Hidden, looted, saved: the scientific research and conservation of a group of Begram Ivories from the National Museum of Afghanistan

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Summary In 2010 a group of 20 decorative ivory and bone plaques from the late first-century AD Kushan city-site at Begram, Afghanistan arrived on deposit at the British Museum (BM). The plaques had only recently been rediscovered after being looted from the National Museum of Afghanistan (NMA) in Kabul during the height of the Afghan civil war (1992–1994), and through the generous intervention of a private individual were acquired on behalf of the NMA. These plaques are part of a larger group collectively known as the Begram Ivories, the largest body of ancient Indian ivory carving to survive from antiquity. The pieces were scientifically examined and treated at the BM and subsequently displayed in the temporary exhibition *Afghanistan: Crossroads of the Ancient World* held at the BM 3 March–17 July 2011 before being safely returned to the NMA in July 2012.

Immediately prior to the exhibition the first ever scientific examination of these objects was carried out. The organic plaque material, the distribution and composition of the polychromy and the composition of the original metal pins were investigated using non-invasive techniques. Raman spectroscopy established an original pigment palette that included vermilion and hematite (red), indigo (blue) and carbon black, while X-ray fluorescence analysis confirmed that the metal pins were a heavily corroded copper alloy. Multispectral imaging, including ultraviolet-induced visible luminescence imaging, suggested the possible use of a now degraded organic pigment. A manganese-containing black deposit on the surfaces of several of the plaques is believed to be post-depositional, rather than a deliberately applied pigment.

The choice of indigo (an organic colourant likely to have been produced in India) as the blue pigment on the plaques, rather than locally available ultramarine (derived from Afghan lapis lazuli), supports a possible Indian origin. The distinctive Indian style and pattern of the carved designs also suggests that these pieces were either imported ready constructed from India or were produced in Afghanistan by local or imported craftsmen working to Indian styles. The opulent sofas and footstools that the vibrantly coloured plaques would once have decorated are prime examples of the lavish international goods that were being traded and used by courtly elites at this time.

INTRODUCTION

The ancient city of Begram lies 60 km to the north of Kabul, Afghanistan, in a fertile valley that was once an important junction of two major routes connecting Afghanistan and modern-day Pakistan. Strategically located at the heart of what modern writers have popularly termed the Silk Road, Begram was at the centre of an extensive international trade network that linked Afghanistan with the rest of the known world including China, India and Roman Egypt, Figure 1 [1]. In the first and second centuries AD, Begram was the site of Kāpiśa, the prosperous summer capital of the Kushan Empire, which at its height stretched from northern Afghanistan to northern India. The archaeological remains at Begram consist of a citadel and a large rectangular walled area known as the New Royal City, which contains a bazaar and a palace complex and which was partially excavated during the 1930s and 1940s by French archaeologists working as part of the Délégation Archéologique Française en Afghanistan.

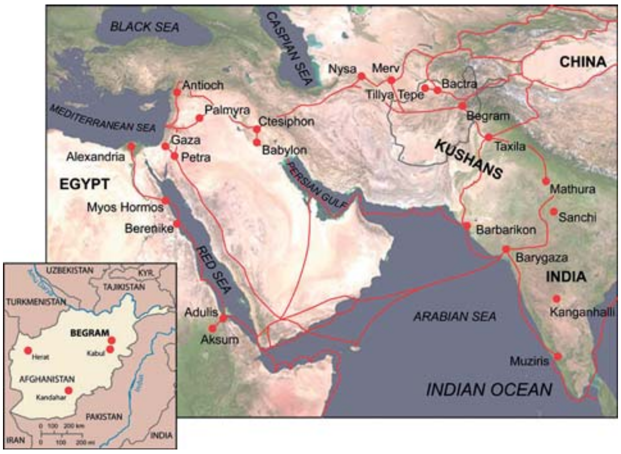

FIGURE 1. Map showing the route of the Silk Road (marked in red) and the outline of modern-day Afghanistan (marked in grey), with an inset showing the location of the ancient city of Begram. Topographic base map courtesy of the University of Texas Libraries; Silk Road map after Whitfield [1]

In 1937 and 1939, some 1800 years since they were last opened, two walled strong rooms were discovered at the heart of the palace complex. These rooms yielded a spectacular and diverse range of precious objects including Roman glass, bronzes, alabaster and porphyry made in and/or imported from Egypt, lacquered bowls from China and even mounted ostrich egg decanters [2, 3]. The favourable preservation conditions within the sealed strong rooms meant that fragile organic objects had also survived. Over 1000 carved ivory and bone plaques were excavated from the strong rooms, many still attached with corroded metal pins to the heavily decayed traces of the wooden furniture that they had once decorated. During excavation numerous photographs were taken and detailed drawings made of the original locations of the plaques relative to one another and to the furniture that they once adorned. These drawings have informed different pictorial and virtual reconstructions of the furniture, which are now interpreted as a mixture of chairs, sofas and footstools, Figure 2. The plaques were carved in both flat relief and openwork and depict exquisitely detailed scenes of bejewelled women, mythical beasts and realistically rendered wildlife. Individual hair and body ornaments were realised in such detail on the carved figures that it has been possible to match them with objects found in contemporaneous contexts, such as conch shell necklaces and anklets [4]. It was noted during excavation that many of the plaques retained visible traces of original black and red polychromy [2, 5], but the implications of this were not explored in detail at the time and the scientific techniques available to examine the polychromy have advanced considerably since their discovery.

The Begram Ivories rediscovered

After their excavation, the finds from Begram were divided between the Musée Guimet in Paris and the National Museum of Afghanistan in Kabul (henceforth abbreviated as NMA). Some of the pieces belonging to Kabul were exhibited there until 1978 when the political situation forced the closure of the NMA. In the following 25 years of social and political turbulence in Afghanistan the

FIGURE 2. Images of the Begram plaques during excavation and examination: (a) plaques in their original positions on the decayed remains of wooden furniture during the 1930s excavation at Begram; (b) the proposed original arrangement of several plaques upon a piece of furniture; and (c) ivory plaque KNM 015 – indicated by the red rectangle in (b) – immediately prior to conservation at the British Museum. Images (a) and (b): © Délégation Archéologique Française en Afghanistan

TABLE 1. Reference numbers and descriptions for each of the plaques, giving the temporary numbers (KNM xxx) assigned for this study

Description	Temporary BM no.	Find spot	Excavation no.	NMA no.	Material	Pigments identified
Female figure with a parrot	KNM 004		Previously unpublished		Ivory	Amorphous carbon
Seated woman, right profile	KNM 005	Room 10, group 321, footstool I		59-1-16	Ivory	Amorphous carbon
Bird walking to the left	KNM 006	Room 10, group 325, footstool V	K.p. Beg. 306.46	59-1-1	Ivory	Amorphous carbon; calcite
Elephant and riders	KNM 007	Room 13	K.p. Beg. 596.336	58-1-166	Ivory	None seen
Female musicians	KNM 008	Room 13, chair 1 or 4	K.p. Beg. 563.303	58-1-164	Ivory	Indigo; vermilion
Lions and elephant	KNM 009	Room 13, chair 3	K.p. Beg. 542.282	58-1-240	Ivory	None seen
Mythical creatures with riders	KNM 010	Room 13, group 327			Ivory	None seen
Carved furniture element	KNM 011		Previously unpublished		Bone	None seen
Woman beneath a gateway	KNM 012	Room 13, chair 1 or 4	K.p. Beg. 583.323	59-1-42	Ivory	None seen
Female figure beneath a tree	KNM 013	Room 10, group 329, footstool IX	Previously unpublished		Ivory	Amorphous carbon
Female figure pirouetting under a tree	KNM 014	Room 10, group 329, footstool IX	K.p. Beg. 333.73	58-1-60	Ivory	Hematite; amorphous carbon
Gate guardian holding a spear	KNM 015	Room 13, plaque	K.p. Beg. 607.347	58-1-76	Ivory	None seen
Seated figure with a feathered crown	KNM 016	Room 13, chair 2	K.p. Beg. 457.197	58-1-213	Bone	Indigo; vermilion; ? organic lake pigment
Seated woman looking to her right	KNM 017	Room 10, footstool I	K.p. Beg. 279.19	59-1-13	Ivory	Amorphous carbon
Seated woman holding a bowl	KNM 018	Room 10, group 321, footstool I	K.p. Beg. 281.21	59-1-12	Ivory	Amorphous carbon
Makara	KNM 019	Room 10, group 325, footstool V	K.p. Beg. 312.52	59-1-4	Ivory	Not analysed
Crested bird standing on a lotus	KNM 020	Room 10, group 321, footstool I	K.p. Beg. 285.25	59-1-5	Ivory	Vermilion
Bird walking to the right	KNM 021	Room 10, group 325, footstool V	K.p. Beg. 307.47	59-1-2	Ivory	Amorphous carbon; indigo
Bird walking to the left with its head turned	KNM 022	Room 10, group 325, footstool V	Previously unpublished		Ivory	None seen
Playful lion	KNM 023	Room 10, group 329, footstool IX	K.p. Beg. 335.75	58-1-54	Ivory	Amorphous carbon

contents of the Museum were packed, moved, repacked and stored in a number of locations, with the staff and officials of the Ministry of Culture putting themselves at considerable personal risk to protect them. Despite this, an estimated 75% of the collection that had remained stored on site was either looted or destroyed during the civil war (1992–1994) and the 20 plaques that are the focus of this study disappeared, Table 1. Despite publication by UNESCO of a catalogue of the contents of the Museum [6], the whereabouts of these plaques remained unknown until an anonymous individual identified and salvaged them from the black market in 2009, after which they were transferred to the British Museum (BM) for conservation and temporary display prior to their return to Afghanistan. Whilst in the BM, and with the permission of the Afghan authorities, the pieces were subject to their first ever scientific examination [7]. Non-destructive techniques were used to identify the materials from which the plaques were made, to map the distribution and identify the composition of pigments used to colour the plaques, and to analyse the composition of the original metal pins used to fix the plaques to the furniture. The findings of the scientific investigation have provided new evidence supporting an Indian origin for the plaques, shedding light on ancient trade routes and giving an idea of the global interconnections of the Kushan Empire nearly 2000 years ago.

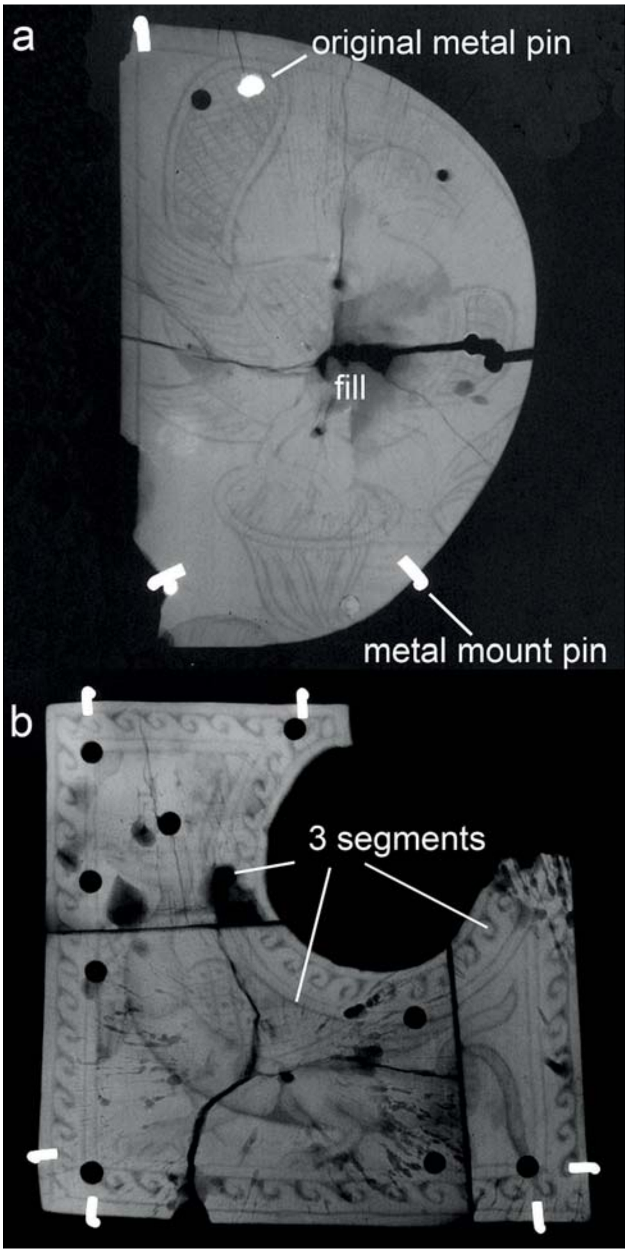

FIGURE 3. X-radiographs of two ivory plaques: (a) KNM 020 showing the locations of a modern fill that appears as a darker area on the X-radiograph and the metal pins that were either original or applied as mount pins prior to arrival at the British Museum; and (b) KNM 006, showing the three pieces of ivory that comprised this plaque and the internal fragility of the ivory, which is apparent in the lower left segment where radiating growth lines are clearly visible

Following scientific examination the plaques underwent condition assessment and conservation treatment at the BM [8], generously supported by Bank of America Merrill Lynch. The plaques were displayed temporarily in the exhibition *Afghanistan: Crossroads of the Ancient World* at the BM in 2011 and the opportunity was taken to produce an additional special publication on these pieces, as they are not in the catalogue of the travelling exhibition [4, 5]. The addition of these pieces as part of the concluding section of the exhibition gave a new element to an exhibition, which interwove the rich cultural interactions of Afghanistan with examples illustrating the fragility of cultural heritage at times of conflict. The hosting of this exhibition by the BM also marked the first time that these plaques had been on public display in over 35 years.

SCIENTIFIC EXAMINATION

Prior to carrying out conservation work on the plaques, they were thoroughly examined using non-invasive techniques. The primary aim was to provide information to aid the essential conservation treatment, but it was also hoped to learn as much as possible about the original materials and manufacturing processes.

Each plaque was initially inspected using optical microscopy to examine the surfaces and identify the substrates. Three of the plaques, given the temporary numbers KNM 008, KNM 016 and KNM 021 while in the BM (for other numbers see Table 1), showing evidence of surviving polychromy were subject to a more intense microscopic study. Next, all the plaques were imaged using infrared (IR), ultraviolet (UV) and X-ray radiation. These images were used to assess the condition of each plaque and to guide the analysis of conservation materials, pigments and metal pins with a range of non-invasive analytical techniques – Fourier transform infrared (FTIR), Raman and X-ray fluorescence (XRF) spectroscopy. Full details of all analytical methods are given in the experimental appendix.

Inlays or overlays? Ivory or bone?

The Begram Ivories have traditionally been referred to as inlays although technically they are furniture overlays, which were originally secured onto the wood with metal rivets; they will be referred to as 'plaques' throughout this study. Moreover, while the plaques are part of a group often referred to as the Begram Ivories, it has always been recognized that some are carved from bone. Knowledge of the composition of the substrate is important for conservation and to ensure correct storage and display conditions. It also reflects a deliberate decision made by the original manufacturers of the pieces, as the intricacy of the carving that could be achieved depends on the material chosen. For example, delicate openwork carving is limited to the ivory plaques as the finer internal structure of ivory relative to bone is more suitable for this type of work. Of the 20 plaques, two were found to be carved from bone (KNM 016 and KNM 011: Table 1), while the remaining 18 are carved from ivory.

X-radiography

X-radiographs were recorded for all of the plaques and clearly reveal the location of the remaining original metal pins used to fix the plaques to items of wooden furniture, despite these pins being heavily corroded and sometimes

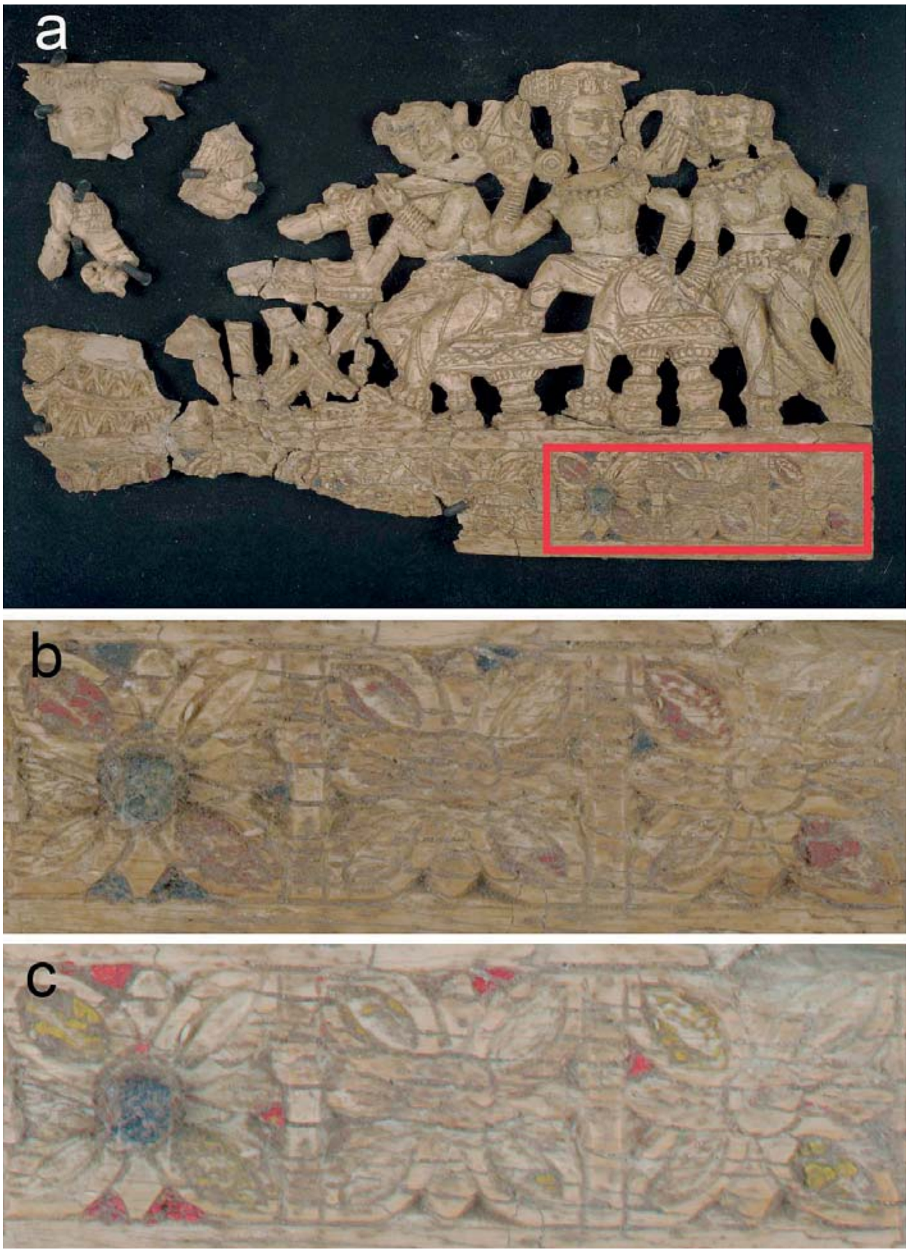

FIGURE 4. Ivory plaque KNM 008: (a) prior to conservation at the British Museum; (b) a detail recorded in visible light showing the decorative border with surviving red and blue pigments (the green circular object to the left is a corroded copper alloy pin, original to the object); and (c) an IR false-colour image of the same area, produced by combining the IR and visible images. In this image, all the red pigment present appears the same tone of yellow, and all the blue appears the same tone of red, suggesting that in each case only one pigment is present

not visible from the surface of the object. Internal areas of loss or weakness within the ivory or bone are also clearly visible, as are the joins between separate pieces of ivory. Modern fill materials used to compensate for areas of loss generally appear darker in the X-radiographs as these areas are less dense than the ivory or bone substrate, Figure 3.

Technical imaging

All the plaques were imaged under visible, IR and UV radiation sources, using a Canon 40D camera.

- *Infrared-reflected imaging*: IR radiation is more penetrative than visible light and can provide information about materials below the immediate surface of the object [9]. It is used most frequently in a museum context to look at underdrawings in paintings but can provide other information. Carbon is particularly opaque to IR making this technique useful for mapping the distribution of carbon-based pigments. For each plaque, IR reflected images were also combined with visible images to create IR false-colour (IR-FC) images. Although the colours of false-colour images have no true meaning, they can prove a useful aid for mapping the distribution of pigments. For example,

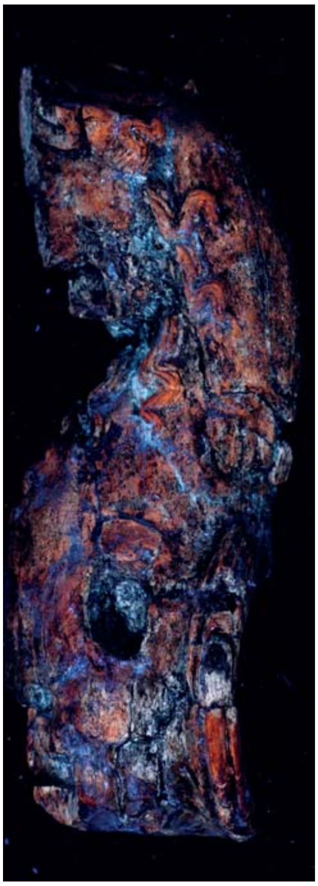

FIGURE 5. A UV-induced luminescence image of plaque KNM 011, a carved furniture element made from bone. The different colours of the emitted light show the various conservation materials that have been applied to the object

Figure 4 shows a detail from the decorative border of plaque KNM 008, imaged in visible light and then combined with an IR image to produce a false-colour image.

- *Ultraviolet-induced visible luminescence imaging*: UV-induced luminescence imaging reveals the distribution of luminescent materials, which includes many conservation materials such as adhesives, consolidants and coatings [10, 11]. It has been noted that certain materials fluoresce with characteristic colours when exposed to UV radiation and this is often used as a preliminary identification technique for conservation materials. However in this case full characterization of all materials introduced during modern interventions was carried out by FTIR and the UV-induced luminescence images were used simply to guide sampling, Figure 5. This type of imaging also reveals the distribution of certain ancient organic materials, such as organic colourants or binders. For example, UV-induced luminescence imaging revealed small areas of pink luminescence on the plaque with the largest amount of surviving pigment, KNM 016, in the cross-hatching detail on the wings on either side of the figure, and in the trousers, Figure 6. These luminescent areas coincide with areas where surface traces of calcium carbonate were detected by Raman spectroscopy. Luminescence of this type is typical of certain organic colourants, particularly madder, a plant widely used at the time the plaques were made to produce a bright pink lake pigment by adsorbing the extracted colourant onto a white substrate such as calcium carbonate. It seems likely that this luminescence represents the much-degraded traces of an organic lake

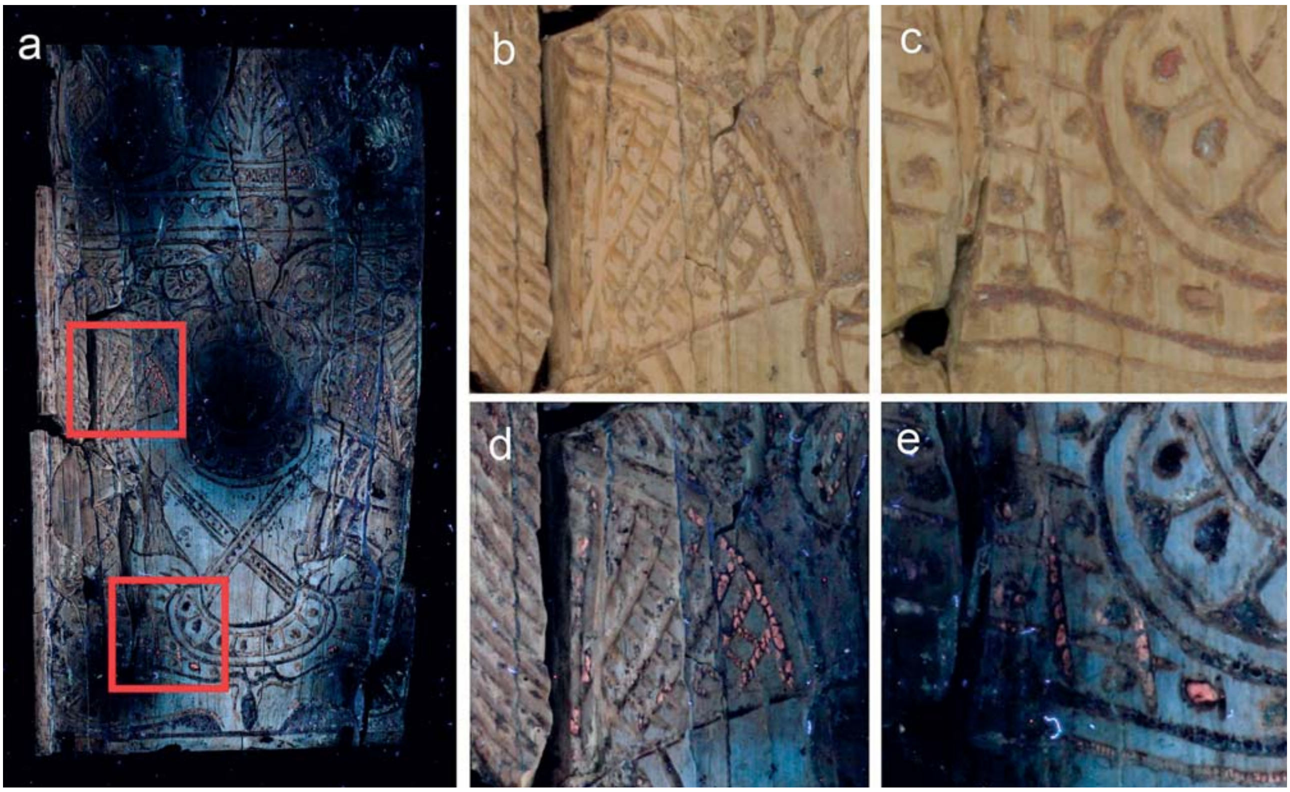

FIGURE 6. Ivory plaque KNM 016: (a) UV-induced luminescence image: (b) and (c) show details of the areas indicated in (a) in visible light; and (d) and (e) show the corresponding details from the UV-induced luminescence image

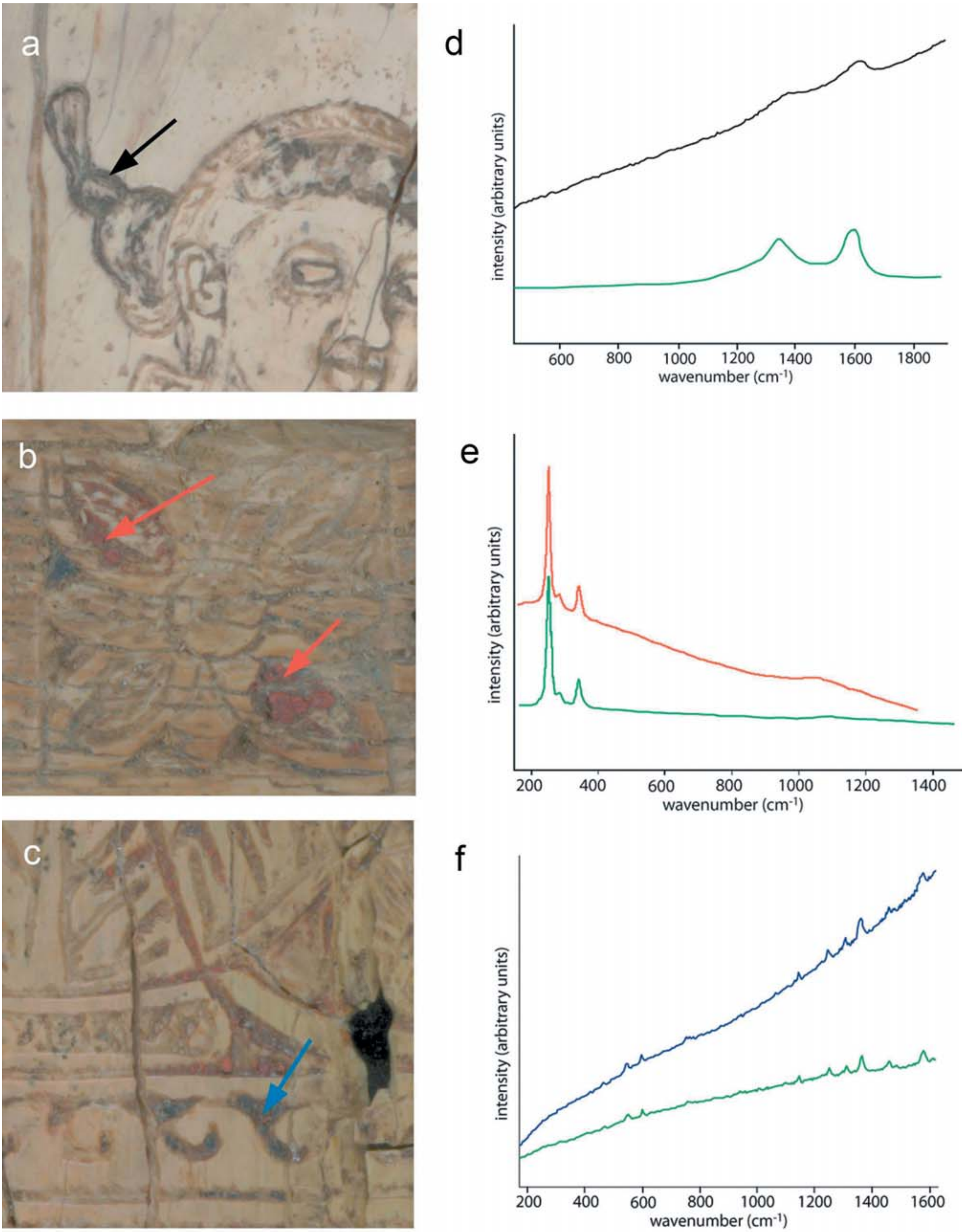

FIGURE 7. Analyses of surviving polychromy; areas with remaining pigment are indicated by the coloured arrows: (a) detail of black pigment used in the outlines of the hair in KNM 014; (b) detail of red pigment used in the deeply recessed petals of the flowers in the decorative border of KNM 008; (c) detail of blue pigment used in deeply recessed decorations on KNM 016; (d) Raman spectrum acquired from the black pigment in (a), shown in black with a reference spectrum for amorphous carbon shown in green; (e) Raman spectrum acquired from the red pigment in (b), shown in red with a reference spectrum for vermilion shown in green; and (f) Raman spectrum acquired from the blue pigment in (c), shown in blue with a reference spectrum for indigo shown in green

FIGURE 8. Images taken in visible light of the black dendritic material on the surfaces of two plaques: (a) plaque KNM 004; and (b) plaque KNM 016

pigment that has faded, leaving behind only the substrate. Unfortunately it was not possible to confirm this without taking a sample; given the delicate nature of the objects and the very small amount of surviving material, which may in any case be contaminated with recent conservation materials, destructive sampling was deemed inappropriate in this instance.

Pigment analysis – XRF and Raman spectroscopy

Twelve of the plaques retain traces of original polychromy, Table 1. Investigation by light microscopy revealed that the pigments had been applied in two ways: either as thin layers in shallowly incised lines, such as those outlining the hair of the figure on plaque KNM 014, Figure 7a; or as thick layers in deliberately recessed areas, such as those on the decorative border of plaque KNM 008, Figure 7b, and those surrounding the seated figure on plaque KNM 016, Figure 7c. Unsurprisingly, more pigment survives in the deeply recessed areas than in the incised lines.

Analyses were carried out *in situ* on the untreated surfaces of the objects, prior to any conservation work, using a combination of XRF and Raman spectroscopy, both non-destructive techniques. XRF spectra were also recorded from an area of undecorated ivory or bone for each plaque and these analyses were used to subtract any elements relating to the background substrate from those relating to the pigments. This examination confirmed an original palette for the polychromy that includes multiple examples of amorphous carbon, vermilion (mercury sulphide, HgS, in this case the pigment probably derived from the mineral cinnabar) and indigo (an organic pigment extracted from certain plant species), in addition to one instance of the use of hematite – iron(III) oxide (Fe_2O_3), the main colourant of natural red ochre – see Table 1. Examples of the areas of remaining polychromy and the Raman spectra acquired from these pigments are shown in Figure 7.

The composition of a black, dendritic material that occurs on the surfaces of several of the plaques, most notably on KNM 004 and KNM 016, was also investigated, Figure 8. This material does not appear to have been applied to recessed regions or even to incised lines, but seems to sit superficially on the plaques. XRF analysis of these areas showed the presence of manganese (Mn), while Raman spectroscopy produced a poor spectrum with a broad, diffuse peak centred at 625 cm^{-1}, which seems to correspond to the Mn–OH stretching frequency at 630 cm^{-1} [12], and closely resembles the reference spectrum for hausmannite ($Mn^{2+}Mn^{3+}{}_2O_4$; [13]), a type of manganese oxide. However, as manganese oxides/hydroxides are notoriously difficult to characterize by Raman spectroscopy it is best to interpret this material as an unidentified manganese compound. The seemingly random distribution of this material suggests that it is a post-depositional, or even post-excavation, product and was not deliberately applied to the plaques as a pigment.

Three of the plaques had a greater amount of surviving polychromy, and the distribution of these pigments was mapped using optical microscopy. By combining the results of the scientific analyses with the mapped distribution of the pigments, it has been possible to produce a digitally recoloured image of one of the plaques, Figure 9. While only an approximation of the original appearance, this image gives at least an indication of the colour and vibrancy of the pieces when they were first manufactured, perhaps revealing the true intentions of the artist.

Metal pin analysis – XRF spectroscopy

The original pins used to fix the ivory and bone plaques to wooden furniture through pre-drilled holes are still

FIGURE 9. Images of KNM 016. The left image shows the plaque in visible light immediately prior to conservation at the British Museum. The right image shows a partial digital recolouring of the plaque, based on observations made using microscopy and scientific analyses. Other incised details, such as the cross-hatched wings, are left uncoloured here but were probably also coloured using a now degraded organic pigment, such as madder lake. (Note that the bent metal mounting pins visible in the left image were removed during conservation treatment and do not appear on the right image.) Digital recolouration courtesy of Antony Simpson

present on many of the pieces. The locations of the pins were usually obvious from visual examination alone as they are now corroded to a deep green colour, but the pins are also easily identified from the X-radiographs, where they appear as bright circular objects, e.g. Figure 3. To avoid potential damage, XRF analyses of the metal were made on the surfaces of the pins without cleaning and hence record the composition of the corrosion products, rather than that of the original metal, which limits interpretation of the data. However it is clear that the original pins were an impure copper [14], or even bronze (an alloy of copper and tin), which would have been a bright yellow metal when first manufactured. In some instances it seems that the pins were used as part of the decorative scheme, as in KNM 008, where a pin has been positioned at the centre of one of the symmetrical flower designs in the border, Figure 10a. In others, such as KNM 016, Figure 10b, the position of the pins appears to have been dictated more by the desire to secure the plaque through the centre.

CONSERVATION

Conservation history

As mentioned above, the Begram plaques are made from both ivory and bone and during the original excavation it had been noted that the plaques were highly fragmented and in a poor state of preservation. To strengthen the plaques prior to lifting from the soil, layers of warm gelatine and fine tissue were applied directly onto the objects. This procedure stabilized the plaques temporarily and was instrumental in their successful excavation. After entering the collections of the NMA in the 1940s the objects are known to have been packed, moved and stored, possibly on numerous occasions. During this period multiple conservation and restoration treatments seem to have been applied; FTIR analysis of surface coatings, fillers and adhesives on the plaques showed these to include polyvinyl acetate-based

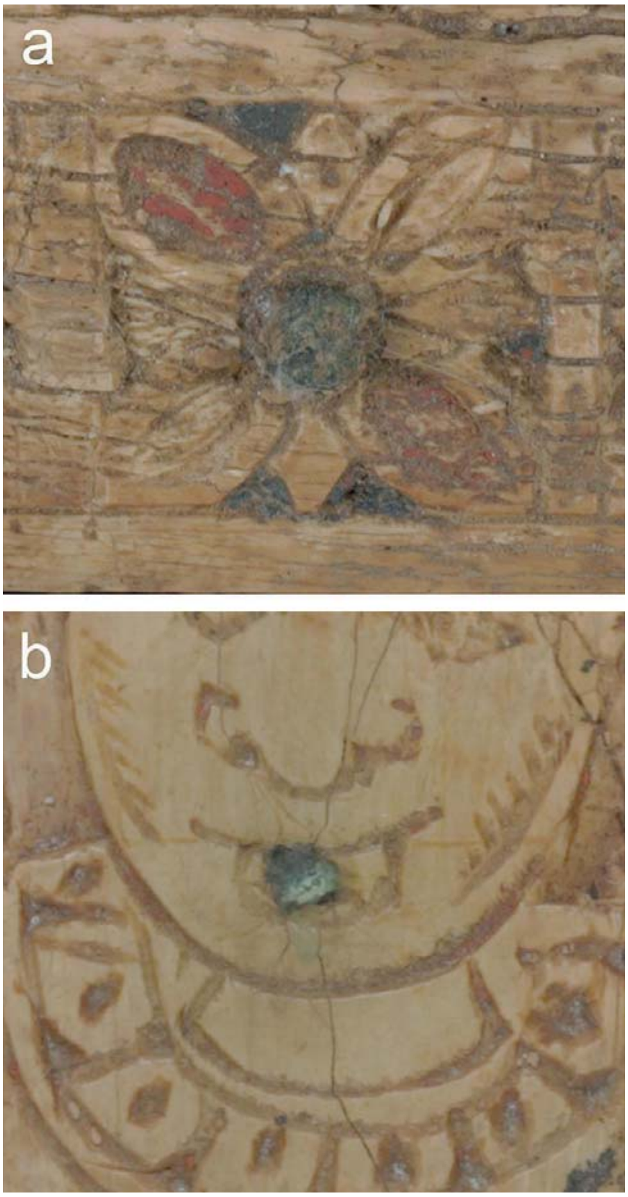

FIGURE 10. Original metal pins used to fix the plaques to pieces of furniture: (a) a metal pin in the centre of a floral decoration on plaque KNM 008; and (b) a metal pin passing through the centre of plaque KNM 016, apparently with greater concern to secure the plaque than to ensure the integrity of the design

adhesives, wax-resin coatings, wax coatings, an unidentified modern synthetic polymer and an adhesive containing ethyl methacrylate copolymer with cellulose nitrate (possibly HMG Acrylic B72 [15]), which is probably from a more recent treatment, see below. The plaques have undoubtedly deteriorated since they were looted from the NMA in the early 1990s; when rediscovered in 2009 they were in a very poor condition, sometimes fragmented into many pieces. In 2010, shortly before they arrived at the BM, the objects underwent limited conservation, including mechanical removal of some of the previous restoration materials under ×10 magnification and cleaning using water. Joins were made good using HMG Acrylic B72 adhesive and toned in using reversible watercolour paints. All the pieces were then mounted on black Corian tiles and held in place with non-ferrous clips.

Condition assessment

In 2011, after completion of the scientific analyses and prior to conservation treatment and display, the plaques underwent a detailed condition assessment by organic artefact conservators at the BM.

The plaques were found to be extremely fragile and were cracked and broken. The use of warm gelatine to strengthen the objects during the initial excavations had resulted in the formation of a hard surface layer, which also trapped dirt and may have caused some movement of loose pigment on the surface. Gelatine is an inherently unstable material that shrinks and embrittles with age and on a fragile ivory or bone surface this can result in lifting and flaking. Over time, additional resin coatings had also been applied, presumably in an attempt to rectify this issue. Such coatings can degrade and also give the surface an unnatural shine, obscure surface detail and absorb dust and dirt. The coatings and consolidants had largely failed in their initial intention; since all these treatments were primarily superficial, the interior of the ivory or bone had remained very weak and fragile. Cracks and breaks had been joined with a variety of adhesives and there was no evidence of prior consolidation of the fragile join edges. Repeated reattachment had resulted in multiple layers of glue and ivory, and had led to increasingly weaker joins and inaccurate reconstructions. Some of the fragments had been incorrectly positioned, while in other cases sections from separate ivory plaques had been assembled by making false joins. Excess adhesive, hairs and cotton wool deposits were found on the plaques, the remnants of previous treatments. In some cases the bent metal pins securing the plaques to the Corian tiles were not holding the objects securely and there was concern that these hard metal pins could be damaging the plaques. In many cases the joins made with HMG Acrylic B72 adhesive had already failed and the plaques were in pieces.

Conservation treatment

All conservation examination and treatment (apart from gap filling and toning) was carried out under magnification using an optical microscope. The plaques were first removed from their black plastic supports, enabling the investigation and treatment of both the front and back of each piece. Glossy, unstable surface coatings and other extraneous surface deposits were removed where possible using appropriate solvents, including deionized water, acetone and industrial methylated spirit (IMS), applied with cotton wool buds. Fragile pieces were consolidated as necessary with a 3% (weight to volume) solution of Paraloid B72 (ethyl methacrylate copolymer) in a 1:1 mixture of acetone and IMS and joins were examined and improved where possible. Incorrectly placed fragments were reattached correctly using HMG Heat and Waterproof adhesive (cellulose nitrate). Where they were required for stability, fills were made using glass microballoons in a 20% (weight to volume) solution of Paraloid B72 in a 1:1 mixture of acetone and IMS. In some cases a stronger fill was required and HMG Heat and Waterproof adhesive bulked with calcium carbonate powder was used. The fills were toned in using dry powder pigments mixed with Paraloid B72 and acetone. For further conservation details see [8]. Some extremely fragile pieces were supported on Perspex mounts.

AFGHANISTAN: CROSSROADS OF THE ANCIENT WORLD

The original discoveries at Begram in the 1930s exceeded the French excavators' wildest dreams of finding archaeological evidence for trade along the Silk Road. The Begram Ivories, in particular, added a new chapter to the appreciation of early Indian art as relatively few early ivories had survived and the closest parallels were to carved sculpture on Indian temples, while the imagery and context of the Begram pieces is secular. Although elements of the decoration recur on monuments as far removed as Kanganhalli in Karnataka (southern India), the closest parallels are with the Great Stupa at Sanchi (in Bhopal) and the Kushan city of Mathura, both in north central India, Figure 1 [16–18]. Fitters' marks on some of the pieces (although none of the 20 examined here) support an Indian origin as they include letters in Kharoshthi and Brahmi script [2]. While it is possible that these craftsmen made or assembled the furniture at Begram [19], the strong Indian feel and scale of other imports suggests that they were made elsewhere, possibly at more than one centre, and brought to the site. There continues to be debate over the interpretation of the buildings where the plaques were found: the overall plan and presence of wall paintings within these particular rooms suggest that they were part of a palace, and were later transformed into hidden strong rooms by being sealed at either end in order to conceal their contents [20]. Others view the building as a form of caravanserai and the items as goods belonging to Silk Road merchants [19]. Although the number and variety of objects is staggering, there are few items of intrinsic value and much that was either relatively bulky (furniture) or fragile (glass, plaster type-casts or *emblemata* and ostrich egg decanters). This suggests a deliberate decision; items of precious metal may have been taken away rather than left on site. There has also been considerable discussion over the date of the sealing of these rooms, with the excavator initially suggesting a fourth-century date [2], then revised to the second century [3]. Following his own excavations at the site, Ghirshman proposed that the so-called second period of Begram, which included this complex, was destroyed during a Sasanian attack in AD 241 [21], although the evidence is circumstantial. An even later date of the mid-fourth century was proposed by Rütti [22], and a correspondingly wide date range for the contents has been followed by some authors [23, 18]. However, studies of the Roman plaster type-casts, glass and bronzes, Chinese lacquer bowls and many of the Indian ivories converge in pointing to a first-century AD date and it seems inconceivable that there would not be later imports if the rooms were sealed two or more centuries later [23–25]. Moreover, a re-analysis of the find spots of coins used to suggest a later date has shown that these are not reliably stratified [24]. Although the reason why the rooms were sealed remains unclear, they contain an exceptional body of contemporaneous material and provide a vivid glimpse into patterns of circulation and elite consumption in the Kushan Empire, shortly before the reign of the great Kushan ruler Kanishka I (*c.*AD 127–150).

DISCUSSION AND CONCLUSIONS

The plaques examined here are part of a group of ivory and bone carved plaques that would once have decorated elaborate pieces of furniture used in the late first-century AD Kushan court. The plaques were fixed onto the furniture with metal pins (made from impure copper, probably bronze), which are now heavily corroded. The pieces have had a complex conservation history, which has often added to their instability. Conservation work undertaken at the BM focused on the removal of degraded conservation material, which was replaced with fully reversible modern materials, stabilizing the objects for storage, display and future transport back to Afghanistan.

The scientific analyses of ancient pigments on some of these pieces are an important new development. Some 12 of the plaques show traces of surviving polychromy in carved recesses (seemingly designed for this purpose) and in the shallowly incised outlines of carved figures. The pigments were investigated by optical microscopy, multispectral imaging and Raman and XRF spectroscopy. A rich and colourful palette including carbon (black), vermilion and hematite (red) and indigo (blue) has been confirmed and imaging suggests that at least one other organic-based pigment was originally present. Areas of dendritic black material on the surfaces of some of the plaques, distributed in a manner that does not respect the carving, have been identified as a type of manganese oxide or hydroxide, which is likely to be a post-depositional product rather than a deliberately applied pigment. Digital recolouring of one of the Begram pieces gives an impression of just how striking these plaques must once have been.

Amorphous carbon is the pigment found most frequently on the plaques and is a common pigment in antiquity. One instance of the use of hematite as a red pigment was found on plaque KNM 014; hematite is a similarly ubiquitous pigment in antiquity. Vermilion was found on three of the plaques and is also common in ancient contexts. It is likely that the vermilion was obtained by grinding up the mineral cinnabar (HgS) to form a deep red powder, but it has not been possible to confirm if the vermilion is natural or synthetic from the data acquired in this study.

Indigo was used as a blue pigment on three of the plaques and its presence is particularly significant. Indigo is an organic colourant that can be produced from plants from many geographical areas, but is most frequently referred to in the contemporary literature as coming from India [26; chapter 39]. Indigo has been used as a dye since long before the first century AD (the estimated age of the Begram Ivories), but its use as an insoluble pigment is less widely known at this time; indeed, its occurrence on the Begram plaques marks one of the earliest known instances of the use of indigo as a pigment. Paradoxically, Afghanistan contains the only ancient source of the blue pigment ultramarine derived from lapis lazuli, a deep blue rock that contains the mineral lazurite [27]. Lapis lazuli was ground to produce ultramarine, a common if very expensive pigment used in the region at this time [28]. At the time of production of the Begram Ivories, lapis lazuli was in extensive use for jewellery, inlays, seals or as a pigment, and was exported far beyond Afghanistan. Its use as a pigment has been confirmed analytically on slightly later wall paintings and cave paintings from Afghanistan and Central Asia [29, 30]. The preference for indigo rather than lapis lazuli on the Begram Ivories suggests that these pieces were either imported ready constructed from India or were produced in Afghanistan by local or imported craftsmen to Indian patterns and styles, using Indian-derived pigments. The other objects in the Begram storerooms – including Chinese lacquer bowls, Roman glass and Egyptian bronzes – certainly reflect the cosmopolitan tastes of a powerful kingdom at the crossroads of the ancient world.

These results significantly expand previous knowledge of the polychromy on these objects, where only black and red were noted and not analysed. Moreover, the results have implications for the future re-examination and interpretation of either broadly contemporary Indian sculptures, such as those from Amaravati [31], or more ancient ivories from parts of the Near East [32] where the extent of use of pigments is ambiguous.

EXPERIMENTAL APPENDIX

Ivory and bone identification

It is usual at the British Museum for ivory and bone to be identified using examination in a variable pressure scanning electron microscope (VP-SEM). However, the Begram material was considered too fragile to be subjected to even a partial vacuum. Consequently, the 20 plaques were examined using a Leica Metallux optical microscope at magnifications ranging from ×20 to ×1000. Comparative specimens of worked and unworked ivory and bone, as well as high resolution VP-SEM images of comparable archaeological examples of ivory and bone samples were used as reference materials.

X-radiography

X-radiographic images were produced using a Siefert DS1 X-ray tube at 60 or 70 kV, with exposures of 5 mA and five minutes. The images were collected on Agfa Structrex D4 and D7 films held in rigid cartridges with 0.125 mm lead sheets on either side of the film. These films were then scanned using an Agfa RadView digitizer with a 50 μm pixel size and 12-bit resolution to allow digital manipulation and enhancement of the images.

Technical imaging

All images were taken using a Canon 40D camera body modified by removing the inbuilt UV-IR blocking filter in order to exploit the full sensitivity of the CMOS sensor (*c.*300–1000 nm). The lens used was a Canon EF 50 mm f/1.8II. The spectral range under investigation was selected by placing a filter or filters in front of the lens and/or light source.

- *Infrared-reflected imaging*: The radiation source used for infrared-reflected imaging was two photographic Classic Elinchrom 500 Xenon flashlights equipped with a softbox (diffuser), which produce a large amount of infrared (IR) and visible light, but a negligible ultraviolet (UV) component. These were symmetrically placed, positioned at 45° with respect to the focal axis of the camera [33]. The visible component from the flashlights was blocked by a cut-on Schott filter RG830 (which has a 50% transmission at 830 nm) placed in front of the camera lens, making the radiation range under investigation *c.*800–1000 nm. IR reflected images were combined with visible images to create IR false-colour (IR-FC) images by splitting the visible image into its red, green and blue (RGB) components. The data from the blue channel were then discarded and the values from the reflected IR image inserted into the red channel, while those of the red and green components were inserted into the green and blue channels of the new image respectively.
- *Ultraviolet-induced visible luminescence imaging*: The radiation source used for UV-induced luminescence imaging consisted of two sets of four Philips PL-S 9W double BLB fluorescent lamps equipped with Schott DUG11 interference filters (bandpass *c.*280–400 nm). For the excitation source a Schott DUG11 filter was used and for the emission a combination of Schott KV418 and IDAS-UIBAR filters that transmitted in the visible range (400–700 nm). The Schott KV418 filter is a cut-on filter with 50% transmission at 418 nm. The pre-set white-balance chosen for the camera for this type of imaging – where no identification of pigments was attempted – was 5600 K.

Raman spectroscopy

Traces of pigments were analysed *in situ* on the surface of the objects. Raman spectra were obtained using a Dilor Infinity Raman spectrometer with green (532 nm) and near infrared (785 nm) lasers at a maximum power of 4 mW at the surface with a spot size of a few microns. Spectra were collected for total times of between 2 and 10 minutes (including multiple repeats to avoid the effect of cosmic rays). Spectra were identified by comparison with a British Museum in-house database of reference spectra.

X-ray fluorescence (XRF) spectroscopy

XRF analyses were carried out *in situ* on the surface of the objects using a Bruker Artax spectrometer fitted with a molybdenum X-ray tube and operated at 50 kV and 500 µA. Spectra were collected for between 100 and 300 seconds with an analytical spot size of *c*.0.65 mm diameter. Helium gas was introduced into the area between the object and detector in order to allow greater sensitivity in the detection of lighter elements.

Fourier transform infrared (FTIR) spectroscopy

Microsamples of conservation materials identified using UV-induced visible luminescence imaging were taken, using a scalpel, from the plaques. Fourier transform infrared (FTIR) microscopy was performed using a Nicolet 6700 spectrometer attached to a Continuum IR microscope equipped with MCT/A detectors. The samples were analysed in transmission mode, flattened in a diamond microcompression cell. The cell was used open with the flattened sample supported on one diamond window, a clean area of which was used for background spectra collection. The field of view was controlled by the sliding aperture that, when fully open, gives a maximum area of analysis of 100 × 100 µm. The spectra were acquired over a range of 4000–650 cm^{-1} at a resolution of 4 cm^{-1} and automatic gain. Spectra produced were identified by comparison with reference spectra.

ACKNOWLEDGEMENTS

The objects that were conserved, analysed and displayed at the BM were recovered and generously presented by an anonymous donor to the National Museum of Afghanistan in 2010 with the understanding that the BM would facilitate their exhibition and later return to Kabul. The authors are very grateful to this individual and to the director, Dr Massoudi, and staff of the National Museum of Afghanistan, Kabul for their support and permission to undertake this scientific research and conservation and to the Ministry of Culture of Afghanistan for its agreement. The exhibition was greatly facilitated by the Foreign and Commonwealth Office in London and Kabul and the authors are grateful to them and many others for their support. The objects were stored at the BM until July 2012 when Dr Massoudi requested that they be returned as part of his preparations for new displays at the NMA. They were transported to Kabul with the assistance of the British Armed Forces and a selection was placed on temporary display at a handover ceremony in Kabul on 5 August 2012. The authors are also grateful to Antony Simpson for producing the digitally recoloured figure and to Giovanni Verri for acquiring and processing the multispectral images. The conservation work conducted at the BM was generously funded by Bank of America Merrill Lynch, in addition to its sponsorship of the exhibition *Afghanistan: Crossroads of the Ancient World*.

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