A new look at an old cat: a technical investigation of the Gayer-Anderson cat

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Summary The Gayer-Anderson cat (EA 64391:1947,1011.1) is one of the best-known objects in the collections of the British Museum's Department of Ancient Egypt and Sudan. It is a life-size cast copper alloy figure of a cat sitting upright, probably dating to the Egyptian Late Period (around 600 BC). Despite the iconic nature of the sculpture no scientific or technical examination had been made of the piece until recently. This article describes a full technical investigation within the context of the archaeological and religious significance of the object. This revealed that the figure, although now repaired, had suffered an unexpected level of damage in the past. It also showed evidence of the original manufacturing techniques used. Indications were also found of the possible original appearance of the object, including the use of polychromy.

INTRODUCTION

The Gayer-Anderson cat (1947,1011.1: EA 64391) is one of the best-known and best-loved objects in the collections of the Department of Ancient Egypt and Sudan (AES) at the British Museum, Figures 1 and 2. It is a life-size (c. 42 cm high) cast copper alloy figure of a cat sitting erect. The cat wears a gold-coloured nose ring and earrings and has an inlaid white metal plaque of an udjat-eye on the front of the chest. There is a wide band of incised decoration around the neck representing a broad collar and a raised scarab between the ears. It was acquired by the Museum in 1939 as a gift from Major Robert Grenville Gayer-Anderson with a supposed find spot of Saqqara in Lower Egypt, although it did not finally arrive in the Museum until 1947 (an account of the lengthy process of acquisition of the cat by the British Museum is given in [1]). On stylistic grounds it is attributed to the Late Period (around 600 BC), although the manner of its acquisition, through a collector rather than from a controlled excavation, makes both period and find spot uncertain.

This article describes the results of a recent technical examination of the figure made by the Department of Conservation and Scientific Research, within the context of the archaeological and religious significance of the figure.
the finest. The cat is a statue of a goddess, in all likelihood dedicated in a temple by a wealthy individual, perhaps even royalty. The dedication of votive statuettes of deities in massive numbers became a widespread phenomenon in Egypt only in the late first millennium BC [2, 3]. It is known from the inscriptions preserved on the bases of some of these figurines that the donors sought favours from the gods in return for the dedication of statues. The surviving bronzes range from crude little figurines of Osiris, by far the most common god represented, to lavish examples such as the Gayer-Anderson cat. The standing of the donors must have echoed this range. Another fine cat, now in the Musée du Louvre in Paris (Figure 3), bears an inscription upon its base stating that a man named Mer-sopdu, son of Hor, offered the statue to receive protection from Bastet. It is also specified that the temple-dancer Djed-bastet-iwefankh was responsible for the statue once it was housed within the temple [4].

Such statues must have caused considerable clutter in the temples, and periodically these would have been gathered up and buried in specially prepared caches within the sacred area. Unfortunately, the majority of securely provenanced bronze figures come from these caches, not their original context [5, 6]. Nonetheless, these caches at least provide an indication of the range of sizes, quality of workmanship and divine forms that could be dedicated in one temple. Such bronzes could also be used to house sacred cat mummies (in the body cavity) or be placed in chapels associated with burials. Sacred cat burials were also placed in wooden and ceramic containers.

Which god does the Gayer-Anderson cat represent? Due to the nature of Egyptian religion, it is impossible to say with certainty, as gods could typically manifest in a variety of anthropomorphic, theriomorphic and hybrid forms. However, the best candidate is Bastet. This goddess could be represented as a lioness, as in her principal temple at Bubastis in northern Egypt, reflecting her association with Sekhmet [1]. The latter goddess is described in the Destruction of Mankind, an ancient Egyptian mythological text, as attempting to destroy mankind. In another myth,
an enraged leonine Sekhmet leaves Egypt but returns as an appeased cat. Thus Bastet as a cat could be interpreted as the benign form of Sekhmet. Votive figurines of Bastet always represent her as a cat, or cat-headed woman, not as a lioness.

The fertility, motherly nature and hunting abilities of cats must have been seen as appropriate divine attributes, and the additional symbolism found on the Gayer-Anderson cat further emphasizes these associations. A scarab beetle appears upon her head, with a further winged example incised into the figure's chest. The scarab represents the morning form of the sun, and was thus associated with creation and rebirth. The tufts of hair found inside cats' ears have been rendered stylistically, to echo the hieroglyphic sign for Maat, an ancient Egyptian concept perhaps close to modern concepts of truth, order and righteousness. Finally, the silver plaque hung from a necklace around her chest is embellished with the adjat-eye, a symbol of protection that would have been recognizable to many Egyptians. The complex collar incised around the cat's neck, formed from three rows of rectangular beads above a row of drop-shaped pendants, echoes that worn by humans in the funerary banquets shown in tombs, but also placed around the mummies of the elite. All of this symbolism would have reflected the hopes of the donor of the Gayer-Anderson cat to achieve rebirth into an eternal life. If associated with the burial of a cat, specially bred for the purpose of dedication in specific temples (the vast majority of cats analysed were Felis silvestris libyca, although some examples of wild cats (Felis chaus) have been identified [7]), the imagery of rebirth would have been doubly appropriate.

Where was this figure dedicated, and when? Without a recorded archaeological context, its original provenance cannot be known, but Gayer-Anderson tentatively suggested it came from Saqqara near Cairo. Other cat bronzes have been found at the site, in addition to a considerable number of sacred cats buried in reused tombs on the escarpment edge. However, the principal cult place of Bastet, Bubastis, 80 km north east of Cairo, would also be plausible as a find spot: the temple and cat cemetery at the site were badly pillaged in the late nineteenth and early twentieth centuries. A number of other sites have yielded votive figurines of cats and contain sacred cat burials in their cemeteries. Due to the unique nature of such objects produced by lost-wax casting, and the lack of a surviving inscribed base, dating the Gayer-Anderson cat with any accuracy is currently not possible. A tentative dating of 600 BC would be consistent, in terms of style and method of manufacture, with similar objects from secure archaeological contexts of that date, and with those bearing datable inscriptions.

It is regrettable that the date of its production, the place of its dedication and the identity of the donor will probably never be known. However, new scientific analyses have revealed information about the ancient manufacture of, and modern modifications to, this famous metal statue of a cat, another reminder that even the most familiar of objects can reveal new information.

BACKGROUND TO THE SCIENTIFIC EXAMINATION

Prior to the investigations described here the cat had not been the subject of any detailed scientific or technical examination. It is not mentioned at all in the early treatment records archived in the Egyptian Department of the British Museum, which date from the 1950s onwards, and is referred to only once in the centralized records of the Department of Conservation, which was formed in 1975. A reference in a condition survey from the mid-1970s gives the cat a grading indicating that it needed no treatment, while a conservation treatment record from 1982 includes reference to minor work on the cat in preparation for moulding to allow the production of replicas. This included some work to fill and improve the appearance of a large crack visible along the back, to make it less obvious in the replicas intended for public sale. At this time the gold jewellery was removed to aid the moulding procedure. It was noted that the nose ring had been held in place via a modern painted plaster septum and that the earrings were attached with modern copper wire. Both of these
were improved and replaced after moulding. In 2007 it was proposed that the cat be the subject of a short book by one of the authors [1], and scientific examination was requested to inform the text and to provide a range of images. The results of this study produced sufficient new information (and surprises) to form a major part of a temporary exhibition in the Museum (Divine Cat: Speaking to the Gods in Ancient Egypt; 9 November 2007 to 28 February 2008).

INVESTIGATIVE METHODS

The figure was subject to a detailed optical examination, using both conventional microscopy for the external features and boroscopy to allow access to internal areas. Additionally, extensive radiographic investigation was carried out using both film and real-time equipment. Analysis of the metal was undertaken using X-ray fluorescence (XRF) spectrometry, both directly on the surface of the cat and on a drilled sample from the base, while X-ray diffraction (XRD), Raman spectroscopy, gas chromatography-mass spectrometry (GC-MS) and Fourier transform infrared (FTIR) spectroscopy were all used to identify deposits on both internal and external surfaces and areas of corrosion. Finally, biological examination was carried out on small samples taken from the inner cavity. Full technical details of methods used are given in the experimental appendix.

RESULTS AND DISCUSSION

Surface and subsurface examinations

Some of the greatest surprises about the nature and history of the cat came from X-radiography, combined with internal and external surface examinations by optical microscopy and boroscopy. These investigations showed that the object has features relating to two major events: its initial production and an extensive ‘modern’ reconstruction. These are discussed separately here, in chronological order. The clearest images of most of the features mentioned can be seen in Figure 4, a side view X-radiograph of the whole statue.

Original features

The statuette is largely hollow (Figure 5), as would be expected for a direct lost-wax casting made with a temporary clay core, the method known to have been used in Egypt to produce such unique sculptures at the supposed date of the cat. A layer of wax, or perhaps wax mixed with resin or oil, of the intended thickness of the metal wall was applied around a clay core, which would prevent the molten metal filling the centre of the casting (see Figure 6 for a schematic representation of this process). The form was modelled and carved into the wax, which was then covered with an investiture or outer mould, made of a mix of clay, straw and dung and held apart from the central core by a series of metal core pins or chaplets. The mould was then fired (causing the wax to run out) and molten metal poured into the resulting gap between core and investiture. When cool, the core was removed and the outer mould cleaned off before finishing the metal surface. The current investigations showed features entirely consistent with the use of this production method [1; p. 44]. From the X-radiograph (Figure 4) it is clear that the front legs, the main part of the tail and the ears are solid metal and therefore must have been modelled in solid wax. The casting is generally of very high quality, with few casting defects visible, apart from an area of minor imperfections on the top of the shoulder and some porosity in the solid front legs. In addition, visual examination shows at least one added rectangular metal patch at the base of the tail which may indicate the casting was flawed in this area. Also clearly visible on the X-radiograph are the vestiges of a number of square-sectioned core pins, used during casting to hold the core in position. These are clearest towards the rear of the body, but are also present in the apparently damaged area at the top of the back. They are remarkably similar in size and shape to those described by Schorsch and Frantz on a small cat figure from the Metropolitan Museum of Art, registration number 1956 (56.16.1) [8]. Although iron is probably the most likely, attempts to identify the material of the core pins using XRF and a small magnet have so far been unsuccessful, mainly because of the heavily altered outer surface of the cat. Further internal cleaning of the cat might extend the understanding of these
FIGURE 5. The Gayer-Anderson cat viewed from beneath to show the central cavity.

FIGURE 6. Schematic representation of the lost-wax casting process.
features, but this has not been undertaken at the present time. Some small square features (Figure 7) were noted during optical examination of the surface of the cat at many points where core pins are recorded on the X-radiographs.

While the outer surface of the cat has been much changed (see below) the underlying form appears to be original. One of the most prominent surface features is a complex of jewellery around the neck, consisting of a wide collar with three rows of rectangular beads above a row of drop-shaped pendants, all incised into the bronze, and an inlaid plaque with an udjat-eye, hung from a necklace. Optical examination shows the multiple collars to have been produced by chasing rather than engraving or casting. It clearly predates the later crack running around the body, which will be discussed below (Figure 8), and there is no reason to doubt that it is an original decorative feature. The second necklace of inlaid white metal (identified as silver, see below) also shows no visual signs of being anything other than contemporaneous with the initial production.

**Modern features**

The X-radiographic images of the piece are dominated by evidence of modern damage and repair, as the object has evidently been broken into at least two, or probably more, pieces.

A major (but repaired) break, clearly visible in Figure 4, runs around the whole body dividing the top of the back from the lower part. The break is jagged in nature and quite wide (1–2 mm in places). It is filled at irregular intervals with a radio-opaque material, presumably a solder tacking the joint, but for most of its length appears black on the radiograph and must, therefore, be packed with a relatively light material. This is likely to be an adhesive, possibly bulked out with a filler such as plaster, but a fuller identification of these restoration materials would only be possible with a more invasive investigation than that so far undertaken. This repair seems to be a straightforward rejoining of ancient material, with no evidence of the use of any infill sections, but such extensive damage must have allowed access to the hollow centre of the object. As discussed above, the existence of this crack was known prior to this examination – it is visible on the surface, particularly across the back (Figure 9), despite the later application of colouring to the surface – but its significance was not always fully appreciated. The X-radiographs also show many other smaller discontinuities, some of which may have led to complete fractures, but most of which seem to be merely cracks. One such group of cracks, not easily seen on the X-radiographic films because of the orientation of the figure, but clearly visible on the real-time X-ray footage, radiates out from a central point on the top of the head, suggesting that the figure must have received a heavy blow to the head at some point.

Further evidence of modern intervention is found in the X-radiographs of the head, Figure 10. Here an elaborate structure, based around a cut-down cylinder, has been inserted inside the figure, presumably as a ‘scaffold’ to support the head and neck, while some of the many cracks have been repaired in soft solder, visible on the image as thick white amorphous lines. Close examination of the top and bottom of the cylinder show other features, made from...
of mummified cat remains within the central cavity. These organic remains may reflect the original presence as ‘coffins’ to hold the mummified bodies of sacred animals, figures such as the Gayer-Anderson cat were sometimes used.

It was initially hoped that boroscopy would allow a direct view of these repairs to the head. Unfortunately, when the camera was introduced into the body, the neck cavity proved to be filled with a yellow/brown clay-like material that prevented the boroscope probe from passing into the head. This material cannot be part of the original core, as it shows no signs of having been subjected to the heat of casting, and must relate to the modern repairs. It would certainly help to hold the structure inside the head in place. Small samples gathered from this material and subjected to Raman spectroscopy showed it to contain quartz and goethite. Gypsum was also present, and probably represents the additional use of plaster as a repair medium. A black sticky material was also recovered from this area. This was identified using FTIR followed by GC-MS. It was found to be bitumen, which was presumably applied to help maintain the stability of the repair.

A number of fibre samples was also recovered from inside the figure. Most were clearly modern cotton wool, but a few appeared to be older, and these were subjected to biological examination by optical microscopy. They were found to be degraded flax threads, possibly from linen cloth. Very degraded areas of skin or hide were also visible at high magnification under reflected light. While these could be confirmed as animal, insufficient diagnostic features have survived to enable conclusive identification to species. It is known that figures such as the Gayer-Anderson cat were sometimes used as ‘coffins’ to hold the mummified bodies of sacred animals, and these organic remains may reflect the original presence of mummified cat remains within the central cavity.

Turning to the outside of the figure, visual examination of the external surface showed it to have been extensively reworked. On cursory inspection two coloured ‘corrosion’ layers are present, the lower one brick red and the upper consisting of varying shades of green. This would seem to accord with the most commonly found natural patina formed on ancient bronze, with a lower layer of cuprite, a copper(I) oxide (Cu₂O), and an upper layer consisting of one of the green copper corrosion products – most commonly malachite (a copper carbonate: Cu₂CO₃(OH)₂) or atacamite (a copper chloride: Cu₂Cl(OH)₃). However, closer examination shows that most of the surface green ‘patina’ is an artificial layer applied to the metal surface after removal of the majority of the naturally formed corrosion stratigraphy. In places it is possible to see the marks of the tools used to achieve this. Some striations also appear on the surface of the green paint layer but leave the underlying cuprite or metal surface untouched, showing that in some places the surface of the cat was worked again after the paint layer was applied. In other areas the underlying authentic cuprite layer survives as patches on the original surface of the bronze. Although the account below includes neither the repairs nor the overpainting, these findings are in accord with Major Gayer-Anderson’s own description of the cleaning process he used:

I followed a technique in which I was already highly proficient from long practice and which if carefully and successfully carried out brings a good sound bronze such as this proved to be back to its original surface and condition. Using only a hammer, chisel and burner I carefully flaked off little by little the layers of outer grey-green and inner brick-red patines and gradually an exquisite figure of a cat emerged as if from under a veil that was being slowly stripped off her [cited in 1; p. 57].

At first reading, Gayer-Anderson’s method seems a rather robust approach to cleaning. However, it is in fact similar to a standard manual cleaning technique that is used on well-preserved archaeological bronzes today, where a small tool such as a scalpel is used to follow the cleavage plane between the original surface and the overlying corrosion. While it is possible that a burner was used, there is no evidence of heating present on the cat’s surface and, since Gayer-Anderson’s notes were handwritten, it may be that the word ‘burner’ in this text is a misreading of either ‘burrin’, an engraving tool, or ‘burnisher’, a polishing tool. The exceptionally good condition of the original surface of the cat that Gayer-Anderson laboriously exposed indicates that the piece was relatively lightly corroded, an inference that is confirmed by examination of the uncleared corrosion stratigraphy on the underside. Those parts of an object usually hidden to the eye or embedded in a mount, such as the interior of a hollow-cast Egyptian bronze, its basal tangs and underside, are rarely cleaned to the same degree as the visible parts and often never cleaned at all. The fortuitously
preserved evidence of a full corrosion stratigraphy can be particularly useful in the reconstruction of the sequence of corrosion and cleaning [9].

It is clear from the current appearance of the piece and from early descriptions that after cleaning the cat must have been painted green, presumably with the pigment mix that currently covers it. Small samples collected from a number of positions on the surface of the sculpture and analysed by XRD and Raman spectroscopy confirm the red material to be cuprite, probably naturally developed, and show the applied green to contain lead white (basic lead carbonate: 2Pb(CO3)2·Pb(OH)2), barium white (barium sulphate: BaSO4), chrome yellow (lead chromate: PbCrO4) and Prussian blue. This pigment mixture is known to have been commercially available in the early part of the twentieth century, the period when the cat was in Gayer-Anderson’s possession, under the name Brunswick green [10]. Some original green corrosion seems to survive on the base where atacamite, often found on the surface of ancient Egyptian bronzes, is present in some quantity.

Small deposits of lime plaster (identified by Raman spectroscopy) were also found around the eyes; these rest over, rather than beneath, corrosion products, suggesting that they are late cosmetic repairs rather than original survivals.

The known history of the piece and the nature of the repairs to the cat make it most likely that they were undertaken at some time in the early twentieth century, probably while the cat was in the hands of Major Gayer-Anderson (possibly in response to accidental damage during excavation, after the initial cleaning, or during the cat’s transit from Egypt to England).

Metals analysis

Attempts to analyse the metal of the figure were complicated by the heavily painted surface, which would affect any analysis carried out directly on the object. To avoid this difficulty, and produce a good quantitative analysis for the metal of the body, a small sample of clean metal was removed from the base of the front paws by using a modeler’s electric drill fitted with a 1 mm diameter drill bit. The sample was collected into a gelatine capsule and analysed by XRF using a Bruker Artax spectrometer and following procedures outlined by Cowell [11]; see the experimental appendix for details. Analysis of the drilled metal indicated a metal content of c.84.7% copper, 13% tin, 2.1% arsenic and 0.2% lead. These results have a precision (a measure of reproducibility) of c.±1–2% for copper, c.±10% for tin, c.±20% for arsenic and c.±50% for lead at these levels. The accuracies of the analyses should be at similar levels. Very small amounts of other elements such as antimony, silver, iron and cobalt were also present at levels close to their respective detection limits. Zinc, nickel and chromium were not found to be present at levels above the detection limit of the technique (c.<0.1%). Many hundreds of analyses of Egyptian copper alloy metalwork have been carried out that show the wide range of alloys used at this time, for example [12–16]. The results from the analysis undertaken here fall into these overall ranges, but a close match with other analyses has not been found, as the tin and arsenic contents are at the higher end of their ranges (especially when combined together) and that of lead is relatively low.

Careful visual examination of the object showed that the stripes on the cat’s tail were not the result of casting or chasing processes, but were instead produced by wrapping metal bands around the cast cylinder of the tail. This raised the intriguing possibility that metal of different composition might have been deliberately applied to produce a polychromic effect. It is well established that such bimetalism occurs in the Greek world, where examples of golden, bronze statuary with reddish, low-tin bronze metal lips are known [17], and many Egyptian bronzes are known to have been polychrome, with inlays of glass, stone or coloured alloy being used to produce surface decorative effects [18]. The cat was already known to show some polychrome features, as it wears both gold and silver jewellery.

Qualitative XRF of uncleaned areas on the added stripes of the cat’s tail produced a consistent pattern of elements that was different to that of the solid parts of the tail: the added stripes were lower in tin and silver, but higher in nickel and iron. Unfortunately the applied metal bands were too thin to permit drilling for samples of clean metal, preventing a direct comparison with the drilled sample of the body. However, a small area on the underside of one of the applied stripes was cleaned to remove surface corrosion and thus allow direct XRF analysis of the underlying metal (although there is still a possibility of some contamination remaining, and thus the results should be regarded as semi-quantitative). The following result was obtained: c.94.6% copper, 3% tin, 1% arsenic, 0.7% lead, 0.8% iron, 0.1% nickel and 0.1% antimony. No silver or cobalt was seen above the detection limit of c.0.05%. This analysis is generally similar to those for the surface of the applied stripes, but significantly different from that for the drilled sample of body metal, supporting the hypothesis that the stripes were intended to be visually different to the base metal of the cat. Quite what the effect would have been is difficult to ascertain; Gayer-Anderson’s vigorous cleaning has removed most of the original surface, while the presence of the paint layer makes it impossible to search fully for any remaining unaltered areas. It is known that the Egyptians used patination of metal surfaces for decorative effect [18], and it is possible that either the whole figure or just the stripes may have been treated in this way. Even unpatinated the appearance would have depended on the ‘finish’ – matt or polished – given to the surface. Figure 11 shows the current appearance of the tail together with two possible colour combinations, based on the metal compositions given above. Other areas of the surface may also have been coloured; while it has not been possible to confirm this by surface analysis, visual examination suggests traces of possible gold leaf near the droplet pendants on the lower register of the incised collar.
The white metal of the udjat plaque proved impossible to analyse using the Artax XRF equipment employed for the other metal analyses, as the relatively large X-ray tube could not be placed in a suitable position. Therefore, a smaller Bruker Tracer III-V portable XRF (see the experimental appendix for details) was employed here and showed the plaque, its inlaid ‘chain’ and the disc beneath all to be of silver.

Surface analysis of the metal of the two earrings both gave semi-quantitative results of c.92% gold, 6% silver and 2% copper. However, an early photograph of the cat taken while it was still in Gayer-Anderson’s collection (Figure 12) shows it with larger earrings, suggesting that these may not be original. Examination of the nose ring showed it to be of a different alloy, containing c.79% gold, 15% silver and 6% copper. Again it is possible that the nose ring is not original.

Few analyses of Late Period Egyptian gold could be found in the literature with which to compare these figures. In general, Egyptian gold seems to have a wide range of compositions [19, 20] covering those of the cat’s jewellery, although the analyses are not particularly distinctive; gold alloys of similar compositions are known to have been used in a wide range of cultures and periods. However, the shape of these earrings is typically pharaonic. Such rings have been found in secure excavated contexts at Athribis, Memphis, Tanis and Tell Defenneh in northern Egypt, datable to the second half of the first millennium BC. This date is consistent with that suggested for the cat on stylistic grounds.

It is almost certain that the figure originally had other inlays. While no remaining traces could be found in the eye sockets they probably held inlays of stone or glass similar to those still in place in a securely dated cat figure held in the Musée du Louvre, Paris (registration no E 2533: Figure 3) [21]. In the French example the eyes are inlaid with stone and outlined in faience, although the use of rock crystal is another possibility. During investigative cleaning minute areas of what seemed to be gold leaf were discovered on the head of the Gayer-Anderson cat – in one eye socket and in an area adjacent to the nose, to where it may have
be deposited after being dislodged from the eye cavities. Although these have not been confirmed by analysis they may be the only currently accessible survival of a gold leaf backing for a transparent eye inlay such as rock crystal or glass [22; p. 98, 23; p. 52], used to echo the reflective nature of the eyes of a living cat. Another example in the British Museum of this high naturalism, although in another medium, is the gilded eye of the cat represented in the ‘fowling scene’ from the wall paintings from the tomb of Nebamun (Figure 13), which, coincidentally, also shows a striped tail [24]. Various other varnished, painted or gilded embellishments for composite inlaid eyes have been found on a number of seated cats in the Museum’s Egyptian collections, including two important smaller pieces from the Harris collection, acquired in 1875 (1875,0810.111a: EA 11560 [2; p. 103], and 1875,0810.112: EA 36172).

CONCLUSIONS

This scientific and technical study of the Gayer-Anderson cat has led to a number of discoveries including the identification of previously unreported features, the composition of the metals present and to a fuller understanding of the technology of the object. New information has been collected about the possible original use and extent of polychromy, while X-radiography has revealed a great deal about the original methods of manufacture and the scale of the restoration. Despite the clear evidence of repair, nothing that has been discovered about the figure suggests it has anything other than an origin in late dynastic Egypt or that its form has changed in anything other than colour since that initial production. What does seem clear is that the history of the figure falls into two distinct phases. In the first it was produced in antiquity as a fine piece of religious apparatus, in many ways a working object with specific ritual purposes, by highly skilled craftsmen working in a tradition of polychrome metalwork. In the second, it was rediscovered and subsequently restored in the early part of the twentieth century. At this time it was given a very different surface appearance with an overall dull green, much more in accord with modern perceptions of ‘antique’ bronzes than with the tastes of its original audience. In its current state, as an outstanding example of animal sculpture from ancient Egypt, it remains one of the ‘treasures’ of the British Museum, hopefully to be appreciated for many generations to come.

FIGURE 13. A cat in a fragment of the wall paintings from the tomb of Nebamun (EA 37977) showing the gilded eye and striped tail: Eighteenth Dynasty, c.1350 BC.
EXPERIMENTAL APPENDIX

X-radiography

Radiographs were taken using a Siefert Isovolt DS1 X-ray tube held within a lead enclosure. For film radiography Kodak Industrex MX and AA films were used. Real-time images were viewed using a fluorescent screen and recorded on video via a camera unit. For film radiography voltages of between 220 and 250 kV were used with exposures of around 40 mA minutes. In all cases 0.125 mm lead screens were used at both the back and front of the films and the X-ray beam was filtered with a 0.6 mm copper sheet. The film radiographs were then scanned using an Agfa RadView digitizer with a 50 micron pixel size and 12-bit resolution in order to allow digital manipulation and enhancement of the images. Images shown here have been slightly enhanced with an 'unsharp mask' to emphasize edges and discontinuities, and subjected to manipulation of greyscale levels. Nevertheless, all reflect features detectable on the unenhanced films.

X-ray fluorescence (XRF)

The majority of the XRF analyses were carried out using a Bruker Artax spectrometer on uncleaned surfaces and are, therefore, qualitative only, as the analyses would be affected by the presence of corrosion, paint or other surface materials. The analyses carried out on abraded areas or on drillings enclosed in a gelatine capsule should be regarded as semi-quantitative, as some corrosion products may have been included in the analyses. The spectrometer is fitted with a molybdenum X-ray tube, and was operated at 50 kV and 0.8 mA. Spectra were collected for between 100 and 300 seconds. The area of analysis was c.0.65 mm in diameter for most analyses, although a smaller beam size of 0.2 mm was used for the analysis of the abraded area. Analysis of the silver plaque was undertaken with a Bruker (formerly made by KeyMaster) TRACeR III-V portable XRF. This is fitted with a rhodium X-ray tube, and was operated at 40 kV and 1.5 μA. Spectra were collected for between 30 and 50 seconds. The beam size is c.6 mm in diameter.

Boroscopy

Boroscopy was carried out using an Olympus Maj-522 boroscope.

Raman spectroscopy

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 repeat measurements being used to produce each spectrum. The resultant spectra were identified by comparison with a British Museum in-house database.

Fourier transform infrared (FTIR) spectroscopy

FTIR spectroscopy was carried out in transmission mode with a Nicolet Avatar 360 spectrometer using the main bench compartment and DTGS KBr detector. The samples were compressed with KBr crystals in a diamond cell, after collection of a background spectrum of the cell with no sample. The spectra were acquired over a range of 4000–400 cm\(^{-1}\) with 128 scans performed at a resolution of 4 cm\(^{-1}\). FTIR spectra for the black material collected from inside the figure gave a good match to a combination of the spectra for calcium carbonate and various bitumens, asphaltums, etc.

Gas chromatography-mass spectrometry (GC-MS)

Following preliminary analysis using FTIR, the samples were prepared for GC-MS. Each sample was extracted using 100 μL of dichloromethane. Insoluble material was allowed to settle out and the solution was decanted to a fresh vial before being evaporated to dryness under nitrogen. Prior to analysis the dry residues were derivatized with bis(trim ethylsilyl)trifluoroacetamide (BSTFA) with 1% trimethylchlorosilane (TMCS) (to form trimethylsilyl derivatives). Procedural blanks were prepared alongside the samples to monitor for background contamination. The samples were analysed using an Agilent 6890N GC coupled to an Agilent 5973N MSD. An Agilent AS7683 autosampler was used for the introduction of 1 μL samples. Mass spectral data were interpreted manually with the aid of the NIST/EPA/NIH Mass Spectral Library version 2.0 and by comparison with published data [25]. The black material from the interior of the cat was found to contain a range of n-alkanes (C\(_{19}\)–C\(_{31}\)) plus polyaromatic hydrocarbons (PAHs) and hopanes including 17β(H),21α(H)-moretane;17α(H),21α(H)-30-norhopane and 17α(H),21α(H)-hopane. These compounds are typical of bitumen and confirm the interpretation of the FTIR data.

Biological examination

Examinations were carried out using a Leica Aristomet biological microscope at magnifications ranging from ×100 to ×500.
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