Scientific aspects of ancient faces: mummy portraits from Egypt

CAROLINE CARTWRIGHT AND ANDREW MIDDLETON

Summary Mummy portraits found in Roman Egypt represent a fusion between Egyptian religious rites, Roman artistic style and Greek cultural traditions. They are considered to be the only survivors of the renowned Graeco-Roman tradition of painting using tempera or wax (encaustic). Revealing the full spectrum of northern Mediterranean influence on these mummy portraits has fascinated scholars for a considerable period of time. Many of the portraits show overt Graeco-Roman influences on the way in which the individual’s costume, hairstyle or jewellery has been depicted, as well as in their physiognomic traits. However, such influence is far more extensive than artistic style alone; scientific investigation at the British Museum has revealed that much of the wood selected for the mummy portraits is not local Egyptian timber but northern Mediterranean and is heavily reliant on lime wood. Some of the pigments identified e.g. red lead (minium, lead tetraoxide) were probably not used in Egypt prior to the Roman period. This contribution provides an updated summary of the scientific results of wood and pigment research, not only from the mummy portraits in the BM collections, but also from the wood samples from collaborating museums, galleries and academic institutions. Special mention is made of the analysis of pigments from the six famous paint saucers excavated by Petrie at Hawara. The scientific results have shed new light on the technology, composition and history of these extraordinary ancient faces, popular from the first century AD for 200 years.

INTRODUCTION

In 1995 the British Museum (BM) organized a major colloquium on burial customs in Roman Egypt, which was followed by a special exhibition Ancient Faces that brought together mummy portraits from many institutions around the world [1, 2]. These portraits are well known to represent in Roman Egypt a fusion between Egyptian religious rites, Roman artistic style and Greek cultural traditions, Figure 1. Appearing in Egypt in the first century AD, mummy portraits remained in favour there for about 200 years. The exhibition triggered a programme of scientific research at the BM, which not only resulted in publications directly linked to the event [3, 4], but which continued to attract collaborative investigation thereafter [5, 6]. This contribution provides an updated summary of wood identifications conducted at the BM on samples from the mummy portraits that were offered for study by collaborating museums and galleries as a consequence of the exhibition. It also characterizes pigments identified on four of the BM mummy portraits, as well as providing pigment analysis for six paint saucers (Figure 2) excavated by W.M. Flinders Petrie at Hawara in the Faiyum region of Egypt.

METHODOLOGY

Techniques of wood identification

Standard techniques of wood identification and terminology as set out by the International Association of Wood Anatomists (IAWA) are usually adopted for the identification of modern wood [7, 8]. For each sample, the key features are compared with reference collection specimens and textual descriptions [9–11]. This IAWA methodology can often be applied to archaeological or historical wood, providing it is modified to accommodate the effects of the conditions of preservation such as charring, desiccation or waterlogging [12]. In all cases, each sample needs to be prepared to expose transverse, radial longitudinal and tangential longitudinal sections or surfaces for identification (TS, RLS and TLS respectively). For modern and certain types of archaeological wood, thin sections of approximately 12–14 microns (micrometers) are cut on a base-sledge (or rotary) microtome, mounted on glass microscope slides and examined by transmitted light microscopy. A variation on these standard techniques was applied to the mummy portraits on account of the extremely small sample size permitted.
from such thin boards of wood. In order for wood identification to be carried out successfully, sampling had to take place in an unobtrusive area that was free from pigments, binding media or any conservation consolidant, so that the fine details of the cellular structure remained clear. It was not possible to remove the standard sample size necessary for modern wood thin sectioning, $25 \times 25 \times 50$ mm. The tiny samples that could be taken were treated as though they were charcoal fragments (see [12] for the full methodology) and were examined mainly using reflected light microscopy with the selective use of the scanning electron microscope (SEM) for fine resolution and high magnification of crucial
diagnostic features, Figure 3. Charcoal is fractured by hand to expose fresh TS, RLS and TLS for examination. Fracturing rather than cutting the charcoal fragment exposes the clearest view of the cellular structure, as cutting with a scalpel or microtome blade creates fine debris that penetrates and fills the cells. Fracturing was also successful for the mummy portrait wood samples.

Pigment analysis

The paintings (and also the paint residues in the paint saucers) were examined with the aid of a hand lens and a binocular microscope. In addition, the painted and painted surfaces were observed under ultraviolet (UV) light for any visible fluorescence. On the basis of these observations, qualitative chemical analyses of selected areas were made using air-path X-ray fluorescence (XRF). This technique permitted non-invasive analysis to be carried out on areas that were typically c.2 mm². As the technique is non-invasive and relatively rapid to perform, it was possible to 'survey' numerous points on the paintings. This elemental information was supplemented by the analysis of very small samples (considerably smaller than a pinhead) removed from areas that already exhibited some damage. These samples were analysed using a combination of optical microscopy, X-ray powder diffraction (XRD) using Debye-Scherrer cameras and, in a few cases, examination and analysis in a SEM equipped with an energy dispersive X-ray (EDX) analyser.

At the time that these analyses were carried out, Raman spectroscopy was not available to the authors, but recent experience has shown that it offers great potential for non-invasive (or minimally invasive) analysis of painting pigments, either in situ or from extremely small samples [13]. It would now be the primary technique of choice for the identification of the paint pigments, coupled with non-invasive XRF analysis.

RESULTS

Wood

The wood analyses published in 1997 were carried out on 82 mummy portraits from the following collections: British Museum (31 examples); the Petrie Museum of Egyptian Archaeology, University College London (32 examples); the Ashmolean Museum, University of Oxford (13 examples); the Fitzwilliam Museum, University of Cambridge (3 examples); and the Myers Collection, Eton College Museum (3 examples) [3, 4].

These results, which are summarized in Table 1, show the predominant selection of European woods: 63 mummy portraits consist of Tilia sp. (lime wood), eight are Quercus sp. (oak) and two are the softwood Abies sp. (fir). The wood from only one tree indigenous to Egypt was used: Ficus sycomorus, the sycomore fig, which featured in eight portraits. One mummy portrait was classified as ‘indeterminate’, as its wood could not be identified owing to its poor condition.

The second tranche of wood identifications reported here was carried out on samples from the following mummy portraits:

- 1902.70: Edinburgh, Royal Museum, National Museums Scotland, portrait of a woman in tempera on wood, about AD 200, 42.5 (height: h) × 23 (width: w) cm, excavated at er-Rubayat with 1902.4 by Grenfell and Hunt in 1901 [2].
- 1902.4: Dublin, National Museum of Ireland, portrait of a young boy in tempera on wood, about AD 200, 26 (h) × 14.5 (w) cm, excavated at er-Rubayat with 1902.70 by Grenfell and Hunt in 1901 [2].
- 326: Norwich, University of East Anglia, Robert and Lisa Sainsbury Collection, Sainsbury Centre for Visual Arts, portrait of a boy in encaustic on wood, about AD 90–120, 43.2 (h) × 24.1 (w) cm, excavated at Hawara by Petrie in 1888 [2].
- 4946: London, Freud Museum, portrait of a middle-aged man in tempera on wood, about AD 220–240, 36 (h) × 24 (w) cm, said to be from er-Rubayat [2].
- 4947: London, Freud Museum, portrait of a middle-aged man in tempera on wood, about AD 140–160, 35.6 (h) × 19.1 (w) cm, said to be from er-Rubayat [2].
- 1545.9: Salford, City Art Gallery, portrait of a boy in encaustic on wood with gilded stucco, about AD 130–160, panel: 39.4 (h) × 24 (w) cm; portrait: 37.5 (h) × 23.2 (w) cm, excavated at Hawara by Petrie in 1888 [2].
- X 300: Vienna, Kunsthistorisches Museum, portrait of an elderly bearded man in tempera on wood, about AD 100–140, 33.2 (h) × 22 (w) cm at base; 11.5 (w) cm at top, said to be from er-Rubayat [2].
- X 301: Vienna, Kunsthistorisches Museum, portrait of a woman in encaustic on wood, about AD 170–190, 36.9 (h) × 21.7 (w) cm, said to be from er-Rubayat [2].
- 129 (Mp SS 2/6): Stuttgart, Landesmuseum Württemberg, Antikensammlung, portrait of a man in encaustic on wood, mid-first century AD, 35.5 (h) × 18 (w) cm, provenance unknown [14].
- 130 (Mp SS 2/7): Stuttgart, Landesmuseum Württemberg, Antikensammlung, portrait of a woman in encaustic on wood, time of Caligula or early Claudian, 34 (h) × 20.2 (w) cm, provenance unknown [14].

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of samples identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilia</td>
<td>63</td>
</tr>
<tr>
<td>Quercus</td>
<td>8</td>
</tr>
<tr>
<td>Ficus</td>
<td>8</td>
</tr>
<tr>
<td>Abies</td>
<td>2</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE 1. Summary of 1997 mummy portrait wood identification results
• 131 (Mp SS 2/8): Stuttgart, Landesmuseum Württemberg, Antikensammlung, inscribed portrait of Eirene in encaustic on wood with added gold leaf, about AD 100–120, 37 (h) × 22 (w) cm, provenance unknown [2, 14].
• 135 (Mp SS 2/12): Stuttgart, Landesmuseum Württemberg, Antikensammlung, fragment of a portrait of a woman in encaustic on wood, Hadrianan, 28 cm wide, provenance unknown [14].

Samples 326, 4947, 1954.9, 129 (Mp SS 2/6), 130 (Mp SS 2/7), 131 (Mp SS 2/8) and 135 (Mp SS 2/12) displayed some or all of the anatomical characteristics listed in the appendix, including the presence of conspicuous spiral thickening in both narrow and wide vessel elements, Figure 3. This combination of features allows these mummy portrait wood samples to be identified as the hardwood Tilia sp., lime. The genus Tilia contains a number of species but these cannot be differentiated on the basis of their wood anatomy. In the original study Tilia was specified as T. europaea [3], but subsequent taxonomic revision recommends that the ‘europaea’ designation should only be used for hybrid lime trees, i.e. Tilia × europaea. As a consequence, the Tilia in the present study has been identified to genus level only, i.e. Tilia sp. but it is likely that the species used for the mummy portraits would be among the following European taxa: T. cordata, T. platyphyllos, T. parvifolia, T. vulgaris and possibly even T. × europaea (depending on the date when lime trees first started to hybridize).

Samples 4946, X 300 and X 301 displayed some or all of the characteristics listed in the appendix. This combination of features allows sample 4946 and the samples from the Kunsthistorisches Museum, Vienna, to be identified as the indigenous Egyptian species, Ficus sycomorus, sycomore fig. As noted by Neumann et al., the presence of very broad rays and the common occurrence of lacticifers are particularly diagnostic of this taxon in trunk wood [15].

Sample 1902.70, National Museums Scotland, portrait of a woman in tempera (er-Rubayat) and sample 1902.4, National Museum of Ireland, portrait of a young boy in tempera (er-Rubayat) displayed the combination of anatomical features listed in the appendix, which allowed the wood in these mummy portraits to be identified as the softwood yew (Taxus baccata). The wood of yew is hard, heavy and dense but also elastic, which makes it highly suitable for archery bows. It is also used for carved decorative objects as it can be polished to a high finish.

Within the added taxa of the latest study the summary of all 94 mummy portrait wood identifications carried out to date at the BM can be seen in Table 3.

### Pigments

The results of the analyses of the pigments in the four paintings from Hawara and er-Rubayat are summarized in Tables 4 and 5. For those pigments characterized by XRD, the diffraction patterns were identified by reference to the International Centre for Diffraction Data (ICDD) database. The identification of madder was based mainly upon its frequent use, distinctive colour and characteristic bright orange fluorescence under UV light. A sample of the pink pigment from one of the saucers excavated at Hawara that showed such fluorescence was confirmed by high performance liquid chromatography (HPLC) to contain dyestuff components associated with madder, although it has not yet been possible to confirm which Rubia species was used. The high pseudopurpurin content of the dyestuff is consistent with the high degree of fluorescence noted for the pigment.

As mentioned above, when this study was conducted Raman spectroscopy, which offers the potential to identify carbon black, was not available to the authors, so the identification was instead based on the lack of evidence for any other black pigment (e.g. those based on iron or manganese oxides). Recent analysis of the black pigment in the portrait of a woman (1931,0711.1: EA 63394) by Raman spectroscopy has confirmed the presence of carbon black.

In addition to the applied paints, gold foil was used to depict the jewellery worn by the subject of 1994,0521.15 (EA 74717), from Hawara. The observations showed that the techniques used for the two paintings examined from Hawara and those from

---

**Table 2. Summary of the previously unpublished mummy portrait wood identification results carried out at the BM**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Taxus baccata (yew)</th>
<th>Tilia sp. (lime)</th>
<th>Ficus sycomorus (sycomore fig)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1902.70</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1902.4</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>326</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4946</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1954.9</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X 300</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X 301</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>129 (Mp SS 2/6)</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130 (Mp SS 2/7)</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>131 (Mp SS 2/8)</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>135 (Mp SS 2/12)</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 3. Summary of all 94 mummy portrait wood identification results carried out at the BM (to date)**

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of samples identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilia</td>
<td>70</td>
</tr>
<tr>
<td>Quercus</td>
<td>8</td>
</tr>
<tr>
<td>Ficus</td>
<td>11</td>
</tr>
<tr>
<td>Taxus</td>
<td>2</td>
</tr>
<tr>
<td>Abies</td>
<td>2</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>1</td>
</tr>
</tbody>
</table>
er-Rubayat were different: those from Hawara were painted onto lead white grounds, whilst those from er-Rubayat had gypsum grounds. In addition, the er-Rubayat paintings appeared to have been painted using an 'encaustic' technique, with the paint held in a wax medium. However, these differences, based upon only four paintings may be fortuitous and reflect only the diversity of techniques used by individual painters of the Fayyum portraits [16, 17].

**DISCUSSION**

Mummy portraits are considered to be the only survivors of the renowned Graeco-Roman tradition of painting using tempera or wax (encaustic). Revealing how fully northern Mediterranean tradition and practice influenced these mummy portraits has long fascinated scholars. Many of the portraits show overt Graeco-Roman influences on the way in which the individual’s costume, hairstyle or jewellery has been depicted, as well as in their physiognomic traits. However, such influence is far more extensive than artistic style alone; the first tranche of scientific investigation at the BM revealed that much of the wood selected for the mummy portraits is not local Egyptian timber but northern Mediterranean and is heavily reliant on lime wood, Table 1 [1, 2]. The latest results (detailed above and in Tables 2 and 3) confirm the popularity of lime wood, but why was this wood so favoured?

The genus *Tilia* has 35 species indigenous to Eurasia (31) and North America (4), but is not recorded as being indigenous to Egypt at present, or in the recent past [18, 19]. All the *Tilia* species are virtually indistinguishable on the basis of their microscopic wood anatomy, so if they are attributed to a species in a wood anatomical study, it is likely to be on the principle of feasible or known geographical distributions of particular species. In Europe, the most frequent vernacular names for *Tilia* include: common lime, English lime, European small-leaf lime, European large-leaf lime, lime, limetree, linden, lind, linde, tilieul and tiglio. *Tilia* is commonly known in North America as basswood, bass and bast-tree. Lime's wide distribution across Europe makes it a ready source of wood. As *Tilia* often reaches heights of 30 m (100 feet), with a diameter of 1.3 m (4 feet) and with a clear bole for 15 m (50 feet), it offers an attractive source of straight-grown timber for boards and planks, as well as turnery. The sapwood of *Tilia* is indistinguishable from its white to pale yellow heartwood, whose fine, even texture turns pale brown on exposure to air. Lengths of *Tilia* timber benefit from being seasoned before use in order to maximize its mechanical and working properties and minimize susceptibility to insect attack, permeability or reduced durability. In the context of mummy portrait carpentry it is significant that *Tilia* wood performs satisfactorily when sawn or cross-cut, and well when glued, stained or polished. *Tilia* was clearly a very useful timber for creating the fine, thin light boards of the mummy portraits. The radial longitudinal plane of lime wood was most often selected for the prepared surface onto which the ground and paint layers were applied. Figure 4 shows the reasons why this was an informed choice: the even nature of the ray parenchyma cells in their characteristic brick-like arrangement oriented at right angles to the equally evenly distributed vessels, fibres and axial parenchyma cells results in a highly consistent and uniform cellular structure which will perform predictably and reliably when sawn, split or carved. Although the brick-like ray parenchyma cells appear horizontal in Figure 4, their orientation in the tree is parallel to the axis of the trunk or limb, so the terms ‘axial’, ‘radial’ and ‘tangential’ are more meaningful than horizontal or vertical.
It is clear that the properties of lime wood are ideal for portrait boards and that *Tilia* species are readily available in Europe including Greece and Italy, but are these the main reasons for preferring *Tilia* above other woods for mummy portraits? This may be the case, but the story may be more complicated and it is possible that further consideration should be given to the likelihood of discrete centres of production of mummy portraits within which the craftsmen preferred specific woods. There are hints of that possibility in this study (see below), to which should be added the observation that very different methods were used for the painted surfaces, including encaustic, tempera (or mixed), and the application of gold leaf for decorative emphasis [20, 21]. It may not simply be a matter of some families being able to afford more expensive mummy portraits, but that certain workshops had their own distinctive preferences for wood type, method of painting, style and execution, from which their customers might choose.

The finished mummy portrait, which would have been roughly life size, was placed on the outside of the cartonnage coffin over the head of the individual and was often carefully wrapped into the mummy bandages, Figure 1 [1, 2]. Most mummy portraits that have survived have unfortunately been separated from the coffins to which they were attached, so that the identities of the subjects are rarely known. Some can be dated quite accurately on the basis of their hairstyles, jewellery and garments, but the question of whether each portrait actually depicts the mummified individual as he or she appeared during life has generated much debate. Computed tomography (CT) scans of the mummified bodies, combined with forensic facial reconstruction techniques [1], have shown that in some cases there is a remarkable similarity between the facial features depicted on the portrait and those of the head of the mummy inside the coffin; others show some artistic licence. It has been suggested that it is possible to identify members of a family by their physical similarities [2], but Prag urges caution when considering similarities, familial or otherwise, as not all artists involved in producing the images were equally skilled, and there might be instances in which a more ‘production line’ approach may have been adopted for dress, hairstyle and jewellery for people in the same social or cultural group [21]. This might have resulted in the portraiture occasionally being more generic in nature than specifically representative of an individual.

Picking up the various threads of theory and argument outlined above, and bringing the current wood identification results to the fore, a case can be made for suggesting both the specialist workshop and the verisimilitude of family depictions. In 1901 Grenfell and Hunt retrieved two mummy portraits in tempera from er-Rubayat in close proximity to one another [2]. One (1902.70) depicts a woman whose jewellery, hairstyle and manner of dress suggest an Antonine or Severan date. The other (1902.4) is a young boy who bears such a striking physiognomic resemblance to the woman that it has been suggested that they are members of the same family, perhaps son and mother [2]. It seems more significant than just a coincidence that this present study has identified the wood from both these portraits as *yew*, a species not identified hitherto in the repertoire of mummy portrait woods [3]. More research and data will undoubtedly assist in a better understanding of the issues involved and permit, in due course, a synthetic overview.

There are several features of the painting technique and pigments used that set these portraits apart from the long tradition of painting in ancient Egypt, and serve to link them with the Graeco-Roman world. The use of wax in the paint layer of the two paintings from Hawara is perhaps the most obvious and, as noted above, this is a key characteristic of many of the Faiyum mummy portraits. The difficulties in determining the precise technique used to apply the wax-based paint layers was discussed briefly by Doxiadis [16]; difficulties that are compounded by Petrie’s re-melting of the wax and the application of paraffin wax to conserve the surface [2].

While several of the pigments used are typical of those used in ancient Egypt [22], others are unusual. Madder, present on paintings from Hawara and from er-Rubayat (Figure 5) and also identified in one of the paint saucers, was more commonly used in pre-Roman Egypt as a dye rather than as a pigment [23, 24]. The use of the man-made pigment lead white, found as the ground on the Hawara paintings (Figure 6), has not been reported from earlier periods. Neither has a second man-made pigment, red lead (minium), which was identified as the bright orange-red pigment in one of the paint saucers, been reported from ancient Egyptian contexts.

Thus, the palette of painting pigments, as well as the choice of painting techniques and the selection of woods for the portraits, provides further evidence for Graeco-Roman cultural influence at this period.
CONCLUSIONS

The scientific work carried out in 1997 on a large number of mummy portraits from the BM and other museums produced new data that enabled, for the first time, an appreciation and understanding of the importance of European woods, particularly lime, to these mummy portraits [3, 4]. The influence of Graeco-Roman tradition on the materials of the paintings (as well as its influence on the style and use of portraiture) is reflected also in the use of madder as a painting pigment and the introduction of artificial lead-based pigments, lead white and red lead. The continuing identification of mummy portrait wood (detailed above) reinforces the importance of lime wood, but also brings into sharp focus the interesting relationship between the selection of raw materials, artists’ workshops and stylistic depictions of related individuals in terms of generic versus specific portraiture.

Scientific research continues to shed new light on the technology, composition and history of the extraordinary ancient faces that are the mummy portraits.

APPENDIX

Characteristic anatomical features of Tilia sp. (lime)

Distinct growth ring boundaries marked by two to three rows of thick-walled, radially flattened cells and distinctly flaring rays; diffuse to semi ring porous wood; vessels in multiples – mostly radial rows but sometimes in clusters; angular or polygonal vessel outline; simple perforation plates; alternate intervessel pits; vessel-ray pits with distinct borders (similar to intervessel pits); crossfield pits much smaller than intervessel pits; conspicuous spiral thickenings present in narrow and wide vessel elements; very thin-walled fibres or fibres of medium wall thickness; libriform fibres non-septate; distinctly bordered fibre pits common in both radial and tangential walls; banded axial parenchyma present in short, uniseriate, oblique to tangential bands (often also marginal or terminal up to three cells wide); apotracheal axial parenchyma present in diffuse and diffuse-in-aggregates distribution; axial parenchyma as strands; multiseriate rays (one to five cells wide); rays of two distinct sizes; mainly homocellular rays with procumbent
cells; storiied structure present (axial parenchyma, vessel elements, some rays and some fibres).

**Characteristic anatomical features of Ficus sycomorus (sycomore fig)**

Growth ring boundaries indistinct; diffuse-porous wood; vessels in multiples – in short radial rows or small clusters; thin-walled tyloses present in some vessels; simple perforation plates; alternate non-vesured intervessel pits; vessel-ray pits simple or with reduced borders; some laticifers present; septate and non-septate fibres of medium wall thickness; fibre pits simple to finely bordered; multiserate rays of two distinct widths; some rays 4–10 seriate; some rays greater than 10 seriate; heterocellular rays with square and upright cells only on marginal rows; sheath cells present; banded axial parenchyma with most bands greater than four seriate; scanty paratracheal or vasicentric axial parenchyma; fusiform cells common; prismatic calcium oxalate crystals occasionally present in chambered cells in axial parenchyma and in ordinary cells in ray parenchyma; no silica crystals observed.

**Characteristic anatomical features of Taxus baccata (yew)**

Gradual transition from early wood to late wood; high density wood; resin canals absent; mostly uniseriate pits in the radial walls of tracheids; homocellular rays without ray tracheids; cupressoid ray pits in crossfield area; transversal walls of rays generally thick; tangential walls of ray cells thin; indentures present at junction of transverse and tangential walls; conspicuous spiral thickenings in longitudinal tracheids.

**ACKNOWLEDGEMENTS**

The authors are grateful to Sylvia Humphrey who carried out many of the XRD analyses, Janet Ambers and Satoko Tanimoto for Raman spectroscopy and Jo Kirby (National Gallery, London) and Catherine Higgitt for examining the madder sample from Hawara by HPLC.

**AUTHORS**

Caroline Cartwright (ccartwright@thebritishmuseum.ac.uk) is a materials scientist and Andrew Middleton (amiddleton@thebritishmuseum.ac.uk) an emeritus researcher in the Department of Conservation and Scientific Research at the British Museum.

**REFERENCES**


**NOTE**

1. The taxon *Ficus sycomorus* is rather confusing, and is frequently misspelled and misused: *Ficus sycomorus* is a fig tree from the Moraceae family and is totally unrelated to the European sycamore or field maple which belongs to the genus *Acer* from the Aceraceae family.