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Andrea del Verrocchio, *The Virgin and Child with Two Angels*, NG 296, detail of fig. 18, page 16

TITLE PAGE
Andrea del Verrocchio, *The Virgin and Child with Two Angels*, NG 296, photomicrographs (see page 17 for details)

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Mastic and Megilp in Reynolds's *Lord Heathfield of Gibraltar*: A Challenge for Conservation

RACHEL MORRISON

Sir Joshua Reynolds (1723–1792) is one of Britain's most celebrated painters. Having painted the portraits of many of the wealthy men and women of British society in the second half of the eighteenth century, and as the first president of the Royal Academy, he was enormously influential. Yet Reynolds's painting techniques have long been a subject of intrigue and discussion. His paintings have always been notorious, even amongst his contemporaries, for their tendency to fade and crack; phenomena associated with his choice of materials. The drying cracks and wrinkled paint visible in many of his works are often ascribed to his use of experimental binding media, sometimes in complicated combinations. These methods have rendered many of his paintings particularly difficult and in some cases impossible to clean. The National Gallery's portrait of *Lord Heathfield of Gibraltar* (FIG. 1) was recently examined in the conservation studio in order to determine whether it would be possible to carry out conservation treatment to improve the appearance of the picture. Since the task of removing discoloured varnish layers and old repaints was unlikely to be straightforward, a careful technical and analytical study of the picture was instigated with the aim of informing any potential conservation treatment. This also presented the opportunity to study Reynolds's painting technique and the possible reasons for the cracking and deterioration of the paint in more detail. The results of this study have increased our understanding of how the painting was made and informed our assessment of its condition. Examination of cross-section samples in combination with the analytical study of small paint scrapings has allowed us to relate the physical defects visible on the paint surface to the materials chosen by Reynolds and to his particular methods of painting.

Lord Heathfield of Gibraltar was purchased for the National Gallery in 1824 as part of the Angerstein collection. It was commissioned by Alderman John Boydell and painted in 1787, towards the end of Reynolds's career. Lord Heathfield, a national hero, was celebrated for his defence of Gibraltar against the three-year siege by Spanish and French troops which began in June 1779. Reynolds depicts him, defiantly grasping the symbolic 'key of Gibraltar' in his hands, at the decisive moment of the final battle that ended the siege. The two cannons and the smoke-filled sky behind him suggest the defeated Spanish fleet of 'battering-ships' which were set ablaze on the morning of 13 September 1782. Heathfield sat to Reynolds five years after his triumph at Gibraltar, on 27 August 1787. This was the first of seven sittings recorded in the 'sitter book', the rest of which took place in September of that year, and the portrait was finally purchased by Boydell for the sum of £105 in October 1787. Further details of the history and provenance of the painting are given in Judy Egerton's catalogue of the British School Paintings in the National Gallery.[1]

The portrait of Lord Heathfield is the latest of the five portraits by Reynolds belonging to the National Gallery. It is an extremely well-known image after which many copies were made, and it was admired as one of Reynolds's most accomplished portraits.[2] However, the painting has suffered from many of the usual kinds of paint defects and deterioration associated with Reynolds's painting technique, and perhaps now appears in poorer condition than the other paintings by Reynolds in the National Gallery. Extensive drying cracks are present throughout the picture but are most disturbing in parts of the dark background, where they are so wide that at some point in the past they have been filled and repainted. The paint surface now seems to be covered with a pattern of smooth, untextured fills in amongst the cracked and wrinkled paint (FIG. 2). The fills themselves have a slightly dipped surface and are

FIG. 1 Sir Joshua Reynolds, *Lord Heathfield of Gibraltar* (NG 111), 1787. Oil and resin (identified) on canvas, 142 × 113.5 cm.

FIG. 2 NG 111, detail showing the wide cracks in the background which have been filled and overpainted.

surrounded by raised ridges, making them obviously discernible even from a normal viewing distance. Elsewhere, the drying cracks have caused the upper layers of paint to retract, allowing the underlying paint, often of a completely different colour, to show through (FIGS 3 and 4). Similar defects, perhaps to an even greater degree, are also visible in the National Gallery's portrait of *Colonel Tarleton* (NG 5985), which dates from 1782, just a few years earlier. However, the portrait of Lord Heathfield also appears extremely yellowed, which compromises the appearance of the painting even further. The surface is covered with thick and ingrained coatings which create a blotchy, mottled appearance (FIG. 5). In the lighter passages of the painting, particularly the flesh paint of the hands, the waistcoat and the breeches, this is especially disfiguring (FIG. 6). The discoloured surface layers have collected in the uneven texture of the paint, making the wrinkling and cracking appear even more pronounced.

Conservation history

Reynolds's clients and his contemporary audience were well aware of the tendency of his paintings to crack.[3] The portrait of Lord Heathfield was no exception, and barely twenty years after its execution it was already known to be marred by severe cracking. The diarist and landscape painter Joseph Farington (1747–1821) reports a conversation at Charles Long's dinner table on 10 June 1809 in which 'pictures painted by Sir Joshua Reynolds were spoken of. Mr. Knight sd. His fine portrait of John Hunter is utterly gone by cracking &c. West sd. the same of His portrait of Lord Heathfield.'[4]

Since its acquisition by the National Gallery in 1824 the painting has received some conservation treatment. It was strip lined by William John Morrill in 1938, presumably to repair weakened tacking margins, but no other structural problems are apparent. In 1986 some of the most pronounced drying cracks in the coat were retouched. The appearance of these cracks seemed to be more prominent than in a photograph from 1931, suggesting that over the intervening period of some 55 years the paint had continued to contract. The portrait has also been revarnished at least twice since it joined the National Gallery Collection. It was examined in 1859, when it was noted as being 'very much bitumen cracked throughout', but there was no recorded conservation treatment until 1867, when it is documented that some repaints were removed from the background and the painting was repaired and varnished. A surface-polishing treatment, carried out by the restorer William Vallance, is recorded in 1945

FIG. 3 NG 111, detail showing the drying cracks in the epaulette of Lord Heathfield's uniform.

FIG. 4 NG 111, detail showing the drying cracks in the rocky foreground to the left of Lord Heathfield.

FIG. 5 NG 111, detail showing Lord Heathfield's head.

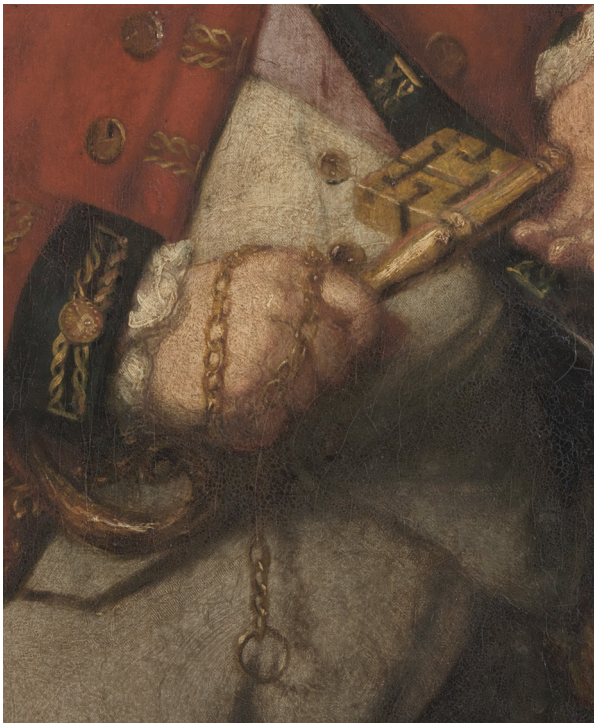


FIG. 6 NG 111, detail showing the blotchy appearance of the lighter passages of paint.

and a further varnish was applied by Arthur Lucas in 1956.[5] This unusually complete record of the history of the picture proved to be an extremely useful resource during this research. Knowledge of these conservation treatments was vital for the interpretation of both cross-section samples and the results of medium analysis and allowed a more precise understanding of the condition of the picture. With these factors in mind, some of the recent study was directed towards building up a more detailed picture of the restorations that had already taken place.

Cross-sections taken from restored areas of the background show that there are two distinct layers of varnish above the uppermost layer of repaint (FIG. 7), which presumably correspond to the varnishes applied in 1867 and 1956 respectively. The two layers are most clearly seen under ultraviolet light (FIG. 8) and are separated by a thin line of material which does not fluoresce and which appears dark. This probably represents particles of surface dirt and suggests that a period of time elapsed between these varnish applications which is consistent with the dates of the documented conservation treatments. The most recent application of varnish was identified as the synthetic resin AW2, probably with the addition of a little heat-bodied linseed oil.[6] Interestingly, an old bottle of varnish found in the conservation studio and thought to date from the period in which Arthur Lucas was working at the National Gallery contains a varnish of similar composition, with a handwritten label that reads 'A.W.2 Resin, 50g resin / 100ml white spirit + 5% stand oil'. The mixture contained within is now rather orange in colour, and the AW2 varnish on the portrait of Lord Heathfield probably contributes to its overall yellowed and discoloured appearance. Analysis suggests that the varnish applied in the 1867 treatment is an oil–resin mixture consisting mainly of heat-bodied linseed oil with a little mastic and traces of oxidised pine resin. Several varnish samples were also found to contain small quantities of microcrystalline wax.[7] Helmut Ruhemann cites Cosmolloid 80 H, a brand of microcrystalline wax, as the main ingredient in wax polish for pictures, and it is likely that a similar recipe was used by William Vallance at the National Gallery during the 1940s.[8] The application of a thin layer of wax polish may have encouraged the pick up of surface dirt and perhaps accounts for the layer of dirt particles trapped between the two varnishes.

The extent of the 1867 conservation treatment is somewhat unclear, and it is difficult to be certain about how much of the evident retouching was applied at this point. Nevertheless the records do not imply that a full cleaning was undertaken at this time and it is likely that much of the restoration visible on the painting surface was carried out before this date. Indeed, the records state that repaints were removed from the background in 1867, suggesting that considerable repairs had already been made. It seems unlikely that the treatment to fill and retouch the cracks in the background was carried out at the National Gallery, and therefore these repairs must date from some time before the acquisition of the picture in 1824. Many of Reynolds's paintings had to be repaired not long after they were completed and Reynolds himself, or one of his assistants, was frequently called upon to restore damaged pictures. The Revd William Mason, a poet who became a close friend of Reynolds, wrote about the portrait of Lord Holderness that it 'very soon faded, and soon after the forehead particularly cracked, almost to peeling off, which it would have done long since, had not his pupil Doughty repaired it'.[9] Reynolds kept detailed technical notes about many of his paintings, which were written in his account ledgers in his own particular mixture of English and Italian, and in 1772 he even records a specific example when he had to retouch the cracks of a portrait he was working on.[10] After Reynolds's death in 1792, his most long-standing studio assistant, Giuseppe

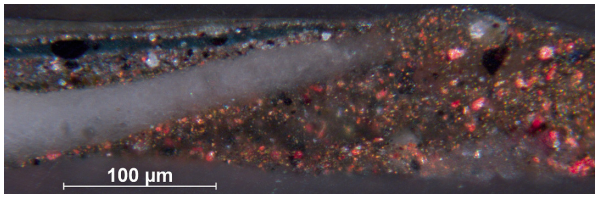


FIG. 7 NG 111, cross-section from an overpainted, filled crack in the dark background, showing the original plum-coloured paint at the right end of the sample, the chalk fill and several layers of overpaint. Two thin layers of varnish are visible above the overpaint.

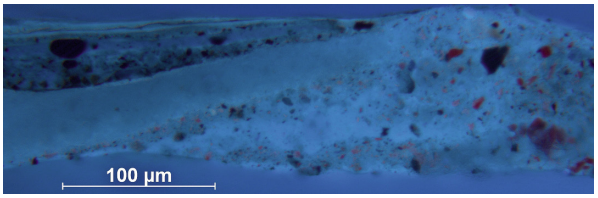


FIG. 8 NG 111, cross-section illustrated in FIG. 7 shown in ultraviolet light. The two thin layers of varnish at the top surface are visible and are separated by a dark line. The original plum-coloured paint fluoresces strongly.

Marchi, built a reputation for restoring his paintings, a practice which appears to have kept him extremely busy until he died in 1808.[11] However, it seems unlikely that the portrait of Lord Heathfield was restored by either Reynolds or an assistant. The painting was displayed in the Guildhall in London from 1794 until 1808–9, when it was removed by Josiah Boydell, John Boydell's nephew and heir, on the grounds that its condition was deteriorating. This circumstance, along with Farington's comments of 1809, suggests that the wide drying cracks in the background were still highly visible at this time. It seems most probable that the filling and repainting of the background took place in the early nineteenth century, some time between 1809 and 1824, when the painting entered the National Gallery Collection.

On examining the painting in the conservation studio it immediately became clear that the repaints in the background were not confined solely to filled areas. In fact much of the background is entirely repainted. The murky brown overpaint extends beyond the raised ridges at the edges of the fills, and covers almost all of the smoke-filled sky. In cross-section it is evident that the overpaint has been built up in several layers above the restorer's white chalk putty (FIGS 7 and 8).[12] An initial grey-brown layer is followed by a thin layer of intense Prussian blue.[13] A subsequent application of another thin layer of grey paint, similar in composition to the first layer of overpaint, completes the sequence. In a further cross-section from an area of the background where no fill was present (FIG. 9), the overpaint can be identified since the same pattern of layers is visible, but here they have been applied directly over the original paint, with no evidence of a varnish layer separating the two. The blue and grey paint layers seen at the bottom of this sample are part of the original background paint, and are only distinguishable from the later repaint by their increased fluorescence seen in the ultraviolet light image (FIG. 10). The pigments used in the layers of repaint are extremely similar to those found in the original painting. The only notable differences are the red lake pigment used by Reynolds in the original and the presence of a starch extender associated with the Prussian blue in the overpaint.[14] Conversely no starch was detected in the original paint mixtures containing Prussian blue, and this difference again suggests that the restoration was carried out in the early nineteenth century. Starch was commonly used as an extender in the nineteenth century, particularly for pigments with a high tinting strength such as Prussian blue, but its use is less common in the eighteenth century.[15]

During the recent examination some small cleaning tests were carried out in areas of repaint in the background to establish if it was possible or desirable to remove this material. The layers of overpaint were found to be relatively soluble in organic solvents despite being bound in heat-bodied linseed oil. This is perhaps due to the presence of intermediate varnishes like that visible in cross-section above the layer of Prussian blue (FIG. 10), but in any case it was possible to remove some of the restoration from an area of filling. The fill itself, as expected for a chalk and glue putty, could be softened with moisture before being mechanically removed. However, the difficulty of removing these layers from parts of the surface where no fills are present produces an additional challenge. The cross-sections demonstrated that there is no clear division between overpaint and

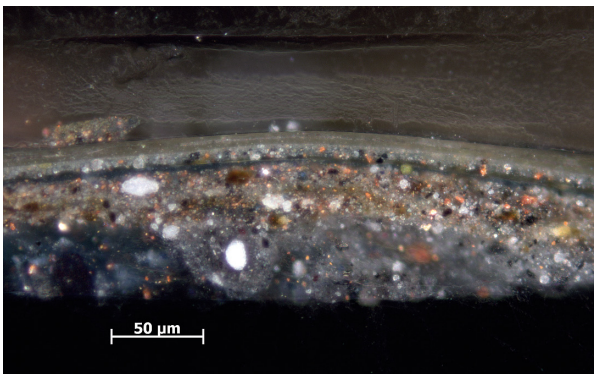


FIG. 9 NG 111, cross-section from an overpainted area of the dark background where no fill is present, showing the same build up of overpaint layers as visible in the sample illustrated in FIG. 7.

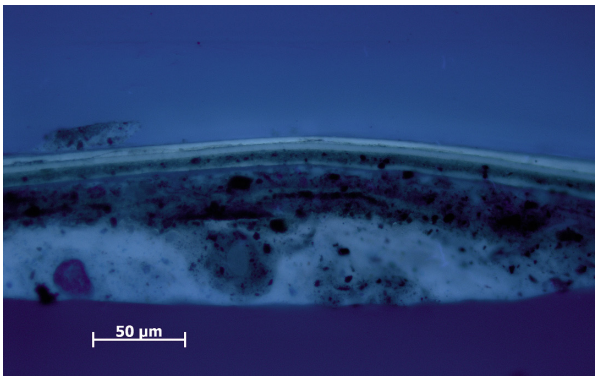


FIG. 10 NG 111, cross-section illustrated in FIG. 9 shown in ultraviolet light.

original and the removal of the repaint would rely on a significant solubility difference between the two, not at all guaranteed given what we known of Reynolds's painting techniques. Furthermore, making the visual distinction between the original and the overpaint during cleaning was likely to present considerable problems.

Cracking and Reynolds's paint medium

Nonetheless, the cleaning test on the background did offer the opportunity to study the materials of the original paint in more detail. The test was carried out at the top edge of the painting in a dark area of the smoke-filled sky. The uncovered original paint was warmer in colour than the overpaint, with a more plum-coloured tone. It contains vermilion and some large particles of a cochineal carmine-type red lake with, in addition, some black, a little lead white and some particles of Prussian blue. Once the fill had been removed from the large drying crack and the original paint exposed, the extent of the deformations and the plastic distortion in the original layers became evident. The paint had retracted and stretched, creating wide valleys with glossy, raised edges where the mobile paint had pooled and collected. For the most part the paint appeared so ductile that it had not actually cracked all the way through, although in a few places the bright blue underlayer had become visible where the upper layer had pulled apart. The ridges visible around the edge of each of the fills in the background actually seem to be formed in the original paint layers. A cross-section taken through the edge of one of the fills (FIG. 7) shows how the original paint at the right end of this sample bulges up around the white chalk fill and almost appears to flow over the top of it, suggesting that the paint continued to move even after the restoration was carried out. A sample was taken for medium analysis from a comparable raised part of the background paint. The fragments, when examined under the microscope, consisted largely of a translucent, varnish-like matrix containing only a relatively small proportion of pigment particles characteristic of Reynolds's paint mixtures. In particular some large and distinctive particles of red lake and some Prussian blue were discernible. Analysis by gas-chromatography–mass-spectrometry (GC–MS) identified a mixture of heat-bodied linseed oil with a large proportion of mastic resin. Although these materials were also found in samples of varnish, in this case the sample was taken from within a cleaning test where the upper layers had been removed. It is therefore possible to be reasonably certain that the mastic resin detected is indeed part of Reynolds's paint medium and is not attributable to varnish contamination. This assertion is supported by the strong fluorescence of this paint layer in ultraviolet light (FIG. 8), which implies that the paint is rich in organic binding medium and suggests the presence of a resinous component. A second sample of the same background paint was taken from a flatter, less glossy area further away from the edge of the uncovered drying crack where the paint appeared less medium rich and translucent. The same combination of materials was detected by GC–MS analysis, but with a lower proportion of mastic resin relative to the heat-bodied linseed oil. It is tempting to suggest that there has been some partitioning of the materials within Reynolds's paint medium which has caused the paint defects to form, and that his oil resin mixture was inherently unstable. It may not be possible to draw such a conclusion or to determine whether this is indeed the mechanism by which the cracks have developed, but it is clear that from an early date Reynolds's use of a varnish which contained medium was held responsible for the severe cracking in many of his pictures. One of Reynolds's pupils, James Northcote, wrote about Reynolds's technique in a letter to his brother dated 23 August 1771, shortly after he joined the studio.

> 'He uses his colours with varnishes of his own because the oils give the colours a dirty yellowness in time, but this method of his has an inconvenience full as bad, which is that his pictures crack; sometimes before he has got them out of his hands.'[16]

Northcote also remarks that 'it is common with painters in London to use mastic varnish with their colours'.

Reynolds may simply have added some mastic varnish to his oil while mixing the paint on his palette. However, as discussed by Joyce Townsend et al., it is interesting that the earliest known written mention of the gelled painting medium megilp is found in a 1767 ledger belonging to Reynolds, where he notes the materials used for specific paintings.[17] A true gelled megilp is made by combining mastic varnish with a dry-

ing oil which has been prepared by heating with either litharge (lead oxide) or sugar of lead (lead acetate), and it may be that Reynolds made his own megilp medium in this way. Indeed, one of Reynolds's notes specifically refers to a varnish made from mastic dissolved in oil with lead acetate, 'Varnished with Gum Mast. dissolved in Oil with Sal Saturni(?)'.[18] Whatever the exact recipe, there are frequent mentions of 'magilp', 'mag.' or 'magp.' dotted through Reynolds's ledgers after the initial entry. The notes often include a complicated list of media with megilp featuring as only one of the possible ingredients. Sometimes mastic varnish, or varnish without oil, is mentioned rather than megilp and it is clear that Reynolds used different media at different stages, and most probably in different passages, of the same painting.[19] This also seems to be the case in the portrait of Lord Heathfield. During this study the lower layers of paint from the cracked original background were also investigated. In the area of the cleaning test the background was initially painted blue, presumably to indicate the sky, before being rendered dark to give the impression of smoke. A cross-section shows the build up of the original paint layers (FIG. 11) including the initial mixed grey layer, the intensely coloured layer of Prussian blue and lead white and the dramatic colour change to the reddish brown visible at the top of the sample. The layers are extremely disrupted and at one point the bright blue layer has fractured and moved towards the upper surface of the sample with the red brown paint running in underneath it. Organic analysis of the blue layer alone found the binding medium to consist of linseed oil with no evidence of the addition of a resinous component. In this case the linseed oil had not been heated to pre-polymerise or thicken it before use.[20] It is likely that this layer would have dried at a different rate than the subsequently applied maroon

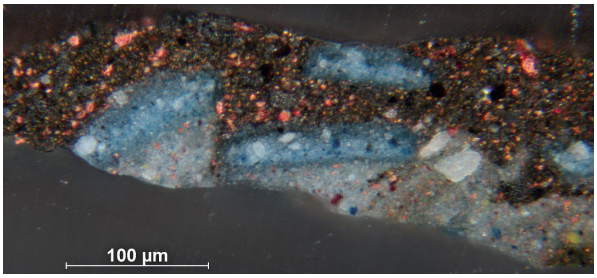
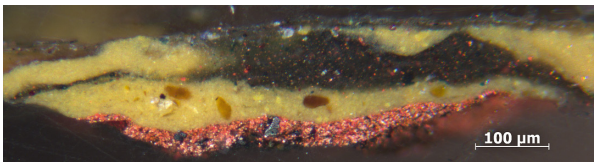


FIG. 11 NG 111, cross-section from the cleaning test in the background showing the fractured and distorted layers of original paint.



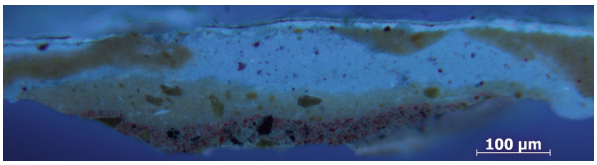


FIG. 12 NG 111, cross-section from the cracked paint in the rocky foreground, showing the thick application of medium-rich translucent paint between layers of yellow ochre. The translucent layer contains particles of vermilion, Prussian blue, black, some yellow, a few particles of white and a little red lake.

FIG. 13 NG 111, cross-section illustrated in FIG. 12 shown in ultraviolet light. The thick application of medium-rich paint, between the layers of yellow ochre, is highly fluorescent.

paint, which contains a proportion of mastic resin. This layering of different media must have been a major contributing factor in the formation of the drying cracks.

Similar results were obtained from the cracked paint of the rocky landscape in the lower left foreground. Here the upper brown layers have cracked to reveal a bright yellow underpaint identified as a yellow ochre of a particularly brilliant colour. A cross-section from this area (FIG. 12) shows the thick applications of yellow ochre separated by a brown layer containing a complex mixture of pigments dispersed in a translucent matrix. In the centre of the sample this translucent layer is present at the surface, where the yellow paint has apparently cracked. On either side, above the yellow paint, several thin translucent layers containing similar mixtures of pigments are present.[21] The appearance of this sample again suggests that the combination of medium-rich layers applied between layers of more conventional solid-looking paint has led to the development of the wrinkling and drying cracks. In the same way as the original paint in the background, the translucent brown layer is highly fluorescent under ultraviolet light (FIG. 13), suggesting the presence of a natural resin. Furthermore, attenuated total reflectance Fourier transform infrared (ATR–FTIR) imaging performed on this cross-section allowed the organic materials to be localised within the layer structure.[22] An individual FTIR spectrum from the translucent paint layer in the centre of the sample was extracted from the data. This matches well with library spectra of natural resins and suggests that a triterpenoid resin such as mastic is

FIG. 14 Sir Joshua Reynolds, *Colonel Tarleton* (NG 5985), 1782. Oil and resin (identified) on canvas, 236 × 145.5 cm.

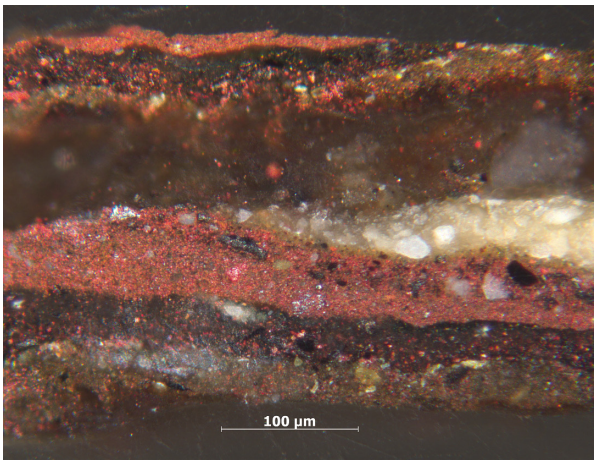


FIG. 15 NG 5985, cross-section from the brown paint of the cannon at the left edge of the picture, showing the reworking of the area and the repeated sequence of layers separated by a thick, translucent glaze.

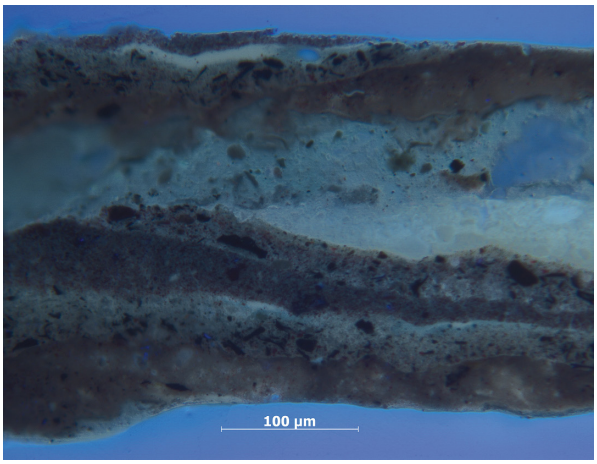


FIG. 16 NG 5985, cross-section illustrated in FIG. 15 shown in ultraviolet light.

present. It therefore seems very likely that a similar combination of materials to those found in the background has been used in this passage.

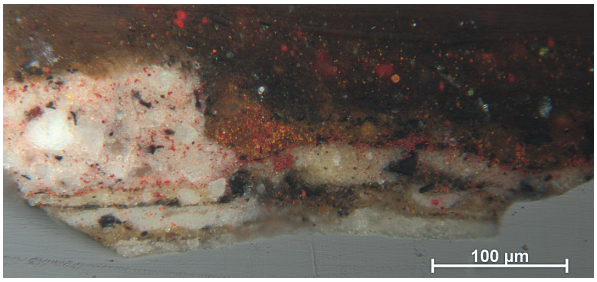
Parallels can be drawn between the techniques described above and those employed in the portrait of *Colonel Tarleton* (FIG. 14), which also displays extensive drying defects. Reynolds used comparable pigment mixtures and in some cases even more complicated applications of paint. A cross-section from the brown paint of the cannon at the left-hand edge of the picture shows how Reynolds reworked the area using a repeated sequence of mixed red, black and brown layers separated by a thick, medium-rich layer in between (FIGS 15 and 16). Similarly, a cross-section taken from the cracked brown paint of the horse's neck (FIGS 17 and 18) shows a thick upper layer of brown, medium-rich paint, containing vermilion, black and a little yellow. This appears closely similar in composition to the translucent layer in the sample from the rocky foreground of *Lord Heathfield*. In both cross-sections these semi-translucent brown layers display a milky fluorescence under ultraviolet light. Early medium analysis of paint samples from the portrait of Colonel Tarleton, carried out in 1975, identified combinations of oil and a natural resin, thought to be of a conifer type.[23] The analysis was performed before the National Gallery Scientific Department acquired a mass-spectrometer, so the type of resin could not be characterised further. However, fragments of the samples from the 1970s still remain and recently a little more analysis has been undertaken. The upper layer of brown paint from the horse's neck was separated and analysed with GC–MS.

The binding medium of this paint was identified as heat-bodied linseed oil with a significant addition of both pine resin and mastic resin.[24] The results suggest that the drying defects in this painting are caused by similar combinations of oil and resin to those used in *Lord Heathfield of Gibraltar*.

However, Reynolds used a wide variety of painting techniques, and one cannot assume that other pictures which show similar types of cracking have been painted in the same way or with the same types of materials. Research carried out at Tate on several paintings by Reynolds in their collection identified beeswax in the medium of three paintings.[25] Two of these, the portrait of *George IV when Prince of Wales*, 1785 and *The Age of Innocence*, about 1788, are painted within a few years of the Lord Heathfield portrait.[26]

Interestingly, bitumen, which is commonly referred to as the cause of deterioration in many paintings by Reynolds, was not identified in either the portrait of Lord Heathfield or that of Colonel Tarleton. In fact, the use of a bitumen-containing pigment has so far only been analytically confirmed in one of the five paintings by Reynolds in the National Gallery. Bitumen was used to create the black shadows on the red drape in the background of *Lady Cockburn and her Three Eldest Sons* (FIG. 19).[27] Although some cracking is evident, this picture does not contain pronounced shrinkage cracks and the dark bituminous glazes are not noticeably more disrupted than other areas of the painting. Rica Jones et. al also concluded that the use of mixtures of different media, rather than an excessive use of bitumen, as is sometimes supposed, was the more likely cause of the cracking and shrinking in the paintings they examined in the Tate collection.[28]

FIG. 19 Sir Joshua Reynolds, *Lady Cockburn and her Three Eldest Sons* (NG 2077), 1773. Oil on canvas, 141.5 × 113 cm.



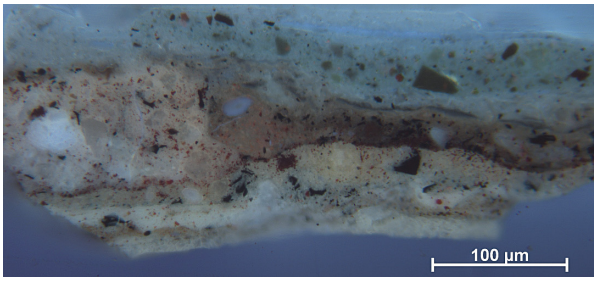


FIG. 17 NG 5985, cross-section from the horse's neck, showing a complicated layer structure with a brown upper glaze layer containing scattered coloured pigment particles including vermilion and black.

FIG. 18 NG 5985, cross-section illustrated in FIG. 17 in ultraviolet light.

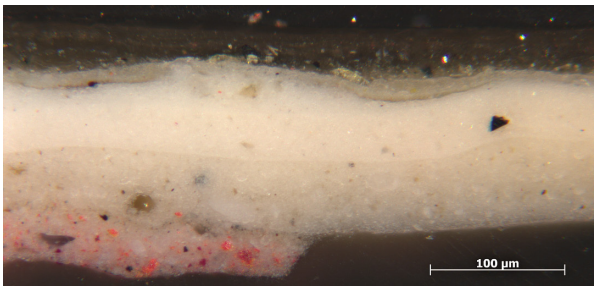
The use of final varnish-like glazes

Many areas of the portrait of Lord Heathfield have been finished with varnish-like glaze layers, which contain only a sparse scattering of pigment particles. The status of these layers is difficult to understand and, given their appearance, it would be very easy to misinterpret them as simply old varnish layers or perhaps a restorer's toning or glaze-like retouching. One of the main objectives of this study was to establish clearly the distinction between material from the original painting and that from later restoration treatments; not an easy task but obviously a question of particular importance when a potential cleaning treatment is being considered. To this

end it was vital to understand the restoration history of the painting, and we are extremely fortunate that such records as already described do exist.

The restorers' varnishes previously discussed and visible in cross-section above the layers of overpaint are relatively thin and together measure only ~7–15 microns thick. However, in several of the cross-sections taken from areas without any evidence of restoration the fluorescent, varnish-like layers at the surface of the samples are much thicker, measuring between 30 microns and up to as much as 70 microns in one case. These are clearly of a different composition from the restoration varnishes applied since the National Gallery acquired the picture. Reynolds frequently noted in his ledgers that he finished a painting by glazing or with layers of varnish, either with or without pigments incorporated.[29] Therefore, it seems possible that much of the translucent varnish-like material on the surface may in fact be part of the original painting, and these layers are indicative of the methods Reynolds used to achieve particular effects of rich glaze-like paint. Two areas of the painting especially warrant closer attention, since they demonstrate the difficulty of discerning between restoration and original material and show how the appearance of the paint surface can be extremely misleading.

The waistcoat of Lord Heathfield's uniform appears discoloured and uneven, seemingly due to layers of yellowed varnish and dirt on the paint surface (see FIG. 6). One would imagine that it is intended to appear white, or close to white, in colour and that cleaning to remove the old surface coatings would reveal a much brighter paint surface. A cross-section from the waistcoat shows that the surface is covered with an extremely thick translucent brown layer (FIGS 20 and 21). At first glance this might be interpreted as old varnish, and it clearly accounts for the brown-yellow patches of material which have collected in the texture of the paint. However, this layer is pigmented, containing fine particles of vermilion, some black and some larger particles of a pale lemon yellow colour. This pigment was identified by energy-dispersive X-ray analysis in the scanning electron microscope (SEM–EDX) as lead-tin-antimony yellow. At this date, it is more common to find Naples yellow, the oxide of lead and antimony without the additional tin, so this finding is unusual. Lead-tin-antimony yellow was first described by Ashok Roy and Barbara Berrie in 1998.[30] Nonetheless, positive analyses of this pigment are still fairly rare and depend on demonstrating that both tin and antimony are found together within the individual particles in order to differentiate it from Naples yellow. In this case, the identification of lead-tin-antimony yellow within the thick brown glaze over the waistcoat strongly suggests that this layer is original, particularly since the same pigment was also identified in the original paint of the pale yellow sky at the horizon (FIG. 22).[31] The cross-section from this part of the painting (FIG. 23) contains larger particles of the pigment, and the backscattered electron image (FIG. 24) shows the individual highly scattering particles of lead-tin-antimony oxide within a glassy matrix of lead calcium silicate comparable with the literature examples.[32]



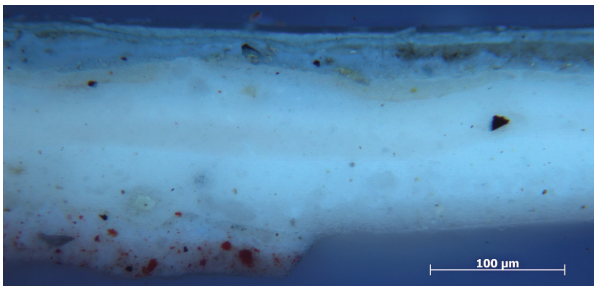


FIG. 20 NG 111, cross-section from the waistcoat showing a thick translucent layer above the white paint which contains fine particles of vermilion, a little black and some yellow particles.

FIG. 21 NG 111, cross-section illustrated in FIG. 20 shown in ultraviolet light.

Reynolds presumably applied the thick glaze over the waistcoat as the final touch to this part of the painting, perhaps with the intention of giving it a creamy yellow tone and to distinguish this passage visually from the cooler white breeches. The notes he recorded in his ledgers demonstrate that this method of working was one he regularly employed. In one instance in 1769 he describes how a painting was finished with varnish alone (presumably this means without oil) and yellow,

FIG. 22 NG 111, detail showing the pale yellow paint of the sky at the horizon behind the cannon on the left of the picture.

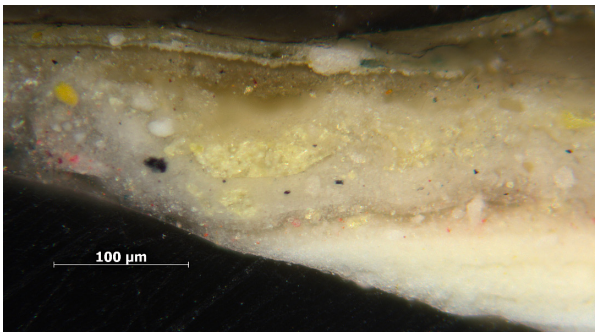


FIG. 23 NG 111, cross-section from the pale yellow sky showing large particles of lead-tin-antimony yellow.

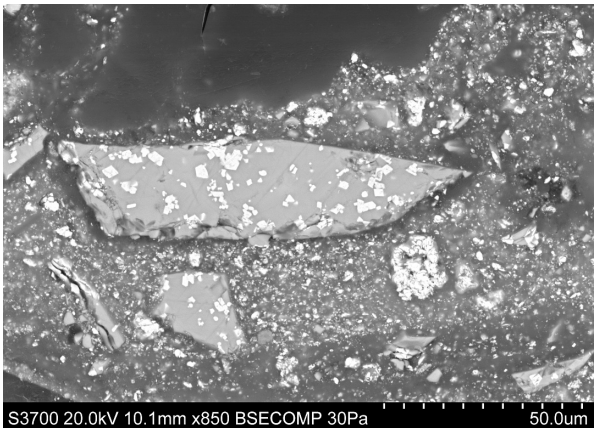


FIG. 24 NG 111, detailed backscattered electron image in the SEM of the cross-section illustrated in FIG. 23 showing large particles of lead-tin-antimony yellow.

'Vernicio Solo / e giallo'.[33] In another example from 1774 he records that a picture was glazed with varnish and Naples yellow, '...glazed with Varnish & Giallo di Napoli'.[34] Although the medium of the glaze on Lord Heathfield's waistcoat has now darkened sufficiently to give the appearance of an old and discoloured varnish, the documentary evidence and the identification of the pigments all point towards the fact that the glaze was applied by Reynolds to create a specific effect. Without the aid of sampling and technical study it would have been impossible to resolve the status of this layer, compromising our understanding of both the painting's appearance and its condition. This finding also has serious implications for any cleaning treatment of the picture, since it shows that at least some of the brown-yellow material on the surface is part of the original painting and was intentionally applied. It would be extremely difficult to remove just the later varnishes, leaving in place the original glaze, and it is doubtful whether any visual improvement would be gained by the attempt.

The second area of the picture worthy of discussion is Lord Heathfield's red coat. This has been painted with vermilion to create the strong, opaque red colour but the shadows of the folds appear to have been glazed with a rich red lake paint. However, a cross-section taken from the bottom of the coat in an area where one might expect to find a red lake glaze shows a rather different layer structure. Above the vermilion there is an extremely thick, translucent brown layer (FIG. 25). There is no evidence of any red lake pigment, as might have been expected in this passage, and it is not clear that a red lake glaze was ever applied. The photomicrograph of an unmounted fragment of this upper layer (FIG. 27) gives a better indication of the quantity of pigment within the translucent brown matrix, including a little Prussian blue, some brown, black and a few red particles. The UV light image of the cross-section (FIG. 26) shows that it is rather inhomogeneous, with different parts fluorescing to a different degree, suggesting that several different materials are present. The distinct thin fluorescent layers at the upper surface

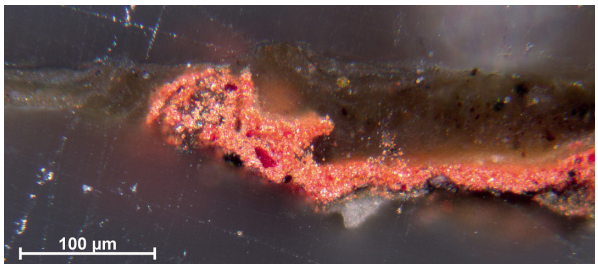


FIG. 25 NG 111, cross-section from Lord Heathfield's red coat showing the vermilion underlayer and a thick brownish glaze above containing pigment.

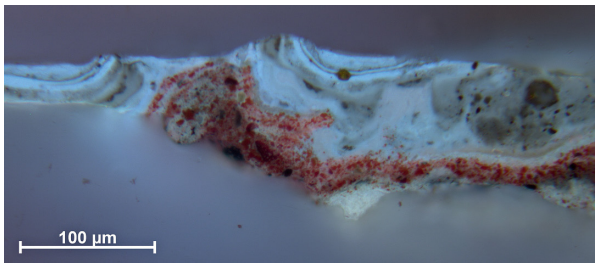


FIG. 26 NG 111, cross-section illustrated in FIG. 25 shown in ultraviolet light.

probably correspond to the restorers' varnishes, indicating that the thick brown layer must have been applied prior to these conservation treatments. Furthermore, the interface between the underlying vermilion paint and the glaze is blurred. The layers are swirled together with particles of vermilion swept up into the brown layer above. It seems likely that this was applied before the vermilion paint had dried, which again suggests that this varnish-like application is part of the original painting technique employed by Reynolds to create the glaze-like shadows.[35]

A small quantity of red lake has undoubtedly been used in some parts of the coat, and large particles of a cochineal carmine-type pigment similar to that found in the background were identified in a nearby sample from the coat tail, but it has been used less extensively than one might imagine from a visual examination of the painting. The majority of the colour of the coat is provided by the vermilion, and the depths of the shadows are built up with translucent medium-rich layers containing relatively little pigment. A similar technique has been used to create the dark shadow on Lord Heathfield's cuff. A small paint scraping taken from this area again consisted mainly of translucent varnish-like material with particles of black, Prussian blue and a little red pigment within the medium-rich matrix. In this case GC–MS analysis identified heat-bodied linseed oil with, in addition, both mastic and pine resin.[36] A cross-section of the upper layer was also taken from a nearby area and the photomicrograph of the unmounted fragment (FIG. 28) shows the translucent glaze, with particles of pigment unevenly distributed through the layer.

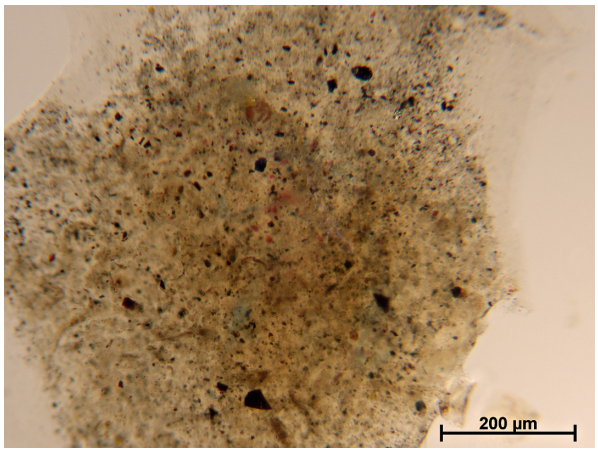


FIG. 27 NG 111, photomicrograph of an unmounted fragment of sample from Lord Heathfield's red coat. The sample consists only of the thick upper glaze layer.

The use of glaze layers of this type is evidently a factor in the deterioration of paintings by Reynolds. The darkening of the medium is bound to have a greater visual effect in a layer which contains very little pigment, and must influence the appearance of the painting. Although it is difficult to separate out this effect from the yellowing of subsequent varnish layers, in this case the use of medium-rich glazes seems to have contributed to the overall yellowed and ingrained appearance of the layers over the surface of the portrait of Lord Heathfield. In addition, many of the final glazes which appear particularly rich in medium seem to have a greater tendency to form drying cracks, for example the brown rocky foreground to the left of the figure. This passage is discussed above, but a further sample from a similar area of cracking shows the final glaze layers even more distinctly. The brown rocks were finished with several thin medium-rich layers, containing a mixture of pigments, over the bright yellow ochre paint. In cross-section it is difficult to gauge the quantity of pigment in these glazes and again it might be possible to mistake them for later retouching, especially since here they are separated by what appear to be intermediate varnish applications. However, the photomicrograph of an unmounted fragment of these upper layers, which was used for medium analysis, gives

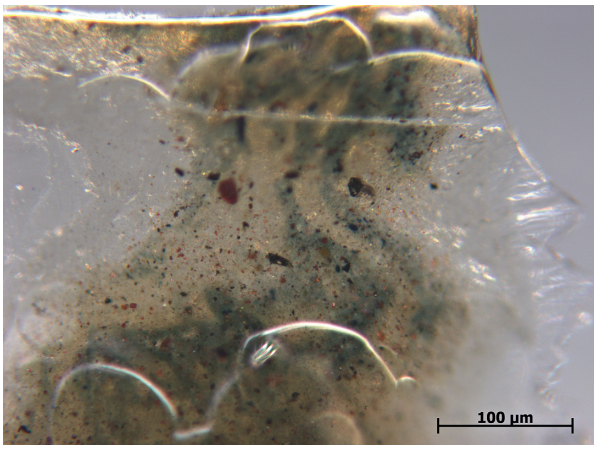


FIG. 28 NG 111, photomicrograph of an unmounted fragment of glaze taken from the shadow of Lord Heathfield's sleeve, showing the pigment particles dispersed through a translucent medium-rich matrix.

a better indication of the composition. The similarity of the pigment mixture within the translucent matrix to that observed elsewhere on the painting leaves little doubt that this is part of the original painting, and once again Reynolds has applied his final touches in a medium-rich, varnish-like paint containing a mixture of heat-bodied linseed oil with some pine and mastic resin. William Mason comments on this aspect of Reynolds's technique after seeing him hastily finish his painting of the Nativity, which was to be used for the design of the west window of New College chapel, in time for the opening of the Exhibition in 1777.

'I saw him at work upon it, even the very day before it was to be sent thither; and it grieved me to see him laying loads of colour and varnish upon it, at the same time prognosticating to myself that it would never stand the test of time, but that it would.'

Further aspects of Reynolds's technique: pigments and palette

RED

Two red pigments were employed by Reynolds in the portrait of Lord Heathfield. Vermilion was used for the red coat and throughout the picture in various paint mixtures. Lord Heathfield's ruddy complexion suggests that vermilion was also used in the flesh paint of the face, although no sample was taken to confirm this.[37] In addition a red lake pigment was also used for some of the shadows on the coat and extensively in the original background paint of the smoke-filled sky. The large red lake particles observed in this paint mixture are one of the distinguishing features which differentiate the original from the subsequent overpaint. The dyestuff was confirmed by high-performance liquid chromatography (HPLC) analysis as cochineal; a result which is consistent with previous analyses of red lakes from paintings by Reynolds and from this period in general.[38] Fourier transform infrared (FTIR) microscopy suggested that the individual pigment particles were rich in cochineal, since absorption bands relating to the dyestuff itself were observed in some spectra, suggesting that the pigment could be interpreted as a carmine rather than a more conventional cochineal lake.[39] Bands indicating the presence of protein were also observed in the spectra from some of the large pink particles and suggest that a source of protein such as egg white or gelatine was added during the preparation of the pigment to aid precipitation.[40]

YELLOW

Two yellow pigments were identified in the portrait of Lord Heathfield: a bright, intensely coloured yellow ochre and the more unusual lead-tin-antimony yellow already discussed. This pigment has not so far been identified on any of the other paintings by Reynolds in the National Gallery Collection. It is not referred to specifically in any of Reynolds's notes, although Naples yellow is mentioned. As discussed by Ashok Roy and Barbara Berrie, the terminology surrounding yellow pigments is rather confused and Reynolds may in fact have purchased his lead-tin-antimony yellow under the name of Naples yellow.[41] He certainly would not have known the exact composition or indeed the difference between this pigment and the lead antimonate pigment we now term Naples yellow. The National Gallery's portrait of *Anne, 2nd Countess of Albemarle* (NG 1259) interestingly also contains lead-tin-antimony yellow in the upper layer of flesh paint from the shadow on the Countess's arm. In this case it was not applied in a medium-rich glaze but was used in a more opaque, pigment-rich paint layer. In *Colonel Tarleton* orpiment has been used extensively in the crumpled yellow fabric on the floor, in the gold highlights of Tarleton's uniform and in the flag. The same pigment is found in the golden yellow drapery in the portrait of *Lady Cockburn and her Three Eldest Sons*. Orpiment is mentioned in

Reynolds's ledgers and the studio canvas belonging to the Royal Academy of Arts contains a colour sample inscribed as orpiment. The inscription also suggests that Reynolds was experimenting with applying the yellow pigment in a varnish medium, perhaps testing out a similar technique to that employed for Lord Heathfield's waistcoat.[42]

WHITE

As well as lead white, Reynolds may also have incorporated other materials into his paint mixtures, for example in the upper layers of paint over the pale yellow horizon on the left of the picture. These layers now have a rather translucent brownish appearance on the surface of the painting, presumably due to the darkened paint medium, and again could be mistaken for discoloured varnish layers. In cross-section the upper white and pale yellow layers appear less opaque than the lower layers in the sample and are less highly scattering in the backscattered electron SEM image, since a proportion of an extender such as chalk may have been included in the pigment mixture.[43]

BLUE

The only blue pigment to be identified in the *Portrait of Lord Heathfield* is Prussian blue; this has been shown by EDX to contain aluminium and is therefore the earlier form of the pigment. Reynolds refers to Prussian blue as 'turchino' in his ledgers and the pigment is frequently mentioned.[44] It has been used extensively in the background and in many of the darker glaze layers in areas of shadow. Reynolds describes how, in place of black, a mixture of Prussian blue, vermilion and yellow lake can be used, and indeed similar combinations were observed in the portrait of Lord Heathfield.[45]

Conclusion

The direct result of this study was the decision not to clean the portrait of Lord Heathfield. Although it may have been possible painstakingly to remove the layers of overpaint from the background, the combination of oil and resin detected within the medium of the underlying original paint suggested that this was likely to be vulnerable to a cleaning treatment. Furthermore, in the small cleaning test that was carried out, the disruption of the original layers and the huge variance in surface gloss of the uncovered paint suggested that in all likelihood a large amount of retouching would then have been necessary. In addition, the presence of a great many medium-rich glazes bound in a varnish-like mixture of oil and resin meant that the removal of the restorers' varnishes could not have been accomplished safely. In the end, very little restoration work was undertaken, with only some careful retouching being carried out to reduce the worst of the patchy and blotchy appearance.

Perhaps the most interesting result of this work is the increase in our understanding of how this picture was created and the reasons behind the deterioration in its condition and appearance. The use of complicated applications of paint and the combination of oil and resin in certain passages, possibly formulated into a gelled megilp medium, appears to be responsible for the drying defects, which are so characteristic of many paintings by Reynolds. However, the analytical study was not without its complications. The characterisation of the original glaze layers was especially challenging. The difficulty of discerning visually between later varnish and original material, and the associated problem of trying to obtain suitable samples for medium analysis without including either later surface coatings or underlying paint, makes the interpretation of any analytical results very problematic. Since the materials used by Reynolds in this portrait – heat-bodied linseed oil and resins such as pine and mastic – are exactly those that might be expected in subsequently applied varnish layers, the results of organic analysis alone will always be difficult to decipher. The conclusion that many of the glaze layers observed on the surface of the painting are original was only reached through a combination of careful examination of the samples, identification of the pigments within the translucent layers and the appearance of the material in cross-section. In addition the large body of documentary sources and anecdotal stories about Sir Joshua Reynolds's working methods provide support for these observations. Only by piecing together all the information was it possible to understand fully the complexity of the way in which the painting was executed and the problems that would be involved in restoring it.

The portrait of Lord Heathfield, so much admired in its day, has unfortunately suffered from the irreversible effects of Reynolds's particular painting techniques. M. Constant de Massoul, whose treatise on the art of

painting was published in London in 1797, only ten years after the picture was painted, cautions against just such methods.

> 'Many Painters both in Glazing and in Painting, make use of varnish mixed with *fat oil*, because then the Picture appears brilliant and not *imbibed*.
>
> This method, so pleasing, and therefore so seducing in practice, may, without doubt, be useful; but then it ought to be used with precaution. To this may be attributed the change that the Pictures of the celebrated Sir Joshua Reynolds have undergone.'[46]

Acknowledgements

I would like to thank Ashok Roy for the preparation of the cross-sections from the portrait of *Lord Heathfield of Gibraltar*, which have been so vital to this paper. In addition, his previous work on the other paintings by Reynolds in the National Gallery Collection, and the technical notes he compiled for Judy Egerton's British School catalogue, have been most useful. I am very grateful to Marika Spring and Helen Howard for carrying out the SEM–EDX analysis and for the identification of the lead-tin-antimony yellow.

I would also like to thank Jo Kirby for invaluable advice about documentary sources and many helpful discussions about red lake pigments. My thanks must go too to Martin Wyld, who carried out the conservation treatment of the painting, and Satoko Tanimoto of the British Museum, for the Raman analysis of the lead-tin-antimony yellow.

Notes

1 J. Egerton, *National Gallery Catalogues: The British School*, London 1998, pp. 228–33; see also D. Mannings, *Sir Joshua Reynolds: a complete catalogue of his paintings*, New Haven and London 2000, Vol.1, pp. 180–1.

2 Sir Thomas Lawrence was so impressed by the portrait, admiring it as 'the best of Sir Joshua's pictures of men', that he purchased it to serve as a model for his own works. See Egerton 1990 (cited in note 1), pp. 231–2.

3 M. Kirby Talley, Jr. '"All good pictures crack" Sir Joshua Reynolds's practice and studio' in N. Penny (ed.), *Reynolds*, exh. cat., Royal Academy of Arts, London 1986, pp. 55–70.

4 K. Cave (ed.), *The Diary of Joseph Farington, Vol. IX*, New Haven and London 1982, p. 3483.

5 The National Gallery Conservation Dossier for NG 111.

6 Analyses of organic materials within varnishes and binding media reported in this article were carried out by gas chromatography–mass spectrometry (GC–MS). In the sample of the uppermost varnish layer several components were detected with mass spectra containing the base peak m/z 95, relating to the cyclohexanone monomer and indicating that a synthetic polycyclohexanone resin was present. See E.R. de la Rie and A.M. Shedrinsky, 'The chemistry of ketone resins and the synthesis of a derivative with increased stability and flexibility', *Studies in Conservation*, vol. 34, 1989, pp. 9–19.

7 Obtaining a sample for GC–MS analysis of only the layer of varnish applied in 1867 was extremely difficult. Microscopic examination of the sample used for organic analysis indicated that some pigment particles were also present, suggesting that some original material may have been included. The microcrystalline wax was identified by the pattern of both even and odd numbered hydrocarbons detected in the GC–MS chromatogram.

8 H. Ruhemann, '*The Cleaning of Paintings. Problems and Potentialities*', London 1968, Appendix C, p. 317.

9 W. Cotton (ed.), 'Rev. W. Mason's observations on Sir Joshua's method of colouring', in *Sir Joshua Reynolds' Notes and Observations on* Pictures, London 1859, p. 51.

10 M. Cormack, transcriber, 'The ledgers of Sir Joshua Reynolds', *The Walpole Society*, 1968–70, Vol. XLII, p. 168, folio 178 r. 'Oct. 2, 1772. Miss R (cancelled) Churchmar (cancelled), "Kirk" substituted Gum Dr. et Whiting / poi cerata poi / ovata poi verniciata e retoccata / cracks.' Translated literally, this is as follows: Gum tragacanth and whiting then waxed then egged then varnished and retouched cracks.

11 http://www.npg.org.uk/research/programmes/directory-of-british-picture-restorers.php. See also Kirby Talley 1986 (cited in note 3), p. 68.

12 A sample of the white fill was analysed with Fourier transform infrared (FTIR) microscopy, which identified chalk.

13 Prussian blue was identified by FTIR microscopy.

14 Starch was identified in overpaint samples containing Prussian blue by FTIR microscopy.

15 J. Kirby and D. Saunders, 'Fading and Colour Change of Prussian Blue: Methods of Manufacture and the Influence of Extenders', *National Gallery Technical Bulletin*, 25, 2004, pp. 73–99.

16 W.T. Whitley, *Artists and their Friends in England 1700–1799*, Vol. 2, London and Boston, 1928, p. 282.

17 Cormack 1970 (cited in note 10), p. 141, folio 52 v. An entry dating from 1767 records the materials used for specific paintings and reads 'Miss Cholmondley con olio e Vernicio di cera. poi / verniciulo con yeos (?) lake e magilp.' Similarly in the same year the next entry is as follows 'Lord Townsend. prima con magp. poi Olio. poi Mag. / Senza olio. Lacca. poi Verniciata con Virmilion.'
J.H. Townsend, L. Carlyle, A. Burnstock, M. Odlyha and J.J. Boon, 'Nineteenth-century paint media: The formulation and properties of megilps', in *Painting Techniques: History, Materials and Studio Practice, Contributions to the Dublin IIC Congress, 7–11 September 1998*, A. Roy and P. Smith (eds), London 1998, pp. 205–10; L. Carlyle, *The Artist's Assistant*, London 2001, pp. 101–6 and *passim*.

18 Cormack 1970 (cited in note 10), p. 141, folio 52 v. FTIR microscopy identified lead soaps in the plum-coloured background paint, but only a small amount of lead white was included in the pigment mixture and no other lead-containing pigments were evident. This may indicate that in this case a leaded oil was used in combination with the mastic varnish, perhaps formulating a true gelled megilp.

19 Cormack 1970 (cited in note 10), p. 141, folio 53 r. 'Glazing senza olio / vernich. of Masti. – solo', literally glazing without oil, varnish of mastic alone.

20 GC–MS analysis identified a trace quantity of mastic resin, just detectable within the sample, but given the small quantity it seems most likely that this is related to traces of the overlying plum-coloured layer which were also included and were visible

upon microscopic examination of the sample before analysis. This highlights the difficulty of sampling separate layers of paint for analysis by GC–MS without contamination. However, the difference in the ratio of the azelate and suberate diacids detected in this sample compared to that for the sample of the plum-coloured layer demonstrates that there is a clear difference in binding media, and that the oil used for the lower blue layers of paint was not heated to thicken it before use.

21 Prussian blue was identified by FTIR microscopy in a scraping taken from the surface layers in this area.

22 I am very grateful to Varian Inc. for allowing the use of their ATR–FTIR imaging microscope during a demonstration visit.

23 J. Mills and R. White, 'Analyses of Paint Media', *National Gallery Technical Bulletin*, 1, 1977, pp. 57–9.

24 Trace quantities of the methyl ester of copalic acid were also just detectable in the GC–MS chromatogram of this sample. This suggests that a *leguminosae* resin, such as cobaiba balsam, may also be present in tiny quantities. However, this is clearly not the major constituent within the paint analysed in this sample. Further analysis of other samples from this painting may indeed show that different diterpenoid resins have been employed in different passages of the painting.

25 R. Jones, J.H. Townsend and J.J. Boon, 'A technical assessment of eight portraits by Reynolds being considered for conservation treatment', *ICOM-CC 12th Triennial Conference, Lyon, 29 August – 3 September 1999, Preprints. Vol. I*, J. Bridgland (ed.), James and James, London 1999, pp. 375–80.

26 R. Jones, 'Sir Joshua Reynolds (1723–1792). *The Age of Innocence c.*1788', and 'Sir Joshua Reynolds (1723–1792). *George IV when Prince of Wales* 1785', both in *Paint and Purpose: A Study of Technique in British Art*, S. Hackney, R. Jones and J. Townsend (eds), Tate Gallery Publishing, London 1999, pp. 60–5 and 146–51 respectively. Cross-section samples from both these paintings display fluorescent paint layers when viewed under ultraviolet light and, in *The Age of Innocence* particularly, medium-rich translucent-looking layers. However, in these paintings beeswax is a major part of the paint medium and is perhaps responsible for the milky fluorescence. Beeswax was not identified in the portrait of Lord Heathfield.

27 GC–MS analysis of samples from the portrait of *Lady Cockburn and her Three Eldest Sons* (NG 2077) was carried out in 1986. See Egerton 1998 (cited in note 1), p. 210, and J. Mills and R. White, 'Analyses of Paint Media', *National Gallery Technical Bulletin*, 11, 1987, pp. 92–5.

28 Jones, Townsend and Boon, 1999 (cited in note 25) p. 380.

29 Cormack 1970 (cited in note 10).

30 A. Roy and B. Berrie, 'A new lead-based yellow in the seventeenth century', in *Painting Techniques: History, Materials and Studio Practice, Contributions to the Dublin IIC Congress, 7–11 September 1998*, A. Roy and P. Smith (eds), London 1998, pp. 160–5. The authors characterised the pigment as the ternary oxide of lead, tin and antimony with a cubic pyrochlore structure and identified it in several seventeenth-century Italian pictures, postulating a link between its manufacture and Rome. More recently the pigment has been identified on a number of eighteenth- and nineteenth-century works and it is clear that use of the pigment, although it may have started in Rome, spread beyond Italy in the seventeenth century. See D Hradil, T. Grygar, J. Hradilová, P. Bezdicka, V. Grunwaldová, I. Fogas and C. Miliani, 'Microanalytical identification of Pb-Sb-Sn yellow pigment in historical European paintings and its differentiation from lead tin and Naples yellow', *Journal of Cultural Heritage*, 8, 2007, pp. 377–86.

31 Lead-tin-antimony yellow was identified in this sample by SEM-EDX analysis and Raman spectroscopy.

32 The backscattered electron image shown in FIG. 24 was acquired using the scanning electron microscope at the British Museum. For further discussions of the particle characteristics of lead-tin-antimony yellow, see C. Sandalinas and S. Ruiz-Moreno, 'Lead-Tin-Antimony Yellow', *Studies in Conservation*, 49, 2004, pp. 41–52.

33 Cormack 1970 (cited in note 10), p. 142, folio 53 r. 'Prima in olio ultima con Vernicio Solo / e giallo', literally first in oil finally with varnish alone and yellow.

34 Cormack 1970 (cited in note 10), p. 168, folio 178 r. '...glazed with Varnish & Giallo di Napoli', literally glazed with varnish and Naples yellow.

35 Unfortunately the medium of this layer remains a little ambiguous. GC–MS analysis detected heat-bodied linseed oil, but only small amounts of mastic and pine resin were observed. The chromatogram also contained several unidentified peaks, with base peak m/z 236, suggesting that an additional unknown component may also be present.

36 This area was locally cleaned with xylene and isopropanol to remove as much as possible of the later varnishes prior to sampling. In addition the uppermost surface of the glaze layer was removed mechanically before taking the sample for medium analysis. Nonetheless it was extremely difficult to determine by microscopic examination whether some varnish had inadvertently been included in the sample. However, the appearance of the pigment particles and the identification of Prussian blue by FTIR microscopy imply that the majority of the material is an original glaze. Therefore the GC–MS results can be interpreted as indicating that the binding medium of the original glaze layer contains pine and mastic resin as well as heat-bodied linseed oil.

37 Kirby Talley 1986 (cited in note 3) suggests a date of 1759, based on Mason's testimony of Reynolds's technique, for when Reynolds started to use vermilion. By the date of the Lord Heathfield portrait he had clearly given up relying entirely on 'carmine' for the pink tint required for flesh paint.

38 J. Kirby, M. Spring and C. Higgitt, 'The technology of eighteenth- and nineteenth-century red lake pigments', *National Gallery Technical Bulletin*, 28, 2007, pp. 69–95.

39 See Kirby, Spring and Higgitt, 2007 (cited in note 38), pp. 74–5 for a discussion of the terminology surrounding cochineal lakes and carmine pigments.

40 The presence of protein within the cochineal-containing red lake pigment found in the portrait of Lord Heathfield is discussed more fully in Kirby, Spring and Higgitt, 2007 (cited in note 38), p. 75. Examples of recipes including a source of protein are given in this article, pp. 94–5.

41 Roy and Berrie, 1998 (cited in note 30), p. 160–1.

42 H. Dubois, '"Use a little wax with your colours, but don't tell anybody" Joshua Reynolds's painting experiments with wax and his sources', *Hamilton Kerr Institute Bulletin Number 3*, 2000, pp 97–106, esp. p. 99. One of the inscriptions written on the Royal Academy of Arts Panel, *Studio Experiments in Colour and Media*, reads 'Orp. white Y with the Varn.' literally orpiment, white, yellow with the varnish.

43 Barbara Buckley noted that the flesh paint of Lady Amabel's chest in the portrait of *The Ladies Amabel and Mary Jemima Yorke*, in the Cleveland Museum of Art, contained chalk in addition to lead white. See B. Buckley, 'Sir Joshua Reynolds, *The Ladies Amabel and Mary Jemima Yorke*', *The Bulletin of The Cleveland Museum of Art*, vol 73, number 9, November 1986, pp. 350–71.

44 Kirby Tally 1986 (cited in note 3), pp. 64–5. The author links the term 'turchino' with the pigment Prussian blue.

45 Cormack 1970 (cited in note 10), p. 141, folio 53 r. 'July 29th 1768 – in vece di nero. Si puo servire di / Turchino e cinabro – e Lacca Giallo', literally, in place of black one can use Prussian blue and vermilion and yellow lake.

46 M. Constant de Massoul, *A treatise on the art of painting and the composition of colours containing instructions for all the processes of painting. Together with observations upon the qualities and ingredients of colours*, London 1797, translated from the French, printed by T. Baylis, pp. 24–5.