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Three Panels from Perugino's Certosa di Pavia Altarpiece

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History and treatment: alteration and reclamation

David Bomford

Of projects undertaken in recent years by the Conservation and Scientific Departments, one of the longest and most complex has been the investigation and treatment of three panels by Perugino (No.288 of the National Gallery Collection) from an altarpiece in the Certosa di Pavia, the Carthusian monastery near Milan.

Painted at the beginning of the sixteenth century, the pictures show, in the centre, the Virgin and Child with an angel; on the left, S. Michael; and on the right, S. Raphael and the young Tobias [1]. They are shown before treatment in Plate 3 (p.22).

Since their removal from the Certosa, the three panels have been framed as a triptych (Fig.1), but originally they formed the lower row of a six-part altarpiece, shown as it appears today in Fig.2. Of the original altarpiece, only the upper central panel of *God the Father* is still *in situ*. The two panels now occupying the upper left and right positions are by Ambrogio Bergognone, taken from a different altarpiece at the Certosa; it is thought that in these positions originally were two panels by Albertinelli, documented as being of 1511, and now at Geneva.

The frame, of red marble, is not that originally made for the altarpiece, since it is known to date from c.1650, almost a century and a half after the paintings. The nature or precise shape of the original frame is not known. It is not known, either, whether the present marble frame was made specifically for this altarpiece: there are some indications that it was not. For instance, the remaining pictures appear to fit it rather badly; in particular, the panel of *God the Father* has a rounded top which is clearly an addition (it may or may not have been this shape originally) and a painted marbled piece below it has been inserted to fill an empty space. There are also smaller marbled inserts beneath the pictures in the lower row.

The three pictures now in the lower row are copies of the National Gallery panels substituted at the time of their removal in the eighteenth century. The copies are on canvas and of poor quality, but they do record (with reasonable accuracy, it is assumed) the extent and shape of the original compositions. It is fortunate that they do, because between leaving the Certosa in 1784 and arriving at the National Gallery in 1856 the original panels became considerably changed; the copies provide the only reliable indication of how they once appeared.

Comparison of Figs.1 and 2 shows the nature of the

alterations. At the bottom of the copies are details which were not visible at all in the National Gallery panels before the present treatment began; Tobias' dog and the figure of Satan below S. Michael's feet were missing. In the upper part of the pictures, the situation was reversed: the panels had rounded arched tops which the copies did not have. These were simply painted semi-circles, considerably discoloured, on rectangular additions and not at all convincing. When the panels were removed from their frames, additions also became apparent at the other edges; in the S. Michael panel, the situation was even more complex.

The state of the panels was this: at some point after their removal from the Certosa, they had been cut down at the top and bottom and then subsequently made larger at all four edges. In 1977 an extensive examination was begun to investigate the extent of the cutting-down and the nature of the additions; if possible, the sequence, dating and authorship of the alterations were to be deduced. An investigation of this kind draws on every available source of information; history, provenance, macroscopic examination, microscopic analysis — all are relevant. Even when the preliminary examination has ended and treatment has begun, new information emerges; cleaning and panel treatment of early pictures are often, in themselves, investigative. Treatment, in this case, was aimed at removing concealment and ambiguity and returning the panels to an approximation of their original (although now incomplete) state.

Provenance and acquisition

Following the suppression of the Carthusians of Pavia in 1782, the three panels comprising No.288 were removed from the Certosa in 1784 and taken to the Accademia at Milan. Despite some interest in their acquisition by the Gallery at Vienna, they were purchased in January 1786 by Count Giacomo Melzi of Milan. After his death in 1802 they passed to his nephew and then to his nephew's son, Giovanni Francesco, who died in 1832. Giovanni Francesco's collection was divided between his three children and the Perugino panels passed to Duke Lodovico Melzi who sold them to the National Gallery in 1856.

The circumstances of their purchase in 1856 are described in the notebooks of Sir Charles Eastlake [2], then director of the National Gallery and in the diary of Otto Müндler [3], the Gallery's Travelling Agent, who negotiated some outstanding purchases in Italy and elsewhere during that period.

Eastlake set out on a European journey in August 1855 with a list of important pictures he wished to



acquire for the National Gallery [4]. The three Perugino Panels in the Melzi collection, mentioned by Vasari and described by the nineteenth century French art historian Rio as one of Perugino's 'most astonishing masterpieces', were high on the list. In September 1855, Eastlake visited both the Casa Melzi and the Certosa, where he examined the only remaining panel (*God the Father*). He drew a sketch of the frame and made a note of the blank area below the *God the Father* panel, concluding that the arched top of the lower central panel (which he apparently did not suspect to be false) had once 'reached up into the dark empty part'. He also noted, '... copy of centre picture below now not arched', but made no comment on the copies of the lower side panels which were also not arched, although the originals in the Melzi collection would have appeared to be so. The possibility has to be considered here that when Eastlake saw the originals only the centre panel had its added arch, but the measurements of all three given in his notebook discount this.

Eastlake was determined on their acquisition. Duke Lodovico Melzi was said to have demanded £4000; Eastlake intended to offer £3500, but the Duke was away and Müндler, who had accompanied Eastlake on his tour, was left to conduct the negotiations.

The Duke finally agreed to sell on the 11th February 1856; the price, including commissions, was £3571 8s. 7d. [5]. That was not the end of the matter, however. Before the Peruginos could be brought to London, an export licence had to be granted by the Accademia di Belle Arti in Milan which looked to the Imperial Government in Vienna for instructions. The

local *Commissione di Pittura* recommended that export should be refused, but the final decision had to come from Vienna. From February until May, while Müндler waited uneasily, the panels were stored at the Palazzo Brera under the care of the *conservatore*, Giuseppe Molteni and a Professor Brison who also appears to have been a restorer of sorts. Müндler recorded in his diary for 7th April, 'Brison . . . has been to the Academy to fix some particles in the Perugino which threatened to rise' Brison is known to have treated the pictures on at least one other occasion. The National Gallery Manuscript Catalogue notes that in 1847 some repaintings had been, '... removed by Professor Brison of Milan. It is probably to such earlier repaintings, now no longer visible, that Rumohr alludes.' [6].

Not until 1st May did permission arrive from Vienna for the pictures to be exported to London. They were placed in the National Gallery in August 1856.

Examination of the panels

An examination carried out at the time of acquisition gives a concise account of the condition of the pictures, accurate enough but rather more concerned with detail than with overall structure:

Actual State: The three pictures originally ended in a straight line above. The semi-circular tops were added by one of the Melzi family in the present century.

Centre Compartment: The blue sky in the added semi-circular top has darkened in this compartment more than in the others. Some restored spots visible in the blue drapery of the

Figure 1
Perugino,
Three Panels from
the Certosa di
Pavia Altarpiece
(No.288) as they
were framed until
1977.



Figure 2 The altarpiece in the chapel of S. Michael in the Certosa di Pavia, as it appears today (photograph: *Chiolini, Pavia*).



Figure 3 (Left) *S. Michael*, X-ray mosaic.

Figure 4 (Right) *Virgin and Child*, X-ray mosaic.

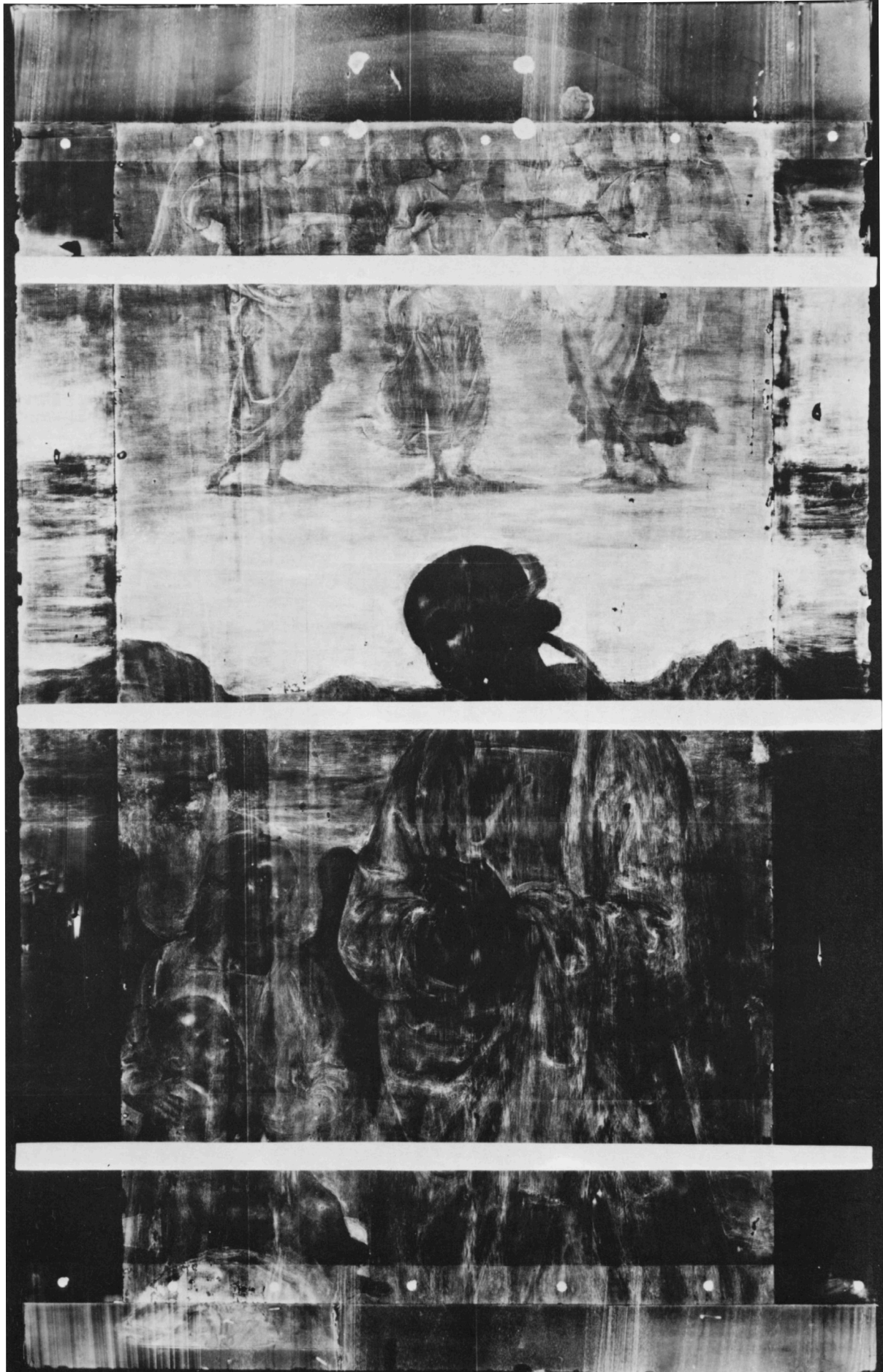
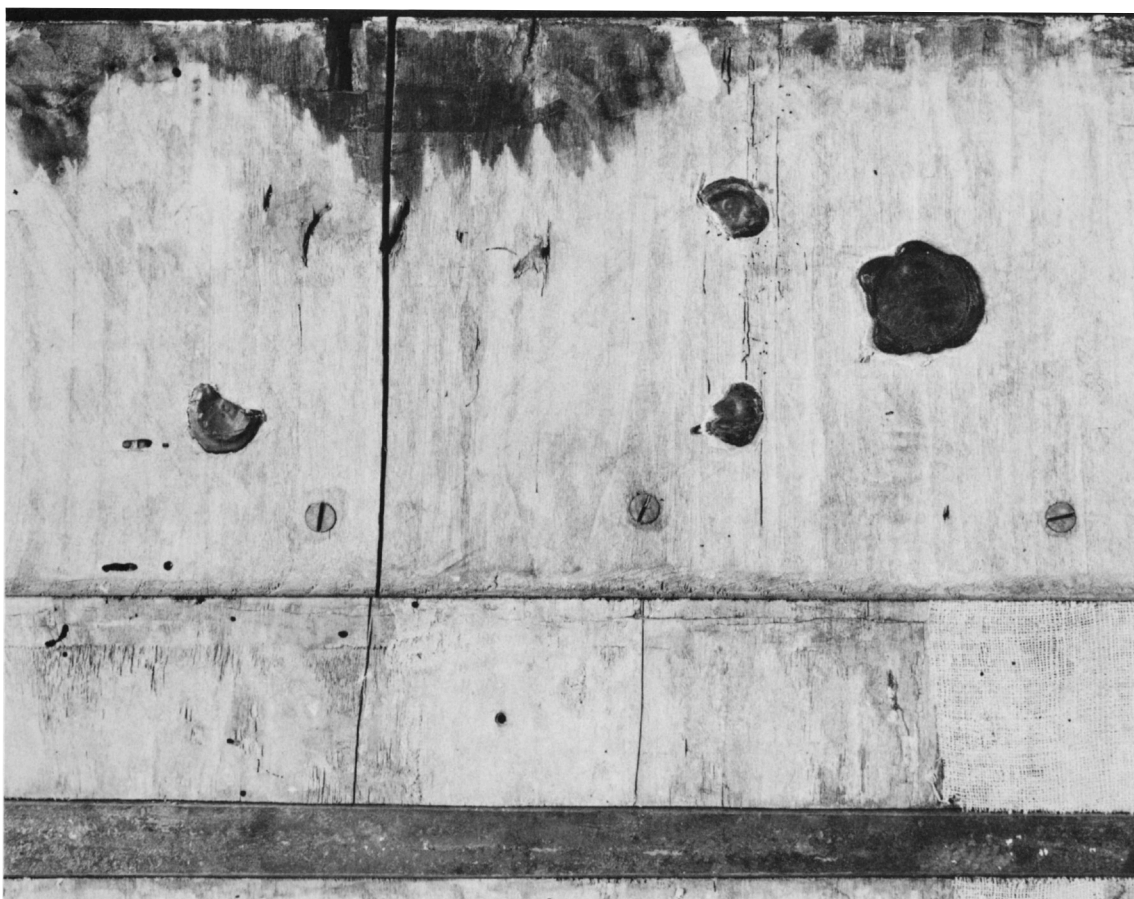




Figure 5 (*Left*) *S. Raphael*, X-ray mosaic.

Figure 6 (*Right*) *S. Michael*, detail of the back, centre top edge, showing addition (upper part) overlapping original, attached with screws. Below is one of the tapered metal bars dovetailed into channels cut in the original. Stresses set up by these restraints have caused two splits, one of which continues in from a break in the addition.



Virgin, and in her red tunic, above the hands. A spot on the wrist of the Virgin's left hand. The half tints of the Infant, and partially in some other figures, have acquired an olive colour — as is observable in many of Perugino's works. One or two minute points have chipped off from the drapery of two of the angels above, on the right.

Compartment with Archangel Michael: A thin vertical split in the wood passing through the face of S. Michael has been formerly repaired. Slight spots visible in the hands.

Compartment with Archangel Raphael: Cracks visible in the head and hands of Tobias. A thin vertical split, passing through his head and neck, at some former period restored. In the figure of the angel, some slight repairs are visible in the red drapery, some minute cracks and spots in the feet, and some fine cracks in the neck. A minute spot is seen on the upper part of the nose. The frame appears to have once covered about an inch more on the left side.

General History: The three principal pictures came into the possession of the Cavalier Melzi in 1786, a few years after the suppression of the convent of the Certosa. The pictures were then entire, and as they are now represented by the copies, but about six inches were removed from the lower edges, it appears, soon after they were purchased in 1786. The semi-circular tops were not added til after the beginning of the present century.

(Extract from Manuscript Catalogue, 1856)

From 1856 until 1977 there is a full record of treatment carried out. Although the Conservation Record gives details of treatment to one or more of the panels on eleven separate occasions, these amount to no more than routine blister-laying and superficial repairs. The state of the panels when the present

treatment began was essentially the same as when they left the Melzi collection. It must be assumed also that they were in the same frame; there is certainly no evidence to the contrary.

The pictures were examined before treatment in 1977 using stereomicroscopy, infrared photography and X-radiography. They were also sampled at various stages during treatment and the findings of the microscopical examination appears on p.25.

X-ray mosaics of the three panels (Figs.3–5) showed their condition clearly. In each case, what remained of the original panel was surrounded on all four sides by additions of wood attached with nails, double-pointed cleats and screws. Across the back of each of these compound structures were three heavy metal bars, dovetailed in cross-section and tapered from one end to the other; by sliding them into similarly dovetailed and tapered channels cut in the wood and hammering them home, the panel and its additions had been forced rigidly together and flattened. The restriction of movement in the original panels imposed by the additions and metal battens must have been considerable, but the only evidence for it were two concave splits in the top of the *S. Michael* panel, one of which had begun in the addition and travelled into the original (Fig.6).

The examination of 1856, while it mentioned the added semi-circular tops (which, in fact, were painted on rectangular additions) made no mention of the additions at the other three edges. It is quite probable that the pictures were examined without being removed from their frames, in which case they may

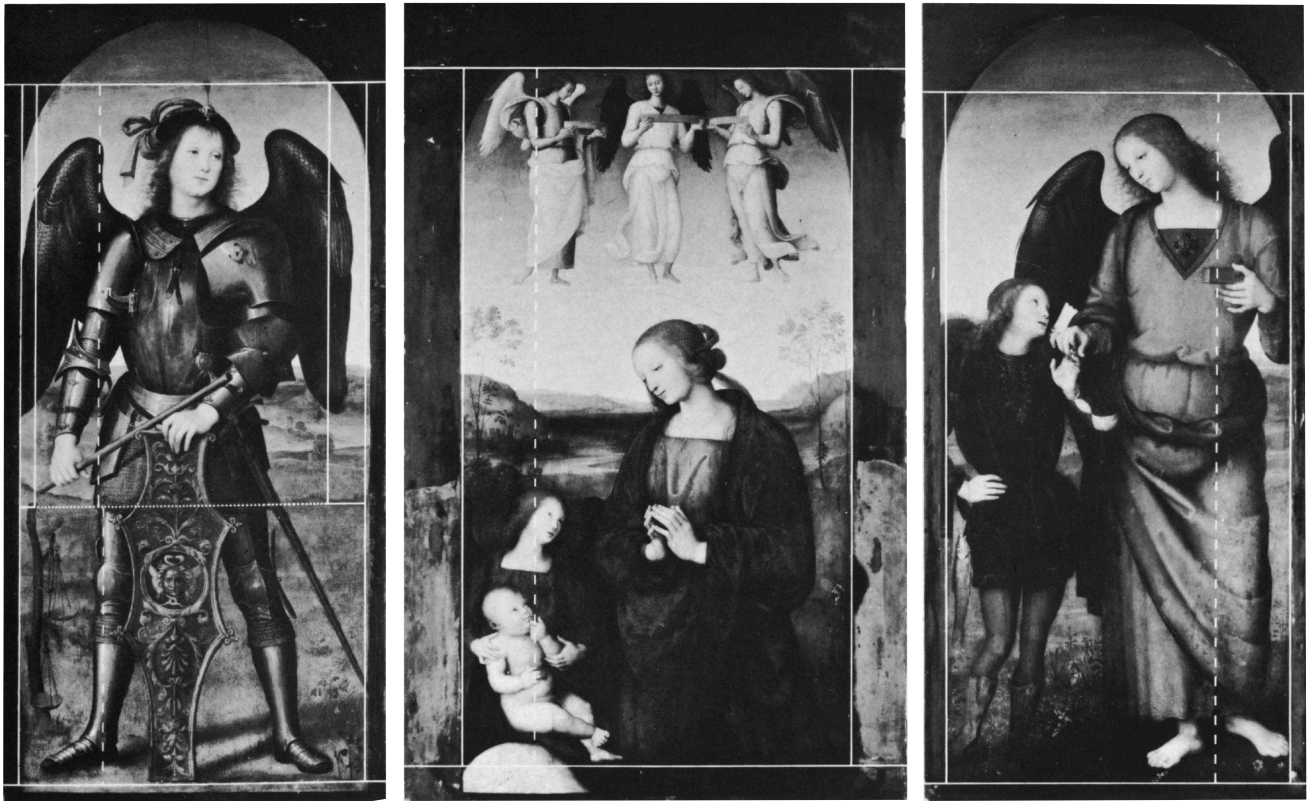


Figure 7 Diagram of the construction of the panels before treatment, showing additions, original panel joins and the further cutting-down of *S. Michael*.

Key
 — Additions
 - - - Original joins
 Original joins
 - · - Cut across *S. Michael*

not have been noticed. By this stage, in any case, the front sides of all the additions (other than the arched tops) were simply painted black (see Plate 3, p.22) and a black border around the pictures, false or otherwise, may have been thought not worth mentioning. When the pictures were cleaned it was found that, underneath the black paint, the side additions had first been painted with a continuation of the landscape; the X-rays (taken before cleaning) clearly showed this.

X-rays also showed that the condition of the *S. Michael* panel was even more complex than that of the other two. The remains of the *Virgin and Child* and *S. Raphael* panels formed simple rectangles within their additions. Each consisted originally of two vertical members; there is a single original vertical join in the *Virgin and Child* near the left edge and an original join on *S. Raphael* near the right edge (Fig.7). *S. Michael* also was originally of two members, the join running parallel to and near the left edge. At some point, however, it was cut into two horizontally, just below the centre. That this is a cut and not an original join subsequently repaired is evident in the X-rays from the continuity of the wood-grain and the line of the original join between the upper and lower pieces.

Why the panel should have been cut in this way is not entirely clear. A probable reason is that somebody wanted to make a smaller picture of *S. Michael*'s upper half and display it separately. This explanation is supported by the fact that, from this upper section, a narrow strip at the left edge and a wider strip at the right edge have been cut away; this made the composition more or less symmetrical and presumably reduced the picture to the required width.

At some later time the panel was put back together again. Fortunately the lower section had been kept; it

was simply reattached with double-pointed cleats and glue, but, irritatingly, displaced to the right by about 1 mm (there was no question in the present treatment of breaking and rejoining it to correct this, as it was too firmly attached; it did present slight problems during retouching, however, in the linking of straight lines such as the edges of the sword). Unfortunately, the strips from the sides of the upper section had been lost and had to be replaced by new wood, made up to the same width as the lower section. These new strips were painted to match the original, although how accurately it is difficult to say; certainly in the Certosa copy, *S. Michael*'s wings appear considerably wider than they do on the reconstructed original.

Comparison of all three panels with their copies in the Certosa gave an indication of how much they had been cut down before being extended. It was clear that each panel had lost about one inch from the top and several inches from the bottom. In the central panel the lower edge now excluded most of the cushion on which the Child is sitting together with the immediate foreground. In the *S. Raphael* panel most of Tobias' dog had been cut away but part of its head, which had been painted out, showed in the X-ray by *S. Raphael*'s right foot. The *S. Michael* panel, partly cut at the sides (as described above) had lost the outside edge of each of his wings as well as some sky and landscape; at the bottom, the recumbent figure of Satan had been cut away, only fragments of his head, shoulder and wing (which had also been painted out, but were visible in the X-rays) remaining.

It is difficult to envisage circumstances irrational enough to account for the quite arbitrary cutting-down and subsequent extending of the Perugino panels. However it is possible, by a combination of

documentary and technical evidence (derived from surface examination, cross-section analysis and during cleaning) to deduce the sequence of the alterations. While a precise chronology cannot be established, this sequence can be compared in a general way with the known facts of the provenance, as follows:

1. In 1784, the three panels were removed from the Certosa and replaced by copies. Presumably at this stage they were still complete.
2. In 1786, they were acquired by Count Giacomo Melzi.
3. 'Soon after 1786', each panel was cut at the top and bottom. A portrait in the Hospital at Milan of Giacomo Melzi painted in 1802 [7], the year of his death, shows in the background a picture generally taken to be the Perugino *S. Michael*; although the reproduction of it is not wholly accurate, it does appear to be already cut at the bottom, but not yet with its arched top.
4. At some point after the reduction of the three panels, the *S. Michael* panel was cut across the lower centre to make a smaller picture excluding the legs and foreground (and, incidentally, Perugino's signature in gold by *S. Michael's* right foot). Strips of $\frac{3}{4}$ in. and $2\frac{1}{2}$ in. were cut from the left and right sides of the upper part; these strips were lost, but the lower part of the panel was kept.
5. The *S. Michael* panel was rejoined and new wood let in to replace the lost strips. The new strips were painted to match the original.
6. Additions were made to either side of all three panels, butt-jointed and attached with glue, nails and cleats. The dovetailed and tapered metal bars may have been inserted at this stage or later. The side additions were painted to match the original (a continuation of figures and landscape).
It is likely that stages 5 and 6 were carried out at the same time.
7. 'After the beginning of the nineteenth century' additions were made to the top and bottom of each panel. These were across the entire width of the panel, including the side additions, half-lapped and glued (and strengthened with screws at some later date). At this stage the false arched-topped configuration was introduced by painting black borders on the top and bottom additions and over the top corners of the original panel; at the same time the false landscape on the side additions was painted out with black paint. The side additions clearly predated the top and bottom additions; this was evident from their construction. Cleaning subsequently indicated that an appreciable time may have elapsed between stages 6 and 7.
8. The extended panels were placed in a frame with three arched-topped compartments. In this state they were acquired by the National Gallery in 1856.

It is unlikely that the precise dating or authorship of these alterations will ever be known. However an intriguing possibility is suggested by the presence in

Milan, during the later years of this period, of a man who is mentioned many times in the diaries of Eastlake and Mündler. This was Cavalière Giuseppe Molteni (1800 – 1867), a well-known restorer who became *conservatore* of the Accademia di Belle Arti at the Palazzo di Brera. On several occasions he undertook the restoration of pictures purchased in Italy by Eastlake prior to their being sent to London. In one case, an altarpiece by Garofalo (No.671) cleaned in 1970, it was almost certainly he who added a false curved top with an elaborately painted *baldacchino*; and other pictures that passed through his hands have, upon cleaning, been found to have been altered in different ways.

It is not to be thought that Molteni's connection with Eastlake had anything to do with the alterations to the Peruginos; but his services would undoubtedly have been available to the Melzi family in the years leading up to 1856, although it must not be forgotten that it was Brison who treated the pictures in 1847 and again in 1856. Nevertheless, Molteni was the leading picture restorer in Milan at that time and likely to have been approached by wealthy collectors to restore their most important works. It is by no means impossible, given his propensity for imaginative restoration, that the false arched tops on the Peruginos are his.

Examination of the paint layers

X-ray examination thus established the structural state of the panels, the ways in which they had been cut down and the nature of the additions. X-rays also assisted surface examination in providing information on the paint layers, their condition and their structure.

Many of the damages to the paint layers were listed in the examination of 1856. However, more attention was paid then to small losses in important areas of the pictures than to greater ones elsewhere. In 1977, the main areas of damage were seen to be: substantial paint losses on either side of the cut across *S. Michael*; some areas of his brown shield which appeared worn and repainted; two pitted areas near his left shoulder which seemed scorched — perhaps candle burns; on *S. Raphael*, a broad band of paint loss and abrasion running down his red robe, and damage to Tobias' left hand; on the centre panel, pronounced wearing on the Child and an uneven, cracked appearance to the blue robes of the Virgin and the angel, disfigured also by many darkened retouchings.

The signature, PETRUS PERUSINUS PINXIT in gold, near *S. Michael's* right foot, was authentic except for the first 'P' which was on top of retouching and clearly new; the last 'S' was missing and five of the other letters were quite worn. The gold decoration on the draperies and elsewhere in all three pictures was viewed with considerable caution. Some was certainly authentic, some was obviously new, but the status of much of it was unclear. In the subsequent cleaning, only that which was demonstrably false was removed: some of it lay on or within the varnish layers, some overlay areas of retouching and some ran alongside or over original gold (see p.28 for microscopical

evidence). The rest of the gold was left, although it is likely that part of it is not original. Even where it was clearly new and removed, the remains of mordant lines could sometimes be seen over the paint, showing that there had once been gilded decoration.

There were retouchings on all three paintings, mainly confined to the areas of damage described above and scattered smaller damages elsewhere. The most disturbing were those on the Virgin's robe which had become black; the most crucial for understanding the true state of the panels were those covering the remaining fragments of Tobias' dog and the recumbent Satan. Around the limits of the original panels there was retouching, too, where layers of paint from the additions encroached on the true edges. A substantial ridge of overpaint had built up in some places and had to be scraped away during cleaning to recover the original level. When this was done, the cut edges proved to be in surprisingly good condition — considering the extensive paint loss around the cut across the centre of the *S. Michael* panel.

Apart from their use in assessing the condition of a painting, X-rays will, in a general way, indicate its technique, the sequence of paint layers, *pentimenti* and so on. It could be seen, for instance, that the hill behind Tobias' head was first painted three inches higher; that the river behind the Virgin once flowed further into the foreground; and that the mountain range behind had been lower in several places. Original alterations such as these are an entirely usual occurrence in the development of a painting.

While *pentimenti* are of considerable interest and can even, under certain circumstances, verify authenticity, their significance rarely extends beyond the picture in question. Of wider interest are findings which establish painting methods and allow comparisons between passages of the same and other works.

Thus, at the simplest level, X-rays show how the construction of the faces and flesh passages on the Peruginos compare with that of other light areas. For example, on the pictures themselves, the faces (although obviously of an entirely different colour) are about as luminous as the sky surrounding them; and yet their X-ray image is seen to be dark, while that of the sky is bright. The explanation for this is that the sky is made light by admixture of the dense pigment lead white (which appears white on the radiograph) while the thinly-painted faces derive their luminosity partly from the white gesso ground which hardly registers on the radiograph at all.

The fact that the flesh passages are painted very thinly is confirmed rather strikingly if the paint surface is viewed obliquely against the light. The faces and hands are seen to form perfectly smooth areas at a level somewhat lower than the surrounding paint. Eastlake, in an account of Perugino's technique in his profoundly influential *Materials for a History of Oil Painting* [8], speaks again and again of the flesh areas being 'embedded in the surrounding colours'. At one point he describes a hand set against a dark shadow and speaks of 'the divisions of fingers, where they appear as projecting ridges opposed to the thin flesh'; the left hand of *S. Raphael* and the right hand of



Tobias fit that description exactly.

Another comparison that can be made is that between *S. Raphael*'s blue robe and that of the Virgin. They appear quite dissimilar, *S. Raphael*'s robe being pale and luminous while the Virgin's is dark and intense; the X-rays show why. The dense white image of *S. Raphael*'s robe indicates that it is undermodelled with bright lead-white containing paint and glazed with a transparent blue. The image of the Virgin's robe, on the other hand, is more or less dark and suggests that mainly blue is present and rather little lead white (see p.26; also Plates 1a and 1b, p.21). Blue pigments by themselves are not particularly luminous; painted thickly, as they are here, they do not even allow the white ground to shine through and therefore the robe appears to have little modelling.

The notable difference in technique between the two robes drew attention, in the examination before treatment, to their relative condition. Apart from some minor flake losses, *S. Raphael*'s robe was well-preserved. That of the Virgin looked extremely unsatisfactory. The black retouchings were unsightly, but could be disregarded as being only superficial; much more disturbing were the really pronounced shrinkage cracks in all areas which seemed to be revealing a black underlayer. In addition, the blue paint itself seemed to vary in colour alarmingly within a single area.

Naturally it was not possible to come to any real

Figure 8
S. Raphael, upper left, during cleaning. Removal of varnish and black overpaint indicates the rectangular shape of the original and reveals earlier paint on the side addition but only bare priming on the top addition.

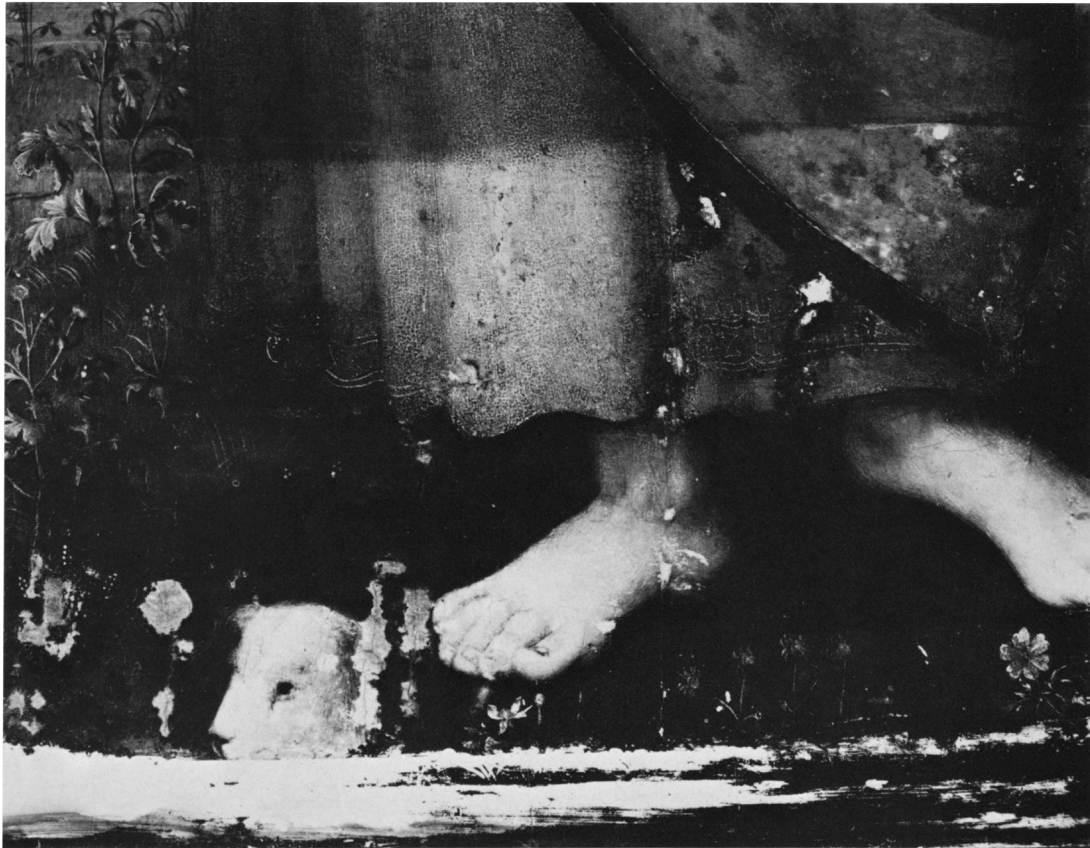


Figure 9 *S. Raphael*, lower edge during cleaning. The dog's head is revealed: the horizontal edge passing through its mouth is the lower limit of the original paint remaining. Gold decoration on *S. Raphael*'s robe is seen to be on top of darkened retouchings, showing it to be false.



Figure 10 *S. Michael*, lower edge during cleaning. Partial removal of overpaint shows remaining fragments of Satan. The lower limit of the original is the horizontal line immediately below the base of the shield. Satan's wing was painted over the shield and the highlight now shows through.

conclusions before cleaning, since the varnish layers obscured the surface quite appreciably. Interpretation of the true condition of the Virgin's robe was to be the most difficult problem encountered during the cleaning and analytical stages.

Treatment proposed

Before treatment could begin, a report was drawn up containing a summary of the findings of the preliminary examination and the treatment proposed. The proposals were (a) that the pictures should be cleaned of their discoloured varnishes, retouchings and overpaint (b) that the metal battens and additions should be removed from each panel, but for the *S. Michael* panel the two strips replacing missing wood at the sides should be retained (c) that the pictures should be retouched (inpainted) where necessary and revarnished.

This sequence of treatment was logical. The cleaning would reveal the extent of the remaining original paint and show the exact positions of the joins with the additions. The removal of battens and additions was proposed on two counts. Most importantly, they were restraining the panels and setting up stresses which would cause splitting of the wood — indeed they had already done so at the top of *S. Michael*. Also the retention of the additions could not be justified historically — they were misleading and changed the nature of the composition entirely; even where they replaced lost wood at the top and bottom edges their sizes were quite arbitrary and bore no relation to the original dimensions of the panels.

An exception was to be made for the new wood strips let in to the upper sides of *S. Michael*; it was thought that to take these away would make the shape of the panel quite distracting and a better solution would be to indicate by retouching that they were not original. This requirement followed necessarily from the decision to remove the other additions and reveal the fragmentary state of the original.

Cleaning

The purposes of cleaning were several: to remove the disfiguring effects of discoloured varnishes and retouchings; to establish the limits of the original paint; to reveal the fragments remaining of Tobias' dog and Satan, thereby confirming the cutting-down from the composition seen now in the Certosa copies, to verify (in conjunction with analytical evidence) that the additions were not original; to confirm the sequence of the additions.

The varnish covering the paint layers on all three figures was uneven and considerably discoloured; there was little surface dirt. Cleaning was carried out using propan-2-ol in white spirit which was sufficient to remove the varnish and many of the retouchings. Harder retouchings and overpaint were removed with ammoniacal reagents and mechanically. Preliminary cleaning tests were made in less important parts of the paintings in order to gauge the solubility and discolouration of the varnish layers.



Figure 11 *Virgin and Child*, detail during cleaning. Removal of black border from the side addition reveals an earlier extension to the landscape, darker than the original adjacent to it.

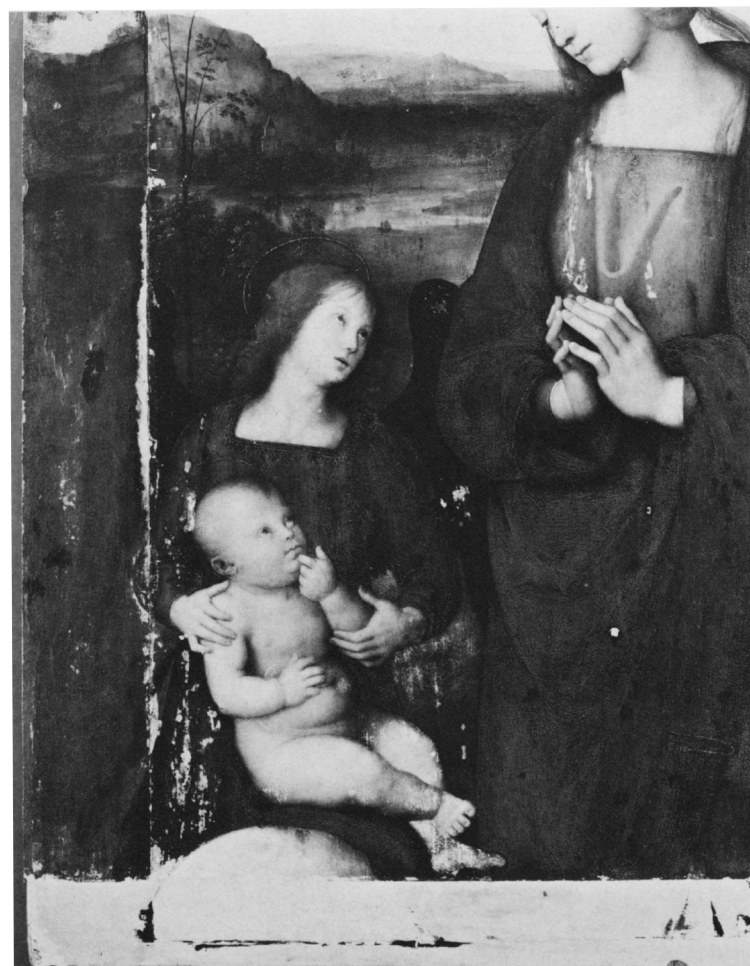


Figure 12 *Virgin and Child*, detail after cleaning, showing cracked and uneven condition of the blue robes of the Virgin and angel. The worn state of the Child's legs and feet and the immediate background is also seen.

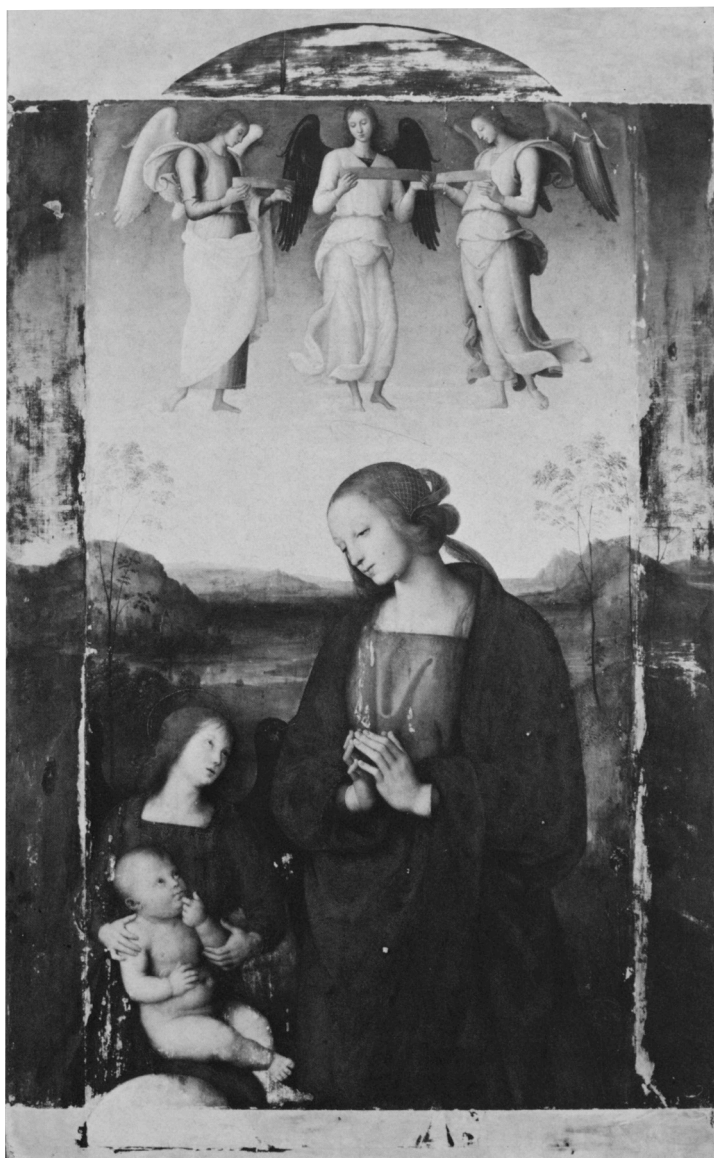


Figure 13
Virgin and Child,
after cleaning,
before panel
treatment.
The appearance
of *S. Raphael* at
the same stage
was similar.

Systematic cleaning was begun in areas which had been altered by overpainting. Thus, the black paint outlining the arched top was removed from the top left corner of *S. Raphael* — demonstrating the rectangular nature of the tops of the panels (Fig.8); at the bottom of *S. Raphael*, extensive overpaint was removed from the foreground revealing a number of flake losses, but also some hitherto unseen flowers and, most importantly, the remaining fragment of the head of Tobias' dog, cut off just below the nose (Fig.9); at the bottom of *S. Michael*, removal of overpaint revealed parts of Satan's head (with one curly horn), shoulder, wing and wrist. The overpaint here was exceptionally hard and had to be removed with a scalpel (Fig.10).

Cleaning tests on the additions showed the considerable differences between those at the top and bottom of each panel and those at the sides. The normal cleaning solvent removed the black painted border quite easily. On the top and bottom additions there was nothing below it but a bare priming layer (see Fig.8). (The blue paint of the arched tops — containing lead-white — was much tougher and was



Figure 14 *S. Michael*, after cleaning, before panel treatment, showing the cut across the centre and associated paint losses. The reduction in width of the upper part of the panel and the strips replacing the missing wood can also be seen.

relatively unaffected by the solvent: thus, after cleaning they continued to float, disembodied, above the compositions.) On the side additions, the black border cleaned away to reveal a reconstructed continuation of the landscape (Fig.11). The paint here was very hard and must have been considerably earlier than the black paint which had been covering it. It was somewhat darker than the paint of the original landscape adjacent to it: this was possibly because it had been painted to match an already discoloured original, but it was more probably due to a staining effect of the overpaint. In confirmation of this effect, the upper corners of each panel were found to be similarly stained when the black border was removed.

Conclusions could be drawn from these cleaning tests. It was already clear from their construction that the top and bottom additions must have been put on after the side additions, but it had not been possible to say whether it was immediately afterwards (even in

the same operation), or some time later. Cleaning indicated that they were entirely different operations and that probably a period of some years separated them. It was almost certain that the black edging was contemporary with the making of the top and bottom additions, since it lay directly on the priming; but it had been shown by cleaning to be appreciably later than the landscape which it had covered on the side additions.

At the same time as evidence was emerging from cleaning, samples taken at various points on the additions were providing microscopical evidence. The anachronistic pigment Prussian blue was found in the paint layers of all of them (see p.28).

Re-examination of the X-ray mosaics gave another clue to the sequence of alterations described earlier. The same type of double-pointed cleat had been used to rejoin the cut across the *S. Michael* panel as had been used to attach the side additions in all three panels. It seems reasonable to conclude that the reassembling of the *S. Michael* panel was done in the same operation as the adding of the side additions. The paint on the inner side additions on *S. Michael* was markedly similar to that on the outer side additions, suggesting they were contemporary.

Cleaning was also carried out systematically on the rest of the original paint surface. The condition of the paint proved to be entirely as expected from the preliminary examination. The most prominent damages were around the cut across *S. Michael*, in *S. Raphael's* red robe, and in the lower left corner of the *Virgin and Child*, especially the Child's left foot.

With the removal of discoloured varnishes and the worst of the retouchings, it was now possible to consider the status of the Virgin's blue robe and also that of the angel's robe which (although to a lesser degree) showed the same characteristics (Fig.12).

The scattered black retouchings apart, there were three notable features about the condition. The first was the exceptionally prominent network of shrinkage cracks over the entire area. These had been made to look worse by retouchings which had discoloured, but even after cleaning they still appeared black in most places. It was difficult at first to see whether this was due to a residue of the retouching paint remaining in the cracks, but it became apparent that there was, in fact, a black underlayer in certain areas which showed through.

Secondly, the colour of the robe varied oddly from place to place. Before and during cleaning it was observed that some areas were much greener than others and that the distribution of those areas appeared random. However, when fully cleaned, the robe was seen to have a modelling which had not been apparent before. The green areas were now seen to be a deliberate device for indicating the folds; furthermore, the craquelure in these parts revealed white ground, not black underpaint — suggesting that they were intended to be more luminous and form the light areas of the drapery. Details of the microscopical examination of these areas appear below on p.26.

Thirdly, the highest lights were painted in a particularly vivid blue, reminiscent of synthetic



pigments. This fact, together with the pronounced shrinkage cracks (a phenomenon most often encountered in the eighteenth and nineteenth centuries) led to a suspicion that some of the robe had been repainted. The greener areas seemed authentic — the bright blue cracked areas were suspect.

There were several ways in which the problem of verification could be approached. Firstly, historically: was the appearance of the robe unique to this painting, or does it occur in other pictures of the same period — especially others by Perugino? We find that it does. Even within his own lifetime some of Perugino's pictures were beginning to suffer from severe cracking; Vasari, in his 'Life of Perugino', thought it sufficiently significant to write about it at some length (see Note [10] on p.30). Eastlake, too, gives several examples of paintings by Perugino exhibiting pronounced cracking: he ascribes the cause of it to the pictures being 'repeatedly covered' by layers of thick

Figure 15
(Above)
S. Michael, after cleaning and panel treatment. All additions have been removed except those replacing missing wood at the sides of the upper part.



Figure 16
(Above)
Virgin and Child,
after cleaning and
panel treatment.
All additions have
been removed.



Figure 17
(Above, right)
S. Raphael, after
cleaning and panel
treatment.
All additions have
been removed.

paint and the underlayers not being dry 'before another is superadded'. Few of the examples he quotes are specifically areas of blue drapery, but those he does describe appear to be very similar to the Virgin's robe in No.288. For example the blue robe of the Madonna in the *Nativity* from Spinola, now in the Vatican, is described as 'extremely thick and cracked'. In one case, the Montone altarpiece, he actually mentions the use of a black underlayer: '... he used smalt in tempera on a black preparation'. The identification of both pigment and medium here must be regarded as highly speculative, but, nevertheless, the description of black underpaint is significant in relation to the present case.

It must be concluded, from the above, that there are historical precedents for the appearance of the blue robe. The second approach to the problem was by examination, once again, of the X-radiographs. If the robe had been repainted, it was presumably done in

order to conceal damage. Did the X-rays, therefore, show damages present in the lower paint layers which were not visible on the surface? Detailed examination showed that they did not — and that this had to be ruled out as a reason for any possible repainting.

Thirdly, surface examination showed that strands of the Virgin's hair passed over some areas of bright, cracked blue. Since the authenticity of the hair was not in doubt, this indicated that the blue was original also.

Fourthly, the most significant evidence emerged from the microscopical investigation of cross-sections taken from areas representing the various states of the blue robe. This is described in detail by Ashok Roy on p.26. In summary, the conclusions drawn from this investigation were that the black underlayer contained ultramarine, possibly in some degraded state, and that the vivid blue upper layer was an exceptionally refined natural ultramarine of great purity. It does seem logical that Perugino should have used the very finest

material available for the central figure of the Virgin.

It was concluded, therefore, that the blue robe was wholly authentic, although clearly not in a satisfactory state of preservation. It has to be said that, even if it had been proved false there was no possibility of removing it without damage to the surrounding and underlying paint. It would thus have remained anyway.

The panels were now in their cleaned state (Figs.13 and 14). The extent of the additions was clearly visible and the next stage was their removal. The long and painstaking panel treatment was carried out by David Thomas and Janet Brough, who describes the work below.

Restoration and display

The panels are shown, after the removal of the additions in Figs.15 – 17. It can be seen that *S. Raphael* and the *Virgin and Child* have been reduced simply to what remains of the original panels. In *S. Michael* the later wood strips at the upper left and right have been retained, thus preserving the rectangular shape of the panel.

In the retouching of the pictures there were certain clearly defined objectives. The flake losses, whether caused by neglect or by conscious acts such as the cutting of *S. Michael* were to be fully compensated, since they disturbed the unity of each composition. Areas of wearing such as that in *S. Raphael's* red robe would be reduced but not entirely disguised. Similarly, areas such as the Virgin's robe, where faulty technique had led to an unsightly surface appearance, would be slightly reduced but their condition would still be evident. Finally, the additions remaining on *S. Michael* would be made fractionally different in tone to the adjoining original paint so that they could be seen to be non-original on close inspection, while not being obtrusive enough to be disturbing.

Retouching was carried out using pure pigments ground in the acrylic resin Paraloid B72. The only significant reconstruction needed was along the cut across *S. Michael*, where parts of the shield and armour had been lost. It has already been mentioned that a slight displacement to the right of the section of the panel below the cut presented minor problems of continuity, especially in the line of the sword.

The final varnish was a semi-matt application of the polycyclohexanone Ketone N in white spirit. The paintings after completion of treatment are shown in Plate 4 (p.22). Comparison with their appearance before (Plate 3, p.22) shows the gains achieved by cleaning and panel treatment. Freed from the restraints, both physical and aesthetic, imposed by their additions, the panels are secure, the state of the pictures is clear and unambiguous and the scale of the figures in relation to the whole is corrected. Freed from the distorting effects of discoloured varnishes and retouchings, the paint surface is properly visible for the first time in two centuries or more.

Little has been said above of the most striking change brought about by cleaning: the revelation of the brilliance and clarity of Perugino's colours and

handling. The cleaning of paintings to reveal pigments of undiminished brightness has become so familiar that it is sometimes easy to overlook or take for granted the improvement; it is invariably difficult to remember afterwards how obscured they were.

The impression given by the Peruginos until 1977 was one of muddled tones and disturbing retouchings. The impression now is one of brilliant colour juxtapositions such as those of *S. Raphael's* clothes; of subtle, almost Mannerist harmonies such as the 'shot' robes of the three angels above the Virgin; of the vigorous, impressionistic handling of landscape and foreground; of precise delineation of armour and drapery; and of smooth, softly modelled flesh passages. All this was present before: but cleaning revealed it and panel treatment and retouching brought it more sharply into focus.

The manner in which the panels should be displayed on their return to the exhibition rooms of the National Gallery was determined by the nature of their condition. They were fragments (albeit large ones) and therefore could not be framed in a conventional way: the presence of a frame around a painting implies that it is complete. They had to be exhibited in a way which acknowledged their fragmentary nature. This was achieved by hanging them essentially unframed, with their edges showing. It was important, too, not to imply that they formed a self-contained triptych, since they represent only part of a larger altarpiece. Therefore they were not mounted on any unifying backboard, but merely placed separately on the wall in their correct relation to each other.

Notes and references

1. For information on dating, provenance and so on, see DAVIES, M., *National Gallery Catalogues: The Earlier Italian Schools*, 2nd ed. (London 1961), pp.403 – 407.
2. Sir Charles Lock Eastlake, Keeper (1843 – 1847) and first Director (1855 – 1865) of the National Gallery. His notebooks (1852 – 1864) are in the Gallery archives.
3. Otto Müндler (1811 – 1870). His diary (1855 – 1858) is in the National Gallery archives.
4. For details of this and all other aspects of Eastlake's life, see ROBERTSON, D., *Sir Charles Eastlake and the Victorian Art World*, Princeton University Press (Princeton 1978).
5. National Gallery, Director's Report, 6 April 1857.
6. Karl Friedrich von Rumohr had referred to these repaintings in his pioneer work *Italienische Forschungen* (1827 – 1831) and had described the Peruginos as '... throughout Raphaelized'.
7. Probably by Antonio Schieppati; photograph in the Gallery archives.
8. EASTLAKE, C.L., *Materials for a History of Oil Painting* (London, 1847), republished as *Methods and Materials of Painting of the Great Schools and Masters*, Dover Publications (New York, 1960).

Panel treatment

Janet Brough

Before work began on the panels the paint surface of each was given a double facing of Eltoline tissue, brushed on with a dammar and wax mixture in white spirit. When dry they were placed face downwards on Melinex film with felt underneath. Once the brown paper which covered the backs had been scraped off it was possible to see how the additions were attached (see Fig.18): the top and bottom extensions in all the panels were joined to the original by a half-lap joint, strengthened by screws (Fig.19), whereas the side joints were butt-jointed. X-ray photographs showed that in two of the panels (*S. Michael* and *S. Raphael*) nails and double-pointed cleats helped to hold the side additions.

Since the top and bottom additions overlapped both the original panel and the side extensions, these had to be removed first. Bars of wood clamped to the bench were used to immobilize the panels during work: some ran over the back of the panel, cushioned with rubber, and others were used to brace it at the end and sides. These were moved around during work as necessary. The screws from one end addition were then taken out, and the seals on this section cut off and preserved (Fig.21). The section of the addition

overlapping the original was then cut away, using gouges and hand pressure. (See Figs.20 and 22.) These were the tools used throughout as they provided the greatest amount of control and caused the least vibration. Fortunately, in all the panels, the extensions were of poplar which cut cleanly and easily (except the side additions in the *Virgin and Child*, which were of pine). When the addition and the original were level the addition was further cut away at an angle exposing the original edge (see Fig.20). The reverse of the ground on the addition was uncovered right up to the edge of the original and this was then cut through with a scalpel. In this way all the false paint and wood were removed without endangering any of the original. At this point each panel was turned over and checked, and wax-resin was used to seal the edge now revealed. This procedure was repeated for the other end of the panel and on the other two panels as well.

Cutting away the side additions then exposed presented some problems. Firstly the nails and cleats had to be cut around so that they could be easily withdrawn. In this X-rays proved useful in pinpointing their exact locality. Secondly, the tapered iron bars dovetailed into the backs of the panels had to be removed so that the wood underneath them could be cut away. This was done using a sash clamp, one end of which was placed against the thinnest end of



Figure 18 Back of *Virgin and Child*, before panel treatment. The original panel is surrounded by additions and traversed by three tapered metal bars let in to dovetailed channels. Two butterfly button-inserts can be seen, one securing a split at the top and the other reinforcing the join at the lower side.

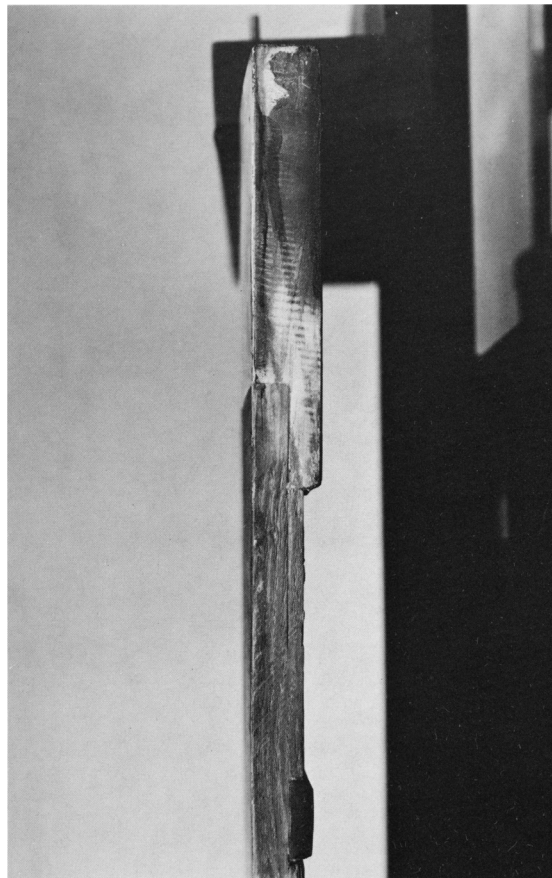


Figure 19 *Virgin and Child*, side of the panel, upper right corner. The top addition is half-lapped over the original panel and side additions. The dovetailed channel and iron bar can also be seen, end-on.

Plate 1 Perugino, *Three Panels from the Certosa di Pavia Altarpiece* (No.288).

Photomicrographs of paint cross-sections (a,b and e-j), photographed by reflected light at 220× magnification; actual magnification on the printed page shown beneath each photomicrograph.

(a) *Virgin and Child*: Brightest blue of Virgin's robe.

1. Gesso ground (trace).
2. Azurite underpaint.
3. Dark layer containing genuine ultramarine in a discoloured matrix.
4. Genuine ultramarine + lead white (trace); the layer has a grey, blanched-looking appearance.
5. Finely-ground genuine ultramarine of high purity (see (c) below).

(b) *S. Raphael*: Pale blue of S. Raphael's dress.

1. Gesso ground (trace).
2. Thick lead white underpaint.
3. Thin glaze of pure genuine ultramarine.

(c) *Virgin and Child*: Brightest blue of Virgin's robe.

Crushed and dispersed sample of layer 5 from cross-section (a), showing the pigment to be fine, sharp-edged lazurite mineral fragments (genuine ultramarine). The sample when viewed between crossed polars show birefracting impurities to be virtually absent, indicating a highly-purified form of ultramarine to have been used. Sample mounted in Aroclor 5442 and photographed by transmitted light at 500× magnification.

(d) Synthetic ultramarine.

Reference sample of synthetic ultramarine (Reckitts no.H9957) for comparison with (c); mounted in Aroclor 5442 and photographed by transmitted light at 500× magnification.

(e) *S. Michael*: Blue of sky (original).

1. Gesso ground (trace); principally anhydrite.
2. Azurite + lead white.
3. Genuine ultramarine + lead white.

(f) *S. Michael*: Blue of sky (non-original paint from inner added strip, r.h.s., see Fig.7, p.10).

1. Gesso ground; pure gypsum.
2. Prussian blue + lead white.
3. Ultramarine + lead white.

(g) *S. Raphael*: Blue arabesque on S. Tobias' sleeve.

1. Gesso ground.
2. Orange of sleeve; finely-ground orange-coloured earth pigment + a small proportion of vermilion and red lake.
3. Blue of design; thin layer of pure genuine ultramarine.

(h) *S. Raphael*: Deep purple-red drapery at S. Raphael's waist.

1. Gesso ground.
2. Pure vermilion.
3. Two layers of vermilion + red lake pigment.
4. Thick final red glaze; probably a madder lake.

(i) *Virgin and Child*: Green of angel's wing, centre of trio.

1. Gesso ground (trace).
2. Azurite + lead white.
3. Genuine ultramarine (slightly blanched) + lead white.
4. Green of wing; pure azurite in a matrix of discoloured medium.
5. Trace of original gold of wing decoration.

(j) *S. Raphael*: Deep green lining of S. Raphael's red drapery.

(Gesso ground missing from sample.)

1. Thin lead white layer.
2. Thin pale green paint layer containing lead-tin yellow mixed with green glaze material.
3. Several layers of copper 'resinate' green incorporating a small proportion of lead white to lend opacity to the paint.
4. Partially discoloured copper 'resinate' glaze.

Plate 2 Claude, *Seaport: The Embarkation of the Queen of Sheba* (No.14).

(a) Slightly blanched, dull green of trees, r.h.s. (see Plate 6, p.48). Photomicrograph of the top surface of a paint sample photographed by reflected light at 110×, showing the highly heterogeneous pigment mixture involved. Laser microspectral analysis and microscopy of a dispersed pigment mount from an adjacent sample point indicated a mixture for the green comprising: ultramarine, smalt (possibly), a copper green (probably verdigris), red crystalline ferric oxide (haematite), lead-tin yellow, yellow ochre, a brown earth pigment, carbon black and lead white.

(b) Green of trees, r.h.s.

Cross-section to show the paint layer structure; photographed by reflected light at 110×. A double ground underlies the paint of the trees which in turn consists of two layers: a lower buff-pink paint and an upper dull green layer similar in composition to the sample shown in (a) above.

Plate 1

Perugino, *Three Panels from the Certosa di Pavia Altarpiece* (No.288)
 Photomicrographs of paint cross-sections.
 Full caption on facing page.

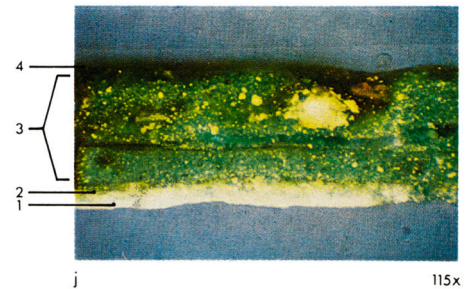
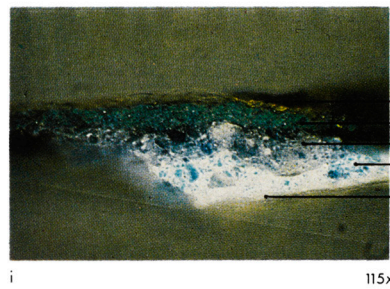
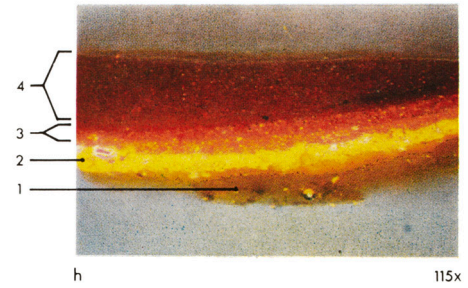
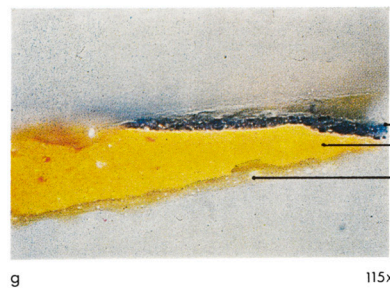
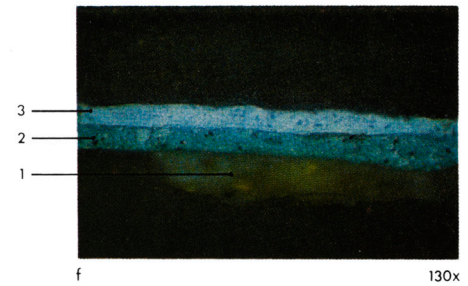
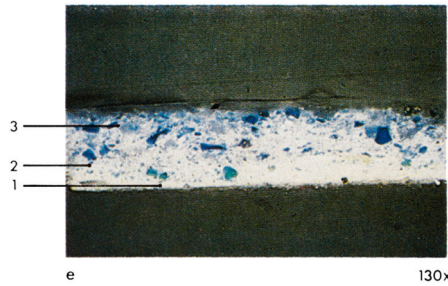
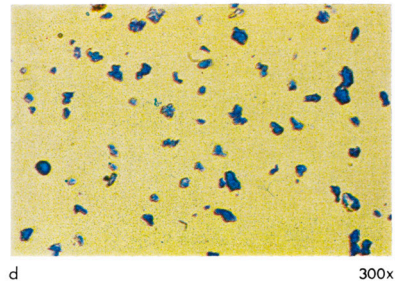
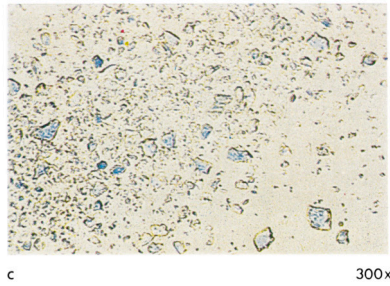
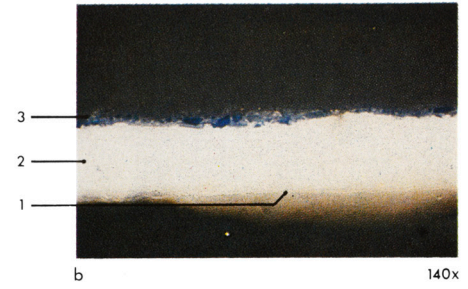
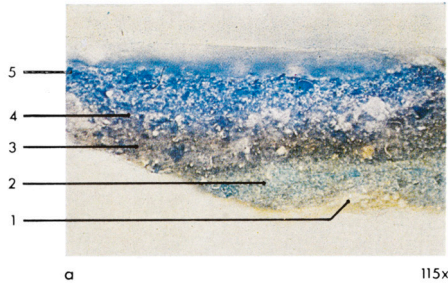


Plate 2

Claude, *Seaport: The Embarkation of the Queen of Sheba* (No.14)
 Photomicrographs of the top surface of a paint sample and related cross-section.
 Full caption on facing page.

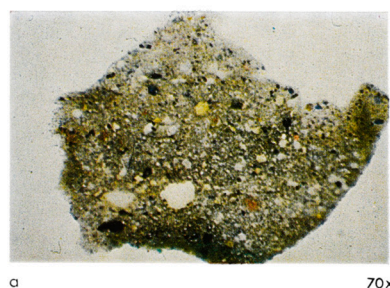
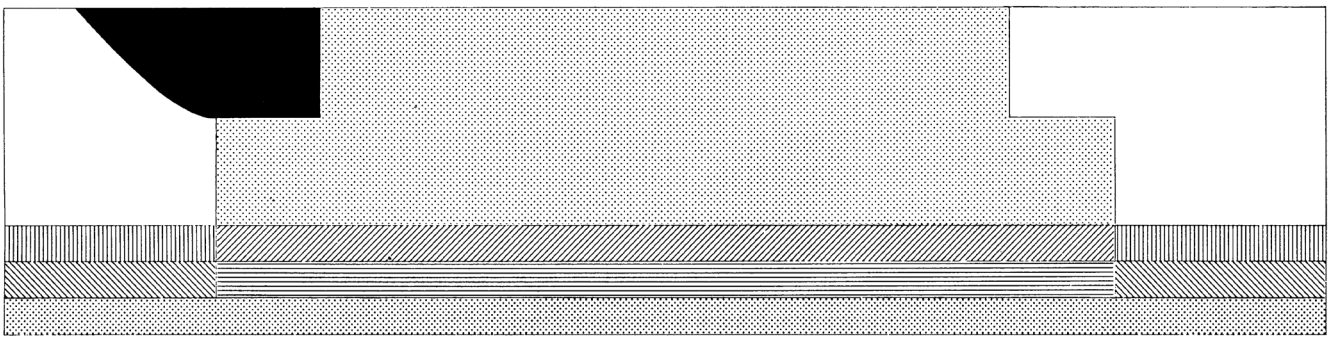
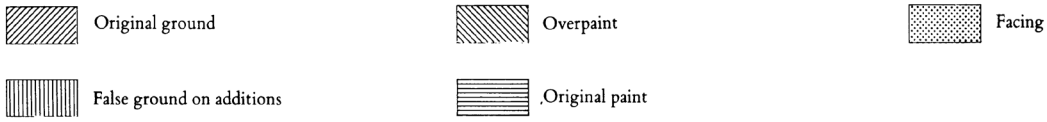
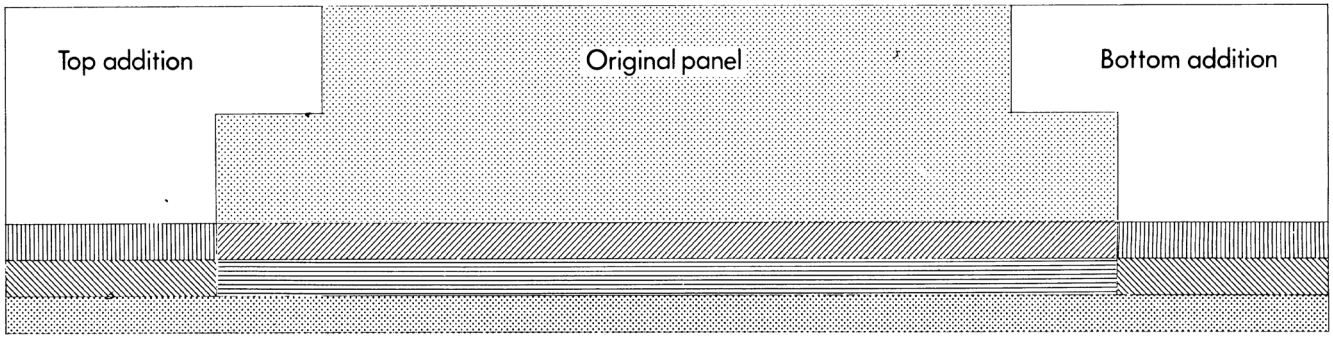


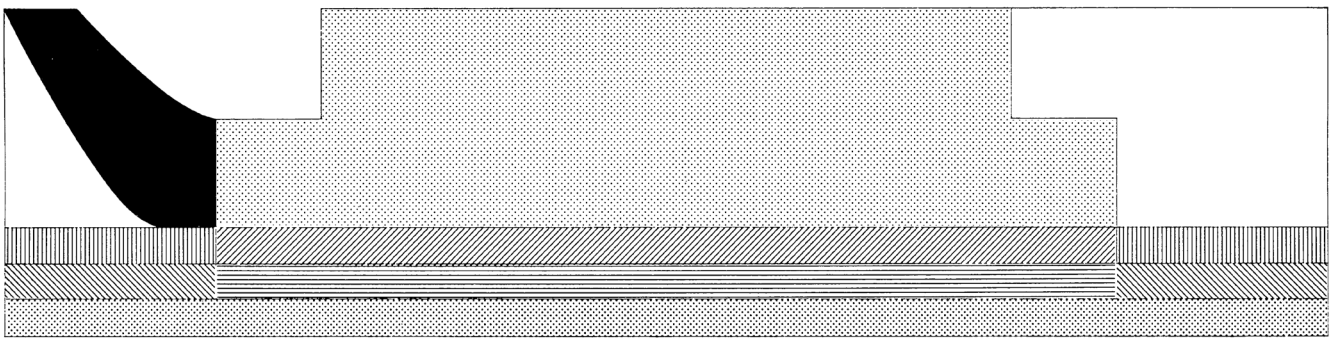


Plate 3 (Top) Perugino, *Three Panels from the Certosa di Pavia Altarpiece* (No.288), before treatment.

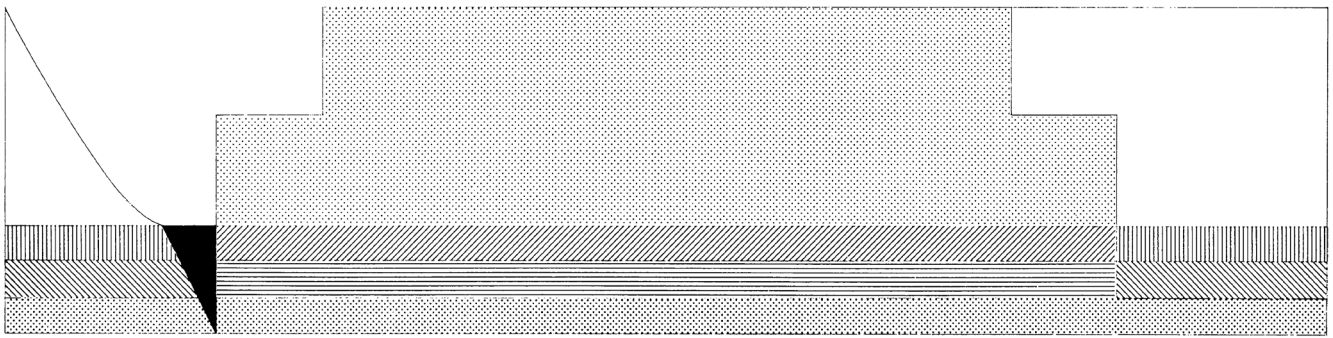
Plate 4 (Below) Perugino, *Three Panels from the Certosa di Pavia Altarpiece* (No.288), after treatment.



Stage 1 Solid area cut away



Stage 2 Solid area cut away



Stage 3 False ground, overpaint and facing cut through with scalpel separating remains of addition from original, leaving original paint intact.

Figure 20 Cross section through length of panel (not to scale)

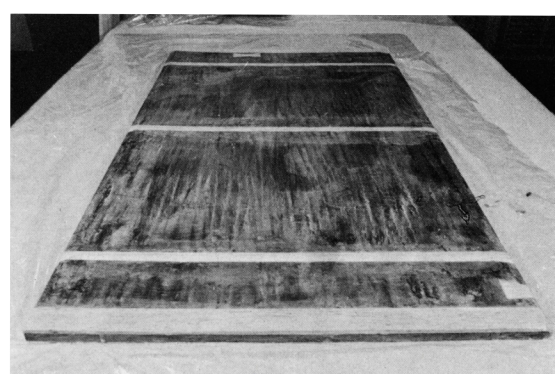
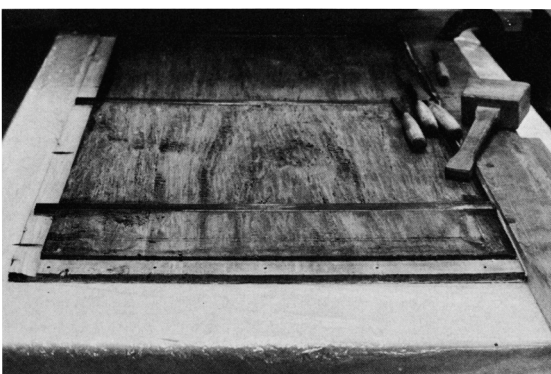
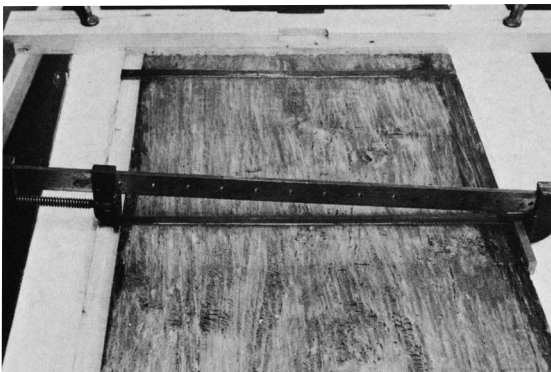
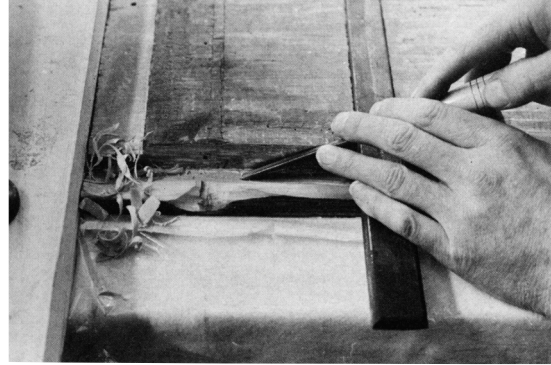
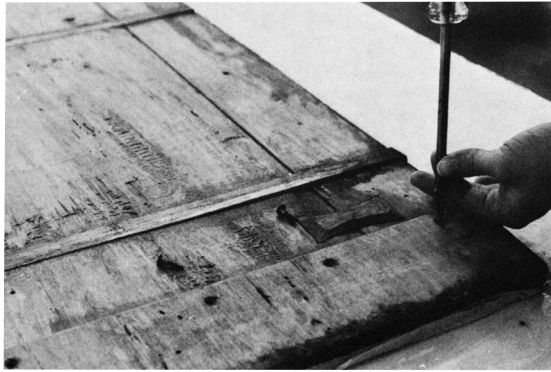


Figure 21 *Virgin and Child*: removing screws from the bottom addition. The butterfly button was later removed.

Figure 22 *Virgin and Child*: cutting away the top addition, showing the half-lap joint partially removed. At the left, a wooden bar, clamped over the panel and cushioned by a rubber mat, prevents movement.

Figure 23 *S. Raphael*: removal of iron bars. As much wood as possible was removed from the side additions around the bars before attempting to move them.

Figure 24 *S. Raphael* with bottom addition completely removed. One side addition is partially cut away showing the position of the cleats.

Figure 25 *S. Raphael*: removing a side addition. The entire edge of the original panel is exposed and the back of the ground on the addition is visible; this will be cut through with a scalpel.

Figure 26 *S. Raphael* with all additions removed. The metal bars have been replaced temporarily.

Figure 27 *Virgin and Child* before covering back with a waxed canvas. All additions are removed and balsa wood replaces the iron bars, the butterfly inserts and the half-lap joints at the top and bottom.

the iron bar. The other end of the clamp was then braced against the opposite side of the panel (protected by a block of wood). When the clamp was tightened, this had the effect of pushing the bar out in the same direction it had originally gone in (see Fig.23). When the wood had been cut away from underneath, each bar was replaced so that the panels were not subject to sudden change. The side extensions were cut away at a sloping angle revealing the original edge in the same manner as for the top and bottom additions (see Figs.24 and 25). Once the ground was reached it was cut through with a scalpel in the same way.

The removal of the additions was completed (Fig.26) in accordance with the proposals made before treatment began. At this point the iron bars could be dispensed with; each bar had been bent the opposite way to the slight warp of the panels in order to force them flat. This meant that the panels must have been in a permanent state of tension and it seemed advisable to allow them to relax back into their natural shape by removing the bars and replacing them with balsa wood slips. Balsa was also used to bring the rebates up to the level of the rest of the back. The *Virgin and Child* had two button inserts removed and replaced with ones of balsa. One of the buttons no longer served any function since it had strapped the original to the side addition (see Fig.21); the other had covered a crack running into the original from the top extension. Since the cause of the crack was now removed it was not expected to move further; casein glue was rubbed into the crack from the back to secure it, before the balsa wood was inserted. All the balsa inserts were held in place with wax – resin and wood-flour (Fig.27).

The backs and sides of all the panels were then coated with wax – resin and canvas was ironed over them as a moisture barrier.

Scientific examination

Ashok Roy

This section is devoted to some of the aspects of Perugino's painting technique as revealed by microscopic investigation of samples of paint taken from the panels during cleaning. It was fortunate to be able to examine three indisputably linked panels together, partly because the chances of interpreting the paint structures are considerably enhanced by being able to compare one with another, but also because the painter's technique proved to be more elaborate than might have been predicted for Italian panel paintings produced at the turn of the fifteenth century. Martin Davies has noted in his *Catalogue of the Earlier Italian Schools* [1] that all three panels forming No.288 have been both reduced and subsequently added to at some time during their history and so it was also of interest to try to determine when these alterations may have been made. However, before the technical aspects of the Perugino panels are described, it is perhaps worthwhile to consider briefly the relevance of scientific examination to conservation and to our understanding of the nature of paintings as physical objects.

In general, the immediate motivation for a technical study of a painting which is to undergo cleaning and restoration is to provide the restorer with supplementary information on which to base the most appropriate decisions concerning the course of conservation treatment. Frequently the removal of an old and disfiguring varnish throws up a set of questions as to the condition and status of the underlying paint which are unique to the picture in hand. Whilst minute visual assessment of the painted surface, the exposed edges and the rear of the picture when coupled to the non-destructive examination techniques of X-radiography, IR-photography and UV-fluorescence observations all provide the restorer with essential information in order to establish the *overall* conservation programme, specific questions of internal structure may often only be answered by selective sampling.

The use of paint cross-sections has gained wide acceptance as a direct means of revealing the hidden structure of paintings, providing information of three basic kinds:

1. The broad structural features of the ground, paint and surface coating are displayed; thus the sequence and thickness of the layers and the particle size distribution of the various pigments present may be judged. The sequence of layers is self-evidently crucial to an understanding of the way in which the composition was evolved, as well as potentially enabling alterations, whether original or by a later hand, to be identified.

2. More or less information about the materials employed, especially the pigments, is available by direct observation under the microscope, although ancillary analysis is often required for fuller interpretations of composition. (Media identifications which also provide fundamental data on painting technique

are best approached in a different, essentially analytical way. See for example [2].)

3. In certain instances the condition of the ground and paint and its vulnerability to degradative change may be assessed from cross-sectional samples. This is particularly applicable to irreversible colour change which results from 'defects' of pigment or paint medium.

When particular problems need to be investigated by sampling, a beneficial side-effect of the procedure is that the cross-sections inevitably yield information in addition to that which is specifically sought. This bonus is valuable in two major ways. Firstly, as technical data on an artist or school of painting is accumulated, it is expected that consistent patterns and logical historical developments of technique will emerge which will be of help both in problems of attribution as well as contributing to our general understanding of the very varied ways in which the old masters achieved their effects. Secondly, it becomes possible to record details of paint structure and materials and to relate these in a sensible way to the future conservation requirements of comparable pictures in the Collection.

It would be misleading to propose that all specific queries of paint structure can be *definitively* answered by examination of cross-sections prepared from paint removed from an appropriate point in the composition, and this is well illustrated by the problem of the Virgin's blue robe discussed by David Bomford above. On the other hand, unambiguous confirmation that the added portions of the Perugino panels were in fact later additions proved straightforward when paint from original and 'added' areas were compared. The features of this technical study which have a direct practical bearing on the course of restoration are discussed first, and there follows for the record a more general summary of Perugino's technique as revealed by paint cross-sections and other analytical work.

Paint layer structure: particular features

The Virgin's Robe

After removal of the varnish, it rapidly became clear that a principal element of the composition — the paint of the Virgin's robe — would need to be investigated in order to understand the problematic appearance of the paint surface described on p.12. It might have been supposed that the robe had been painted basically as a single layer of natural ultramarine mixed with more or less lead white pigment for the highlights. This simple structure was found to be the method employed in a recently cleaned, smaller work by Perugino — No.181, *The Virgin and Child with S. John* — from which a limited number of paint cross-sections were examined [3]. However, the structure of the Virgin's robe in No.288, noticeably the thickest paint on the picture, appeared to be more complex in that although the areas of highlight were bright blue, other parts of the robe possessed a distinctive greenish

tone atypical of paint containing ultramarine alone. In addition, the brightest blue areas displayed a pronounced network of shrinkage cracks, the interstices of which appeared to be in-filled with black material. Surface examination could not ascertain whether a dark interlayer was visible through the fissures or was the result of material forced in some way from the surface into the cracks. It was therefore of interest to analyse the blue robe in terms of the paint layer structure and samples were taken from representative locations as well as from other blue areas on the three panels for comparison.

Although the cross-sections revealed some variations in paint condition and thickness at different points of the blue drapery, the essential features of the layer structure can be illustrated by a single cross-section, which provides an explanation for the variations in tone and hue seen on the picture (see Plate 1a, p.21). The lowest layer of colour is a fairly thick azurite underpaint, and where relatively unobscured by successive overlayers is responsible for the greenish blue colour seen in mid-tones of the cloak. In the section shown on p.21, this lowest layer is virtually pure azurite, although in other samples the azurite was found to be mixed with lead white suggesting that some modelling of the drapery had been developed at an early stage in the painting. The use of azurite as an underpaint for ultramarine is a technique which whilst not unknown in early Italian works [4] is particularly associated with early Netherlandish painting (see, for example [5]) where scarce supplies of the precious pigment extracted from lapis lazuli were eked out by optimizing its effect with a minimum quantity [6]. As lapis lazuli was imported into Europe via Venice [7] it is perhaps to be expected that genuine ultramarine although highly-prized and costly was not quite at the premium in Italy as it was north of the Alps. This is borne out by numerous identifications of ultramarine on Italian paintings of the fourteenth to sixteenth centuries, whereas in German, Netherlandish and Flemish School painting in all but the most important commissions azurite is usually the only blue pigment found [7].

On the three Perugino panels, genuine ultramarine has been used generously, not only for the drapery of the iconographically important figures, but also for the blue paint of the sky (mixed with lead white for the final layer on all three paintings), for certain mixed greens of the landscape and even in paint totally obscured by a final layer of azurite. It seems likely, therefore, that the use of the green-tinged azurite underpaint for the Virgin's robe was intended to exert a genuine influence on the final colour composition rather than merely as a means of saving ultramarine. Further evidence for this point is provided by the contrastingly simple paint structure of S. Raphael's pale blue dress, which comprises a single thin layer of pure ultramarine laid over lead white; a perfectly effective means of representing the blue cloth (see Plate 1b, p.21).

The upper layers of the Virgin's robe all contain ultramarine, and three distinct applications of paint are discernible from the cross-section (Plate 1a, p.21). The

role of the lowest of these is not immediately obvious, comprising as it does quite large particles of deep blue lazurite embedded in a translucent dark brown matrix. Laser microspectral analysis (LMA) [8] has shown the only inorganic pigment present to be ultramarine (spectrographic lines recorded for Al and Si [9]), and it is probable that the layer was intended to depict the deepest shadow areas of the cloak. Perugino's paint medium is discussed below, but at this point it is worth noting that the brown matrix is likely to be darkened oil medium which appears to be present to a large excess in this interlayer. Where visible on the picture it is not surprising that the original dark blue colour is no longer evident appearing only black, as the high tinting strength and rather low refractive index of ultramarine, close to that of the dried oil, result in a very dark-coloured film [10].

The two upper layers in the paint structure represent areas of highlight, the lower of which is a rather coarse granular ultramarine paint containing quantities of colourless or pale grey crystalline material of low refractive index, as well as scattered particles of bright blue lazurite mineral. Once again LMA confirmed Al and Si in the layer and in addition Ca as a major component and a low concentration of Pb. The precise nature of this part of the structure is not clear, but two possibilities suggest themselves. The pigment used may have been 'ultramarine ash', the pale-coloured end-product of multiple extractions from lapis lazuli of the finer grades of ultramarine, in which case the grey material would mainly be the colourless mineral congeners of lazurite, such as calcite and diopside [11]. Alternatively, the pigment may have been a more refined grade of ultramarine which has undergone partial decolorization, a phenomenon termed 'ultramarine sickness', leaving the lazurite aluminosilicate lattice devoid of the polysulphide anion responsible for the blue colour of the pigment [12]. Whatever the initial grade of ultramarine used, the spectrographic results indicated that the layer contains in addition some lead white.

Blanched-looking ultramarine paint with the microstructural characteristics just described was also present in several samples from the *S. Raphael* panel, notably as the surface layer over azurite of *S. Tobias'* greyish blue boots, and directly beneath a browned copper 'resinate' glaze from the background landscape. In the former example it was incidentally particularly gratifying to find the paint structure and composition to correspond in every respect with that of the Madonna's robe in a small National Gallery panel attributable to Perugino's pupil Raphael [13]; an interesting instance of a specific way to construct colour presumably evolved under a master's tutelage and retained in his pupil's independent painting career (see also 'blue pigments', p.29).

The surface paint layer of the Virgin's cloak proved to be the most puzzling feature of the structure. The topmost stratum consists of close-packed ultramarine particles of surprisingly high colour intensity in relation to their small particle size (Plate 1c, p.21). Ultramarine in this form has not previously been encountered in the large number of samples examined

by this Laboratory, and raised the question that the synthetic form of the pigment was involved in this instance. The use of artificial ultramarine, invented in France by Guimet in 1828 [14] would of course imply that the bright blue surface layer was in fact a later addition to the picture, so it was of particular concern to discover whether the pigment was from a natural or manufactured source. Unfortunately, artificial ultramarine is chemically indistinguishable from the genuine mineral pigment and possesses an identical crystal structure. Consequently neither chemical analysis nor a crystal structure determination by X-ray powder diffraction are suitable methods to differentiate the two varieties, and their characterization must rest on particle morphology and the detection of mineral impurities associated with the natural pigment [15]. These features are not easy to assess in a paint cross-section when viewed by reflected light, so a dispersed sample from a surface scraping was prepared as an Aroclor mount for high-power transmitted light microscopy. At a magnification of 500× the blue particles were revealed as thin, sharp-edged angular fragments, consistent with natural mineral lazurite. A few of the largest particles were up to 10µm across, but the bulk were in the range 2–5 µm; very fine-grained for genuine ultramarine which commonly contains particles up to 30 µm in diameter. However, that a range of particle size is found at all is also suggestive of a natural source for the pigment, in that the traditional method of extraction described by Cennini [16] would be unlikely to produce a regular grain size (see also [17]). By contrast reference mounts of a number of synthetic ultramarines characteristically showed a relatively even particle size distribution, more intense homogenous colour, and semi-rounded crystallites quite different from the pigment found in the Perugino (see Plate 1d, p.21). Only a very low level of birefracting material was microscopically detectable in the picture sample, also unusual for natural ultramarine, although it was possible to show the presence of traces of calcite in the X-ray powder pattern of the brightest blue surface paint [18]. It was therefore concluded that the pigment was indeed genuine ultramarine rather than its synthetic counterpart, albeit of an unusually highly-purified and fine-grained type. Ultramarine of great purity and small particle size is not confined to the centre panel, being the sole pigment of the intense blue top paint of parts of *S. Michael's* shield, brooch and sword-strap and of the delicate arabesque on *S. Tobias'* orange sleeve [19]. (See Plate 1g, p.21.)

It has been suggested by Martin Davies that Perugino may never have completed the altarpiece for the Certosa di Pavia of which the National Gallery panels form a part [1], and therefore these may have been in themselves unfinished. There is no direct evidence from the paint cross-sections that this was the case. Although the complexity in layer structure and unusual appearance of the surface make a repaint of the Virgin's robe a possibility, no varnish or dirt interlayers were discernible, and where old retouchings were present these all seem to have been carried out in Prussian blue over several layers of old

varnish. In no instance was Prussian blue found beneath ultramarine. Moreover, wisps of the Virgin's hair, evidently original, can be seen to pass over the most intense blue paint of the cloak on her right shoulder. Finally, it is possible to rationalize the complete layer structure in terms of an original and intentionally elaborate treatment of colour, light and shade for the drapery of the principal subject of the composition.

Additions to the panels

It has been explained on p.3 that the extensions made to the three panels clearly were not original; nevertheless it was of interest to be able to confirm this conclusion by examining the structure of the paint on the added sections. The pale blue paint from the inner added edge strip on the right-hand side of *S. Michael* showed the extended portion of the sky to have been painted as a greenish blue underlayer of lead white tinted with Prussian blue [20], succeeded by a light blue layer comprising ultramarine and lead white. By contrast, Perugino's sky paint was executed as two layers, containing natural ultramarine in the top layer and azurite beneath; in both cases the blue pigments had been mixed with lead white (see Plates 1e and 1f, p.21). It was incidentally interesting to see that the early restorer responsible for extending the sky on the *S. Michael* had intuitively understood the paint structure of the original and matched the influence of the azurite underpaint with a blue pigment noted for its slight greenish cast when mixed with white. Paint also containing Prussian blue was found on the three other added side strips of the panel, and on the *Virgin and Child* in the equivalent areas as well as in the lowest layers of the new top section, where the colour matching with the original had turned out to be far from successful. Prussian blue, invented certainly by 1710 and possibly six years earlier [21], found widespread use all over Europe fairly soon after Diesbach's discovery, and its presence on the added portions of the Perugino panels confirms that these must have been painted later than the beginning of the eighteenth century. It is impossible to be more specific than this on the basis of pigment analysis alone.

It was also possible to show by X-ray diffraction analysis that the aqueous white ground which had been applied to the added wood was different in composition to that of the original. In the former case the inert proved to be pure gypsum (calcium sulphate dihydrate) whilst Perugino's ground was found to be composed mainly of anhydrite (anhydrous calcium sulphate) with gypsum as a minor component (see below). The use of gypsum as an inert perhaps owes more to the frame-maker's art than to the painter's, in keeping with the nature of the task involved in extending the woodwork of the panels.

Gold

The status of the small amount of decorative gold seen on the pictures was also of relevance to the course of restoration, and there was evidence from cross-sections that some of the fine lines had been reinforced by a

later hand. In a small sample taken from the golden halo of the foreground angel in the *Virgin and Child*, a discontinuous layer of surface gold was found to lie on top of a thick seam of darkened varnish which in turn covered a very thin original layer of the metal. The latter lay directly on dark green paint of the background landscape. Microscopically, the appearance of the reinforcing layer suggested powdered gold, whilst the underlying original seems to be leaf. On the *S. Michael*, the saint's halo was found to have been similarly reinforced, whilst his gold-edged wing scales proved to be original gold not tampered with in any way. We can conclude that the golden haloes, wing and drapery decoration all represent authentic elements of Perugino's design.

The painter's technique: general features

There is little information in the literature specifically on Perugino's painting methods [22]. Accordingly, the general features of the painter's materials and technique which emerged during examination of No.288 are reported below.

The ground

The three poplar panels carry the usual white gesso ground associated with Italian Renaissance painting, composed in this case of a mixture of anhydrite and gypsum. Rough quantitative estimates of the proportions of anhydrous and hydrated forms of calcium sulphate in the ground layers were derived from their X-ray diffraction patterns and found to be:

	<i>S. Raphael</i>	<i>Virgin and Child</i>	<i>S. Michael</i>
Anhydrite	67%	87%	90%
Gypsum	33%	13%	10%

See [23]

The presence of both materials and the predominance of anhydrite seems to be typical of Umbrian, Sienese and Florentine painting, whilst it has been suggested that the practice in Venice was to use unburnt gypsum alone [24]. The binding material for the ground was shown by staining tests on thin cross-sections to be gelatin, presumably in the form of animal-skin glue. The surface of the ground appears to have been sized with glue before painting, revealed as an intensely stained thin band in several sections from the *S. Raphael*.

The pigments

Excluding the calcium sulphate inerts of the ground, the only white pigment detected on the Perugino was lead white (basic lead carbonate). Black pigments are used very sparingly appearing only in traces of underdrawing, from the IR-photographs clearly not carried out to any major extent, and in the form of finely ground carbon particles in the flesh tones.

The full range of pigments are perhaps as expected, although the paint layer structure is in general more complex than some contemporary works and we can speculate that this may be because a fully-developed oil

technique had still not been perfected by all painters in Italy in the late 1490s and its optical effects less well-understood than those of the more traditional proteinaceous media.

Blue

The role of ultramarine in the sky paint, Virgin's robe, S. Raphael's dress and so on has already been discussed on p.26; in addition to those occurrences cited previously, the pigment was found in a mixture with red lake for the foreground angel's deep brownish purple wings in the *Virgin and Child*. A similar mixture painted over a layer containing azurite, red lake pigment and white forms the scarf draped over S. Tobias' wrist; a second example of a paint system proving to be identical to that found for the mauve shadows on the Virgin's drapery in Raphael's small *Madonna and Child* (No.744).

Azurite was found to have been rarely employed as a blue pigment in its own right, but frequently appeared as an underlayer for ultramarine and as a component of various mixed greens (see below). However, the darkest areas on the wings of the trio of angels depicted in the centre panel were painted in pure, coarsely-ground azurite, but the influence of the yellowed oil medium has caused the paint now to appear decidedly dark green rather than blue (see Plate 1i, p.21). Azurite mixed with lead white also forms the pale blue folds of the right-hand angel's pink and blue changing drapery.

Green

Areas of green were found to have been constructed in a wide variety of ways, mostly involving several superimposed layers in order to achieve the final colour. This is in contrast to Perugino's *Virgin and Child with S. John* (No.181) in which a single layer of malachite with or without a green glaze had been used for the background landscape and foliage. Many of the green paint samples from No.288 contained copper 'resinate' type material, both as the matrix for a range of opaque pigments and as a final glaze. Some examples of the great variability in constitution of the greens are given below:

1. *Virgin and Child*

- (i) Yellow-green highlights on flying angel's wings (centre and right): Azurite and yellow ochre.
- (ii) Brownish green of background landscape, left edge: Azurite in a green glaze, with a final copper 'resinate' glaze (now discoloured).
- (iii) Dark green of landscape beneath gold of angel's halo: Well-preserved copper 'resinate' glaze over lead-tin yellow.

2. *S. Raphael*

- (i) Dark, translucent green lining of S. Raphael's waist drapery: Three or four separate layers of copper 'resinate' green containing a small proportion of lead white [25]; final transparent layer, now discoloured (see Plate 1j, p.21).
- (ii) Brownish green background landscape, left edge: Blanched-looking ultramarine paint, totally browned copper 'resinate' glaze on top [26].

- (iii) Yellow-green foreground foliage: Two layers of yellow ochre mixed with green glaze material, partially browned copper 'resinate' layer on top.

- (iv) Dark, translucent green of S. Tobias' doublet: Thick, intense blue-green copper 'resinate' glaze over a thin lead white underpaint. The glaze layer contains a small quantity of azurite and is slightly browned at the surface.

3. *S. Michael*

- (i) Very deep green of S. Michael's hat: Two thick dark green glaze layers containing some opaque material over azurite embedded in transparent green.
- (ii) Brownish green landscape: Yellow ochre mixed with green glaze painted over a lead-tin yellow layer. Final thin copper 'resinate' glaze (now discoloured).

As is often the case, the thinly applied copper 'resinate' glazes have extensively browned, especially those painted over light-coloured basal layers, whereas those which have been laid in more thickly have survived well beneath the relatively opaque discoloured upper levels [27].

Red and purple

On the centre panel, the paint of the Virgin's red dress, the flying angel's pink changing drapery, and the flesh tones consist of vermilion (red mercuric sulphide) mixed with lead white. The flesh tones, painted as a single layer, contain in addition traces of a copper green and for the areas of shadow very fine particles of carbon black.

In the *S. Michael* and *S. Raphael* vermilion has been used in conjunction with red lake pigments to produce more saturated reds and a range of deep purple tones. Several different techniques seem to have been employed resulting in variations both of hue and transparency. *S. Michael*'s brownish red sword-blade is painted as a single thick layer of vermilion mixed with red lake, whilst *S. Raphael*'s red mantle and *S. Tobias*' stockings consist of an underlayer of vermilion and white glazed with a relatively thick layer of pure red lake. For the darker, purple-red drapery which hangs from *S. Raphael*'s waist, the technique is more complex: the lowest paint layer is vermilion alone containing coarse and fine pigment particles, and is succeeded by two of similar thickness comprising mixtures of vermilion and red lake. A thick red lake glaze completes the structure (see Plate 1h, p.21). Under the microscope by ordinary reflected light the final glaze appeared to be a single layer, but when viewed in UV light three distinct regions of fluorescence emerged suggesting the glaze to have been built up as several thin applications of paint; a sensible precaution in view of the slow-drying nature of lake pigments.

Using a microspectrophotometric technique developed in this Laboratory [28] the absorption spectrum in the range 400–650 nm was recorded for several thin slivers of the top glaze after the varnish had been removed from the sample. The resulting transmittance plots showed absorption features consistent with the red dyestuff (alizarin) extracted

from the madder plant (*Rubia tinctorum*). The same result was found for the red glaze of S. Tobias' stockings. In both cases the lake pigments showed moderately strong orange to mauve UV fluorescence, possibly attributable to the dyestuff purpurin which occurs with alizarin in the madder root, and would be co-precipitated in a lake pigment prepared from the plant extract. The inorganic substrate for the lake in these two samples was identified by LMA as hydrated aluminium oxide (strong spectrographic lines recorded for Al). The same substrate was found for the transparent red which in mixture with azurite forms the deep brownish purple tone of S. Tobias' collar.

In keeping with the relative complexity and scale of No.288 Perugino's treatment of red and purple is notably more painstaking than the austere execution of the Virgin's dress in the small *Virgin and Child with S. John* (No.181), where a single thin red lake glaze is painted over a lead white underlayer.

Yellow and orange

Little pure yellow pigment occurs at the surface on the pictures, with the exception of the changing draperies of the flying angels in the *Virgin and Child*. Here the pigment was found to be lead-tin yellow. The same pigment forms the small impasto highlight touches on background foliage; its identity confirmed by LMA. Pure lead-tin yellow is also present on the S. *Michael* as an underlayer for the brown (ochre) paint of the saint's shield.

The unusual bright orange-brown colour of S. Tobias' inner sleeve proved to be a finely ground mixture of an orange-coloured earth pigment, vermilion and red lake [29] (see Plate 1g, p.21), together producing a colour reminiscent of that seen on some sixteenth century Venetian pictures, but which there often turns out to be a single pigment, realgar [30].

In addition to their role in forming mixed greens, yellow earth pigments were identified in the principal saint's brownish yellow wing scales which grade into a copper 'resinate' green.

The medium

The paint medium of No.288 has been reported in a previous issue of this *Bulletin*: gas-chromatographic analysis showed the presence of dried walnut oil in samples from the *Virgin and Child* and the S. *Raphael* [31]. Traces of egg tempera were also detected in certain of the samples, but because the panels have had a confused history of treatment and retouching it is not possible to reliably attribute a mixed medium to this work by Perugino. The Louvre picture, *Le Combat de l'Amour et de la Chasteté*, was however recorded as being in egg tempera, with an unspecified oil in the upper paint layers [22].

Staining tests on thin cross-sections cut from samples taken from S. *Raphael* confirmed the presence of oil alone in the blue (top) layer of the saint's dress, S. Tobias' red stockings, and in all the layers including a copper 'resinate' glaze of the background landscape. A drying oil was similarly detected in both layers of

the pale blue sky paint, although these also stained positively for egg protein, whereas the pure white underpaint for S. Raphael's blue dress gave a staining pattern consistent with egg tempera and a negative result with the oil stain [32].

It appears that No.288 is essentially a work in walnut oil, but that a limited use of egg tempera either on its own or in combination with oil may have been employed in some of the passages. However, it must be pointed out that all three panels have undergone extensive blister-laying during their time in the Collection and probably also before acquisition, and the injection of glue to reattach flaking paint can easily lead to ambiguities in the interpretation of staining reactions.

Notes and references

1. DAVIES, M., *National Gallery Catalogues: The Earlier Italian Schools* (London 1951), pp.312 – 17.
2. MILLS, J. and WHITE, R., 'Organic Analysis in the Arts', *National Gallery Technical Bulletin*, 2 (1978), pp.71 – 3.
3. Perugino's 'Virgin and Child with S. John' (No.181) was cleaned and restored by David Bomford in 1975, and the work described in the *National Gallery Technical Bulletin*, 1 (1977), pp.29 – 34. At the time a small number of paint samples were taken, but their structure proved to be too simple to justify a published report.
4. In Leonardo's 'Virgin of the Rocks' (No.1093) the Virgin's blue cloak has a very thin glaze of ultramarine over a thick layer of azurite.
5. WYLD, M., ROY, A. and SMITH, A., 'Gerard David's "The Virgin and Child with Saints and a Donor"', *National Gallery Technical Bulletin*, 3 (1979), p.62 and Plate 7f. Even in as important a commission as the Van Eyck 'Mystic Lamb' ultramarine is found principally as a thin glaze over azurite. See COREMANS, P., *Les Primitifs Flamands III: Contributions à l'étude des Primitifs Flamands*, 2. *L'Agneau Mystique au Laboratoire, Examen et Traitement*, De Sikkel (Antwerp 1953), pp.70 – 1.
6. It has been suggested that the Van Eycks employed underpainting techniques consistent with quite a sophisticated understanding of the optical principles involved. See VAN ASPEREN DE BOER, J.R.J., 'On a Rational Aspect of Van Eyck's Painting Technique', *Studies in Conservation*, 18, 2 (1973), pp.93 – 5.
7. PLESTERS, J., 'Ultramarine Blue, Natural and Artificial', *Studies in Conservation*, 11, 2 (1966), pp.63 – 5.
8. ROY, A., 'The Laser Microspectral Analysis of Paint', *National Gallery Technical Bulletin*, 3 (1979), pp.43 – 50.
9. Spectrographic analysis is not the ideal method of confirming ultramarine, but in this case the need was for a means of analysis capable of showing the pigment composition of a single paint layer *in situ* in the sample.
10. Referring to a 'Crucifixion' and two other panel paintings by Perugino (now in the Uffizi), Vasari comments: 'These three panels have suffered

considerably, having darkened, and cracked where the shadows are. The reason for this is that three coatings of paint are superimposed, and when the first coating laid upon the composition is not quite dry, the colours contract in drying and after a time the cracks appear.' See VASARI, G., *Le Vite de più Eccellenti Pittori Scultori ed Architettori*, Gaetano Milanese (ed.), Vol. III (1878), pp.575 – 6.

Ultramarine when used alone in oil, without the addition of lead white, dries slowly frequently with formation of shrinkage or drying cracks, and often with development of discolouration of the medium associated with slowness of drying. Azurite, in common with other copper pigments produces a relatively fast-drying film with oil media.

11. See 'Supplement IIa' compiled by W. Thomas Chase III in PLESTERS, J., *op. cit.*, p.90.

12. 'Ultramarine sickness' is thought to be the result of chemical reaction of the pigment with acids, whether the contact arises from residual acidity in the paint medium, acid atmospheres or unsuitable cleaning solvents.

13. No.744, Raphael, 'Madonna and Child with the Infant Baptist'.

14. PLESTERS, J., *op. cit.*, p.76.

15. A mass spectrometric method has been proposed as a basis to distinguish specimens of natural and synthetic ultramarine from paintings. See KEISCH, B. and CALLAHAN, R.C., 'Sulphur Isotope Ratios in Ultramarine Blue: Application to Art Forgery Detection', *Applied Spectroscopy*, **30**, 5 (1976), p.515.

16. THOMPSON, D.V. (trans.), *Cennino d'Andrea Cennini: The Craftsman's Handbook*, Dover (New York n.d.), p.36ff.

17. VAN ASPEREN DE BOER, J.R.J., 'An Examination of Particle Size Distributions of Azurite and Natural Ultramarine in Some Early Netherlandish Paintings', *Studies in Conservation*, **19**, 4 (1974), p.233ff.

18. The film showed in addition to the diffraction pattern for ultramarine a weak line corresponding to an interplanar lattice spacing (*d*-value) of 3.01 Angstroms. This was interpreted as arising from a low concentration of calcite in the sample, the reflection being the strongest in the diffraction pattern for orthorhombic calcium carbonate. See ASTM data card No.17 – 763.

19. Interestingly, Vasari records Perugino as having a source of particularly well-refined ultramarine: '... the prior was very skilful in making ultramarine blue, and having a great deal he wished Pietro [Perugino] to use it freely. ...' See VASARI, G., *op. cit.*, p.575.

20. The presence of iron in the layer was confirmed by LMA and microchemical tests.

21. HARLEY, R.D., *Artists' Pigments c.1600 – 1835*, Butterworths (London 1970), p.65.

22. A single picture on canvas in the Louvre — *Le Combat de l'Amour et de la Chasteté* — has been the subject of a short published study which includes paint medium analysis, some comments on layer structure and the X-ray of the picture. See DELBOURGO, S., RIOUX, J-P. and MARTIN, E., 'L'Analyse des Peintures du Studiolo d'Isabelle d'Este au Laboratoire

de Recherche des Musées de France', *Annales du Laboratoire de Recherche des Musées de France* (1975), pp.10 – 13 and pp.21 – 8.

It should be pointed out that the early technique of painting on canvas can differ radically from that used on panel, even by the same artist; comparisons of technique between No.288 and the Louvre painting should therefore be made with due caution.

23. The quantitative analysis quoted was determined by microdensitometry of the strongest diffraction lines for anhydrite and gypsum (corresponding to *d* spacings of 3.49 and 4.28 Angstroms respectively) on the strips of X-ray film, and the concentration ratios calculated from data given in BONES, R.A., 'The Analysis of Calcium Sulphate Grounds by an X-ray Diffraction Process', *Studies in Conservation*, **1**, 4 (1954), pp.193 – 5.

24. GETTENS, R.J. and MROSE, M.E., 'Calcium Sulphate Minerals in the Grounds of Italian Paintings', *Studies in Conservation*, **1**, 4 (1954), pp.174 – 89.

25. LMA showed copper and lead as the only metallic elements in the layer.

26. Copper was detected by LMA in this completely browned glaze.

27. For a full discussion of this point, see THOMSON, G., 'Penetration of Radiation into Old Paint Films', *National Gallery Technical Bulletin*, **3** (1979), pp.25 – 33.

28. KIRBY, J., 'A Spectrophotometric Method for the Identification of Lake Pigment Dyestuffs', *National Gallery Technical Bulletin*, **1** (1977), pp.35 – 44.

29. Iron, mercury and aluminium detected in the layer by LMA.

30. For example the orange drapery of the Bacchante with the cymbals in Titian's 'Bacchus and Ariadne' (No.35). See PLESTERS, J., 'Titian's "Bacchus and Ariadne": The Materials and Technique', *National Gallery Technical Bulletin*, **2** (1978), p.41 and Plate 6g.

31. MILLS, J. and WHITE, R., 'Analyses of Paint Media', *National Gallery Technical Bulletin*, **3** (1979), pp.66 – 7.

32. The stains used were: for oil, Sudan black and oil red O; for proteins, amido black and acid fuchsin.