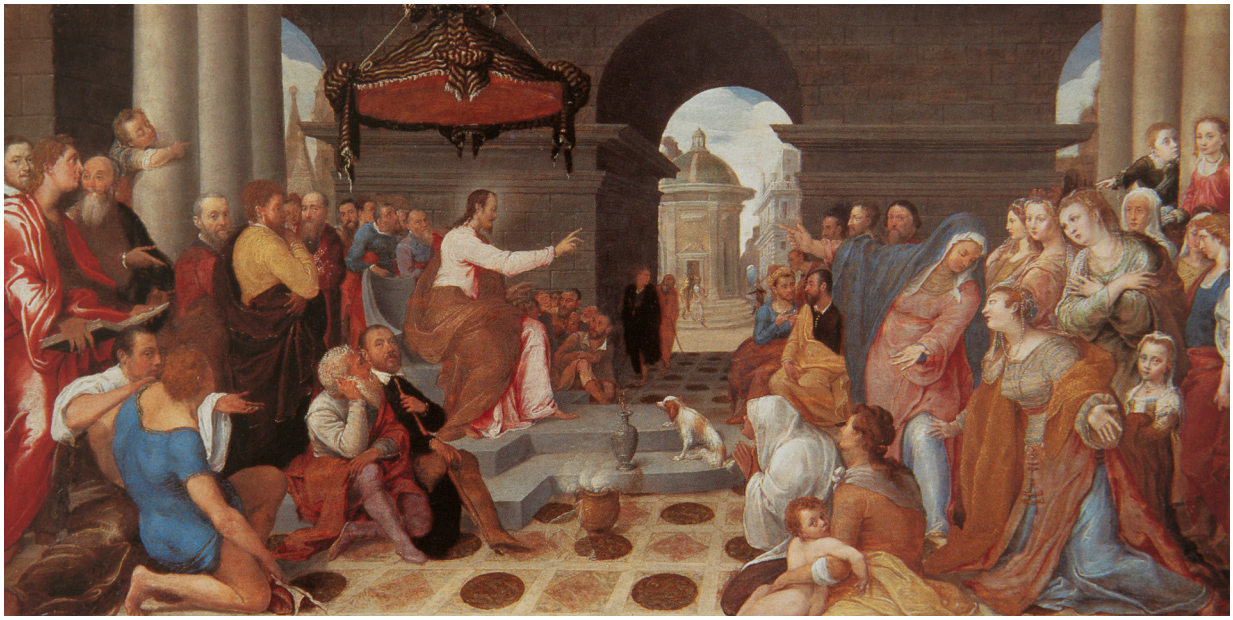


PLATE 1 Attributed to Pedro Campaña, *The Conversion of the Magdalen* (NG 1241). Pear wood, 29.8 × 58.4 cm.

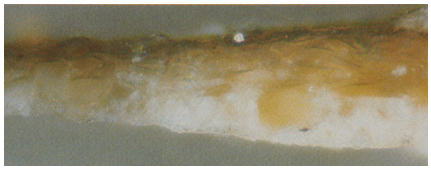
PLATE 2 Luca Longhi, *Christ preaching before the Magdalen*. Wood, 30 × 58 cm. Rome, Villa Borghese.

portraits have been added, and the type of Christ has been changed. This was attributed to Zuccaro himself in the seventeenth century and since then to Carletto Caliari and Luca Longhi.[11] Because the colours of the National Gallery's painting have clearly changed, the better-preserved Borghese picture provides a fascinating opportunity for comparison. It is to the nature of these colour changes that this article is devoted.

The pigments and binding medium in areas of colour change

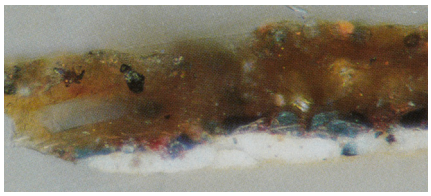
Many of the draperies of the figures in the painting are now brown or yellow-brown. They have discoloured so severely that there is no hint of the original colour. Samples of discoloured paint from some of the principal figures were analysed to identify the pigments, and to investigate whether there was any peculiarity in the technique and materials that could have caused such serious degradation. Three principal

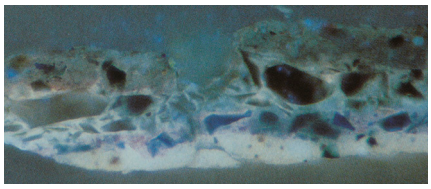
PLATE 3 **Summary of analysis of samples from discoloured areas**[1]



a CROSS-SECTION THROUGH CHRIST'S YELLOW-BROWN CLOAK
The lowest layer contains smalt and lead white, over which is a layer of smalt (now completely colourless) with a very small amount of lead white. The thin brown layer at the surface is not part of the original paint. EDX analysis of the smalt particles detected Si and small amounts of K, Co, Fe, As and Bi.

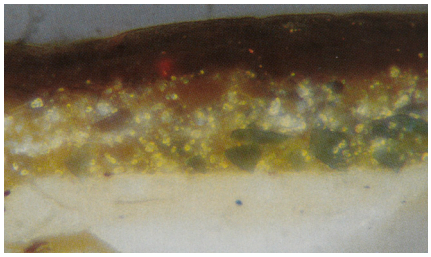
The smalt particles are more easily visible in ultraviolet light, and the surface accretion is distinguishable from original paint. Original magnification 400×, actual magnification 350×.



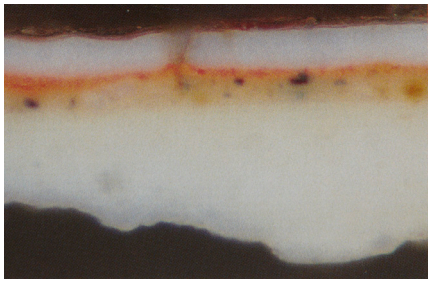


b CROSS-SECTION THROUGH THE BROWN DRAPERY OF THE FIGURE CROUCHING IN THE BOTTOM LEFT CORNER
The uppermost layer of priming is visible at the bottom of the sample, followed by a thin purple underpaint of azurite and red lake, mixed with a little lead white. The thick brownish layer above consists of red lake and smalt, now entirely discoloured. A brown surface accretion similar to that on Christ's drapery is visible at the top of the sample.

The separate brown layers, and the red lake and smalt in the original paint, are more easily visible in ultraviolet light. Original magnification 500×, actual magnification 300×.



c CROSS-SECTION THROUGH THE BROWN DRAPERY OF THE STANDING BEARDED MAN (WITH A YELLOW ROBE) NEAR THE COLUMN ON THE LEFT
The lowest layer in the sample is the first lead white preparatory layer, over which is a second off-white layer (lead white, a little yellow earth and black). The first green underpaint layer is a mixture of azurite, lead-tin yellow and yellow lake (on a calcium-containing substrate). A second green underpaint contains more lead-tin yellow, mixed with ultramarine and yellow lake. The uppermost dark brown layer is a discoloured copper-containing glaze (copper detected by EDX analysis), originally green. A small amount of Cl was also detected in this layer. Original magnification 940×, actual magnification 467×.



d CROSS-SECTION THROUGH A WHITE HIGHLIGHT ON THE RED CLOAK OF THE LARGE FIGURE AT THE EXTREME LEFT EDGE
The two preparatory layers (lead white followed by an off white layer) are visible at the bottom of the sample. Above these is a layer of vermilion (the base colour for the red drapery), then the white paint of the highlight. A very thin red lake glaze has been applied over the white, just visible in the cross-section. This has faded so that the highlights appear white rather than pink.[2] Original magnification 500×, actual magnification 300×.

1 The pigments were identified by EDX analysis in the Scanning Electron Microscope.
2 The faint pink fluorescence of the thin glaze at the surface in ultraviolet light confirms that this thin yellowish layer is, in fact, a faded red lake glaze.

types of pigment deterioration are responsible for most of the changes: deterioration of the pigment smalt, fading of a red lake pigment, and discoloration of green copper-containing glazes. The samples are illustrated and described in detail in PLATE 3.

The discoloration of smalt

Smalt is a potassium silicate glass, coloured blue with cobalt oxide, which is crushed and ground for use as a pigment.[12] It is not, however, a stable pigment; discoloration of smalt on sixteenth-century paintings is not at all unusual. Earlier studies have implicated a number of factors in the degradation.[13] The low refractive index and tinting strength could result in it being disproportionately affected by the change in refractive index of the oil medium as it ages. Conditions of high humidity could cause leaching of metal salts from the silicate network, particularly the alkaline potassium and sodium salts, which are added to glass as network modifiers. Potassium glass is more vulnerable to leaching than sodium glass, a process which, as well as causing deterioration of the glass itself, could cause saponification or condensation reactions in the oil medium, and would account for the excessive yellowing often observed in paint samples containing deteriorated smalt. Concurrent loss of cobalt into the medium has been proposed, but because the percentage of cobalt in smalt is very low – typically less than 10% – this has proved difficult to confirm by analysis. Some kind of interaction between the cobalt and the oil medium must be occurring however, since it accelerates drying of the oil.[14]

The composition of smalt varies, depending on the conditions and ingredients of manufacture. It often contains impurities that reflect the source of the cobalt ore used.[15] These impurities would almost certainly have had an influence on the hue of the pigment, and could also affect the stability of the glass.[16] The smalt in this painting contains impurities of arsenic, iron, nickel and bismuth in concentrations almost equal to cobalt, but at levels that are not unusual in smalt on sixteenth-century paintings.[17] The level of potassium in the smalt particles in the paint from Christ's cloak is rather low (of the same order as cobalt) and elemental mapping by EDX of the cross-section indicates that there are, in fact, higher levels in the matrix around the smalt particles and on the surface of the sample, which may be an indication that some alkali leaching has taken place.

The pigment is usually relatively coarse, as it becomes pale when finely ground, making it necessary to use a high proportion of oil to make a paint of acceptable working properties. This is manifested in this painting by the rather lumpy texture of the areas containing smalt, distinguishing them from the green paint which has discoloured to a similar brown. Smalt has often survived better when mixed with lead white, probably because the paint is less medium-rich. In Christ's cloak only a very small amount of lead white was mixed with smalt, however, and in the purple draperies of other figures smalt was mixed only with red lake.

PLATE 4 *The Conversion of the Magdalen*. Detail of the two standing figures at the left edge of the painting.

Deterioration of smalt has also affected the appearance of the Virgin's blue cloak, although in a more subtle way. The smalt-containing underpaint, now a brownish-yellow colour, is visible at the surface where the well-preserved upper layer of ultramarine-containing paint was thinly applied. Smalt was also used, mixed with red lake, for purple draperies such as the robe of the man sitting in the left corner, which is now brown. It was clear, from looking at the surface of the smalt-containing areas with a stereomicroscope, that originally a wide variety of purple and purplish-blue hues had been used. The robe of the figure in a red cloak at the extreme left edge must have been a dark purple, as it was painted with a layer of smalt over a dark red lake underpaint. The robe of the bearded figure immediately beside him was painted in a similar way, but appears to have been a lighter purple (PLATE 4). The cloak of the figure in front of the column on the left, behind the man in a dark brown cloak, was perhaps a purplish blue, since the underpaint contains discoloured smalt, with red lake only in the shadows.

The upper layer appears to contain only smalt. These paints are all very translucent, which has probably exacerbated the effect on the appearance of any changes in the pigments. The cloak of the woman with her arms crossed on the right of the composition, also originally purple, is painted with a mixture of ultramarine, lead white and red lake in highlights, with strokes of smalt in areas of shadow. The mid-tones contain a great deal of red lake, with some blue pigment, so the cloak perhaps originally had a reddish-purple hue. These descriptions of the pigment mixtures observed with the stereomicroscope highlight the problem of determining with any degree of accuracy the original colour of paint mixtures that have deteriorated.

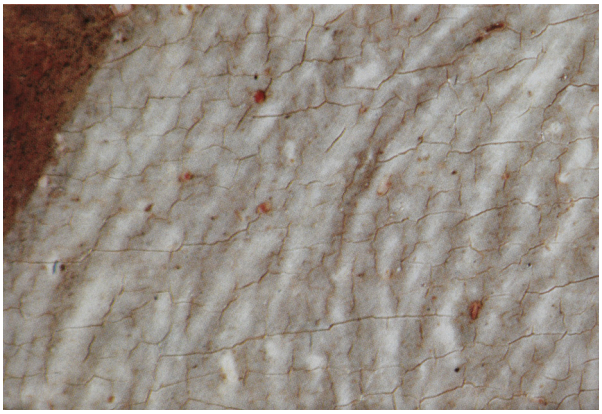


PLATE 5 *The Conversion of the Magdalen.* Photomicrograph of Christ's sleeve. The original deep pink colour, which survives below the surface, is visible through small paint losses.

Fading of red lake

Severe fading of the red lake pigments in this painting has occurred, and this must also have affected the purples described above. Christ's robe is now a very pale pink, but the unfaded deep pink colour that still survives beneath the surface is visible with a stereomicroscope through cracks in the paint (PLATE 5). The fading has exaggerated contrasts in the modelling of the drapery, as red lake fades more quickly when mixed with lead white.[18] The fading is so extreme in this case that the highlights and mid-tones are now the same colour, and the still-red shadows look very stark as they no longer blend in to the colour of the mid-tones. Fading of red lake has also affected many of the other figures. The similarly high contrast of the shadows on the orange cloak of the old bearded figure sitting on the step indicates that it has been affected by fading of red lake. The Virgin's dress, painted with red lake and white, and salmon-pink strokes which probably contain vermilion, is now rather greyish. The Magdalen's cloak has also faded, as has the diamond pattern on the floor tiles and the dress of the woman sitting in the foreground with a child, which appears to have been painted with only a thin translucent glaze of red lake directly on the ground layer.

Less obvious is the fading of a red glaze on the cloak of the figure at the extreme left edge. The solid vermilion colour has survived well, but the highlights, now completely white, are glazed with red lake that has now faded and would originally have blended in to the darker orange-red colour of the rest of the cloak (PLATE 3).

A sample of red lake pigment from the dress of the woman at the extreme right edge was analysed and found to contain a dyestuff derived from the cochineal insect.[19] It seems very likely that the same red lake pigment was also used elsewhere in the painting.

Discoloration of copper-containing glazes from green to brown

The cloak of the bearded man in a yellow robe near the column on the left was originally green. The lower layers (yellow lake, ultramarine, azurite and lead-tin yellow) remain green but are totally obscured by a copper-containing glaze which is now dark brown (PLATE 3). The modelling in the green draperies has been lost as a result, since the modelling in the underpaint would originally have been visible through the transparent green glaze. This method of painting is not dissimilar to the 'new way for making green drapery' described by Armenini in 1587, using a mixture of yellow lake and smalt for the underpaint, then applying a thin glaze of verdigris mixed with 'common varnish' (a mixture of linseed oil and resin).[20]

Verdigris can react with the oil or resin in the medium, forming a transparent green glaze in which no discrete pigment particles are visible. This type of glaze has often been referred to as 'copper resinate' (whether or not the presence of a copper-resin acid salt has been confirmed by analysis),[21] but recent studies of treatises on painting technique indicate that the mixtures of the type described by Armenini were most often used.[22] Transparent copper-containing green glazes can be very well-preserved, but often show different degrees of discoloration, sometimes browning only slightly at the surface or, as in this painting, becoming brown throughout. It is not clear

why they survive so well in some paintings while in others they discolour. Light clearly plays a part, since in some paintings the original green colour has survived where the paint has been protected by the frame rebate, but has become brown where exposed.[23] The composition of the glaze may also be significant, and is worth examining in detail.

Copper was detected in the brown glaze by EDX analysis, but no pigment particles were visible in a thin section under the microscope, nor was there any sign of the original green colour, and the copper was evenly dispersed throughout the layer (PLATE 3). The organic components identified in the glaze were linseed oil and a little resin, in similar proportions to that found in a red lake glaze, confirming that resin is present as an addition to the medium in the green glaze rather than as a 'copper resinate' pigment. The FTIR spectrum does, however, show evidence of copper-resin acid and copper-oil interactions. It seems likely that the paint film was pigmented with verdigris but, since there are no acetate bands in the FTIR spectrum, it appears to have reacted completely with the binding medium.[24] A very small amount of chlorine was also detected by EDX analysis, as well as a calcium-containing layer above the glaze.[25] Previous studies have sometimes found calcium, probably in the form of calcium carbonate, in or above copper-green glazes in paint samples, which could be interpreted as being a yellow lake pigment on a chalk substrate.[26] In this painting, however, residues of a calcium-containing material were also seen at the surface of samples from other colours, so it does not seem to be part of the original paint.

Other areas which were originally green, distinguishable from the browned purple paint by their darker appearance in the infra-red photograph and by examination under the stereomicroscope, include the brown robe of the man sitting on the steps in front of Christ, the brown circle pattern on the floor tiles, the cloak of the bearded figure near the left edge, and the robe of the small figure sitting in the background just to the left of the Virgin. The brown glaze on the standing figure from which a sample was taken is thinner than on other green areas, suggesting that it was intended to be a lighter green.

Reconstruction of the altered colours by digital imaging

The pigment degradation on *The Conversion of the Magdalen* has destroyed the balance of colours on the painting, but has to be accepted as an irreversible change. Some impression of how it would have appeared if the pigments had not deteriorated was attempted, however, by applying image-processing techniques to a digital image of the painting.[27]

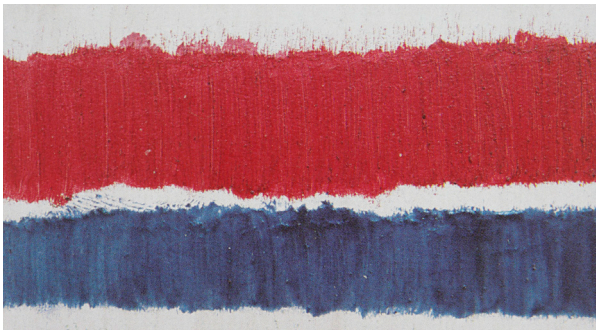


PLATE 6 Painted-out strips of colour imitating the pigments and layer structure of the pink and blue draperies in *The Conversion of the Magdalen*.

Since there were no well-preserved areas of the unstable pigments on the painting, colorimetric measurements on painted-out samples matching the pigment mixtures and the layer structures were used as a reference (PLATE 6). For the smalt and red lake pigments this posed some problems. Smalt manufactured to a nineteenth-century recipe is available today, but contains a higher percentage of cobalt than smalt in sixteenth-century paintings and none of the impurities that are commonly found in the glass.[28] The modern smalt is much stronger in colour, so for the reconstruction it was extended with finely ground alumina, to try to simulate the colour of sixteenth-century smalt. In fact this is a difficult judgement to make, since in paintings of the period smalt has always degraded. It is better preserved in some seventeenth-century paintings, however, particularly where mixed with lead white, and these served as a guide.[29] The smalt was also ground to reproduce the average particle size of the smalt in the painting, as this also has an influence on the colour. A red lake prepared to an old recipe with dyestuff from the cochineal insect was painted out mixed with varying proportions of lead white.[30] Comparison with the deep shadows on Christ's red robe, which retain their red colour, made it clear that the hue of the test plate was more purple than the red lake used in the painting. This highlights a subtle change towards a more yellow hue that occurs relatively quickly in red lakes on ageing.

Reconstructed images of the figure groups on the left and right side of the painting, and of the figure of Christ, are illustrated in PLATES 7, 8 and 9. The deep saturated colours which replace the deteriorated brown, although rather flat because of the loss of modelling which cannot be reconstructed, balance

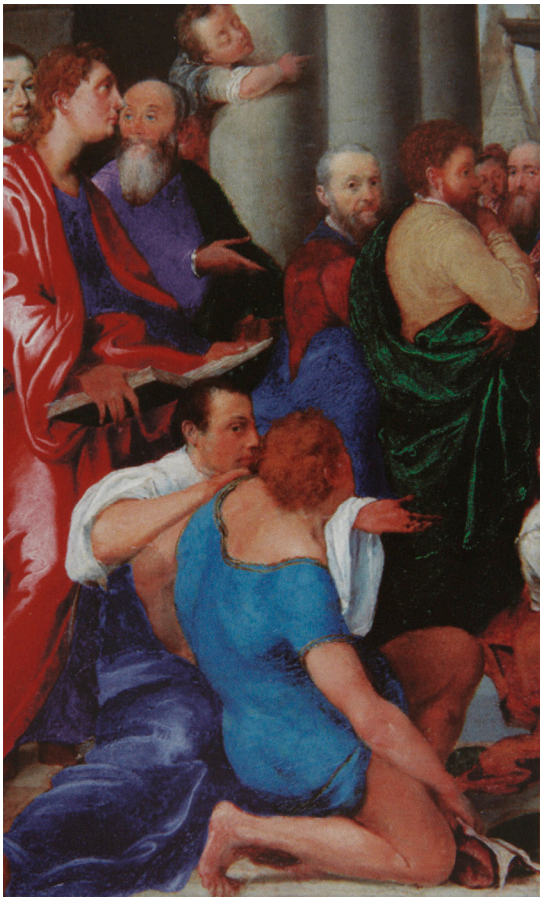


PLATE 7 Digital image showing the reconstructed colours of the draperies of the principal figures on the left of the image.

PLATE 8 Digital image showing the reconstructed colours of the draperies of the figures at the right of the image.

well with the well-preserved draperies painted with vermilion and ultramarine.

Discussion

The National Gallery painting in its current state is very different in appearance from the painting of the same composition in the Borghese Collection in Rome, which was made from it soon afterwards – certainly not more than a few decades later. It is not an exact copy, so there can be no certainty that its creator felt obliged to follow the colour scheme of his model. Nevertheless, analysis of the pigments in the discoloured paint, and the digital reconstruction of the colours in the National Gallery painting made on the basis of this information, suggests that in most of the figures the draperies were originally the same colour. But in the Borghese version they are well-preserved – there are no dead greys and browns where brilliance would be expected, and no sudden transitions to deep shadow. An unexpected consequence of the comparison was that it drew attention to some other colour changes in the National Gallery's painting that had not been suspected – most notably, the yellows are rather grey. A closer look at a sample from a yellow drapery showed that there is a thin greyish layer on the surface of the paint, probably a residue of an old surface coating.[31] This residue is also present over the sky and architecture, and was seen on the surface of samples from the browned greens and purples, although it is unlikely that it has a significant visual effect on these darkened colours.

The fact that the colours in the two paintings were for the most part originally the same does not mean that the same pigments were employed. The artist of the National Gallery's painting used smalt for Christ's cloak (an aesthetic choice rather than an economy measure since he used ultramarine elsewhere) whereas ultramarine was, it seems, used for this area in the Borghese painting, explaining the difference in the state of preservation. However, the better condition of areas painted in red lake in the Borghese painting is strong evidence that it has not been subjected to such harsh environmental conditions as the National Gallery painting. Different red

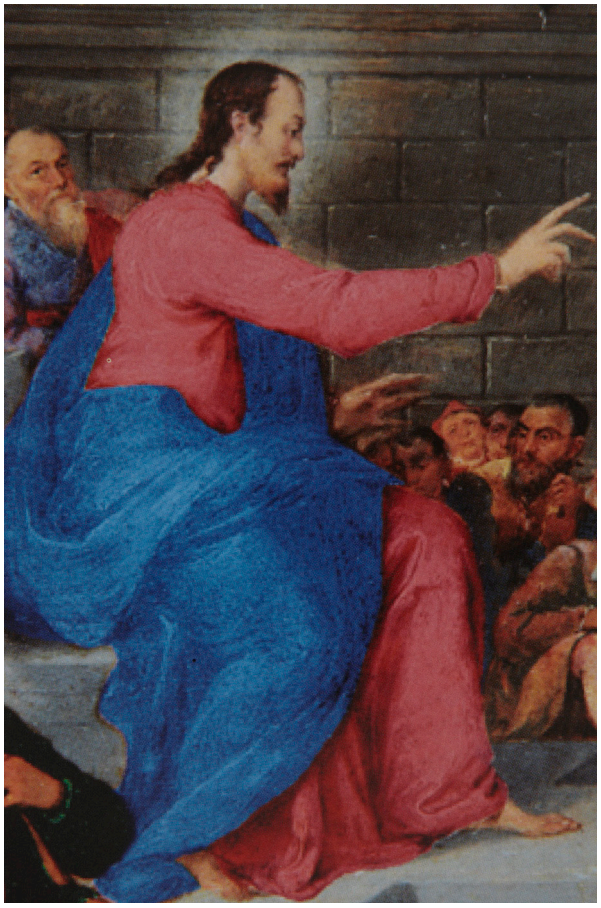


PLATE 9 Digital image showing the reconstructed colours of Christ's drapery.

lake pigments are not so spectacularly different in stability, nor has a particularly fugitive dyestuff been used to make the red lake in the National Gallery painting.[32] The Borghese picture has spent almost all its life in two collections in the same city, whereas the National Gallery's picture has belonged to at least half a dozen collections and has passed on at least three occasions through the art trade, but too little is known about the conservation history of these paintings, and the conditions in which they have been kept, to explain the difference in preservation.

Conclusion

The detailed technical examination of *The Conversion of the Magdalen*, and the process of reconstruction of the colours in the digital image, has produced some deeper insight into how the deterioration of pigments has affected the colours in the painting. Although the strong and deep colours of the reconstruction initially seemed rather startling, they receive strong support from comparison with the Borghese version of the painting – which is especially gratifying since the reconstruction was made before the transparency of the Borghese painting was available to us. The reconstruction is not, of course, an accurate portrayal of the original appearance of the painting – the lost modelling in some of the draperies cannot be recreated, and the colour was only reconstructed in the most seriously affected principal figures. It does, however, give some idea of the original balance of colour of the National Gallery painting, showing that the colours in the two paintings must originally have been very similar, and provide a striking illustration of what can happen to blue, pink and green in a sixteenth-century Italian painting.

Acknowledgements

Clare Richardson carried out the computer reconstruction of the colours in the painting and painted test panels simulating the painting technique, a major contribution to the paper. We would also like to thank Jo Kirby and Catherine Higgitt for their contributions to the analysis of the paint samples.

Notes and references

1 The panel is approximately one centimetre thick and is painted on pear wood, identified by B.J. Rendle of the Forest Products Research Laboratory in a letter of 20 September 1945 in the Gallery's archive and confirmed as such in a recent examination.

2 This was first noticed by Philip Pouncey (without knowledge of Grimani's will) – see the addendum to Paola della Pergola's article, cited below in note 11, in *Bollettino d'Arte*, XL, 1995, pp. 83–4.

3 For Federico Zuccaro in Venice see W. Roger Rearick, 'Battista Franco and the Grimani Chapel', *Saggi e Memorie di Storia dell'Arte*, II, 1958–9, pp. 122–35, and Hermann Voss, 'A Project of Federico Zuccari for the "Paradise" in the Doges' Palace,' *Burlington Magazine*, June 1954, pp. 172–5.

4 *Disegni degli Zuccari*, Galleria degli Uffizi, Florence 1966, cat. 47, pl. 34, no. 47; also E. James Mundy, *Renaissance into Baroque. Italian Master Drawings by the Zuccari*, catalogue of exhibition held at Milwaukee Art Museum and elsewhere, Milwaukee 1984, pp. 173–5. What appears to be the artist's final composition is the Uffizi drawing (sent by Federico to Vasari) but it is clear that Zuccaro's earlier idea for the composition was closer to that seen in the National Gallery's picture. The latter may have been based on a drawing rather than on the fresco.

5 Archivio di Stato di Venezia, Notarile testamenti, Busta 658, no. 396 (Vettor Maffei), 29 August 1592. Michel Hochmann kindly provided a transcription of the relevant patronage and Carol Plazzotta made a fuller tran-

scription of his will for the Gallery's dossier. The will is published and the connection with the National Gallery's painting was first pointed out by M. Mantovanelli Stefani, 'Il testamento di Giovanni Grimani patriarca d'Aquileia. Glosse a una fonte per il collezionismo veneziano rinascimentale' in *Idem*, *Arte e committenza nel Cinquecento in area veneta fonti archivistiche e letterarie*, Padua 1990.

6 Full details of the provenance will be supplied in Nicholas Penny's forthcoming catalogue. It is noteworthy that John Young in his *Catalogue of the Pictures at Leigh Court*, London 1822, no. 29, p. 16, recorded (or himself invented) the idea that the picture included portraits of Francis I, Queen Elizabeth, Bembo, Titian, etc. – nonsense repeated in the Leigh Court sale catalogue (Christie's, 28 June 1884, lot 8) which does, however, acknowledge the interpolated character of the portraiture and the fact that some of the hairstyles and dress date from earlier in the century.

7 The attribution is found in Luigi Lanzi, *Storia Pittorica dell'Italia*, Bassano 1795–6 (see edition of Florence 1968, I, p. 319). Lanzi seems to have known of Grimani's patronage of the artist and of Grimani's will. He may then have looked for a suitable Pieter among documented Flemish artists. He refers only to Palomino, which would suggest that he was searching for an artist who had worked in Spain, and that he already had the name Campaña. The problem of how Lanzi came up with Campaña's name is a major obstacle to acceptance of Meijer's hypothesis discussed below.

8 Cecil Gould, *National Gallery Catalogues*; *The Sixteenth Century Italian Schools*, London 1975, pp. 333–5, classified the painting as by a 'pasticheur' of Zuccaro – the style used by Neil Maclaren (*National Gallery Catalogues*; *The Spanish School*, London 1970, p. 144), whose dismissal of the connection with Campaña is recorded in notes in the National Gallery's dossier.

9 For Campaña see Nicole Dacos, 'Fortune Critique de Pedro Campaña', *Revue belge d'archéologie et d'histoire de l'art*, 53, 1984, pp. 108–16. It should be said that the attempts to reconstruct an Italian period in Campaña's production based on the dubious and contradictory claims made by his Spanish biographers by Dacos and other authors are highly conjectural.

10 Bert W. Meijer, 'Pieter Cornelisz.van Rijck and Venice', *Oud Holland*, 113, 3, 1999, pp. 137–52, especially p. 141.

11 The painting entered the Borghese Collection from that of the Aldobrandini. It was recorded as by Taddeo Zuccari (and the panel is endorsed with this attribution) at least as early as the inventory of Olimpia Aldobrandini's paintings in 1682. Adolfo Venturi (*Catalogo della Galleria Borghese*, Rome 1893, p. 103) proposed Carletto Caliari as the artist; Roberto Longhi (*Precisioni: la galleria Borghese*, 1928, p. 192) preferred 'un manierista venezianeggiante' of the period 1570–90; Paola della Pergola ('Contribuiti per la Galleria Borghese', *Bollettino d'Arte*, XXXIX, January–March 1954, pp. 135–6) made the case for Luca Longhi.

12 B. Mühlethaler and J. Thissen, 'Smalt', *Artists' Pigments. A Handbook of Their History and Characteristics*, 2, ed. A. Roy, Washington 1993, pp. 113–30.

13 J. Plesters, 'A Preliminary Note on the Incidence of Discoloration of Smalt in Oil Media', *Studies in Conservation* 14, 1969, pp. 62–74. Joyce Plesters demonstrated that leaching of alkali from smalt pigment occurs when it is immersed in water. Her observation that a sample of smalt-containing paint from *The Adoration of the Shepherds* (NG 232 Italian, Neapolitan) is more deteriorated near the surface suggests that atmospheric moisture plays a part. Water is known to be a primary environmental agent causing deterioration of the glass itself, see R. Newton and S. Davison, *Conservation of Glass*, Oxford 1989, p. 135. Water causes alkali extraction, resulting in a leached layer at the surface of the glass, with an associated reduction in volume. Eventually the silica network is attacked by the alkaline surface that develops and other ions can migrate out.

14 R. Giovanoli and B. Mühlethaler, 'Investigation of Discoloured Smalt', *Studies in Conservation*, 15, 1970, pp. 37–44. Giovanoli and Mühlethaler propose that a change in the environment of the cobalt ion causes a loss of colour. This could occur with or without migration of the cobalt into the medium.

15 Mühlethaler and Thissen, cited in note 12.

16 Newton and Davison, cited in note 13, p. 7.

17 An attempt at quantitative analysis of a smalt particle in a sample from this painting gave concentrations of approximately 7wt% As, 4wt% Co, 3wt% Fe, 1wt% K, 1wt% Bi and 0.5wt% Ni. This serves only as a rough guide to the relative quantities of these elements, however. Very few quantitative analyses of smalt particles on paintings have been published.

18 D. Saunders and J. Kirby, 'Light-induced Colour Changes in Red and Yellow Lake Pigments', *National Gallery Technical Bulletin*, 15, 1994, pp. 79–97.

19 We are grateful to Jo Kirby for identification of the dyestuff as cochineal by HPLC analysis.

20 G.B. Armenini, *De' veri precetti della pittura*, Ravenna 1587, Libro Secondo, p. 193.

21 H. Kühn, 'Verdigris and copper resinate', *Artists' Pigments. A Handbook of Their History and Characteristics*, 2, ed. A. Roy, Washington 1993, pp. 131–58.

22 K.J. van den Berg, M.H. van Eikema Hommes, K.M. Groen, J.J. Boon, B.H. Berrie, 'On Copper Green Glazes in Paintings', *Art et Chimie, la couleur*, Actes du congrès, Paris 2000, pp. 18–21.

23 For example the stripes on the tablecloth in Giampetrino's *Salome* (NG 3930). See L. Keith and A. Roy, 'Giampetrino, Boltraffio, and the Influence of Leonardo', *National Gallery Technical Bulletin*, 17, 1996, pp. 4–19.

24 Addition of a little pine resin and sandarac to the linseed oil seems to be standard throughout, as the same results were obtained for GC–MS analysis of the organic components of white paint. The FTIR spectrum is broad, with an intense broad band centred at 1640–50 cm^{-1}. Deconvolution of the FTIR spectrum reveals bands for copper–resin acid salts (1608–18 cm^{-1}), copper–fatty acid salts (1584–7 cm^{-1}), as well as bands ascribed to the car-

boxylate of resin acids (1698 cm^{-1}) and bands at 1778, 1745–30 and 1710–12 cm^{-1} corresponding to various absorptions of the drying oil. The breadth of the band centred at 1640–50 cm^{-1} seems to suggest the presence of additional species absorbing in this region. The presence of unsaturated condensation products could account for the observed features. The band at 692 cm^{-1} present in fresh verdigris in oil is entirely absent, and, unlike the major IR bands in verdigris, is not likely to be obscured by bands from any other components in the film.

25 EDX analysis detected a certain amount of silicon and potassium, as well as calcium in this layer. FTIR analysis suggested the presence of protein. Fine black particles can be seen in this layer when examining it under the optical microscope. It is this layer that is responsible for the rather grey appearance of the yellow draperies in *The Conversion of the Magdalen*, although it is unlikely that it has much of an optical effect on the brown discoloured areas. It is not at all clear what this layer is; the inorganic material could be residues of dirt and dust that have become embedded in an old surface coating, possibly an egg-white varnish.

26 Van den Berg et al., cited in note 22.

27 The technical details of the process of reconstruction of the colours by image processing on the digital image will be described elsewhere.

28 The smalt pigment was supplied by Kremer-Pigmente. EDX analysis indicated that it contains a higher proportion of cobalt than is found in samples from sixteenth-century paintings, and no impurities at all.

29 The skies in the landscape paintings of Aelbert Cuyp are invariably painted with smalt, which in most cases is exceptionally well preserved.

30 For the method used to make the red lake pigment see Saunders and Kirby, cited in note 18, pp. 96–7 (cochineal lake CD1b).

31 The painting was recently cleaned by Martin Wyld. The greyish residue in these areas was left, as it could not be removed without possible damage to the paint layer.

32 The dyestuffs most commonly found in red lake pigments do differ to some extent in their stability to light. Cochineal, the dyestuff found in the red lake in this painting, is of intermediate stability, being more stable than madder, but less stable than brazilwood. See Saunders and Kirby, cited in note 18.