PHOEBE A. HEARST MUSEUM
OF ANTHROPOLOGY
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THE STUDY AND TREATMENT OF TWO CROCODILE MUMMIES AT THE PHOEBE A. HEARST MUSEUM OF ANTHROPOLOGY

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DESCRIPTION AND HISTORICAL BACKGROUND

Two crocodile mummies, PAHMA 5-513 and PAHMA 6-20100, were acquired in Egypt around 1900. Both mummies are believed to have been votive mummies dedicated to the god Sobek, or to the composite god Sobek-Ra (6-20100).

PAHMA 5-513

Description: Adult Nile crocodile with approximately thirty juvenile crocodiles massed on its back. The juvenile crocodiles are tied between pairs of sticks. Plain weave linen wrappings had been mostly removed prior to acquisition. Shiny black mummy balm covers much of the adult and juvenile crocodile remains.

Materials: Crocodile remains, mummy balm, linen, palm stem
Culture/date: Ancient Egyptian, Greco-Roman period
Dimensions: 170 cm x 18.5 cm x 18 cm

Figure 1. 5-513, unwrapped crocodile mummy.

PAHMA 6-20100

Description: Elaborately decorated crocodile mummy bundle with a painted mask, separate solar disk head ornament, and painted linen wrappings (red, black, brown, yellow) arranged in a concentric square pattern. Below the linen wrappings on the dorsal surface, lengthwise bundles of reed-like stems bound crosswise with twisted fiber cordage and flat reeds are visible.

Materials: Crocodile remains, linen, plant fibers, pigments, mummy balm
Culture/date: Ancient Egyptian, Roman period, first-third centuries CE
Dimensions: 236 cm x 19 cm x 33 cm

Figure 2. 6-20100, painted mask and sun disk.

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MATERIALS INVESTIGATION

Sample	Techniques Employed	Results
5-513; balm	GC/MS	Beeswax, coniferous resin, animal fat or plant oil
6-20100; balm	GC/MS	Coniferous resin, animal fat or plant oil
5-513; sticks to which juvenile crocodiles are tied	Transmitted light microscopy on thin sections and macerations	Palm stem (*Hyphaene thebaica?*)
6-20100; longitudinal interior plant elements	Transmitted light microscopy on thin sections and macerations	*Cyperus papyrus*
6-20100; flat plant elements bound crosswise around longitudinal elements	Transmitted light microscopy on thin sections and macerations	*Arundo donax* or *Phragmites australis; Cyperus papyrus* or palm leaf petiole
6-20100; pale yellow plaster on mask	FTIR, XRF	Calcium carbonate and arsenic. Arsenic suggests that yellow pigment may be orpiment (As_2S_3)
6-20100; yellow pigment on linen wrappings, dorsal surface	Microchemical spot test for arsenic	Positive
6-20100; black and brown-painted linen wrappings	Visual examination with infrared energy source	Carbon-based and non-carbon based pigments were distinguished

Table 1.

Materials investigation of 5-513 and 6-20100. Mummy balm samples were analyzed with gas chromatography/mass spectrometry (GC/MS) and biomarkers indicative of organic compounds present in the balm were identified. Transverse sections and macerations of samples of plant materials were examined with a transmitted light microscope for species identification. A sample of the pale yellow plaster from 6-20100's mask was analyzed with Fourier-transform infrared spectroscopy (FTIR) and X-ray fluorescence (XRF) to characterize the ground and pigment(s). Yellow pigment from 6-20100's dorsal surface was tested with a microchemical spot test for the presence of arsenic, and the painted wrappings were examined with an infrared energy source in order to distinguish carbon-based media.

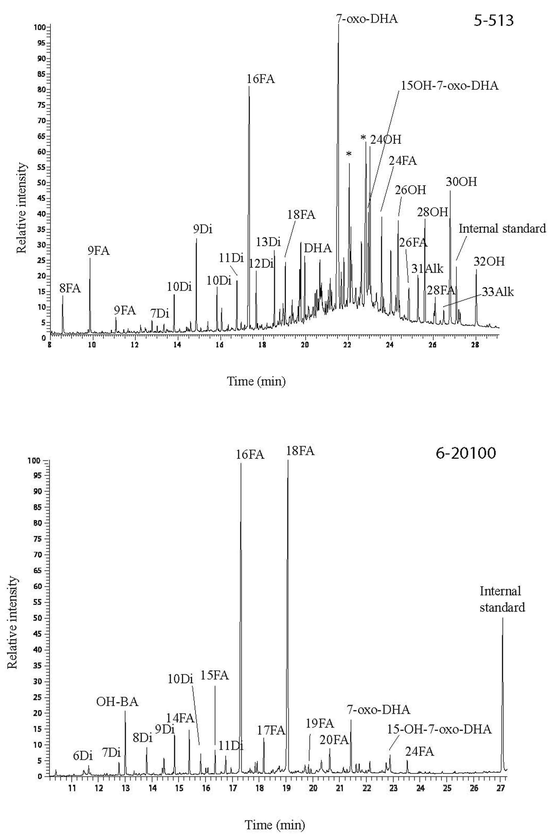

Figure 3.

Partial gas chromatograms from trimethylsilylated mummy balms. Both balms contain diterpenoids (dehydroabietic acid and related components) that are characteristic of coniferous resins. *x*FA = saturated free fatty acid, where *x* denotes the number of carbon atoms, *x*Di = dicarboxylic acid, where *x* denotes the number of carbon atoms, DHA = dehydroabietic acid, 7-oxo-DHA = 7-oxo-dehydroabietic acid, 15-OH-7-oxo-DHA = 15-hydroxy-7-oxo-dehydroabietic acid, *x*OH = *n*-alkanol, where *x* denotes the number of carbon atoms, *x*Alk = *n*-alkane where *x* denotes the number of carbon atoms, OHBA = hydroxybenzoic acid. * = unidentifiable components, likely related to 7-oxo-DHA. High temperature gas chromatography also revealed distinctive distributions of wax esters characteristic of beeswax in 5-513 (hydrolized prior to analysis and not shown here).

COMPUTED TOMOGRAPHY (CT)

CT images of both mummies were acquired using a clinical CT scanner with standard resolution (Siemens SOMATOM Definition, Stanford Medicine Imaging Center) and a C-arm CT scanner with ultra-high resolution (Siemens AXIOM Artis dTA, Dept. of Radiology, Stanford University). Clinical CT data resolution is 512 x 512 x 4028 cm (with.90, .90, .60 cm spacing) for 6-20100, and 512 x 512 x 2944 cm (with .48, .48, .60 cm spacing) for 5-513. C-arm scanner data has resolution of 512 x 512 x 498 cm (with .14, .14, .14 cm spacing) over small volumes of interest for both mummies.

Figure 4.

6-20100's flexibility and squat dimensions raised doubt as to whether the mask, linen wrappings, and plant fiber bundle visible on the exterior contained an intact adult crocodile.

Figure 5.

CT scans of 6-20100 revealed a mass of disarticulated crocodilian bones and bone fragments encased within the linen-wrapped bundle of papyrus stems, a large intact skull in the mask, and several long reinforcing plant stalks running the length of the mummy. Images acquired by Dr. Rebecca Fahrig, Department of Radiology, Stanford University, using a Siemens SOMATOM Definition, Siemens Healthcare.

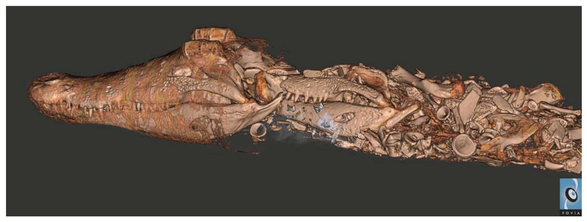

Figure 6.

Bones within 6-20100's papyrus bundle include a fragmentary second skull, a section of osteoderms, vertebrae, neural spines and limb bone fragments. Images acquired by Dr. Rebecca Fahrig, Department of Radiology, Stanford University, using a Siemens SOMATOM Definition, Siemens Healthcare. Image rendered with High Definition Volume Rendering® software provided by Fovia, Inc.

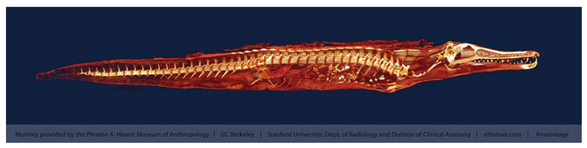

Figure 7.

5-513 was scanned in order to learn more about how the crocodiles lived, died and were mummified. No signs of blunt force trauma were observed, ruling out some modes of death. The adult crocodile was not eviscerated. Among the intact organs is a full stomach. Images acquired by Dr. Rebecca Fahrig, Department of Radiology, Stanford University, using a Siemens SOMATOM Definition, Siemens Healthcare.

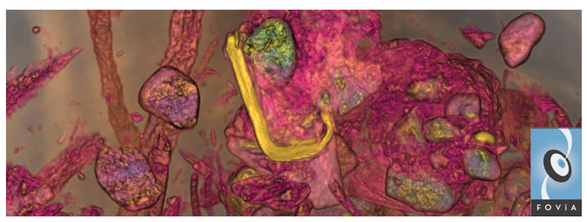

Figure 8.

High resolution CT scanning revealed that 5-513's stomach contains an ancient metal hook (in yellow) in addition to the bones of small prey and rocks swallowed to aid with digestion. Images acquired by Dr. Rebecca Fahrig, Department of Radiology, Stanford University, using an Axiom Artis dTA with DynaCT, Siemens Healthcare. Image rendered with High Definition Volume Rendering® software provided by Fovia, Inc.

CONDITION & TREATMENT

Figure 9.

A widespread network of cracks had developed in 5-513's black coating, resulting in active flaking of mummy balm. Deterioration of the balm coating had caused multiple juvenile crocodiles and sticks to detach, leaving a number of them displaced and only loosely secured with a length of twentieth century wire wrapped around the adult's midsection. Scraps of torn linen wrappings were separating from the sides of the adult's body. The entire mummy was badly soiled with loose dust and straw (an early packing material).

5-513's surfaces were cleaned by gentle vacuuming with a HEPA-filtered Nilfisk vacuum. After solubility tests of the black mummy balm determined that the balm was soluble in acetone and ethanol but not in water or petroleum benzine, trials were conducted to select a consolidant. 2-5% w:v solutions of Aquazol (molecular weights 200 and 500) in deionized water, isinglass, methyl cellulose, funori, and Acryloid B-67 in petroleum benzine were tested on small detached flakes of balm and in discrete locations on the adult crocodile. Strength, penetration, and visual change were evaluated. 5% B-67 performed best, and was used to consolidate the flaking coating. B-67 was applied with a fine brush to cracked and flaking balm on the dorsal, lateral and ventral surfaces of the mummy. Tacks of 20% B-67 in petroleum benzine bulked with glass microballoons and toned with carbon black dry pigment were used to reattach juvenile crocodiles. Loose linen scraps and threads were secured with pre-cast Paraloid F10 film reactivated with petroleum benzine.

Figure 10.

6-20100 was structurally unstable due to widespread breakage of the linen wrappings and interior plant elements, as seen above on the ventral surface. Breakage and displacement of linen strips and plant fiber binding elements rendered the entire bundle overly flexible, and shedding small pieces of linen, plant matter, and mummification balm. Much dust and grime had accumulated on the mummy's surfaces, dulling the appearance of the polychrome mask and wrappings.

Figure 11.

6-20100's treatment sought to restore structural integrity to the mummy while maximizing visibility of its layered decorative wrappings. After surface vacuuming, damaged plant elements on the dorsal surface were realigned and mended using Cellofas, methyl cellulose and Japanese paper. The mummy was then inverted to investigate the ventral surface, which was found to have lost nearly all of its textile outer wrapping. After securing loose and broken ventral plant elements, the mummy's exposed underside was covered with a sheer polyester fabric. The bias-cut fabric had been prepared with evenly spaced rows of crosswise running stitches to maintain its tension and alignment during treatment. The mummy was righted, and placed on a padded support. Next, linen strips on the top surface of the crocodile were realigned. Rather than encasing the mummy entirely in polyester or silk crepeline, bands of silk crepeline (dyed with Lanaset pre-metallized acid dyes) were placed across the top surface and secured with stitching to the edges of the sheer polyester fabric covering the underside. The silk crepeline bands were positioned over areas where the linen wrappings are torn or frayed.