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New visions of a new world: the conservation and analysis of the John White watercolours

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Summary The exhibition *A New World: England's First View of America*, held at the British Museum in 2007, provided an opportunity for conservators and scientists to examine, analyse and treat a unique collection of drawings by the sixteenth-century English artist John White. Before entering the Museum's collection the drawings had suffered fire and water damage, which caused bleeding and offsetting of pigments. They were also fragile at the edges from earlier attachment to and removal from albums, and many had planar distortions. Scientists and conservators studied the drawings to learn more about how they were produced and the changes that have occurred over time. Scientific analysis using X-ray fluorescence and Raman spectrometry showed the palette to be typical of the period, with a heavy dependence on lead white and extensive use of ochres, vermilion, azurite, smalt, indigo and metallic gold and silver. Darkening of the lead white and tarnishing of the silver have altered the appearance of the drawings and digital techniques have been used to attempt to recreate their original appearance. Using microscopic examination conservators were able to confirm that remaining pigment layers in damaged areas were stable. Conservation treatments included repair of skinning and losses using a combination of Japanese and Western papers, flattening of planar distortions and remounting. These aimed to strengthen and stabilize the drawings and ensure their preservation for the future.

INTRODUCTION

The exhibition *A New World: England's First View of America*, held at the British Museum from March to June 2007, provided an ideal opportunity for conservators and scientists to gain new insights into a unique collection of drawings by the sixteenth-century English artist John White. These are some of the earliest English watercolours and are amongst the most iconic images in the Museum's collection of works on paper. Through examination and analysis it has been possible to learn more about how they were produced, the changes that have occurred over time, and also how best to conserve them and ensure their preservation for the future.

HISTORY OF THE DRAWINGS

Very little is known about the life of John White. An Elizabethan 'gentleman artist', he sailed on five voyages to the New World between 1584 and 1590, and was the first Englishman to record what he saw in what was later to be called America [1; pp. 11–38].

The sixteenth century was a period of great exploration and discovery. It was once thought that White had been on an earlier expedition in 1577 with Frobisher in an attempt to find the North West passage as there are several studies of Inuit among his drawings. However, the flora and fauna, coastal maps and plans, and depictions of indigenous people encountered in what is now North Carolina form the main body of extant work. White would have had a brief to record these new discoveries accurately. No work of other artist-explorers of the period survives apart from fragments or in prints made after drawings. Jacques le Moyne de Morgues, a Huguenot who worked in London in the 1580s, is one artist with whom it is known White exchanged ideas. Le Moyne had been to Florida on an earlier French expedition and copies of two of his depictions of Indians (now lost) are amongst White's work.

Seventy-five beautiful watercolours were bound in an album, perhaps intended for presentation to Walter Raleigh who, according to the ink inscription at the beginning of the series, was patron of the voyages. As well as studies from the New World there are also drawings of Eastern costumes and of imagined Picts, whose tattooed bodies White could be comparing to the similarly decorated native Algonquian Indians 'to showe how that the Inhabitants of the great Bretannie haue bin in times past as sauuage as those of Virginia' [2].

Nothing is known of the history of the drawings before they resurfaced in the 1788 catalogue of the London bookseller Thomas Payne the Elder as an album of '75 drawings coloured in the original binding. Folio – 14 gns' [1; p. 94]. This was bought by the Earl of Charlemont, a great collector and patron of the arts. It remained in Charlemont's library in Dublin until 1865 when it was sent for sale to Sotheby's in London. Unfortunately there was a fire in the warehouse adjacent to the auction rooms, and the spine of the album was scorched. Although the edges of the sheets were only slightly charred by the flames, the volume was saturated with water and lay under the pressure of other books for three weeks. This resulted in pigment transferring to the blank sheets interleaving the drawings, creating remarkably clear offsets, Figures 1a and 1b.

The damaged album was purchased by an American, Henry Stevens, who removed the drawings and trimmed the burnt edges before remounting them into a new volume. He did not retain the old album so it is not possible to say whether this was the original binding referred to in the 1788 sale catalogue or a later binding from the Earl's library. The sequence in which the watercolours were first arranged is unknown.

The new volume, and a second containing the interleaving sheets with the offset images, was acquired by the British Museum in 1866. Placed at first in the Grenville Library, they were transferred to the Department of Prints and Drawings in 1906. The drawings were subsequently removed from the album and housed in archival mounts, which have been stored in Solander boxes in the prints and drawings students' room.

It is worth noting that other versions of the drawings may have been made, perhaps for Elizabeth I or other wealthy patrons. Indeed, the British Museum owns an album that Sir Hans Sloane acquired from the descendants of John White in about 1715 (referred to hereafter as the Sloane album). It contains drawings that have traditionally been considered to be copies. However, the relationship of some of these drawings to John White's work is now being re-examined [1; p. 225]. Yet another set of White's drawings, now lost, are known through the engravings by Theodor de Bry in the 1590 edition of 'A briefe and true report of the new found land of Virginia', written by Thomas Harriott, who had travelled with White to America.

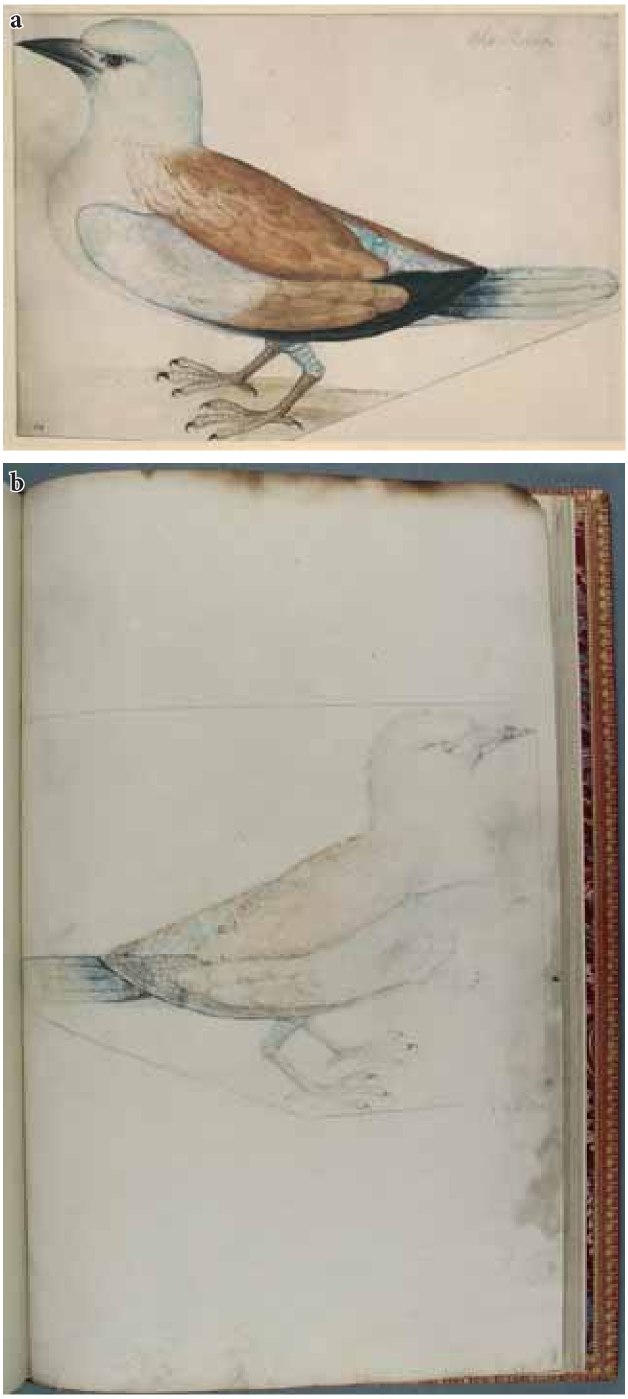

FIGURE 1. The *European roller* 1906,0509.1.64 (160 × 226 mm): (a) the original drawing (b) the offset image, showing how pigments have been transferred during wetting. Smoke damage is visible on both and the charring at the top of the offset image shows how close the drawings came to destruction

TECHNIQUE AND MATERIALS

White's work gives some indication that he had been trained as a 'limner', a term which in his day signified a painter in watercolours. He appears to have started by sketching outlines with 'black lead' (graphite) directly onto the paper, rather than onto a prepared ground, which was the more usual method of miniaturists or illuminators of the period. The outlines are not reinforced by pen and ink but delineated by applying washes of watercolour, building up detail with finer strokes of the brush, Figures 2a and 2b. Sixteenth- and seventeenth-century manuals describe brushes (known as 'pensils' at this time) made from the hair of small mammals

FIGURE 2. White's drawing technique can be clearly seen in this magnified detail of an *Uzbek man* 1906,0509.1.33 (243 × 139 mm), which shows (a) underdrawing in black lead overlaid with (b) fine watercolour brush strokes

such as stoat or squirrel, bound into a quill. This provided a soft texture combined with the resilience necessary for a good point [3]. White's use of the brush rather than the pen, and his broader freer brush strokes, set him apart from other artists, such as Hilliard, working in the same media.

Drawing with watercolour required a smooth, well-sized paper. At this period there were no specialist artists' papers and it was common practice to use paper produced for writing, which was sized with gelatine to prevent running of ink. White's paper has a watermark of a bunch of grapes (Figure 3), which shows a close resemblance to papers made in France in the 1580s [4]. This is not surprising since imports dominated the English market in fine white paper

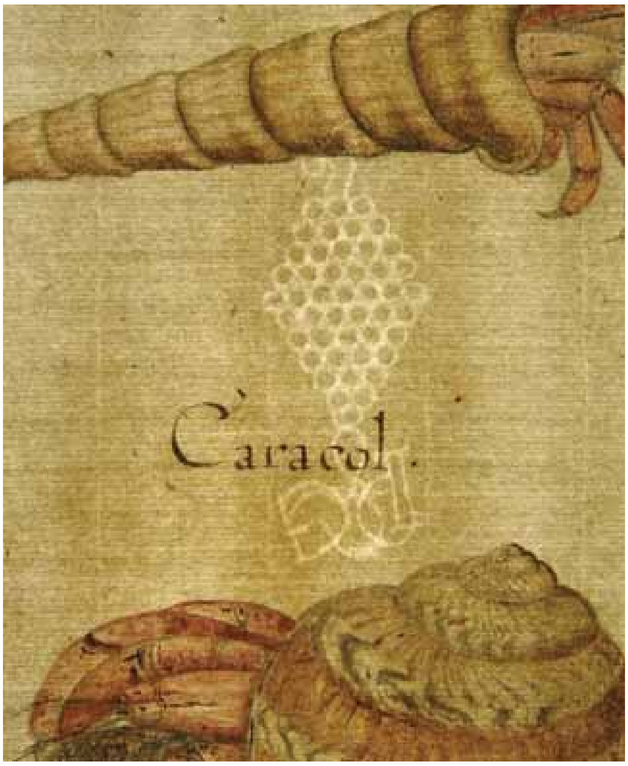

FIGURE 3. Transmitted light detail of *Purple-clawed hermit crabs* 1906,0509.1.57 (188 × 155 mm) showing chain and laid lines in the paper and a bunch of grapes watermark

at this time and it was not until the mid-eighteenth century that English white paper began to rival that of other European countries in quantity, quality or cost [5].

The paints available at the time would have been based on mineral pigments ground to a powder and organic colours such as indigo and sap green [6]. These pigments would be mixed with water and a binding medium such as gum, and the paint held in mussel shells. More opaque body colour (chalk white or lead pigments added to watercolour), which gave a denser effect, would be added last. Gold and silver leaf, traditional decorative elements in mediaeval illuminated manuscripts, are used by White in a more naturalistic way to create highlights and iridescent effects. Many of his drawings also have inscriptions recording names or other details, which are written with a pen and black (carbon) ink; see the later section on the analysis of the watercolours.

EXAMINATION AND CONDITION

The exhibition provided an opportunity to examine the whole body of John White's work and thus gain an overview not only of its current condition but also of how it had been kept during the last hundred years.

Variations in style and mounting materials gave some indication of the age of the mounts. Some drawings may have been mounted in 1906 when the album was transferred from the Grenville Library, but the only precise reference that survives is a pencil note in the empty album, which dates the removal of several items to 1933. The earliest mounts were made of a thin board with a rather shallow aperture. Many of the drawings were 'guarded' to the backboard, a technique in which a continuous paper hinge (guard) is adhered around the edges of the verso to attach the drawing to the mount. Others were 'traditionally inlaid' – a term given to the attachment of false margins, chamfered at the edges and pasted to the drawing [7; pp. 101–102]. These margins were then adhered to the backboard. A thin cream paper was used for early inlays, while mounting carried out for an American loan exhibition in 1985 [8] probably accounts for work inlaid to a heavier white paper. All of these were solid mounts allowing no access to the verso of the drawings [7; p. 40] and most were dirty and worn from years of handling. A small number of new overthrow mounts had been made for more recent loan exhibitions.

The overall condition of the drawings was very good, with the same type of high quality paper being used throughout.

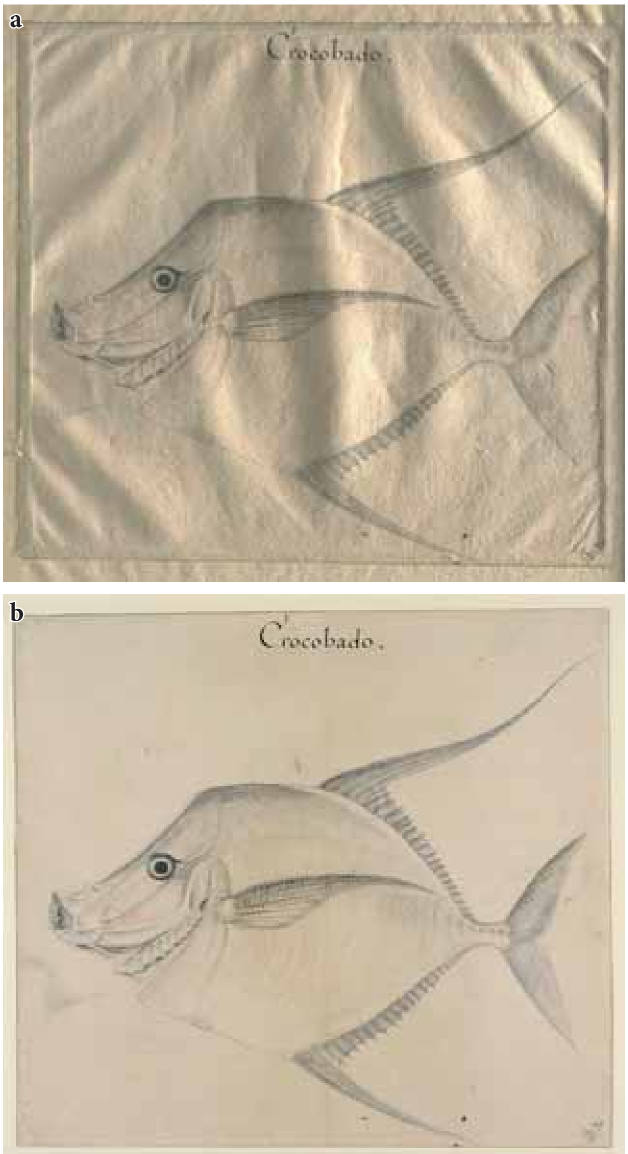

FIGURE 4. *Lookdown fish* 1906,0509.1.49 (191 × 210 mm) showing (a) planar distortions in raking light before treatment and (b) after conservation

It is a fine laid paper, with chain lines about 20 mm apart and approximately 13 laid lines per cm. Transmitted light revealed an even fibre distribution and few impurities. The paper (which at this period would have been made from linen fibres) is still a bright off-white colour, although inevitably there has been some discolouration over time.

Some drawings showed damage resulting from the dramatic effects of the fire and flood – the type and degree of staining depending on where they were positioned in the album. A slight blackening from the smoke can still be seen on some of the edges but, as the drawings are no longer on their original album pages, charring is now evident only on some of the offset sheets, Figure 1b.

Raking light revealed edge ridges and planar distortions in a dramatic way, Figure 4a. In some instances this was directly related to the wetting of the paper and in others to the various methods of attachment to the backboards. There was surface dirt and, on many sheets, a graphite line around the edges, which in some cases extended onto the inlay paper indicating that it dated from previous mounting. Some old repairs were found but many of the drawings had small, unrepaired tears and edge losses (evident in the catalogue photographs which were taken before conservation). When lifted from the mounts many sheets were shown to have quite badly skinned edges on the verso, especially at the top and left. This would seem to have occurred during removal from one of the earlier albums into which they had been directly adhered.

The most obvious damage was to the pigments. Many of the colours would have appeared much more intense before pigment was transferred (offset) to interleaving sheets during the events of 1865. A number of distinct problems were visible. In some areas where the pigment particles were more coarsely ground, or where the paint had been more thickly applied, entire layers of paint had been lost; these could be seen deposited in reverse order on the offset images. When examined under magnification there was no evidence of loose pigment particles or recent cracking, and remaining paint layers were found to be firmly attached to the paper surface. In other areas paints containing pigments of smaller particle size had 'run' into the paper fibres causing indistinct edges, Figure 5. A more soluble light green had bled through many sheets and examination under ultraviolet light revealed the full extent of this staining, Figures 6a and 6b. Some areas containing lead-based pigments (lead white and red lead) had darkened, perhaps due to exposure to sulphur-containing species in the atmosphere, Figures 9a and 9b.

Finally, many of the sheets have a faint horizontal grey line across the centre, indicating that they were once folded. This appears to have occurred before the drawings were executed as no evidence of damage to the pigment layer was observed. Folding into smaller sheets would have made for easier transportation if the work had been carried out on the voyage although, from the condition and uniformity of execution, it is more likely they were drawn on White's return to England from notes and observations made during the voyage.

FIGURE 5. Detail of an *Uzbek man* 1906,0509.1.33. Wetting has caused the blue pigment (smalt) to flake off the paper surface, while the finer particles of red pigment (vermilion) have run into the surrounding paper fibres

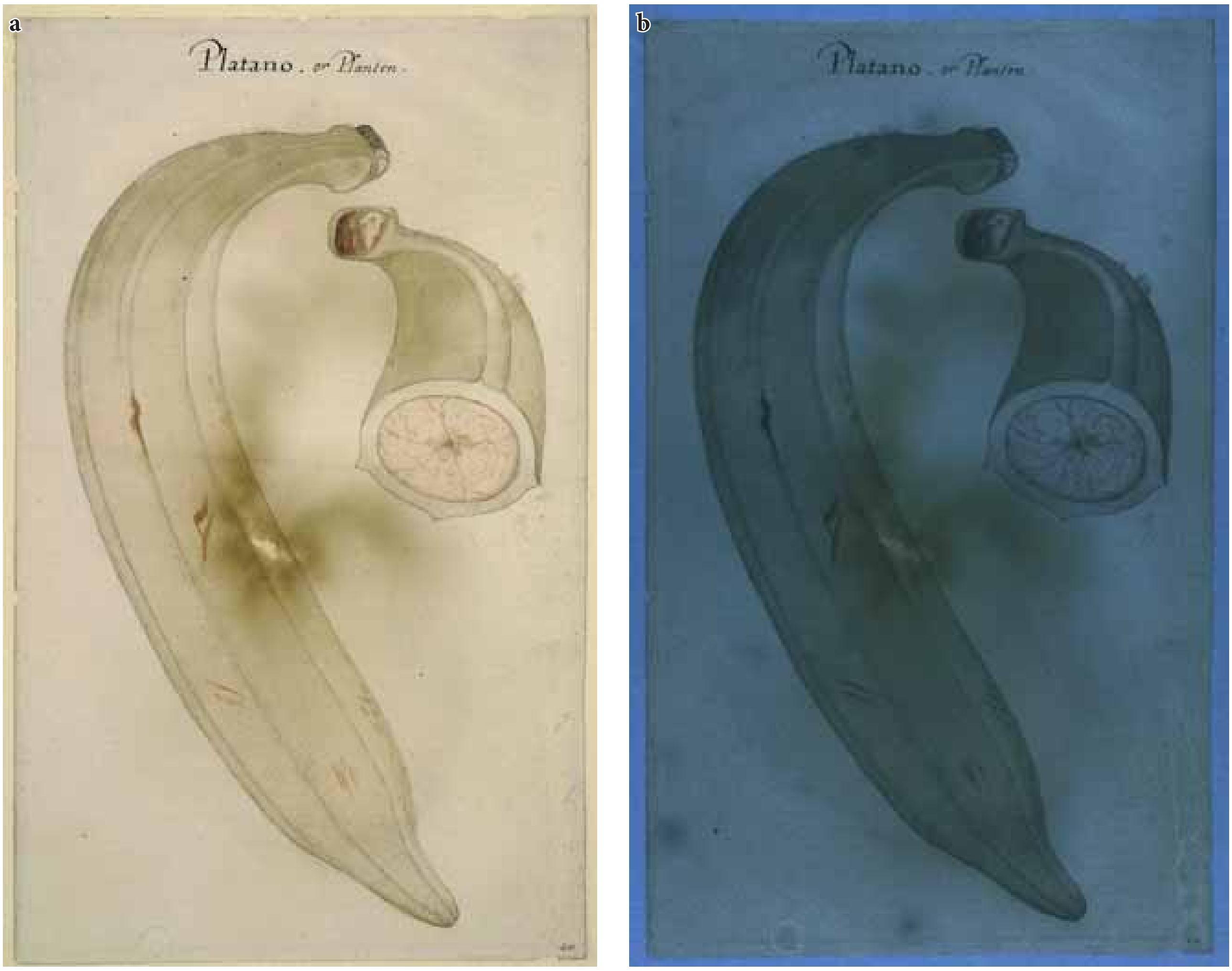

FIGURE 6. *Horn Plantain* 1906,0509.1.40 (294 × 177 mm): (a) an area in the centre stained by green pigment from another drawing; (b) ultraviolet illumination reveals that the affected area is extensive and clearly shows water stains towards the bottom of the drawing

TREATMENT EVALUATION

Although the initial reason for examining the drawings had been their inclusion in the exhibition, the assessment of their overall condition and of appropriate levels of conservation treatment needed to be made in a wider context. The priority for works forming part of a public collection is to ensure they are in a stable condition and preserved for the future while still allowing access for study and enjoyment. Over recent years, public access to prints and drawings in the British Museum collections has increased dramatically, both in the students' room and, in particular, through an extensive loans programme. Due to their unique interest and importance many of the John White drawings have been in considerable demand for exhibitions over the past 50 years and increased interest seemed likely to be generated by the new exhibition. In determining appropriate treatments it was therefore necessary to take into consideration the anticipated future requirements of display, handling, transport and storage.

For display purposes a visual improvement to the edge damage and overall distortions of many of the drawings was desirable. Since the exhibition was subsequently to be shown in the USA, they also needed to be in the best possible physical condition to travel safely. Mounting was an important issue, not only for the immediate display of the drawings, but also for their future handling and storage in a public study collection. The mounting method needed to allow full access to both recto and verso if required, while still providing a good level of protection. Minimizing risk to the skinned edges of the drawings during any future remounting was also a significant consideration.

The most obvious physical problems were the cockling and edge ridges, which were both visually distracting and potentially damaging to the drawings. These posed the risk of surface abrasion with further pigment loss in raised areas and of increased tension and distortion should there be any changes in humidity. Lifting and flattening were therefore considered essential both for aesthetic reasons and to provide better protection, Figure 4b. The processes of lifting and debris removal were delicate, requiring care and skill to avoid further damage to the fragile edges of the drawings. However, once lifted, it was possible to repair and reinforce the edges.

Other factors considered during treatment were the colour changes, pigment losses and staining. Although it might have been possible to treat blackened lead white pigment using ethereal hydrogen peroxide, this is often a time-consuming process and is not always effective. In addition, as this is an irreversible treatment, in which basic lead carbonate ($2PbCO_3{\cdot}Pb(OH)_2$) pigment that has become blackened to form lead sulphide is converted to lead sulphate ($PbSO_4$), it is not generally carried out unless considered essential. Since it was possible to create a very good impression of how the colours might have appeared originally using digital images (Figure 12), the treatment was not considered necessary in this instance. Examination under magnification had shown that although areas of pigment loss were quite extensive on some drawings, the remaining paint layers were stable and were not in need of consolidation. The staining affecting many of the drawings would have been extremely difficult to treat without risk of further damage such as movement of discolouration. Although very noticeable in some cases it was not in general considered visually distracting and indeed was now felt, along with the colour changes and losses, to have become an integral part of the history of the drawings.

CONSERVATION TREATMENT

The drawings were lifted from their mounts by slitting the old inlay paper with a scalpel or, for those which were adhered or guarded around the edges, by undercutting. Light surface cleaning was carried out around the edges of the drawings where necessary using Staedtler plastic eraser, grated to a fine powder. Paper debris (primarily the remains of guards and inlay paper) and adhesive residue were then carefully removed from the edges of the verso. In some cases poor quality repairs had been carried out in the past and most of these needed to be removed to ensure the drawings would lie flat after treatment and to minimize the risk of future cockling or distortion, Figures 7a–7c.

The paper was found to be very absorbent around the edges, probably due to deterioration of the gelatine sizing over time, perhaps exacerbated by the nineteenth-century flood. Because of this extreme absorbency, the introduction of moisture to soften adhesive residue needed to be minimized to avoid any risk of staining. Verso debris was therefore first reduced as much as possible using a scalpel. A poultice of methylcellulose (4% in water) could then be applied quite briefly to remove the remainder, followed by swabbing using cotton buds, lightly moistened with water, to remove traces of adhesive residue. During this process the fragile edges of the drawings were gently pressed to prevent curl. Afterwards, where overall flattening was necessary, the drawings were briefly humidified over capillary matting and Gore-Tex® and pressed lightly between blotters and boards.

New repairs were needed to reinforce the edges and improve the visual appearance of the drawings. For this a combination of Japanese and Western papers was used – the former providing support for skinned, weak areas or small tears and the latter being used for infilling edge losses or carrying out repairs where the original paper was particularly thin. The main Japanese paper utilized was a *Mino*, while several old Western papers of slightly differing thicknesses were employed, all chosen for their sympathetic texture and colour as well as a very similar chain and laid line formation. Repairs were adhered using gluten-free wheat starch adhesive with most of the work being carried out on a lightbox to reveal the weakest areas in the support paper clearly and allow accurate positioning. In some of the most severely damaged areas, several layers of both

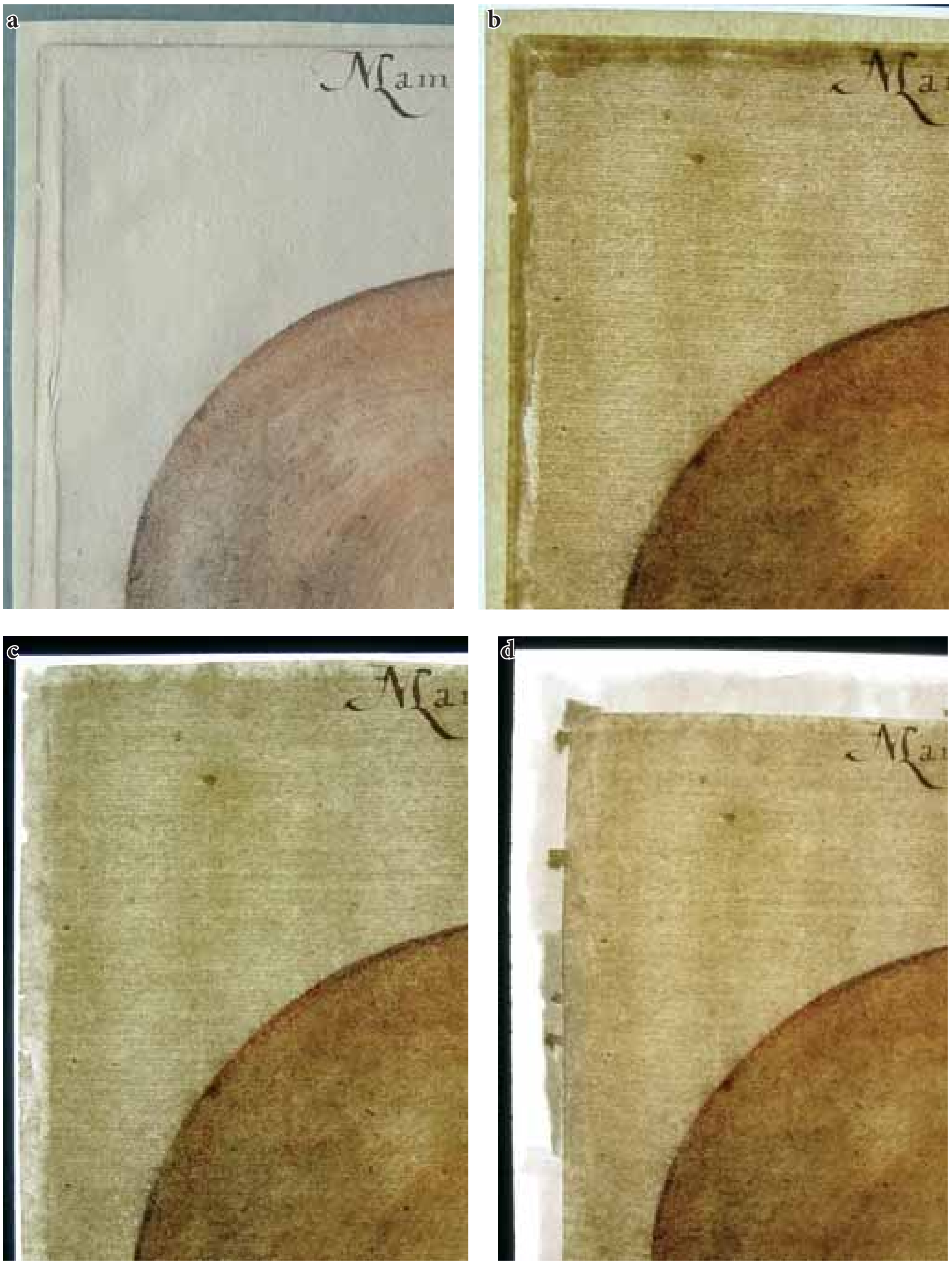

FIGURE 7. Detail of *Mammee apple* 1906,0509.1.40a (210 × 184 mm): (a) after removal from its mount, showing edge ridges caused by the old inlay paper that is still attached to the verso; (b) viewed in transmitted light, showing areas of skinning and loss; (c) in transmitted light after debris removal, revealing the full extent of the damage; (d) layers of Japanese and Western paper have been used to repair and support the fragile edges

Japanese and Western paper needed to be carefully overlaid to match the thickness and opacity of the surrounding original paper. This was an intricate and lengthy process but ensured a result that would not only be strong but would also integrate well when viewed in either reflected or transmitted light, Figure 7d. The completed infills were toned using Winsor and Newton artists' watercolours.

With the edges of the drawings now much stronger and their overall appearance visually improved, it was essential to minimize the risk of further damage occurring in the future. After flattening, the drawings were therefore inlaid into a 100 g.m^{-2} acid-free paper chosen for its sympathetic colour, weight and texture. The false margin provided by inlaying allows safer handling (by reducing the need for direct contact with the object), and safe attachment to a mount, as well as providing protection to the edges. The White drawings were attached to their inlay paper margins using strips of *Tengujo* paper adhered with methylcellulose adhesive [7; p. 103]. This is a more easily reversible method than that used traditionally, and avoids the problem of edge ridges. In future, the drawings can be removed from the inlay paper, if necessary, with only a minimal application of moisture, leaving the

FIGURE 8. Detail of *Greek woman* 1906,0509.1.35 (210 × 94 mm) showing the same severely damaged area at the top edge: (a) in reflected and (b) in transmitted light after lifting and removal of old inlay paper from around the edges; (c) in reflected and (d) in transmitted light after repair and inlaying

edge repairs – adhered with wheat starch paste, which is less soluble – still intact, Figures 8a–8d.

After inlaying, the drawings were hinged to standard royal size (559 × 406 mm) overthrow mounts of cream six-ply acid-free Museum board, which was temporarily overlaid with coloured board for display. For future storage these overlays will be removed and the mounted drawings housed in Solander boxes for protection from light, dust and atmospheric pollutants.

ANALYSIS OF THE WATERCOLOURS

While the John White drawings were undergoing conservation, the opportunity was also taken to investigate the paints used in their production. Time constraints prevented a full investigation of each watercolour, and a subsample was therefore selected for scientific examination, based both on the range of materials and on the practicalities of working around the conservation process. The pictures examined are listed in Tables 1 and 2. Work focused on the drawings accepted as being by White's hand, with only one drawing from the Sloane album (SL 6270.12; Table 2). Visual examination suggests some differences in palette between these two groups, particularly with regard to the greens, and it is hoped that the material from the Sloane album can be examined in more detail at a later date.

Because of the fragile nature of both the paper and the painted surfaces, the methods employed for this study needed to be both non-destructive and non-invasive. For these reasons all analyses were carried out using only optical microscopy, Raman spectroscopy and X-ray fluorescence (XRF) analysis; see the experimental appendix for details. While both these methods have the advantage of posing no danger to the watercolours, there are some drawbacks for this project. First, XRF yields elemental data, giving the elements present on a surface, but does not directly provide identifications specific to a particular compound [9]. In addition, the equipment used cannot detect very light elements (i.e. those below sodium in the periodic table), although with the use of helium gas to flush the region between the X-ray tube, object and detector, the sensitivity for some of the lighter elements can be significantly enhanced. As XRF could not detect carbon it is of limited use in the investigation of organic compounds, especially as identification of these materials relies on additional information about their molecular structure. Raman spectroscopy is a technique that provides compound-specific identifications [10], but when used directly on a painted surface it is also limited when it comes to identifying organic pigments. The Raman equipment available at the British Museum also has some geometric constraints that restricted the areas of the watercolours which it was possible to analyse.

Despite these limitations, these two techniques have served well in answering many of the questions that have arisen about the drawings. However some lacunae are inevitable, with the most obvious omissions being the nature of the media used to bind the pigments. Additionally, with the notable exception of indigo, which is readily detected by Raman spectroscopy, it has not proved possible to identify, or even detect, the organic materials present in the binding medium or pigments.

ANALYTICAL RESULTS

The data collected by XRF analysis for unpainted areas of paper show a wide range of elements, Table 1. The traumatic history of the drawings, particularly the prolonged water damage, makes interpretation of these results difficult. The presence of calcium on all the papers suggests, however, that a calcium compound was used at some point in the preparation of the paper. The Raman results for the unpainted areas offer no further information.

The pigment palette employed seems to be fairly typical for the period [6]. Much use is made of earth pigments (ochres), identified on the basis of the presence of concentrations of iron in the XRF spectrum and/or characteristic peaks for hematite and goethite in the Raman spectra. These ochres provide the main source of the reds, yellows and browns which dominate the drawings of Native American life. Supplementing these ochre colours some use is made of at least two other reds. Vermilion (mercuric sulphide, HgS) is used quite widely, but in far smaller quantities than red ochre (possibly reflecting its higher cost [6]), mainly to emphasize detail and bring out features such as lips. A vivid pink appears on some of the botanical drawings and particularly in the depictions of shellfish. This has not been positively identified, but the absence of metallic elements in the XRF spectrum suggests an organic pigment. Madder is the most common organic red associated with this period and is the most likely candidate for use here. Initial investigations seemed to imply the presence of bromine, perhaps suggesting an organic pigment derived from a shellfish and containing a dibromoindigo-based colourant. However it has not been possible to replicate this finding and careful examination of these areas by Raman has not revealed any indigoid-based pigments in this areas.

The main white used is lead white (basic lead(II) carbonate; $2PbCO_3{\cdot}Pb(OH)_2$), identified by both its Raman spectrum and the presence of substantial quantities of lead in white (or off-white) areas. This reliance on lead white has led to marked changes in appearance of many of the drawings. Lead white is particularly prone to darkening, a phenomenon which has been variously attributed to the formation of oxides (principally PbO_2, plattnerite [11]), or sulphides, mainly PbS [12]. While it has proved difficult to understand the pattern of such darkening on these drawings (perhaps not surprisingly, given their convoluted environmental history) it has certainly occurred. Figures 9a and 9b show an attempt to demonstrate the effects of this colour transformation on one particular drawing using digital imaging. In this case simply correcting the darkening of the pupils of the eyes and reinstating some of the original white highlights on the feathers has a radical effect on how the watercolour is perceived. No other white pigments have been conclusively identified, but calcium has been found in a number of painted areas and may well reflect the use of a calcium-containing white as an extender.

On the basis of Raman results, the blacks used seem to be predominantly carbon-based. In an area where the underdrawing was exposed on a watercolour of a *wife of an Indian werowance or chief and her daughter* (1906,0509.1.13), the black was shown to be graphite.

Three blues were identified. Azurite (copper carbonate; $2CuCO_3{\cdot}Cu(OH)_2$) was identified either by inference, from the presence of copper peaks in the XRF spectra of blue areas, or unequivocally by its Raman spectrum. Smalt, glass coloured by the presence of cobalt, was recognized by the presence in the XRF spectra of cobalt and other elements typically present in glasses, particularly silicon. Indigo, an organic pigment, was readily identified by its clear Raman spectrum [13]. In one particular drawing (1906,0509.1.64; the European roller, *Coracias garrulus*), all three blues were used to give a life-like colour distribution for this spectacular bird, Figure 1a. Even so, when this drawing is compared with modern photographs it can be seen to lack

FIGURE 9. Detail from *An Indian werowance or chief* 1906,0509.1.12 (263 × 150 mm): (a) in its present condition; (b) with the original colour of the lead white digitally reinstated: image Antony Simpson

TABLE 1. Analytical results from the John White drawings

Watercolour	Sample position and colour	XRF results [(a)]	Raman results	Interpretation
1906,0509.1.6 *Indians fishing*	unpainted surface	(Al, Si, Pb/S, Cl, K, Ca, Ba, Fe, Cu, Sr, Zn, As, Rb)	–	
	fish, blue	(Ca, Ba)	indigo	indigo
	flower, red	[Hg, S]	vermilion, carbon	vermilion + carbon
	body of canoe, brown	not measured	hematite, goethite	hematite + goethite (red and yellow ochres)
	fire in canoe, yellow	[Au]	not accessible	gold
	fire in canoe, red,	[Hg, S]	not accessible	vermilion
	fish, blue	no peaks above paper levels	indigo	indigo
	shore, yellow	no peaks above paper levels	goethite	goethite (yellow ochre)
	plants, green	no peaks above paper levels	goethite, indigo	indigo + goethite (yellow ochre)
1906,0509.1.8 *The town of Pomeiooc*	unpainted surface	(Pb/S, Cl, K, Ca, Fe, Cu, Sr, Zn, As)	–	
	central village area	[Pb]	–	lead white
1906,0509.1.12 *An Indian werowance or chief painted for a great solemn gathering*	unpainted surface	(Pb/S, Cl, Ca, Fe, Cu, Sr, Zn, As, Rb)	–	
	white of eye, black	[Pb]	lead white	lead white
	body paint, red	[Pb, Fe] (Ca)	–	ochre lead white calcium-based pigment/extender?
	kilt, white	[Pb] (Zn, Cu)	–	lead white
	hair	no peaks above paper background	not accessible	carbon
1906,0509.1.13 *A wife of an Indian werowance or chief and her daughter*	unpainted surface	(Pb/S, Cl, K, Ca, Fe, Cu, Sr, Zn, Rb)	–	
	clothing, red/brown	[S, Pb, Fe, Hg] (Ca)	not accessible	vermilion, ochre, lead-based pigment? calcium-based pigment/extender?
	doll, yellow	[Au] (Pb, Ca, Fe, Ag)	not accessible	gold
	doll, red	[Pb, Fe] (Ca)	not accessible	ochre, lead-based pigment, calcium-based pigment/extender
	gourd, red area	[S, Hg]	not accessible	vermilion
	gourd, yellow area	(Hg)	not accessible	organic?
	beads	[Pb]	not accessible	lead white
	tattoo	(Pb, Ca, Fe, Hg)	carbon	carbon ink
	caption	(Pb, Ca, Fe ,Hg)	carbon	carbon
	child's beads, grey	[Pb] (Fe, Ag, Hg)	lead white	lead white
	child's beads, black	[Pb] (Ag, Hg, Ca)	lead white	lead white
	woman's beads, white	[Pb]	lead white	lead white
	woman's beads, mid- grey	[Pb] (Hg)	lead white	lead white
	woman's beads, black background	no peaks above paper background	carbon	carbon ink
	woman's beads, mid- grey	[Pb]	not accessible	lead white
	small cross, black	(Fe, Pb)	carbon	carbon ink
	woman's beads, grey	[Pb] (Zn, Cu)	not measured	lead white
	underdrawing	no peaks above paper background	graphite	graphite
1906,0509.1.38 *Sabatia*	paper	(Pb, K, Ca, Fe, Rb)		
	flower centre, red	[Pb] (Ca)	not accessible	lead pigment calcium-based pigment/extender? organic bromine-containing compound?
	flower centre, white	[Pb]	not accessible	white lead
	petals, purple	[Pb]	not accessible	lead pigment organic bromine-containing compound?
1906,0509.1.33 *Tartar or Uzbek man*	paper	(Cl, K, Ca, Fe)		
	robe, blue stripe	[Si, Pb, Bi, Fe, Co] (Mn, Ni, Cu, Zn, As, K)	no spectrum	smalt
	robe, black stripe	no peaks above paper background	carbon	carbon
	shoes, red	[Hg, S] (Ca)	vermilion	vermilion calcium-based pigment/extender?

Watercolour	Sample position and colour	XRF results [(a)]	Raman results	Interpretation
1906,0509.1.34 *Turkish lady*	paper	(K, Ca, Fe)		
	band, red	[Pb/S, Hg]	vermilion	vermilion
	robe, faint blue stripes	[Pb, Cu] (Ca, Fe)	not accessible	copper blue
	robe, white	[Pb] (Cu)	not accessible	white lead
	veil, black	no peaks above paper background	carbon	carbon
1906,0509.1.50 *Grouper*	paper	(Cl, K, Ca, Mn, Fe, Cu, Zn, Rb, Sr)		
	spot, black	[Au] (K, Cu, As)	not accessible	carbon? plus some gilding?
	body, brown	[Pb/S, Fe, Hg] (Ca, Mn, Cu)	not measured	ochre, vermilion, calcium-based pigment/extender?
	eye, gold	[Au] (Ag, Cu)	not measured	gold
	mouth, red	[Fe] (Hg, Ca)	not measured	red ochre vermilion calcium-based pigment/extender?
	mouth, red (2)	[Fe, Hg] (Ca)	not measured	red ochre vermilion calcium-based pigment/extender?
	belly, grey	[Ag] (Cu, Au, Pb)	not measured	silver
	belly, grey (2)	[Ag] (Cu, Au)	not measured	silver
1906,0509.1.64 *European roller*	paper	(Pb, Cl, K, Ca, Fe)		
	back feathers, bright blue	[Cu, Co] (Si, Cl, Ca, Fe, As, Pb)	azurite	azurite smalt
	tail feathers, dark blue	[Co] (Si, Pb, K, Ca, Fe, Cu, As)	indigo	indigo smalt
	wing, mid blue	[Co, Cu] (Si, Fe, As, Pb)	azurite	azurite small amount of smalt
1906,0509.1.47 *Lookdown fish*	paper	(Cl, K, Ca, Fe, Cu, Zn, Rb)		
	lips	[Hg, Pb/S]	not measured	vermilion
	body	[Ag] (Co, As)	not measured	silver
1906,0509.1 *Flying fish*	paper	(Cl, K, Ca, Fe, Zn)		
	blue body	[Co] (Si, Pb, K, Fe, Ni, As, Bi)	no spectrum	smalt
	fin	[Ag] (Pb)	not measured	silver

Note: (a): For the XRF data, the results in square brackets are present in substantial quantities while results in round brackets are present as traces only. All elements detected are listed for unpainted paper, but for painted areas only elements present in larger quantities than in the paper are given.

TABLE 2. Analytical results from the Sloane album

Watercolour	Sample position and colour	XRF results (a)	Raman results	Interpretation
SL 6270.12 *The skirmish at Bloody Point*	unpainted surface	(Si, Pb/S, Cl, K, Ca, Mn, Fe, Cu, Sr, Zn)		
	flag, cream	no peaks above paper background	no spectrum	organic?
	flag, red	[Pb, S, Hg] (Ca)	red lead, vermilion	red lead plus vermilion
	trousers, European figure, blue	[Fe, Cu] (Pb, Hg)	not accessible	copper blue, ochre
	hills, blue	[Fe, Cu] (Hg)	azurite	azurite (plus some ochre)
	canoe, brown	[Fe] (Hg)	not accessible	ochre
	hills, green	[Fe, Cu] (Pb, K, Hg)	azurite, goethite	azurite plus goethite (yellow ochre)
	Inuit body, brown	[Ca, Fe, Cu] (Mn, Pb, Zn)	not accessible	ochre plus unidentified pigments
	Inuit face, red	[Hg, S]	not accessible	vermilion

Note: (a): For the XRF data, the results in square brackets are present in substantial quantities while results in round brackets are present as traces only. All elements detected are listed for unpainted paper, but for painted areas only elements present in larger quantities than in the paper are given.

the dramatic vividness of the living bird. It is possible that blue pigment has either been extensively lost, or has faded to a duller colour; both azurite and smalt are known to be prone to degradation [14, 15]. The offset page (Figure 1b) certainly shows considerable transfer of blue pigment, but not enough to reach the depth of colour apparent on the living bird. Additionally, no sign of degraded pigment particles can be detected by careful microscopic examination of the original, and none are apparent in blue areas on other drawings from the album. Perhaps a more likely explanation is that the drawing shows a juvenile, as the full colours are not developed until adulthood [16]. Alternatively

White may have used a dead and faded specimen as his subject, although in another drawing of a similar nature, and certainly featuring a dead bird, in the British Museum collections (Gg, 2.220; Hans Hoffmann after Dürer, Figure 10) the blue is considerably brighter.

No evidence has been found on any of the drawings for the use of the most prestigious and expensive blue of the period, natural ultramarine, prepared from the mineral lapis lazuli and employed sometimes as a background to contemporary portrait miniatures [17].

Surprisingly, no inorganic green pigments have been identified on the John White drawings, although in the drawings in the Sloane album there are many areas coated with thick green pigment, which is almost certainly inorganic. Greens are generally rare in the drawings from the main series. Green plants occur at the base of *Indians fishing* (1906, 0509.1.6), coloured with a mixture of indigo and yellow ochre, while the few green areas of foliage found on the botanical drawings give no XRF data or Raman spectra, and must be assumed to be organic in nature. On the basis of what is known of the palette of the time the most likely pigment used here is sap green, normally produced from unripe buckthorn (*Rhamnus* sp.) berries [6]. The possibility that the lack of inorganic greens could be due to alteration of an original pigment has been considered, but there is no sign of the brown staining and damage that normally accompanies degraded verdigris or malachite. Some areas, such as the central village area in *the town of Pomeiooc* (1906,0509.1.8), which might logically be expected to be green, were specifically examined and none showed the presence of any element that might suggest a degraded inorganic green. It remains possible that an organic green was originally more widely used but has now undergone total degradation.

FIGURE 10. *Dead blue roller* (Gg 2.220) Hans Hoffmann after Dürer

The final touches to the rich colours of the drawings are provided by metals. Metallic gold seems to have been present originally on most of the Indian drawings and many of the others, usually applied to small areas to enhance details, although little is now visible. The gold was applied as a final layer, making it very vulnerable to physical damage, and much has been transferred to the offset pages. A good example is provided in the watercolour of a *wife of an Indian werowance or chief and her daughter*, 1906,0509.1.13, Figure 11a. Here the doll and medal/coin worn by the Pomeiooc child (incidentally, the only demonstrably European artefacts shown on any of the Indian drawings) were once richly ornamented with gold. Little, if any, can now be seen on the drawing, but detailed examination of the offset page (Figure 11b) shows where it has been transferred. However, even on the offsets it is not always readily obvious; sometimes transferred pigments from the originally lower layers now rest on top of the gold and obscure it. All the gold surfaces examined in this study had been disrupted in this way. For this reason it has proved impossible to state with certainty if the gold was applied as 'shell gold', small pieces of foil suspended in a transparent medium, or as a foil, although shell gold seems the more likely of the two.

Similarly silver, in this case definitely applied as small metal fragments, featured extensively on the depictions of fish. While little has been lost by transfer (possibly because of the position of the drawings in the album, or possibly because it was applied directly to the paper rather than onto a painted surface) the metal has tarnished to a dull grey, making it difficult to distinguish from the black ink or graphite outlines. When first produced the silver areas would have shimmered, closely replicating the appearance of the living fish. Figure 12 shows an attempt to recreate the original appearance of one of these pictures by digitally reinstating the initial colours of both the lead white and silver.

Overall, the pigments on these drawings are unsurprising for the period. While the possible presence of a shellfish-derived pink may be an indication of the use of a pigment of New World origin, the results of this study do not give a firm indication of where these works were produced or where the pigments were sourced.

CONCLUSIONS

Close examination and scientific analysis of the drawings has allowed conservators and scientists to form a picture of their condition, the physical changes that have occurred over time and of the techniques and materials used to create them. Information gained about the pigments used and the colour changes suffered during their traumatic history allows us to imagine, and attempt to reconstruct, their original appearance, with the depth of pigment John White intended, with clear whites and with shining areas of silver and gold. Conservation treatment and remounting have not only improved

FIGURE 11. *A wife of an Indian werowance or chief and her daughter* 1906, 0509.1.13 (263 × 149 mm): (a) in its present condition; (b) the offset page; (c) and (d) enlarged details showing the transfer of gold to the offset page

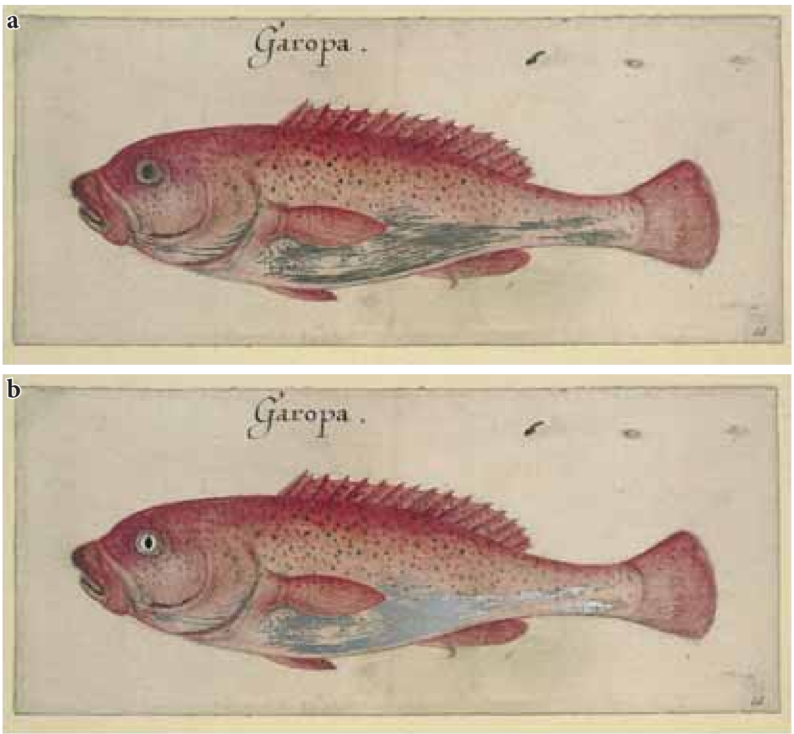

FIGURE 12. *Grouper* 1906.0509.1.48 (93 × 218 mm): (a) in its present condition; (b) with the original colour of the lead white and silver digitally reinstated: image Antony Simpson

the appearance of the drawings but also ensured they are in a more robust and stable condition. The new body of information on their condition, and the records of conservation treatments carried out, will provide an invaluable resource for those responsible for their future care.

EXPERIMENTAL APPENDIX

XRF analyses were carried out using a Brucker Artax spectrometer. The air immediately above the area of analysis was displaced by a gentle stream of helium gas to provide greater sensitivity for lighter elements. The improvement produced is greatest for elements such as aluminium, silicon and phosphorus, while elements such as sodium and magnesium, which are not detectable in air, can just be seen, although their detection limits are poor. While the paint layer on these drawings is thick compared with modern watercolours, it is thin when compared with the depth of penetration of the spectrometer X-ray beam, so that each analysis reflects the elements present in both paper and paint. In all cases, therefore, spectra were also collected for unpainted areas of drawings and these results subtracted from those collected in coloured areas to give results for the pigments alone. The area analysed was *c.* 0.65 mm in diameter. Spectra were collected for between 100 and 300 seconds.

Raman spectroscopy was carried out using a Jobin Yvon LabRam Infinity spectrometer with green (532 nm) and near infrared (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. This allowed tiny coloured areas to be targeted for analysis, with a sample spot size in the order of a few micrometres, depending on the power of objective lens used. Spectra were collected for between 20 and 100 seconds, with at least five acquisitions used to produce each spectrum. The resultant spectra were identified by comparison with a British Museum in-house database.

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MATERIALS AND SUPPLIERS

- 100% cotton archival inlay paper 100g.m^{-2}, museum board: John Purcell Paper, 15 Rumsey Road, London SW9 0TR, UK. Email: mail@johnpurcell.net
- Culminal MC 2000 methyl cellulose, *Tengujo* Japanese paper 15g.m^{-2}: Conservation by Design, Timecare Works, 5 Singer Way, Woburn Road Industrial Estate, Kempston, Bedford MK42 7AW, UK. Email: info@conservation-by-design,co.uk
- Gore-Tex®, capillary matting: Preservation Equipment Ltd, Vinces Road, Diss, Norfolk IP22 4HQ, UK. Email: info@preservationequipment.com
- Gluten-free wheat starch paste: Masumi Corporation, 4-5-2 Sugamo Toshima-ku, Tokyo 170-0002, Japan. Email: info@masumi-j.com

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