The ‘Treu Head’: a case study in Roman sculptural polychromy

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Summary This contribution presents recent work on an important Roman marble head of the mid-second century AD from the collection of the British Museum (1884,0617.1). The head was found on the Esquiline Hill in Rome in 1884 and soon after its discovery was acquired for the British Museum. Unusually, it retained extensive traces of its original polychromy, including otherwise rarely preserved skin pigments. Ever since the German scholar Georg Treu published the sculpture in 1889, it has played a significant part in the discussion of ancient sculptural polychromy and in particular the question of whether or not the flesh parts of marble sculptures were originally painted. However, early doubts about the authenticity of the pigment traces led some twentieth-century scholars to question the authenticity of the sculpture as a whole.

For this study, the polychromy of the head was extensively investigated using non-invasive techniques (ultraviolet and visible-induced luminescence imaging) and invasive analytical methods, including Raman spectroscopy, Fourier transform infrared spectroscopy, high performance liquid chromatography and gas chromatography-mass spectrometry.

It was found that complex mixtures of pigments, and selected pigments for specific areas, were used to create subtle tonal variations. These included: calcite, red and yellow ochres, carbon black and Egyptian blue for the flesh tones; calcite to provide highlights on the flesh areas; lead white and Egyptian blue for the eyeballs; a red organic colourant in the nostrils, the lachrymal ducts and the inner parts of the mouth; and red and yellow ochre for the hair.

The examination confirmed beyond doubt the authenticity of the preserved pigments and thereby the sculpture itself, which can now rightfully reassume its important place in the art historical discussion of the polychromy of ancient sculpture. In addition, it provided valuable insights into Roman painting techniques on marble and allowed revealing comparisons to be made with other ancient polychrome works, such as funerary portraits.

INTRODUCTION

In recent years a strong interest in the original polychromy of ancient sculpture has re-emerged, often taking up questions first raised in the late nineteenth century [1, 2]. However, few detailed articles have been published to date that contain thorough pigment analyses and similar technical details, which are essential to place any art historical discussion on a sound scientific footing [3–5]. The British Museum head (henceforth the ‘Treu Head’ after its first publisher) provides a useful model for the new type of study required. It also demonstrates the practical significance of an imaging technique that was developed recently at the Museum to detect the presence of the pigment Egyptian blue and, for the first time, to map its spatial distribution on objects. As illustrated in some detail below, information on the spatial distribution of pigments can help to evaluate the authenticity of sculptures. Finally, because of the early and continued discussion of its merits in the relevant scholarly literature and its display history within the British Museum, the Treu Head provides an instructive example for the changing significance accorded to questions of polychromy in academic and museological approaches to ancient Greek and Roman sculpture.

THE TREU HEAD

The Treu Head (British Museum sculpture 1597: GR 1884,0617.1) is life-sized, measuring 21.5 cm from chin to crown (37.5 cm including the neck), and was fashioned with a tenon for insertion into a draped body; Figures 1a–1d show four different views of the Treu Head in its
present state. The stone from which it is made has not been identified firmly, but visual inspection suggests that it is Parian marble. The back and the top of the head are only roughly finished; two sections of hair on either side above the temple were added as separate pieces – fragments A (proper right: Figure 1e) and B (proper left: Figure 1f) – held in place by metal dowels. It is unclear whether these were part of the original carving process or the result of ancient or modern repair. Both dowels were removed at an unknown date after c.1920 and the fragments detached from the head. Remains of a much larger iron dowel in the upper back part of the head, at the time interpreted as the

![Figure 1. The Treu Head as it appears today: (a) front; (b) proper right side; (c) back; and (d) proper left side. Two hair fragments associated with the head: (e) fragment A; and (f) fragment B](image-url)
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base of a meniskos (a sharp metal disc added to fend off birds), had already been removed in 1889 to prevent further damage to the marble caused by metal corrosion and were registered separately when they entered the collection (GR 1884,0617.2).

The head, clearly recognizable as female, is turned to the left, with the lips slightly apart. The hair is parted in the centre and sweeps away from the forehead in parallel, wavy strands, gathered in a loose plait at the back. At irregular intervals, some of these strands are divided by deeply drilled grooves, sometimes bridged in places by thin marble struts, Figure 2. This technical treatment of the marble occurs first in the Late Hadrianic and Early Antonine periods (c. ad 130–145), which provides an approximate terminus post quem for dating the head. The absence of distinctive portrait features, in combination with the treatment of the eyes (without incised irises and drilled pupils), indicates that the head represented an ideal figure, such as a goddess. A similar hairstyle can, for example, be found on images of Aphrodite/Venus and Athena/Minerva. Clear traces of pigmentation survive today in several locations and are visible to the naked eye: pink patches of skin tones survive on the neck, chin, cheek and forehead of the sculpture; remnants of black and yellow pigments can be seen around the eyes and in the hair respectively; and a few particles of a pink translucent pigment are preserved within the deepest recesses of the mouth. Most areas of surviving pigmentation are covered in a thick layer of surface deposits, probably accumulated during burial. However, when described by Treu in 1889, the head apparently retained more of its original colours than can be seen today, Figure 3a.

Discovery, acquisition and first publication

From archival evidence in the Department of Greece and Rome at the British Museum, it appears that the head was discovered in early 1884 on the Esquiline Hill in Rome. It was immediately given or sold to the well-known Roman art dealer Francesco Martinetti, in whose premises it was seen in early March of that year by Sir Charles Newton of the British Museum. While excavating the remains of the Mausoleum at Halicarnassos, Newton had become very interested in the colour of ancient sculpture and the associated questions of how best to document and preserve the extant pigments [6]. He was struck by the Treu Head’s well-preserved polychromy and after examining it carefully seems immediately to have expressed a wish to purchase the sculpture, as by April Martinetti had already sent it to London. In June, Newton formally recommended that the Museum’s Trustees should acquire the head, specifically on account of its well-preserved traces of colour. This request was duly granted and on 16 June 1884 the head was purchased for £160 and registered as part of the collections. It was then put on display in the galleries and it was there seen by Georg Treu, who like Newton was a noted pioneer of ancient polychromy studies [7]. Together with some colleagues at the British Museum, Treu studied the head closely and made detailed notes, which he afterwards forwarded to London, asking Museum staff to verify their accuracy. In addition, to document the visible remains of colour as precisely as possible, Treu requested photographs and commissioned a watercolour illustration of the head, Figure 3a. In 1888, he presented his findings in a lecture at the Berlin Archaeological Society and in the following year published an article on the head in the Jahrbuch of the German Archaeological Institute [8]. This article was widely read and ensured that the Treu Head was illustrated and prominently mentioned in subsequent studies of ancient sculptural polychromy [9–12].

Early state of preservation

Treu’s notes and article remain the best record of the pigment remains still visible on the head shortly after its discovery and may be summarized here. The head
was extensively coloured. The eyebrows were black, with a parallel red line below them and the eyelids were similarly framed in black with a red line along the outside that was interrupted above the upper lid where the eyelashes intersected. The eyes had black pupils and a black outline to the iris. The carved section of the hair was light yellow with individual strands of hair picked out in reddish brown and a yellow line marked the transition from forehead to hair. Most important, however, were the substantial traces of pinkish pigment, described as having “the consistency of an oily paste” [8], on the face and neck, which represented the colour of skin. It was this last element that made the head exceptional and turned it into an important piece of evidence in the controversy about the degree to which ancient sculptures were coloured. Scholars were – and to an extent still are today – divided into two camps: the first postulated that only certain expressive parts of the figures, such as eyes, lips, etc. were rendered in colour, while the face and skin parts of the figures in general were represented through highly polished or, at best, waxed marble without any additional pigment layer [11]. The other camp, to which Treu belonged, proposed that the entire marble surface was coloured [8]. Consequently, the Treu Head became the best-preserved piece of evidence for the latter theory. Because of its almost unique status, however, serious questions were raised about its authenticity. In a letter to London on 15 November 1888, written before the publication of his article, Treu explained why he wanted his English colleague to check his own observations so carefully: the German archaeologists Adolf Furtwängler and Georg Löschcke had seen the head in the British Museum and had expressed doubts concerning the authenticity of the paint, in particular the skin colour, as the pigment also appeared to cover what they interpreted as sinter on the marble surface of the head. In a further letter, asking for the utmost discretion, Treu reported what he had been able to find out about the discovery of the head. This information came from Wolfgang Helbig, a German archaeologist based in Rome with close connections to the trade in Classical antiquities. Helbig stated that he knew the exact findspot of the head, which he was not at liberty to divulge, and that he was present when the finder brought the head to Martinetti. Intriguingly, Martinetti asked that his name should not be mentioned in any publication.

**Authenticity**

While Treu seems to have been completely reassured by Helbig’s account, archaeologists today will inevitably be suspicious when the names of Helbig and Martinetti are mentioned, as both have been accused of working together to supply forgeries to a number of collections [13–15].

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**Figure 3.** Historic records of the Treu Head: (a) in a watercolour by an unknown artist made shortly after its discovery. The drawing shows the flesh tones, black and red lines around the eyes and the blonde and red hair; and (b) on display in the Ephesus Room of the British Museum, before c.1920 with fragments A and B attached (the inset shows a magnified detail of the head, which was covered by a diaphanous veil).
ally, the authenticity of the head came to be doubted even by curators at the British Museum. At some stage before 1960, P.E. Corbett at the British Museum wrote to the Swedish scholar P. Reuterswärd, who was then still researching his book on ancient sculptural polychromy, that he was "not absolutely certain that the head has not been tampered with in modern times, or even that it is ancient", citing in particular the tool marks on the sides of the head where they join fragments A and B [11]. Reuterswärd, who never saw the head himself, mentioned it prominently in his book, but included a caveat as to its authenticity.

**Museology**

The display history of the Treu Head in the British Museum echoes its scholarly reception, from initial enthusiasm to ever-increasing scepticism, and can be reconstructed from a series of notes and published guides to the galleries. After its acquisition, the head was prominently displayed in the so-called First Graeco-Roman Room, near the beginning of the suite of sculpture galleries on the Museum’s ground floor, where Treu and others first saw it. By 1899 it had been moved, somewhat out of context, into the Ephesus Room. A photograph of this gallery taken before c.1920 (Figure 3b) shows the head in a protective glass case, sheltered by a diaphanous piece of cloth that was undoubtedly put there to prevent the detrimental effect of direct sunlight on the preserved pigments. While the printed guides to Greek and Roman antiquities in the British Museum from 1899 to 1912 explicitly mention the head and briefly explain its particular significance, from 1920 onwards it is no longer listed and seems to have been taken off display. Although the sculpture has remained accessible for study, with the exception of a brief period after 1985 when it was accommodated on a high shelf in room 85 in the newly opened Wolfson Galleries, the head has not returned to public display since. Several factors may have combined to motivate this removal: a general restructuring of the galleries in the 1920s; the gradual disappearance of the preserved pigment traces; and, finally, unease about whether they and the sculpture itself were genuine.

**Technical study**

The technical study described here was undertaken in an attempt to verify the authenticity of the pigments on the sculpture using analytical methods that were not available to previous researchers and to further current understanding of Roman painting techniques on stone.

**METHODOLOGY**

To inform subsequent observations and further investigations, a preliminary but essential step was to assemble all

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Materials identified</th>
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<tbody>
<tr>
<td><strong>Treu Head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M01</td>
<td>Flesh tones on cheek</td>
<td>Calcite, hematite, goethite, carbon black, Egyptian blue and gypsum</td>
</tr>
<tr>
<td>M02</td>
<td>Pink inside mouth</td>
<td>Organic lake (containing pseudopurpurin and purpurin), calcite + aragonite, hematite, goethite, carbon black, Egyptian blue and gypsum with traces of lead white</td>
</tr>
<tr>
<td>M03</td>
<td>Yellow in hairline</td>
<td>Goethite and gypsum</td>
</tr>
<tr>
<td>M05</td>
<td>White eyebrow</td>
<td>Lead white, calcite, Egyptian blue and carbon black with traces of lead(II) oxide</td>
</tr>
<tr>
<td>M11</td>
<td>Red line on eyebrow above flesh tones</td>
<td>Red line: hematite and vermilion, Flesh tones: calcite + aragonite, hematite, goethite and gypsum</td>
</tr>
<tr>
<td>M12</td>
<td>Black underdrawing of the eyebrow below flesh tones</td>
<td>Underdrawing: carbon, Flesh tones: calcite + aragonite, hematite, goethite, carbon black, Egyptian blue and gypsum</td>
</tr>
<tr>
<td>M13</td>
<td>White over flesh tones</td>
<td>White: calcite, Flesh tones: calcite, hematite, goethite, carbon black, Egyptian blue and gypsum</td>
</tr>
<tr>
<td>M15</td>
<td>Dark red lip</td>
<td>Calcite + aragonite, dolomite, hematite, goethite, carbon black and gypsum</td>
</tr>
<tr>
<td>M17</td>
<td>Red stain on nose</td>
<td>Hematite (possibly a contaminant)</td>
</tr>
<tr>
<td>M20</td>
<td>Red in hair</td>
<td>Hematite, calcite and gypsum</td>
</tr>
<tr>
<td>M21</td>
<td>Yellow in hair</td>
<td>Goethite, gypsum and calcite</td>
</tr>
<tr>
<td>M22</td>
<td>Black eyebrow</td>
<td>Carbon, gypsum and calcite</td>
</tr>
<tr>
<td>M25</td>
<td>Flesh tones</td>
<td>Calcite, hematite, goethite, carbon, Egyptian blue and gypsum</td>
</tr>
<tr>
<td><strong>Hair fragment A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A01</td>
<td>Yellow hair</td>
<td>Goethite, gypsum and calcite</td>
</tr>
<tr>
<td><strong>Hair fragment B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B01</td>
<td>Flesh tones from ear</td>
<td>Calcite, hematite, goethite and gypsum</td>
</tr>
</tbody>
</table>
relevant documentation on the physical and conservation history of the Treu Head. The sequence of examination began with visual examination followed by technical imaging, including variations in lighting angle (raking light), scale (microscopy) and type of radiation used – from the ultraviolet (UV), through the visible to the near infrared (IR). Ultraviolet- and visible-induced luminescence imaging (UIL and VIL, respectively; see the experimental appendix) proved particularly useful for mapping the distribution of pigments. A sampling strategy was developed on the basis of these preliminary investigations. Minute unmounted samples (less than a millimetre across) and polished cross-sections were analysed using Raman and Fourier transform infrared (FTIR) spectroscopy to help identify the inorganic compounds present. The cross-sections were also analysed using scanning electron microscopy with energy dispersive X-ray spectrometry (SEM-EDX) to investigate their elemental composition. High performance liquid chromatography using photo-diode array detection (HPLC-PDA) was employed for the identification of dyestuffs and gas chromatography-mass spectrometry (GC-MS) for the identification of binding media. Details of the scientific techniques used in this study can be found in the experimental appendix.

RESULTS AND DISCUSSION

The results of the investigations undertaken on the surviving polychromy on the Treu Head are summarized below. A rather complex colour palette was used skilfully to achieve different hues and elaborate tonal effects. Figure 4 shows the visible, UIL and VIL images of the front of the sculpture; Figure 4a shows the locations from which the samples listed in Table 1 were taken.

Flesh tones

The paint used for the flesh tones is evenly applied with an average thickness of c.70 μm. It is a finely ground mixture of calcium carbonate (present as both calcite and aragonite, two polymorphs of CaCO₃), hematite (α-Fe₂O₃), goethite (α-FeO·OH) or limonite (FeO·nH₂O), amorphous carbon and Egyptian blue (CaCuSi₄O₁₀) applied in an unidentified binding matrix (see below for further details of the binding medium). Very small quantities of lead white found in the flesh tone layer are probably due to contamination; as explained below, lead white was used in the eyes.

Small traces of dolomite (CaMg(CO₃)₂) were also found alongside calcite and aragonite in one sample (Table 1, sample M15) and particles of gypsum (CaSO₄) in another (Table 1, sample M01); it is unclear whether either of these materials was added intentionally, was present in the source material or represents an alteration product. These findings, along with the absence of coccoliths in any sample, suggest the use of crushed marble rather than limestone [3; p. 32]. Hematite and goethite or limonite are the principal colourants in naturally occurring red and yellow ochres respectively. Black, amorphous carbon is either the product of combustion of vegetable or animal material, or derives from crushed charcoal. In this instance no phosphates, which would indicate the use of burnt animal material such as bone or ivory, were detected. Similarly, no evidence has been found in any of the samples analysed of any cellular structure that would point to the use of crushed charcoal, suggesting, therefore, the blacks derive from carbonized vegetable materials, such as oils (lamp black). Egyptian blue is a synthetic pigment used in the areas surrounding the Mediterranean from about 2500 BC up to the end of the Roman Empire and beyond [16]. A significant property of Egyptian blue, which was utilized in this study, is that when it is excited with visible light, it emits infrared radiation; thus, particles of the pigment can be seen to ‘glow white’ in a VIL image, Figure 4c [17].

The paint used for the flesh tones was apparently applied directly onto the highly polished bare surface of the stone. Although a sealant, generally the same binder used in the paint, would probably have been used to seal the stone surface to facilitate the application of paint, no traces of this could be identified. A large discoloured stain can be seen on the proper right cheek, Figure 5a. This stain, which was too thin to allow it to be sampled for analysis with the techniques used in this study, is not present in those areas where the flesh paint seems to have fallen from the surface of the marble since excavation. This observation suggests that the stain may not be an alteration product of an original material, but rather the result of burial. Lighter patches, probably where post-exavation losses occurred, can be seen scattered around the surface; Figure 5b shows a detail of one such light patch.

In some areas, a thin layer (c.20–30 μm thick) of calcium carbonate, with a composition similar to that used in the flesh tones, was applied on top of the flesh tones, probably as heightening.

Figure 6a shows a detail of the flesh tones on the proper right cheek (sample M01), where the pink and red particles can be seen under a layer of clay-based burial accretions. Figure 6b shows the dark field photomicrograph of the polished cross-section for sample M01, while Figure 6c is the UIL image of the same cross-section. The two layers – flesh tones and the heightening – are clear in both images, with scattered red, yellow and black particles homogeneously dispersed throughout the flesh tone layer. No Egyptian blue can be seen in this section, but its presence was detected in the flesh tones using VIL imaging, Figure 4c. The use of Egyptian blue in the flesh tones – probably to achieve a more lifelike appearance – has recently been observed in other Graeco-Roman artefacts in the British Museum such as the wall painting fragments from the tomb of the Nasonii and certain second century AD funerary portraits from Egypt [18]. As a comparison, an example of the use of Egyptian blue in one of these funerary portraits is...
briefly illustrated here. Figure 7a shows the visible image of a portrait of a man (1994,0521.6: EA 74708) [19]. Of mature years, he is depicted without clothing against a light grey background. The short black hair and full-face composition are typical of Trajanic portraiture (AD 98–117). Figure 7b is the corresponding VIL image of the portrait in which it is clear that Egyptian blue was used in the flesh tones, in the whites of the eyes (see Eyes below) and on the lower lip of the figure.

Individual particles of calcite are difficult to locate in the cross-section from the Treu Head in Figure 6b because of the high translucency of the mineral. However, this property also has its advantages, as it allows coloured particles to be seen through the calcite grains, blending their red, yellow, black and blue colours together to create a uniform naturalistic pink tone. The distribution of the single particles of calcite is clearer in the UIL image (Figure 6c); although there is no significant luminescence from the cross-section, the strong quenching properties of iron-based pigments and the strong absorption properties of carbon black make the particles easier to differentiate.

The pigment composition found on the lobe of fragment B is very similar to that of the Treu Head (see Table 1), suggesting it belongs to this sculpture.
Although the paint used for the flesh tones of the sculpture was described at the time of its discovery as ‘oily’, no organic constituents could be detected by GC-MS above background levels found in laboratory blanks. Lactic, acetic and succinic acids were the only constituents seen and these only at an intensity comparable to that of contamination. No constituents that could be linked to a binding medium of proteinaceous, lipid or resin types were detected and gum-based media would not have been detected by the analytical method used. Although the use of gum cannot be excluded, the absence of binding medium may be due to poor preservation or, very likely, the minute sample size available for analysis.

**Mouth, nostrils and lachrymal ducts**

Certain recesses and anatomical features, such as the inner part of the mouth, the nostrils and the lachrymal ducts, were coloured using a bright pink organic colourant, presumed to be present in the form of a lake pigment (see below). The lake was used as a highly translucent layer (c.5–20 μm thick) on top of the flesh tones. Under excitation from ultraviolet or visible radiation with a shorter wavelength, the areas painted with this pink lake show a strong pink–orange fluorescence with an emission centred at c.608 nm. The distribution of the fluorescence emission was mapped using excitation radiation with a wavelength of 365 nm to produce the UIL image in Figure 4b. This pattern of use on the inside of the mouth and nostrils was also reported in the case of a marble bust of the emperor Caligula in the Ny Carlsberg Glyptotek in Copenhagen [20]. Figures 8a and 8b show the mouth of the sculpture in visible and UIL images respectively. The scattered surviving traces of the organic lake pigment can be observed along the length of the opening. Figures 8c and 8d show micrographs (×20 and ×100 respectively) of a detail at the extreme left of the mouth. A sample (M02) was taken from the particle of pink lake seen at the bottom right of Figure 8d and indicated by an arrow on Figure 8c.

Sample M02 is seen as an unmounted fragment in Figure 9a, while Figures 9b and 9c illustrate the visible and UIL images of the polished cross-section of the same sample and suggest that the strongly fluorescent pink outermost layer was painted using the organic lake. The same cross-section is seen in Figure 9d as a backscattered electron image in the SEM and Figures 9e–9i show the element maps for calcium, iron, silicon, aluminium and magnesium respectively. The lake layer is seen to consist mainly of aluminium-, silicon- and magnesium-containing particles.

HPLC-PDA analyses showed that the pink pigment contained pseudopurpurin and some purpurin, suggesting that a pigment prepared from an organic dyestuff had been used. The colourant contained no alizarin and, by comparison with published results [21, 22], the dyestuff composition is consistent with that prepared from *Rubia peregrina* L. However, the identification of the dyestuff source is not unequivocal and madder from another *Rubia* species may be present [23].

To prepare a pigment, the colourant would have been extracted from the plant source and combined with an inorganic substrate to form an insoluble lake pigment [24]. There is a homogeneous distribution of aluminium
**Figure 7.** Trajanic funerary portrait of a man (1994.0521.6: EA 74708): (a) visible; and (b) VIL image showing the distribution of Egyptian blue as 'bright' white areas in the flesh tones, the whites of the eyes and the lower lip.

**Figure 8.** Details of the mouth showing the pink organic lake remaining inside: (a) visible image; (b) corresponding UIL image, showing orange fluorescence from the pink organic colourant; (c) micrograph (×20) of the proper right corner of the mouth with the site from which sample M02 was taken marked with an arrow; and (d) micrograph (×100) of the corner of the mouth showing the carbon black shadows that were applied at each side of the mouth.
within the coloured layer, associated with the substrate, Figure 9h. Small amounts of silicon and magnesium were also detected, but the distribution is less homogeneous, Figure 9g. This may indicate the deliberate addition of a clay to the solution of dyestuff extract to precipitate the colourant, or perhaps the addition of a clay to the resulting pigment or paint. The presence of aluminium in the substrate could result from the use of a ground alumina mineral (possibly bauxite) or addition of an aluminium salt such as alum. Although potash alum (potassium aluminium sulphate: $\text{Al}_2(\text{SO}_4)_3\cdot\text{K}_2\text{SO}_4\cdot12\text{H}_2\text{O}$) is the most common form of alum, it is one of a number of related sulphates used since antiquity [20, 25, 26].

The lake layer also contains gypsum, which has been found previously as a substrate for madder lakes [27, 28]. However, the concentrations of calcium and sulphur in the lake layer are low in this case, suggesting that here gypsum is a minor component, probably added during lake preparation or subsequently. Alternatively, gypsum may also have been present as an impurity in the substrate onto which the colourant was adsorbed or have been formed in small quantities during the precipitation of the colourant.

A red area on the lips was identified as hematite (sample M15, see Table 1) and the shadows added at each side of the mouth (seen as black areas in Figures 8c and 8d) seem likely to have been applied using carbon black, a typical practice for representing shadows around the mouth that can be seen in several Graeco-Roman funerary portraits [19].

Eyes

The eyes of the Treu Head received a great deal of attention by the artist, Figure 10a. The eyeballs were painted using a thickly applied mixture of lead white and Egyptian blue over a carbon black underdrawing. Details such as the lachrymal ducts were painted using an organic lake, which demonstrates the characteristic pink–orange luminescence noted earlier, see Figure 10b. A yellow–orange luminescence, different to that produced by this pink colourant, can be seen in some areas around the eyes and is also present around the mouth of the sculpture, Figure 4b. Unfortunately, the material causing this luminescence was too thinly applied to be sampled and could not therefore be identified.

A high concentration of particles of Egyptian blue in both eyes and eyebrows can be seen in the VIL images, Figures 4c and 10c. Single particles of Egyptian blue mixed with lead white can be seen under magnification ($\times$200) in Figure 10d and in the unmounted sample M05.
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Figure 10. Detail of the proper right eye showing the use of Egyptian blue and other pigments; (a) visible image; (b) corresponding UIL image showing fluorescence from a pink organic colourant on the lachrymal duct; (c) corresponding VIL image showing the presence of particles of Egyptian blue in the white of the eye; (d) micrograph of the area marked by the rectangle in (a), showing particles of Egyptian blue mixed with a white pigment (lead white) and the point (indicated by an arrow) from which sample M05 was taken; (e) unmounted sample M05; and (f) polished cross-section imaged under dark field illumination at $\times200$ showing particles of Egyptian blue in a lead white matrix above a carbon-based underdrawing.

(Figure 10e), taken from the site marked with an arrow in Figure 10d. The cross-section made from sample M05 (Figure 10f) shows the black underdrawing – also visible in the unmounted sample – and the thick layer of lead white. In this particular cross-section, particles of Egyptian blue are not visible. Only a few particles of the blue pigment were mixed with lead white, probably to achieve a 'brighter' white, as pure lead white can give a cream colour rather than a 'pure' white; the addition of even small amounts of blue reduces this yellowish appearance. The highly sophisticated practice of mixing a small amount of blue into the flesh tones – and particularly in the white of the eyeballs – was apparently common in the ancient world. Since the new VIL imaging technique was developed, similar examples have been documented in, among others, a sculpted head from the Classical Temple of Artemis at Ephesus and in funerary portraits, for example that shown in Figure 7b [17, 18].
The black eyebrow, pupil, iris and perimeter of the eye described by Treu probably correspond to exposed carbon black underdrawing. Traces of red paint, containing a mixture of hematite and vermilion or cinnabar (HgS) are present on the upper eyelid of the proper right eye, Figures 11a–11c. These traces, corresponding to the lines clearly visible in the historic watercolour (Figure 3a), represent a shadow between the eye and the eyebrow, commonly observed on funerary portraits [19]. Traces of the black underdrawing around the eyes and the eyebrow can be seen more clearly in Figure 11d.

Hair

As described by Treu, the hair of the sculpture was painted using yellow and red ochre. The majority of the hair seems to have been painted yellow, as noted by Treu, while red ochre was probably used as a shadow. Figure 12 shows a number of micrographs of details of the yellow and red pigments used in the hair. The pigment composition found on fragment A, illustrated in Figure 12d, is very similar to that on the Treu Head itself, see Table 1. In addition, small amounts of Egyptian blue – probably due to the use of a ‘dirty’ brush – were detected in the hair of the sculpture (Figure 4c) and on both fragments, suggesting the latter are original and belong to the sculpture.

CONCLUSIONS

The Treu Head was painted using a sophisticated technique that included the use of high quality pigments for significant areas, e.g. lead white in the eyeballs, vermilion in the eyelids and a pink organic lake in the lachrymal ducts, nostrils and mouth. Complex mixtures of pigments, including lead white and Egyptian blue in the eyeballs and a combination of calcite, red ochre, yellow ochre, carbon black and Egyptian blue for the flesh tones, were used to achieve refined tonal effects. All the pigments found on the sculpture are consistent with the Graeco–Roman period, including those on fragments A and B. Importantly, the ancient practice of mixing Egyptian blue with white to depict the eyeballs and
the inclusion of Egyptian blue in flesh tones was not known to modern archaeologists or artists until its recent publication [17]. The scant, almost invisible, amounts of Egyptian blue and pink organic lake that survive are unlikely to be the result of a well-executed forgery, but strongly support the authenticity of the sculpture. In addition, according to Riederer, the ‘rediscovery’ of Egyptian blue and its manufacture on an industrial scale was announced at the Chicago World Fair in 1893 [16], well after the discovery of the head, its association with Martinetti and Helbig and its acquisition by the British Museum in the early 1880s.

The results obtained in this study are not sufficient to determine fully the exact sequence in which the pigments were applied and the scarcity of the surviving pigment layers does not allow a complete reconstruction of the painting technique. The superposition of paint layers in certain areas suggests that the artist worked in the same areas more than once; for example yellow paint depicting hair was found both above and beneath the flesh tones. However, a general sequence for the execution of the painted sculpture can be deduced. A carbon black underdrawing (now visible only in the eyes) was applied directly onto the stone surface followed by the application of the flesh tones. The latter were subsequently modelled using white highlights (e.g. calcite on the cheeks and neck) and black shadows (carbon black at the sides of the mouth). The eyes were executed on top of the carbon underdrawing using lead white mixed with Egyptian blue. The lachrymal ducts were painted using a pink organic lake pigment, which was also used in the mouth and nostrils, and a mixture of red ochre and vermilion was used to depict the shadows between the eyelid and the eyebrow. Finally, the hair of the figure was painted using yellow ochre and modelled with red ochre.

The Treu Head can, therefore, be re-established as a significant example of the sophistication and great technical skill involved in the production of Roman sculpture. It demonstrates that the colouring of these objects included subtle tonal variations comparable in effect to the striking appearance of contemporary funerary portraits. In this way, the Treu Head belies traditional art historical beliefs that postulated a steady decline in artistic ability and technical competence from the heyday of such fourth-century BC Greek artists as Praxiteles and Nikias down to the Roman period.
EXPERIMENTAL APPENDIX

**In situ microscopy**

A Keyence VHX-600 microscope equipped with a VH-Z20R lens (×20–200 magnification) was used to image details of the sculpture.

**Photo-induced luminescence imaging**

All images were taken using a Canon 40D camera body modified by removing the IR-blocking filter. For UIL imaging the excitation was provided by two Wood radiation sources (365 nm) filtered with a Schott DUG11 interference bandpass filter (280–400 nm) and the camera was fitted with a Schott KV418 cut-on filter (50% transmission at c.418 nm) and an IDAS-UIBAR bandpass filter (400–700 nm) [29]. For VIL imaging the excitation was provided by red LED light sources (emission centred at 629 nm) and the camera was fitted with a Schott RG830 cut-on filter (50% transmittance at c.830 nm). In the VIL images, materials that emit IR radiation are recognizable as ‘bright white’ areas in the image [17, 30].

**Raman spectroscopy**

Raman spectroscopy was carried out with a Jobin Yvon LabRam Infinity spectrometer using green (532 nm) and near IR (785 nm) lasers with maximum powers of 2.4 and 4 mW at the sample respectively, a liquid nitrogen cooled CCD detector and an Olympus microscope system [31].

**FTIR**

FTIR spectroscopy was performed on a Nicolet 6700 with Continuum IR microscope equipped with MCT/A detectors. The samples were analysed in transmission mode, flattened in a diamond micro-compression cell. Maximum area of analysis: 100 × 100 μm. The spectra were acquired over a range of 4000–650 cm⁻¹ using 32 scans at a resolution of 4 cm⁻¹ and automatic gain.

**SEM-EDX**

Scanning electron microscopy (SEM) using a Hitachi S-3700N variable pressure SEM (20 kV, 50 Pa) with micro-analysis was used to analyse uncoated cross-sections for elemental composition. Imaging was carried out using a Centaurus backscattered electron detector.

**HPLC-PDA**

A sample of a few micrograms was extracted in 20 μL of a 5% boron trifluoride/methanol solution. Analyses were carried out using a Hewlett-Packard (now Agilent) HPLC HP1100 system comprising a vacuum solvent degasser, a binary pump, autosampler and column oven. The column used for the separation was a Luna C18(2) 100 Å, 150 × 2.0 mm, with 3 μm particle size (Phenomenex) stabilized at 40°C. Detection was performed using an HP1100 DAD with a 500 nL flow cell and using detection wavelengths from 200 to 700 nm [32].

Two solvents were used: (A) 99.9% water/0.1% trifluoroacetic acid (v/v); and (B) 94.9% acetonitrile/5% methanol/0.1% trifluoroacetic acid (v/v/v). The elution programme was a first gradient from 90% A/10% B to 60% A/40% B over a period of 60 minutes followed by a second linear gradient to 100% B after a further 30 minutes. After 10 minutes elution with pure B, a third linear gradient was used to return to the initial composition (90% A/10% B). The flow rate was fixed throughout at 0.2 mL per/minute creating a system back-pressure of 128 bars (12.8 MPa).

**GC-MS**

Each sample was hydrolyzed with 100 μL of 6M hydrochloric acid by heating overnight at 105°C, then dried under nitrogen. The samples were dried again after agitation with 100 μL of deionized water and 100 μL of denatured ethanol. Prior to analysis the samples were derivatized with N-(tert-butyldimethylsilyl)-N-methyltrifluoroacetamide (MTBSTFA) to which 1% tert-butyldimethylsilyl chloride (TBDMCS) was added. The analyses were performed on an Agilent 6890N gas chromatograph (GC) coupled to an Agilent 5973N mass spectrometer (MS). Injection was in splitless mode at 300°C and 10 psi (70 kPa), with a purge time of 0.8 minutes. An Agilent HP5-MS column (30 m × 0.25 mm, 0.25 μm film thickness) fitted with a 1 m × 0.53 mm retention gap was used. The carrier gas was helium in constant flow mode at 1.5 mL per minute. After a one minute isothermal hold at 80°C the oven was temperature programmed to 300°C at 20°C per minute, with the final temperature held for three minutes. The MS interface temperature was 300°C. Acquisition was in scan mode (29–650 amu per second) after a solvent delay of five minutes. Chemstation software (G1701DA) was used for system control and data collection/manipulation. Mass spectral data were interpreted manually with the aid of the NIST/EPA/NIH Mass Spectral Library version 2.0 and comparison with published data [32].
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NOTES

1. Minutes from the then Department of Greek and Roman Antiquities for 23 February 1884 record Newton’s request for leave to go to Rome and view antiquities from the collection of the late Alessandro Castellani prior to their sale in Paris and on 14 June 1884 report “… a female marble head, lately discovered, in excellent condition … The head is of special value from the remains of the original ground of colour which can be traced in many parts of its surface.”

2. An example of one of Helbig and Martinetti’s alleged forgeries is given by Guarducci [13, 14], while the case for Helbig is made by Lehmann [15].