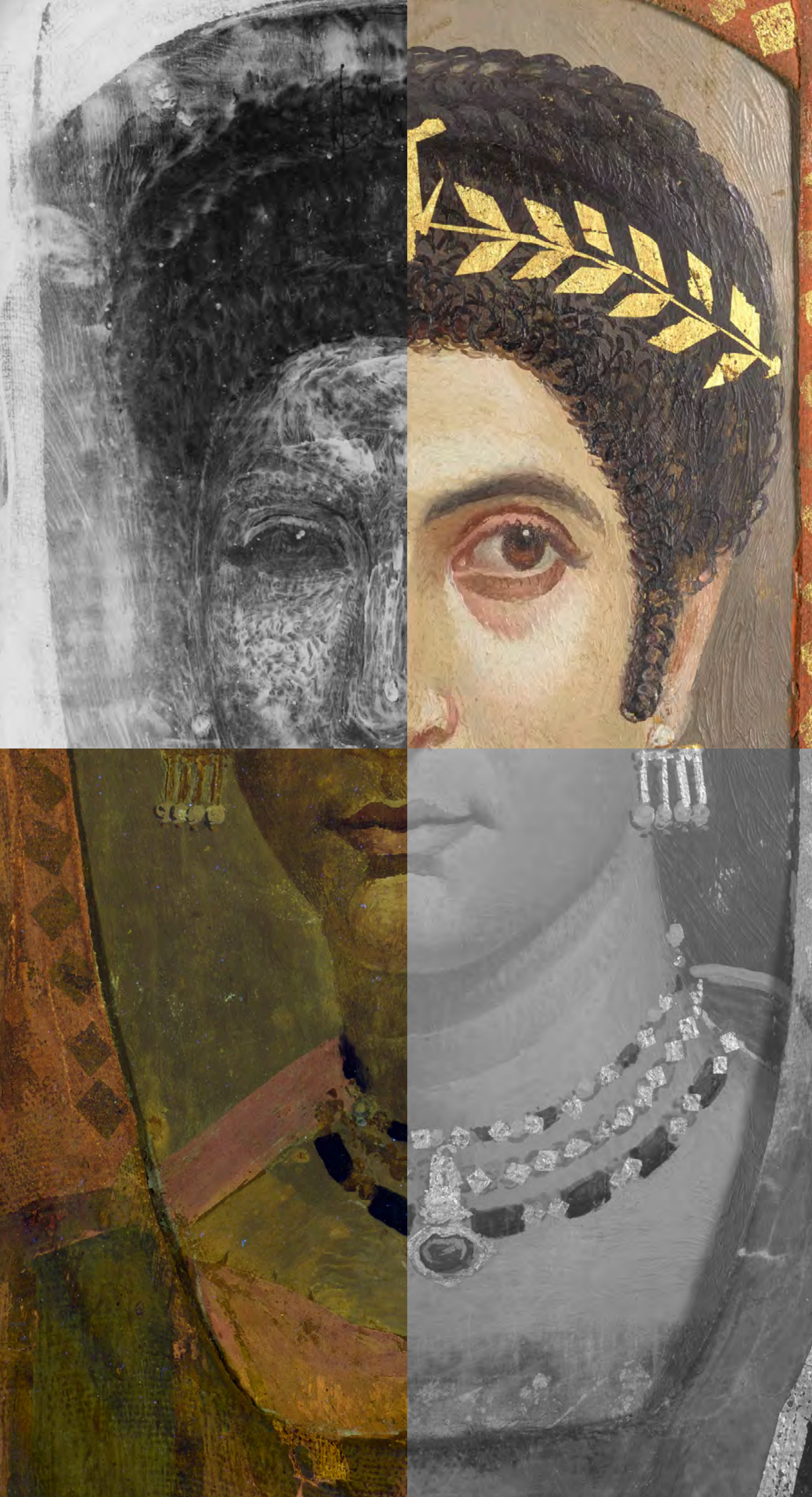

Mummy Portraits of Roman Egypt

Emerging Research from the APPEAR Project

Edited by
Marie Svoboda
and
Caroline R. Cartwright

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J. PAUL GETTY MUSEUM, LOS ANGELES

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First edition, 2020
github.com/thegetty/mummyportraits/

Published by the J. Paul Getty Museum, Los Angeles
Getty Publications
1200 Getty Center Drive, Suite 500
Los Angeles, California 90049-1682
getty.edu/publications

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Distributed in the United States and Canada by the University of Chicago Press

Distributed outside the United States and Canada by Yale University Press, London

Library of Congress Cataloging-in-Publication Data
Names: APPEAR (Project), author. | Svoboda, Marie, editor. | Cartwright, Caroline, editor. | J. Paul Getty Museum, host institution, issuing body.
Title: Mummy portraits of Roman Egypt : emerging research from the APPEAR project / edited by Marie Svoboda and Caroline R. Cartwright.
Description: First edition. | Los Angeles : J. Paul Getty Museum, 2020. | Proceedings of a conference held at the J. Paul Getty Museum at the Getty Villa, Malibu, on May 17 and 18, 2018. | Includes bibliographical references. | Summary: “This publication gathers papers and posters from a 2018 conference organized as part of the APPEAR (Ancient Panel Paintings: Examination, Analysis, and Research) initiative, an international collaboration that promotes the study of funerary portraits from Roman Egypt”– Provided by publisher.
Identifiers: LCCN 2019057806 (print) | LCCN 2019057807 (ebook) | ISBN 9781606066546 (paperback) | ISBN 9781606066522 (epub) | ISBN 9781606066539 (ebook)
Subjects: LCSH: Mummy portraits–Expertising–Congresses. | Mummy portraits–Egypt–Congresses. | Portraits, Roman–Egypt–Congresses. | Portraits, Egyptian–Congresses. | Egypt–Antiquities, Roman–Congresses.
Classification: LCC ND1327.E3 A67 2020 (print) | LCC ND1327.E3 (ebook) | DDC 759.02/16–dc23
LC record available at https://lccn.loc.gov/2019057806
LC ebook record available at https://lccn.loc.gov/2019057807

Front cover: Mummy Portrait of a Woman, Romano-Egyptian, AD 100. Encaustic on linden wood, gilt, linen, 48 × 36 × 12.8 cm (18 7/8 × 14 3/16 × 5 1/16 in.). Los Angeles, J. Paul Getty Museum, 81.AP.42

Ancient Worlds Now

Ancient Worlds Now: A Future for the Past is a multifaceted Getty initiative to promote a greater understanding of the world’s cultural heritage and its value to global society.

Contents

Foreword

Funerary portraits from Roman Egypt depict men and women who lived and prospered two thousand years ago, yet the experience of looking at them feels hauntingly immediate. Their wide eyes return the viewer's gaze, and their expressive faces seem almost familiar. It is no wonder that these ancient paintings have intrigued scholars and the public since their rediscovery after millennia buried under desert sands.

That so many of these artworks, painted in delicate pigments on linen or wood panels, survive today is remarkable; there are almost a thousand in collections around the world. Collectively they impart important knowledge about how the elite of Roman Egypt lived and died—and, especially, how they saw themselves and wished to be seen by others.

Less studied, until now, are the individuals who produced these paintings—the anonymous artists in ancient workshops. What can be learned from investigating the materials they used, the tools they developed, the techniques they mastered? This is the line of inquiry behind the Getty-led research project Ancient Panel Painting: Examination, Analysis, and Research (APPEAR). Begun in 2013 with a technical study of sixteen portraits in the collection of the J. Paul Getty Museum, the project has grown to encompass a third of the known portraits of this type and has garnered the participation of forty-seven museums across the globe. Through the dedication of these institutions to the ongoing study of their collections and the contribution of their data to a central repository, APPEAR has revitalized scholarly interest in ancient paintings and provided a critical tool for understanding their production and influence on the history of art.

Broad dissemination of the discoveries emerging from APPEAR is a central goal of the project. The present publication, available in electronic and print formats, represents the proceedings of the first international APPEAR conference, held at the Getty Villa in May 2018. New research will emerge as the program continues to expand, and plans are already under way for the next symposium, tentatively scheduled for 2021.

I would like to express sincere thanks to all of the APPEAR institutional partners worldwide, and to the many conservators, curators, and scientists at each museum now engaged in the examination of Roman funerary portraits in their collections. The contributing authors to this volume have generously shared their data and their insights, so that old questions can be answered and new avenues of investigation can be explored. Thanks are due to Susan Walker, emerita fellow of Wolfson College, University of Oxford, for her keynote address at the APPEAR conference and her contribution to this book's introduction. Caroline Cartwright, senior scientist at the British Museum, likewise made numerous contributions to the project, including serving as coeditor of this publication. Finally, I would like to acknowledge Marie Svoboda, conservator of antiquities at the Getty Villa and coeditor of this volume, for her inspired leadership of the APPEAR project.

Timothy Potts
Director
J. Paul Getty Museum

Acknowledgments

The APPEAR conference could not have happened without the generous support of James Cuno and the J. Paul Getty Trust, whose encouragement and funding, respectively, provided the foundation on which the project was able to develop and grow; its sustained progression is credited to the wonderful project participants, the forty-seven institutions and their teams who joined the APPEAR project. Through their gracious collaboration, they continue to support the mission of expanding our understanding of the materials and technology used in ancient panel painting and have contributed immeasurably to APPEAR's development and success. Additional praise is due to the many presenters at the conference and the authors within this volume, who have shared their research as well as enthusiasm and passion for the subject; we express our sincere gratitude and appreciation for your participation.

Within the Getty we gratefully acknowledge Timothy Potts, Robin Weissberger, Mary Louise Hart, Giacomo Chiari, Molly Callender, Jack Ludden, Mark Sealy, Nick Hulea, Patrick Skidmore, Amelia Wong, Jeffrey Maish, Susanne Gänsicke, Joy Mazurek, Monica Ganio, and Karen Trentelman for making this project materialize and Danielle Freeman, Ashley Hayes, Heather Leisy, Lisa Guzzetta, Cherie Chen, Mikka Gee Conway, Samantha Monarch, Michael DeHart, and John Giurini for helping to pull all the details together.

Farther afield, we thank our colleagues who have always been ready to offer assistance and guidance: Sylvana Barrett, Yosi Pozeilov, David Saunders, Barbara Borg, Richard Newman, Glenn Gates, Rachel Sabino, Ken Sutherland, Dan Kushel, and colleagues at the UCLA/Getty Program in Archaeological and Ethnographic Conservation.

For the production of this digital publication we express gratitude to Elizabeth Nicholson, Greg Albers, Amanda Sparrow, Laura diZerega, Victoria Barry, Nina Damavandi, Victoria Gallina, Jeffrey Cohen, Kara Kirk, Karen Levine, and Kimberly Wilkinson for their meticulous work and guidance.

It is also with much appreciation that we acknowledge our anonymous peer reviewers for their time, effort, and attention to detail.

And finally, to you, the reader, for your interest in and support of scholarly publications such as this one, thank you.

Introduction

Marie Svoboda
Caroline R. Cartwright
Susan Walker

These proceedings mark the end of the first four years of an international collaboration on the study of funerary panel painting from Roman Egypt, known as APPEAR: Ancient Panel Painting, Examination, Analysis and Research. The APPEAR initiative was developed to create a platform for expanding our understanding of the materials and technology used to produce works of art, especially mummy portraits, painted in the first through third centuries AD during the Roman occupation of Egypt. The papers in this publication are the result of a conference held at the J. Paul Getty Museum at the Getty Villa, Malibu, on May 17 and 18, 2018; it was there that the results stemming from the APPEAR project were first shared. The Getty-organized event brought together more than one hundred attendees to hear presentations by twenty-one project participants on the current and ongoing technical research of ancient painting from Roman Egypt. Over the two-day conference, twelve papers, six lightning talks / posters, and a keynote lecture addressed the topics that have developed through or contributed to the APPEAR project. The speakers—representing five countries and nineteen museums, with backgrounds in conservation, science, Egyptology, classics, and art history—presented new research on the history, provenance, materials, methods, technical imaging, and analysis of ancient painted artifacts.

The APPEAR project was established in 2013 with seven seed institutions; at the time of this publication the project has flourished, expanding to forty-seven collaborating museums from the United States and Europe. Partner institutions participate by examining, analyzing, and researching the history, materials, methods, and technology of the artworks within their collections and contributing the results to a database that is used as a platform for study, investigation, and comparison. This collective data broadens the customary focused studies into a larger corpus of information, facilitating the identification of trends, enabling comparisons, and shedding new light on artistic practice, materials, and techniques. Additionally, as an outcome of the project's expansion, a community has developed in which participants are able to reach out to other institutions and colleagues, exchange information, gain inspiration, and, in several instances, provide guidance and support to those who may not have the same resources or expertise. This collegial outreach has been a very special result of the project's cooperative nature and success.

Mummy Portraits

Portrait paintings of the deceased, created on wooden panels or linen shrouds and placed in front of the face of mummified bodies, evolved from a 2,000-year-old Pharaonic funerary tradition, replacing the stylized three-dimensional mummy mask with a two-dimensional, personalized Greco-Roman portrait. Although the APPEAR collaboration began with a focus on these well-known and very popular mummy portraits, the project has expanded to include other painted artifacts in the Romano-Egyptian tradition. The study now includes painted textile shrouds, wooden framed panels, doors, shields, and stucco mummy masks. Such diversity of painted artifacts offers a broader exploration into the ancient artists' use and sourcing of materials as well as shared practices.

The APPEAR conference opened with a brief overview of recent research on mummy portraits. Twenty-three years have passed since the exhibition *Ancient Faces: Mummy Portraits from Roman Egypt* opened at the British Museum. The 1990s also saw the publication of a cluster of significant research projects on mummy portraits, with lively debate on the chronological development of this regional genre of ancient painting and on how the paintings were commissioned and used. How do we see the painted faces of Roman Egypt today?

Major advances in imaging and scientific analysis have allowed significant progress in our understanding of how mummy portraits were made, especially those painted on wooden panels. Inevitably this has led to a more complex view of the range of choices open to the painters of Roman Egypt. Moreover, some long-established scholarly "certainties" are now dissolving. For example, an apparently clear and widely accepted division between artists painting in encaustic and those working in tempera is now questioned; rather, painters seem to have used a variety of media for specific purposes within a single portrait, and the visibly differing results more likely reflect the choice of tool kit used to work the painted surface rather than the preference for a particular medium.

Some of the observations made in the 1990s still hold true: the painters' workshops were geographically organized by settlement and associated cemetery, and perceived differences in the quality of work reflect local usage rather than a chronologically sensitive decline. In the 1990s the subjects of mummy portraits were identified as the elite populations of the small towns of Egypt; these individuals negotiated an improvement in their status with the ruling Roman authorities by claiming a Greek historical identity. Recent epigraphic research confirms that this group also enjoyed exceptional legal privileges, and field survey has thrown remarkable light on some of the settlements in which they lived.

Through improved scientific analysis and forensic methodologies, major developments in the detection and interpretation of the materials used to create ancient paintings are constantly evolving. These advancements are a direct result of more sensitive and sophisticated analytical instrumentation that requires little or no sampling to obtain results. Technical imaging also plays a significant role in the characterization of materials, further guiding and corroborating scientific analysis nondestructively.

A common denominator among ancient panel paintings is that they have been produced on wooden substrates. Thus, the development of a methodology for wood identification was seminal in understanding funerary portraits and their technology, and as a consequence of the British Museum’s exhibition in 1997, a systematic scientific research program commenced to identify the woods selected for the mummy portrait panels. Given the extensive use of local Egyptian woods in earlier chronological periods for coffins and other funerary artifacts, it was a revelation to find, as early as 1996, that the majority of mummy portraits was constructed on southern European *Tilia europaea* (lime/linden) wood, which is not—and has never been—native to Egypt. For high-status coffins and artifacts in previous periods, *Cedrus libani* (cedar of Lebanon) wood was imported, but the preferential selection of *Tilia europaea* was an innovation.

The APPEAR project has enabled this research to expand, with many participating institutions permitting tiny samples of their wooden panels for incorporation into this scientific research program. Advances in sampling techniques and methodology have contributed greatly to the success of the research. High-resolution scanning electron microscopy (SEM), offering magnification up to an extraordinary 300,000x, has allowed sample sizes to be reduced considerably. Prior to the pioneering application of both variable pressure SEM and field emission SEM to routinely identify archaeological and historical wood, it was usual to seek cubic wood samples of 1 to 2 centimeters in size, principally because wood thin sections had to be made for examination in transmitted light under the optical microscope. Although this technique still remains the preferred method for modern reference wood specimens, SEM has revolutionized wood identification of the mummy portraits, for which sample size is a crucial factor.

In both the pre-APPEAR and the APPEAR phases of systematic scientific identification of mummy portrait woods (now extended to include wooden artifacts from the same period), new results have emerged constantly. As highlighted in this publication, many more species have emerged over the past twenty-four years of research compared with what was known in 1996. One of the major objectives now and in the immediate future is to examine the results in the context of the other studies exemplified in this volume and by APPEAR collaborators, in order to evaluate whether it is possible to pinpoint discrete centers of production of mummy portraits or even workshops; this can be established by comparing distinctive preferences for a particular type of wood, method of painting, style, and execution.

The development of the APPEAR database and website will give scholars across the world a hitherto unavailable, evidence-based view of the making of mummy portraits and related funerary artifacts. The anonymous painters of these rare colored images of the people of Roman Egypt are now beginning to come into a focus unreachable twenty-four years ago.

APPEAR Conference Overview

The papers summarized here are not in any particular order; rather, they are grouped by similarity of subject addressed.

The APPEAR conference began with a fundamental topic in the study of funerary portraits by the J. Paul Getty Museum: the exploration of provenance, the history of collecting, and the dealer market in the twentieth century. The paper, included in this volume, emphasizes the value of preserving historical documentation such as dealer notes, stamps, seals, and markings—sometimes found on the backs of these artifacts and a key to understanding their collection history. This information not only sheds light on a portrait's journey after discovery but also can identify other works from the same findspot as well as provide information on past restoration campaigns. (See Ch. 11)

A study from the Museum of Fine Arts, Budapest, provides a rare glimpse into the well-documented history of five mummy portraits as well as the breadth of new information and rediscovery possible through collaborative technical investigations. (See Ch. 12) A unique approach to painted portraiture—the process of mapping facial features—is addressed by the Ashmolean Museum, Northwestern University, and the Cranfield Forensic Institute. Spatial calculations can be used to better understand the conception of painted portraiture and, through comparative data, potentially identify groups possibly executed by the same hand. This issue raises the question of whether a formula was used to design the mummy portraits. (See Ch. 10)

Several papers explore different types of painted artifacts—those that complement current studies by expanding and enhancing our understanding of artistic practice beyond the scope of mummy portraits. This merging path of research is exemplified by the examination of two unique artifacts. The Heron panel from the Rhode Island School of Design Museum is presented as a case study. Working with colleagues from Rhode Island Hospital and Brown University, the authors analyze the construction and iconography of this special artifact and compare it with other framed, or once framed, panels as well as with later icon paintings. (See Ch. 9) The Dura-Europos shields at Yale University Art Gallery reveal the far-reaching technology of panel painting during the Roman period and underscore the similarities and differences between these excavated artifacts, discovered more than 700 miles away from Egypt. (See Ch. 16)

Almost all of the papers here highlight the mission of APPEAR by illustrating the benefits of collaboration and the special partnerships that have developed as a result of the project. This is most evident in the collective study of two museums: the Kunsthistorisches Museum, Vienna and the Museum of Fine Arts, Budapest. Technical support, guidance, and expertise have been shared in an effort to identify the materials and methods used for mummy portraits housed in both collections. (See Ch. 15) The discovery of mysterious painted features on three portraits, one each in the collections of the Museum of Fine Arts, Boston, the University of Pennsylvania Museum of Archaeology and Anthropology, and the J. Paul Getty Museum, form an unexpected connection centered on a unique discovery. These features, visualized only through technical imaging, have painted details invisible to the naked eye and raise enigmatic questions about their composition and purpose. (See Ch. 8) A unique study and comparison of an object with questionable authenticity, the portrait of Sarap[i]on from the Michael C. Carlos Museum, in collaboration with the University of Memphis, draws from similar corroborative entries in the database and further supports an in-depth exploration of construction, function, and history in order to suggest the true identity of a sitter. (See Ch. 13) On a broader scope, the characterization by APPEAR partners of wood species in eight papers and of binding media in three further showcases the benefits of collaboration. In addition to supporting institutions that lack analytical resources or expertise, these partnerships yield results that provide valuable contributions to the database, expanding current collective scholarship.

The conference focused heavily on the topic of artists' materials and the identification of wood, pigments, and binding media, as well as on the state-of-the-art, innovative, and nondestructive imaging methods now used to identify them. Papers by the British Museum draw on many years of specialist scientific expertise to summarize the range of wood species that were used for more than 180 panels and to chart the development of the leading procedure for multispectral imaging and its application to the study of mummy portraits. (See Ch. 2 and Ch. 6) A focused examination of one well-provenanced collection of mummy portraits from the Roman cemeteries at Tebtunis, Fayum, now at the Phoebe A. Hearst Museum of Anthropology, considers the materials and techniques that characterize one workshop—an exciting and model study; the work was aided by scholars at Northwestern University and the British Museum. (See Ch. 14)

The following papers explore pigments as well as three colorants that were manufactured in the ancient world. One study by the Museum of Fine Arts, Boston, and the Walters Art Museum is on the use and identification of the organic dye madder. The ubiquitous appearance of this bright pink colorant on panel paintings underscores the importance of its production in antiquity. (See Ch. 3) The beloved Egyptian blue, known as one of the oldest manufactured pigments in history, was created to reproduce a color that was not readily available in nature. Its nontraditional use and the geographic centers of its production are reported by the Cantor Art Center. (See Ch. 5) Through innovative technical imaging methods, the Brooklyn Museum and the Metropolitan Museum of Art examine the lesser-known blue dye indigo, also used to produce green (mixed with a yellow pigment) as well as purple (mixed with madder) and black (pure indigo). The identification of indigo illustrates the extensive and creative uses of artists' materials that had previously gone unnoticed in the study of ancient pigments. (See Ch. 7) Equally significant is the characterization of green pigments, investigated by the Kelsey Museum, as both natural and manufactured sources. Utilizing the APPEAR database, a comparison is made between painted artifacts from different time periods, revealing the lengths to which artists went to produce paintings with green. (See Ch. 4)

Finally, the extremely complex issue of binding media is addressed by the Getty Conservation Institute, the Ny Carlsburg Glyptotek, and the Art Institute of Chicago. Two papers are collaborations that examine the organic binding materials used for ancient paintings, to characterize their composition and identify new mixtures. (See Ch. 17 and Ch. 18) A third study on binding media proposes new terminology to describe the information we are gathering today and confronts the discussions still to evolve in the definition of the terms and techniques associated with ancient materials and technology. (See Ch. 1)

Within these proceedings, eighteen contributions to the APPEAR conference focus on the identity, source, use, and function of the ancient artists' painting methods. Additionally, the exploration of how these artifacts were acquired, manufactured, imported, identified, and reused has laid a foundation for ongoing collective studies. This collaborative working approach reveals the broad scope of information possible in the study of ancient painting. Questions still to be answered as well as new directions of research and technological advances will continue to make the APPEAR project a valuable scholarly resource and a conduit for the exchange of future discoveries in the study of ancient art.

Part One

1

Challenges in the Characterization and Categorization of Binding Media in Mummy Portraits

Ken Sutherland
Rachel C. Sabino
Federica Pozzi

Romano-Egyptian mummy portraits have conventionally been divided into two groups according to binding media, described as tempera (implying an aqueous medium such as glue or egg) or wax (specifically beeswax). Prior to the development of analytical capabilities that allowed for precise characterization, these classifications were assigned largely on the basis of the portraits' surface appearance and paint handling. More recently, medium descriptions have been informed by scientific data, but even in such cases there remain substantial gaps in the technical knowledge regarding the manner in which the artists made and applied their paint media. Aside from the practical challenges of materials characterization and the limitations of current analytical protocols, an understanding of the painting techniques is hindered by the use of ambiguous terms that have become embedded in the literature and by changes in scholarly opinions and theories about the artists' methods. This paper examines the technical, historical, and semantic issues that have clouded discussions of the portraits' binding media, with particular reference to two mummy portraits in the collection of the Art Institute of Chicago (AIC).

Acquired in 1922, the AIC portraits date from the early to mid-second century AD. Both show vivid likenesses of young men in three-quarter pose wearing formal dress (a white tunic and *clavus*; figs. 1.1 and 1.2). The paintings exhibit striking differences in their manner of paint application. One bears the hallmark robust impasto and tool marks indicative of wax applied using the encaustic technique (i.e., with the use of heat; fig. 1.3); the other displays a flatter, matte appearance with the distinctive, finely applied lines of *tratteggio* and crosshatching that are often associated with tempera painting (fig. 1.4). A technical investigation, initiated in preparation for the AIC's online catalogue *Roman Art at the Art Institute of Chicago,* was undertaken with the hope of shedding light on this discrepancy as well as other aspects of the portraits' technique.[1] Analysis of the binding medium of the first portrait determined, unsurprisingly, that it was composed of beeswax, supporting a description of the technique as encaustic; however, analysis of the second portrait also revealed the presence of beeswax.[2] These findings—along with published studies of several other portraits that lack the visual characteristics of encaustic but that were found, upon analysis, to be wax based[3]—

highlight uncertainties about the precise composition, working methods, and handling properties of the binders. The growing body of scientific data on mummy portraits has been crucial to enhancing our knowledge of ancient painting techniques, but its significance must be carefully and critically evaluated, taking into account the broader problems associated with interpreting and describing these objects. We must also examine our assumptions and preconceptions about the binding media, considering the history and origins of theories about the artists' methods—as well as the imprecise and shifting meanings of those terms that have been used to describe them.

Figure 1.1 Mummy Portrait of a Man Wearing a Laurel Wreath, Romano-Egyptian, early to mid-second century AD. Lime (linden) wood, beeswax, pigments, gold, textile, and natural resin, 41.9 x 24.1 cm (16 1/2 x 9 1/2 in.). Art Institute of Chicago, Gift of Emily Crane Chadbourne, 1922.4799. Art Institute of Chicago, CC0

Figure 1.2 Mummy Portrait of a Man Wearing an Ivy Wreath, Romano-Egyptian, early to mid-second century AD. Lime (linden) wood, beeswax, pigments, gold, textile, and natural resin, 39.4 x 22 cm (15 1/2 x 8 5/8 in.). Art Institute of Chicago, Gift of Emily Crane Chadbourne, 1922.4798. Art Institute of Chicago, CC0

Figure 1.3 Raking light detail of fig. 1.1, showing impasto and tool marks.

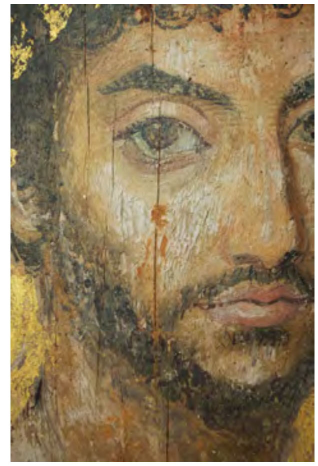


Figure 1.4 Detail of figure 1.2, showing the use of *tratteggio* around the eyes and the bridge of the nose.

Background: The Origins and Evolution of Ideas about the Binding Media

Speculation about the binding media of the portraits was immediate upon their exposure to the public, following the excavations of Theodor Graf and Flinders Petrie at Arsinoë, er-Rubayat, and Hawara in the 1880s. It was Petrie himself who proposed that the warm climate of Egypt was sufficient to allow painting with a simple, unmodified beeswax medium[4] (and others have made the correlation between the wax medium and the use of very thin wood panels, suggesting that the panels may have been warmed to further facilitate painting[5]). But by this time, painting in wax had already been a source of fascination and conjecture for more than a century, prompted in particular by discoveries of ancient wall paintings such as those at Herculaneum and Pompeii, believed by some scholars to have been painted with encaustic. Coupled with the scientific zeitgeist of the Enlightenment, these finds prompted much experimentation to re-create the ancient encaustic technique, described notably in a 1755 treatise by the antiquarian and amateur archaeologist Comte de Caylus[6] and in subsequent works by Vincenzo Requeno[7] and Paillot de Montabert.[8] Many scholars have invoked the writings of Pliny the Elder on this topic and in particular his description of the enigmatic “Punic wax,"[9] the identity of which is still debated today. Pliny's text is cryptic and open to different readings with respect to the process and product: it has been interpreted as describing the preparation of either a purified/clarified beeswax or one (partially or wholly) saponified by the action of an alkaline salt and thus amenable to application with water in a cold state.[10] Despite the sparse evidence, and the challenges of translating archaic texts such as Pliny's, the theory of the ancient painters' use of a modified beeswax medium took a strong hold—especially with regard to the mummy portraits. It was promoted in particular by the influential work of Ernst Berger[11] and by a general interest around the turn of the twentieth century in water-based and emulsified paint media.[12] Some of Berger's contemporaries challenged his interpretations, however, including A. P. Laurie, who concluded, based on his own experiments, that "we may dismiss [Punic wax] as one of the ingenious fictions that have so long obscured the scientific investigation of the classical methods of painting."[13] To this day, attempts to replicate Pliny's recipe and to make a workable paint with a saponified "Punic" wax have met with mixed success.[14]

Aside from the question of saponification, theories have been put forward that the ancient wax medium was modified with additives such as oils and resins to improve its working properties. Such ideas became influential again in the encaustic revivals of the twentieth century, when an assortment of wax painting methods—employing mixed media, solvents, and heating devices—were adopted by artists such as Arthur Dove, Diego Rivera, Jasper Johns, and Brice Marden.[15] Several of the painters were inspired by the writings of Max Doerner on this topic,[16] and Rivera in particular maintained an aspiration to replicate the "true" ancient encaustic technique.[17]

This long history of infatuation with encaustic has left us a confused legacy in the literature on mummy portraits. The evolution and persistence of ideas about the media can be illustrated with reference to selected sources: A discussion by Otto Donner von Richter, based on his readings of ancient texts and personal conjecture, and published in Graf's catalogue of his display of portraits at the 1893 Chicago World's Fair, suggests the use (among other recipes) of "Punic wax, balm of Chios, and a very little olive-oil, all melted together over the fire and mixed up with the pigments."[18] Doerner in 1921 describes a "wax paste" made with wax, pigment, and mastic and comments that "it is not impossible that the late Greek mummy portraits from the Fayum were made in that way."[19] Similar combinations reappear in the 1990s in the influential work of Euphrosyne Doxiadis, supplemented by the results of her own painting experiments; she proposed that the artists used "hot beeswax ... mixed with ... Chios mastic, for instance" or "cold Punic wax ... mixed with egg ... and sometimes a small amount of linseed oil."[20] Although none of these combinations of materials has been indicated to date by scientific analysis of mummy portraits, the recipes are reiterated in authoritative sources such as *The Oxford History of Western Art*, in which we read that "scientific analysis reveals that several types of encaustic were used ... hot beeswax mixed with resin or cold wax with egg and sometimes a little linseed oil."[21] A transmutation from speculation to accepted wisdom to scientifically verified "facts" can be seen in these examples, and once entrenched in the literature such ideas become difficult to challenge or dislodge.

Petrie and Graf's excavations also brought to light the second category of portrait, often flat and matte in appearance, and sometimes painted in a more naïve style, suggesting that the painters were not working solely in wax. We face similar problems with discussions of this "tempera" group. Like encaustic, tempera was experiencing a revival of interest around the turn of the twentieth century, associated with a renewed scholarly appreciation of early paintings and the translation of historical texts describing their technique.[22] The term is chronically ambiguous: in its original and most general sense *tempera* refers to a paint binder (in the sense of "tempering," or modifying), and it was only more recently, and largely because of its use in association with medieval and early Italian paintings, that it took on a specific meaning of the "egg tempera" binder typically used in such works. With reference to mummy portraits, however, the descriptor carries the broader implication of a water-based binder, which may include egg, plant gum, or animal glue. While some interpretations of the "tempera" mummy portraits assume an egg medium, likely from conflation with Italian painting methods,[23] recent research has revealed that, more often than not, those examples not painted with beeswax are made with animal glue.[24]

The Impact and Limitations of Scientific Studies

Before the first applications of instrumental analysis to elucidate the portraits' binding media, many of the widely held theories about their technique inevitably derived from artists' and scholars' reconstructions, based on their empirical experience of paint application and informed by interpretations of the fragmentary historical texts. And although replication is a helpful exercise, it can clearly be misleading, as discussed above: the ability to reproduce a painting's appearance is not in itself compelling evidence that the same method was used in antiquity. Critically, such reproduction doesn't account for alterations in a painting's visual and material qualities over time. Similar caution must be exercised when assessing the first scientific studies that appeared in the 1960s and 1970s. These were early days in the development of methods for the organic analysis of painting materials, and while some of the findings have been widely cited as authoritative information, they deserve reconsideration in light of our current, improved understanding of the chemistry and aging of painting materials. In a 1960 paper Hermann Kühn proposed that Punic wax could be discerned from untreated beeswax by the detection of metal carboxylates (soaps) using infrared spectroscopy.[25] Raymond White reached a similar conclusion in a 1978 study of two mummy portraits using gas chromatography, suggesting that a reduced proportion of wax esters relative to hydrocarbons observed in a sample from one of the portraits was evidence for hydrolysis resulting from the preparation of Punic wax.[26] However, we now know that metal soap formation is a widespread phenomenon in paint films, resulting from the reaction of medium-derived fatty acids with metal ions in pigments such as lead white,[27] and that the discrimination of soaps produced by natural aging from those originally present in the paint—especially in the presence of pigments—is a far from straightforward task.[28] And while wax esters seem to be more resistant to hydrolysis than glyceride esters in oil media, some degree of natural degradation of wax esters is likely over thousands of years, depending on the exact burial and aging conditions. Furthermore, the ratio of alkanes to other beeswax components that was the basis of White's interpretation can be altered substantially by the alkanes' sublimation over extended periods in a hot and dry climate.[29]

Even with today's advanced technology and enhanced knowledge of paint chemistry, we face daunting challenges in characterizing the binding media. A major concern is contamination, which may derive from the original context and treatment of the mummy, its subsequent environment, or later conservation treatments. It's an unfortunate fact that the most common binding media identified to date in the mummy portraits—beeswax and animal glue—are historically also among the most ubiquitous restoration materials: Petrie himself described the use of both beeswax and paraffin wax to secure loose paint on the excavated portraits,[30] and collagen glues have been used for panel repair and consolidation of paint.[31] Contamination may also result from the mummification process, such as from residues of adhesive used to incorporate the portrait into the wrappings or excess embalming materials that have migrated through the panel support.[32] Considering the portraits' complex origins and history, and the sensitivity of modern instrumentation, there is clearly a high possibility of encountering a variety of materials unconnected with the original painting technique (wax, glue, oils, resins, starch, etc.) in samples. Knowledge of the conservation history and careful selection of sampling sites are critical to increase the likelihood that information obtained from the analysis is useful; any sampling and further treatments should also be documented thoroughly to benefit future researchers.[33] With regard to obtaining credible and representative data, a related problem is the conflict with ethical considerations that may limit the number of samples taken. Additionally, samples must often be taken from existing losses or from the edges of paintings—areas that are more likely to have been subjected to previous restoration or handling.

Another significant challenge in scientific studies is the variety of techniques and protocols that have been used by different research groups, hindering a direct comparison of published results. There is no "universal" method for organic analysis; each provides more or less optimal sensitivity and selectivity for the detection of a given type of material. Furthermore, a method may be selected according to expectations for what is likely to be present,[34] potentially creating an unintentional bias in the results. A multianalytical strategy—that is, one that combines complementary information from different techniques—is the most valuable, as exemplified by a recent multi-institutional study comparing the effects of processing and aging on different wax formulations.[35] The study provided new insights into the chemical and physical properties of experimentally prepared wax media, but it is humbling to note a concluding statement by the authors that "the scope for differentiating encaustic recipes is limited in ancient samples." The comment relates that, while we can now readily differentiate the common classes of medium, and in the case of wax, can also see evidence for its age,[36] we still have no reliable scientific test to determine how the medium was prepared or manipulated for use in the paintings. In this respect, some of the fundamental debates we have today about the media are not so much different from those that Berger and Laurie were engaged in a hundred years ago.

The Chicago Portraits Reconsidered

The analytical results from the AIC's portraits epitomize the issues discussed above (figs. 1.5–1.7). The major component in both paintings is clearly beeswax, with a strong depletion in alkanes characteristic for these ancient objects.[37] No general differences were observed in the composition of the wax that might be attributed to some kind of treatment of the medium, such as the degree of esterification or ratios of the various molecular components, to explain the distinct appearance of the two portraits. In addition to beeswax, diterpene (Pinaceae) resin, shellac, a proteinaceous material, and cellulose nitrate were detected in samples from both paintings.[38] While some of these materials can certainly be attributed to restoration—the cellulose nitrate, and most likely the shellac—the origin of others is less certain. Is the protein a component of the paint, an accretion from storage or handling, or another contaminant from later treatment? It might be argued that Pinaceae resin was used in the medium, but is this also a residue of some later treatment, or alternatively of an adhesive used to insert the portrait into the wrappings?[39] Without the possibility of extensive sampling to determine the distribution of the materials in different parts of the paintings, these ambiguities cannot be resolved with any confidence. While the problem of contamination is frustrating from an analytical perspective, in the bigger picture we can perhaps see a positive aspect, since residues of prior treatments may prove useful indicators of the "biography" of the object, tracking its history and provenance.[40]

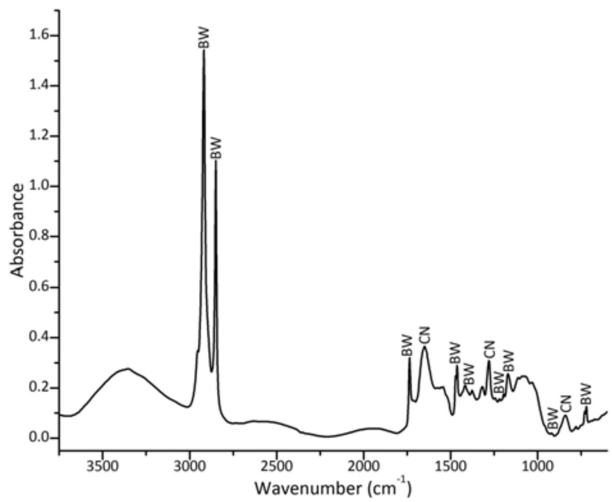


Figure 1.5 Infrared spectrum, black paint sample #1 from the hair of the portrait shown in fig. 1.2, exhibiting characteristic peaks for beeswax (BW) and cellulose nitrate (CN).

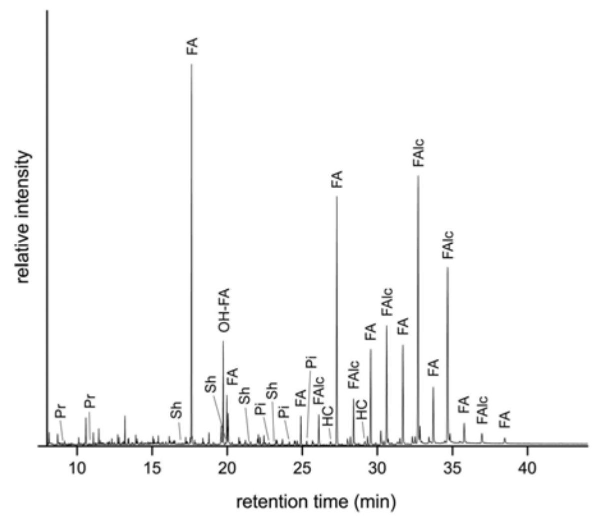


Figure 1.6 Total ion chromatogram (pyrolysis gas chromatography mass spectrometry), dark brown paint sample #2 from the eyelid of the portrait shown in fig. 1.2, exhibiting characteristic marker compounds for beeswax (FA = fatty acid methyl ester, OH-FA = hydroxy fatty acid methyl ester, FAlc = fatty alcohol methyl ether, HC = hydrocarbon), Pinaceae resin (Pi), shellac (Sh), and protein (Pr).

Figure 1.7 Detail of fig. 1.2, showing sample locations corresponding to those described in figs. 1.5 and 1.6.

The Chicago portraits are not alone in indicating the presence of additional components in wax-based paints. Recent studies of examples in other collections have shown evidence of materials such as oils or fats: portraits from several collections analyzed at the Getty Conservation Institute revealed molecular markers associated with a drying oil and with an oil from a plant of the Brassicaceae family (e.g., mustard oil),[41] and one portrait from the Liebieghaus, Frankfurt, was found to contain animal fat in addition to wax.[42] Again we are faced with the question of whether these findings provide evidence for an intentional manipulation of the paint. While the addition of some kind of oil to a wax medium to improve paint handling is not implausible, a broader collection of data derived from systematic studies of well-provenanced portraits in different collections is necessary to support the interpretation that such additional materials are deliberate additives and, if this is the case, to clarify whether their use represents a widespread painting technique, a local workshop practice, or isolated anomalies. Ongoing, collaborative research efforts such as those promoted by the APPEAR project will be invaluable in resolving these uncertainties.

Clarifying Nomenclature

Effective scholarship depends on the use of a clear, consistent, and shared vocabulary, something unfortunately lacking in the study of mummy portraits. The unqualified use of the binary *encaustic* and *tempera* is unhelpful, as we have seen, implying much while specifying little. Some researchers have proposed terms such as *cold wax* or *wax tempera* to account for wax-based paintings that appear flat or brush-applied without the expected textural features of encaustic.[43] But the basis for these descriptors lacks a clear consensus, either from scientific analysis or from the interpretation of historical texts, and it denies the more prosaic possibility—as initially argued by Petrie—that certain artists may simply have had a facility for working rapidly with molten wax paint rather than relying on a special modified medium.

Based on current knowledge, our discussions of the media would instead benefit greatly from a more precise and objective use of existing terms. *Encaustic* should ideally be reserved for portraits displaying visual evidence of application using heat, and preferably supported by analytical confirmation of wax. The more generic term *wax* (or *beeswax*) would be appropriate where this medium has been identified but there are no clear visible indicators such as tool marks. This distinction respects the etymology of *encaustic*, referring to a technique and not only a material, and avoids any unsupported implication of the manner of preparation or application. The problematic *tempera* could be remedied by simple qualification: *glue tempera* where there is analytical confirmation of a proteinaceous, animal glue medium, or similar terms such as *gum tempera* in cases where a more unusual water-based medium is identified. And when describing the medium, one should always make explicit whether the assignment is determined analytically or inferred from similarities in appearance to other known examples.

In a broader sense our problem with terminology stems from the basic human impulse to classify things neatly and simply, which forces reductionism and generalization and stands in direct conflict with the human tendency to be creative and idiosyncratic. Even if we can agree on a descriptive system, we should not be surprised if ongoing research on these enigmatic portraits uncovers further anomalies and exceptions to our categories.

Acknowledgments

We are grateful to our colleagues who have generously shared their expertise and insights in numerous helpful discussions: Francesca Casadio, Karen Manchester, Katharine Raff, and Cybele Tom at the AIC; Patrick Dietemann at the Doerner Institute; Joy Mazurek at the Getty Conservation Institute and Marie Svoboda at the J. Paul Getty Museum; Richard Newman at the Museum of Fine Arts, Boston; Johanna Salvant at the Centre de recherche et de restauration des musées de France; and Jevon Thistlewood and Susan Walker at the Ashmolean Museum. We extend our thanks as well to Caroline Cartwright of the British Museum for performing wood analysis on both portraits.

NOTES

1. See Raff 2016. Specific aspects of the portraits' technique are discussed in Sabino et al., 2019; a publication describing the analytical results in more detail is planned.

2. Criteria for the identification of beeswax have been discussed elsewhere; see, for example, Salvant et al. 2018. Analysis was carried out using Fourier transform infrared microspectroscopy (FTIR) and pyrolysis gas chromatography mass spectrometry with thermally assisted hydrolysis and methylation (THM-Py-GCMS). For FTIR, samples were mounted on a Specac diamond compression cell and analyzed in transmission mode at 4 cm^{-1} resolution and 128 scans per spectrum using a Bruker Hyperion microscope with MCT D315 detector, interfaced to a Tensor 27 spectrometer bench. For THM-Py-GCMS, samples were placed in Agilent micro vials with tetramethylammonium hydroxide reagent (1.5 µL of a 2.5% solution in methanol) in an Agilent Thermal Separation Probe and inserted into the Multimode Inlet of an Agilent 7890B GC. The GC was equipped with an Agilent HP-5ms Ultra Inert column (30 m, 0.25 mm i.d., 0.25 µm film) and interfaced to a 5977B MS. The inlet, operated in splitless mode, was ramped from 50°C to 450°C at a rate of 900°C/min to perform pyrolysis. The final temperature was held constant for 3 minutes and then decreased to 250°C at a rate of 25°C/min. The GC oven was programmed from 40°C to 200°C at 10°C/min, then to 310°C at 6°C/min, and held isothermally for 20 minutes; total run time was 54.33 minutes. The MS was run in scan mode (*m/z* 35–550 from 5–25 min, and 50–700 from 25 minutes).

3. Freccero 2000; Dietemann et al. 2017.

4. Petrie 1911b: "Wax, coloured so as to absorb the heat, will readily soften and run under the glow of an Egyptian sun; and, with a water bath for the pans of colour, wax would be quite as easy a vehicle to work with as oil."

5. Spaabæk 2012.

6. Caylus, Majault, and Pissot 1755.

7. Requeno 1784.

8. Montabert 1829. For the encaustic revival in the eighteenth and nineteenth centuries, see also Rice 1999.

9. Pliny, *Natural History*, vol. 6, bk. 21, par. 49.

10. White 1978; Colinart and Grappin-Wsevolojsky 1999; Stacey 2011.

11. E. Berger 1904.

12. Beltinger and Nadolny 2016.

13. Laurie 1910, 45.

14. Doxiadis 1995, 93–102; Colinart and Grappin-Wsevolojsky 1999; Dietemann et al. 2017; Stacey et al. 2018.

15. Stavitsky 1999, 17–61.

16. Doerner 1934.

17. Zetina 2018.

18. Von Richter 1893. The "balm of Chios" referred to by the author is specifically described as the liquid resin obtained from *Pistacia terebinthus* (sometimes called "Chios turpentine"), rather than mastic resin obtained from *P. lentiscus*.

19. Doerner 1934, 142. This 1934 edition is the first English translation of Doerner's book; it was initially published in German in 1921.

20. Doxiadis 1997. See also Doxiadis 1995.

21. Miller 2000, 58.

22. Sutherland 2017.

23. Von Richter 1893, 48; Thompson 1976, 9; Williams 2010, 130.

24. Pagès-Camagna and Le Hô 2008; Salvant et al. 2018; Mazurek, Svoboda, and Schilling 2019. A widely cited description of a mummy portrait with an egg-based binder is reported in Ramer 1979; however, the basis of his interpretation (fatty acid ratios as determined by GC) is dubious in this context without corroborating evidence, and recent reanalysis of paint samples from the same portrait has indicated a glue-based medium: see Mazurek, this volume. Dietemann et al. 2017 have reported a combination of wax and egg in the binding medium of one portrait in the collection of the Liebieghaus, Frankfurt; the significance of this unusual combination of materials is not clear.

25. Kühn 1960. Similar arguments for the use of saponified wax, or of wax mixed with triglyceride oil–derived soaps, have been made in more recent studies: Freccero 2000; Pagès-Camagna and Le Hô 2008; Cuní et al. 2012. While some authors do not specify the type of soap detected (lead, sodium, etc.), others claim that a specific identification allows a distinction between saponification resulting from deliberate treatment of the wax and saponification resulting from natural aging. This has not

yet been demonstrated convincingly in historical samples, however.

26. White 1978. White's results are reiterated in Ramer 1979, 6; they were later cited by Doxiadis (1995, 97) as “proving beyond all doubt” the use of Punic wax.

27. Casadio et al. 2018.

28. Stacey et al. 2018.

29. Regert et al. 2001.

30. Petrie 1931, 84: “By putting a coat of fresh beeswax over [the portraits] the old colour was revived and safely fixed…. In later years, paraffin wax was used for this purpose.”

31. Spaabæk 2007; Williams 2010, 135.

32. Thistlewood 2018, 8. See also Petrie's comments on staining of portraits by embalming oil, in Petrie 1911a, 6; Spaabæk 2007, 117.

33. See Spaabæk 2007, 126; Ramer 1979, 9.

34. This is true especially for GCMS analysis, for which the selected sample preparation and analysis parameters generally provide optimal detection of a limited range of chemical compound classes.

35. Stacey et al. 2018.

36. From depletion of the more volatile alkane components of the wax; see Regert et al. 2001. This phenomenon could have diagnostic value in cases where contamination from a modern application of beeswax is suspected.

37. Regert et al. 2001.

38. Nine samples were analyzed from variously colored paints in portrait AIC 1922.4798 and six from AIC 1922.4799. Pinaceae resin was identified based on the detection using THM-Py-GCMS of oxidized abietane acids such as dehydroabietic acid (DHA), 7-oxo-DHA, and 15-hydroxy-7-oxo-DHA (see Van den Berg et al. 2000); shellac from the presence of aliphatic and cyclic hydroxyacids such as butolic, aleuritic, and shellolic acid (see Sutherland and del Río 2014); and protein from the presence of several pyrolysis products (see Schilling et al. 2016).

39. Pinaceae resin, or pitch, was identified in samples of resinous material, presumably adhesive from the wrappings, from the edges of both portraits. The detection by THM-Py-GCMS of retene, along with other oxidized abietanes, suggests the use of heat in the preparation or extraction of the resin.

40. See Barr, this volume.

41. See Mazurek, Svoboda, and Schilling 2019.

42. Dietemann et al. 2017.

43. E. Berger 1904, 180–81; Freccero 2000, 107; Dietemann et al. 2017.

2

Understanding Wood Choices for Ancient Panel Painting and Mummy Portraits in the APPEAR Project through Scanning Electron Microscopy

Caroline R. Cartwright

Introduction

After the Battle of Actium in 31 BC, Egypt became part of the Roman Empire. In the first through third centuries AD, a new form of funerary artifact—the mummy portrait—became very popular in Egypt. Not only are many of these portraits remarkably realistic depictions of individuals, they also reflect an extraordinary fusion of funerary preferences. The naturalistic style of these works evokes Greco-Roman painting in the Mediterranean area, but they were made to be incorporated into the traditional practice of Egyptian mummification in highly decorated wooden coffins.

In 1995 the British Museum organized a major colloquium on burial customs in Roman Egypt; this was followed in 1997 by the special exhibition *Ancient Faces: Mummy Portraits from Roman Egypt*, which brought together mummy portraits from many institutions around the world. The exhibition triggered a program of scientific research of mummy portrait wood identification at the British Museum that not only resulted in publications but also continued to inspire collaborative research thereafter.[1]

Given that I have identified local Egyptian woods for coffins and funerary artifacts in earlier chronological periods, I was surprised to find, from the outset of the research in 1996, that most mummy portraits were made of *Tilia europaea* (lime/linden) wood—which is not, and has never been, native to Egypt.[2] Before the Roman period in Egypt, there had been extensive importation of *Cedrus libani* (cedar of Lebanon) wood for high-status coffins, but such intensive exploitation of lime wood for (portrait) panels was an innovation.

Essential Facts about Scientific Wood Identification

Wood anatomy is a recognized specialist area of botanical science; therefore, there are precise taxonomic nomenclature requirements as well as specific protocols inherent to the identification process.[3] Fortunately the APPEAR project has adhered to the principles of scientific rigor, applying them consistently to those mummy portraits and painted panels that could be microsampled.

This precision resulted in a collaborative corpus of secure scientific wood identifications, which benefit all concerned.

For accurate scientific identification of ancient, historical, and modern woods, preparation of the following three sections is mandatory: transverse section (TS), radial longitudinal section (RLS), and tangential longitudinal section (TLS). For modern and some historical wood samples (particularly those that are not desiccated), wood sectioning coupled with optical microscopy using transmitted (polarizing) light is standard practice, generally on sample sizes greater than those needed for scanning electron microscopy (SEM; see below).[4]

Wood identification must strictly comply with the International Association of Wood Anatomists (IAWA) protocol, terminology, and numerical feature classification in order to ensure universal comparability of reliable results. This means that each genus or species requires recognition of between forty to sixty predefined characteristics, of which 90 percent are anatomical cellular features. It is important to note that such features can be seen only by examining all three sections (TS, RLS, and TLS), and for this reason it is recommended that a tiny cubic sample is removed, rather than a splinter, as the latter restricts the preparation of a TS.

Mummy Portrait Wood Sampling

Those wooden objects that have survived the particular conditions within ancient Egyptian tombs are remarkable, not least in the level of preservation of their wood anatomy. That said, although the condition of the cellular features is good, the wood may be brittle macroscopically. For that reason, it is preferable to fracture samples of these wooden artifacts in TS, RLS, and TLS (as would be done for charcoal) for microscopical examination, rather than to thin-section them.

At the time of writing (May 2018) thirty-five institutions (from both the pre-APPEAR and APPEAR phases of scientific analysis) have permitted the removal of tiny wood samples for identification. So far, the woods of 180 mummy portraits have been identified by the author, in addition to the woods of twenty nonportrait Egyptian painted panels. This is ongoing research and the numbers grow daily, with numerous samples currently being prepared for identification using SEM. Two different SEM processes are being used: a variable-pressure (VP) SEM, for uncoated wood samples, and a field-emission (FE) SEM, for very high resolution and magnification (up to 300,000x) of ultra-tiny samples that require coating by gold or platinum or palladium to avoid the surface charging that results from the electron beam's interaction with the wood.

When sampling mummy portraits or painted panels, the following should be avoided:

- wood with consolidant or adhesive;
- wood that has been affected by rot or insect or fungus attack;
- areas of wood with knots or burls, and areas with nails, nail holes, labels, signatures, or saw or drill marks; and
- areas of paint, decoration, gilding, or other surface modifications, such as heavy patination.

Sometimes it is possible to sample from the back or underside or from a damaged edge, although it is important to avoid the areas designated above. If frames, dowels, tenons, repairs, or additions are present, it will be necessary to sample these various elements as well, as different woods may have been selected to create them. With the use of high-specification SEM for the wood identifications, I can accept cubic wood samples of 1 millimeter in size (although if samples of 2 to 3 millimeters are permitted, those are preferred). Because specific recommendations for packing, international mailing, and sending by courier are subject to change, participating APPEAR institutions should contact me for regularly updated instructions.

Wood Identification Results: The Current Status

Figure 2.1 shows the current status of mummy portrait and nonportrait panel wood identification results, as of May 2018. The range of woods utilized has been extended, particularly in terms of the use of native woods such as sidr (*Ziziphus spina-christi*), at 3.1 percent, especially (but not exclusively) for nonportrait painted panels. Tamarisk (*Tamarix aphylla*), another native Egyptian timber, is represented in small quantities at 1.9 percent of the overall total. By far, the most frequently used native timber is the local fig wood (*Ficus sycomorus*; fig. 2.2), with 15.6 percent of the total. Five imported European woods are present, dominated by lime wood (*Tilia europaea*; fig. 2.3), at 69.4 percent; followed by oak (*Quercus* sp.), at 4.4 percent; cedar of Lebanon (*Cedrus libani*; fig. 2.4), at 2.5 percent; fir (*Abies* sp.), at 1.9 percent; and yew (*Taxus baccata*), at 1.2 percent. This means that imported European species make up 79.4 percent—principally lime wood, at 69.4 percent—

whereas only 20.6 percent are native Egyptian species—principally fig, at 15.6 percent.

Figure 2.1 Wood Identifications of Mummy Portraits and Painted Panels: May 2018

Genus	Species	Common Name	Native to Egypt?	%
Tilia	*europaea*	lime, linden	NO	69.4
Quercus	sp.	oak	NO	4.4
Cedrus	*libani*	cedar of Lebanon	NO	2.5
Abies	sp.	fir	NO	1.9
Taxus	*baccata*	yew	NO	1.2
Ficus	*sycomorus*	sycomore fig	YES	15.6
Ziziphus	*spina-christi*	sidr, Christ's thorn	YES	3.1
Tamarix	*aphylla*	tamarisk	YES	1.9

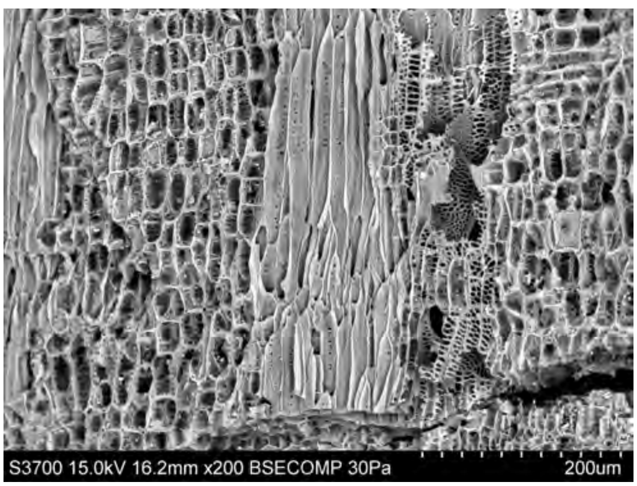


Figure 2.2 SEM image of an RLS of *Ficus sycomorus*, sycomore fig wood; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

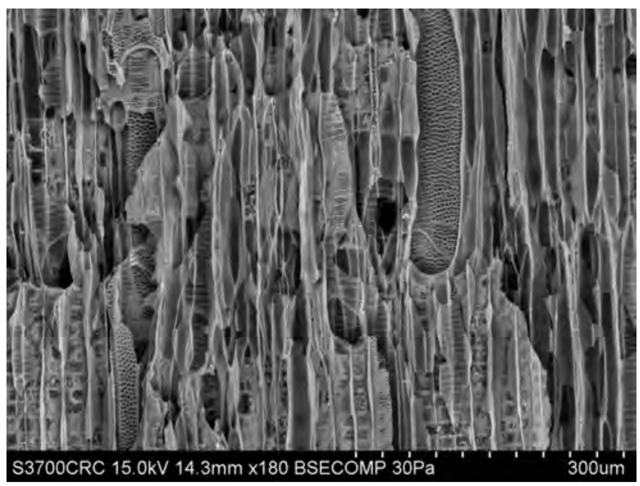


Figure 2.3 SEM image of an RLS of *Tilia europaea*, lime wood; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

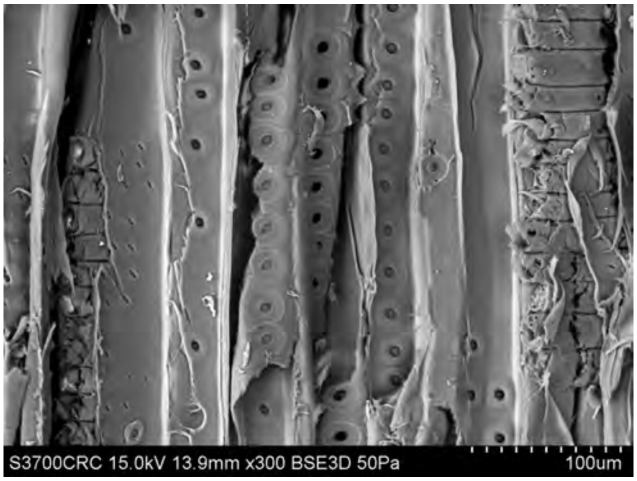


Figure 2.4 SEM image of an RLS of *Cedrus libani*, cedar of Lebanon wood; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

Figure 2.5 A *Tilia europaea* (lime) tree in the Royal Botanic Gardens at Kew. Image: © 2012 C. R. Cartwright

Why Was Lime Wood So Desirable?

Tilia europaea (including *Tilia platyphyllos* and *Tilia cordata*) trees have a long history of wide distribution across Europe and were a ready source of timber over time. Some lime trees can reach heights of 30 meters (100 ft.) and diameters of 1.3 meters (4 ft.). Many have a clear trunk for 15 meters (50 ft.), thus offering good-quality, straight-grown timber for planks, panels, and boards (fig. 2.5). Lime wood planks benefit from being seasoned before use. Controlled seasoning reduces the moisture content in the timber to the required level. As a consequence, strength and elasticity are developed—qualities that maximize the wood's mechanical and working properties for the carpenter or woodworker. Seasoning lime wood can also minimize its susceptibility to insect attack, permeability, or reduced durability. The color of lime heartwood varies from white or gray to shades of brown, and its sapwood is virtually indistinguishable in color from the heartwood.

After examining the TS, RLS, and TLS of lime wood in more detail, it is interesting to see how directly the anatomical features contribute to making it such a desirable woodworking resource. Thin sections of *Tilia europaea* wood (from the reference collections in the wood anatomy laboratories of the Department of Scientific Research at the British Museum) are used here to demonstrate these features (figs. 2.6–2.8).

Figure 2.6 shows a transverse thin section of *Tilia europaea* wood seen in transmitted light in the optical microscope (in this instance, the Leitz Aristomet, modified for biological applications). The growth rings are distinct, and although there is a tendency for a ring-porous distribution of slightly larger vessels at the beginning of the growth ring, most of the vessels are diffuse-porous and have similar diameter size throughout the growth ring. The mean tangential diameter of the vessels varies between 50 to 100 micrometers (microns). Solitary vessels (often angular in outline), clusters, and small vessel chains are present. There are usually between 40 and 100 vessels per square millimeter, sometimes more. Axial parenchyma is present as diffuse-in-aggregates, in narrow bands or lines up to three cells wide, and in marginal or in seemingly marginal bands. There are between 4 and 12 axial rays per millimeter and, although best described from the TLS, narrow rays of 1 to 2 cells wide can be seen in the TS, as can larger rays with widths varying between 4 and 10 cells wide. Some rays show a tendency to flare out at growth ring boundaries.

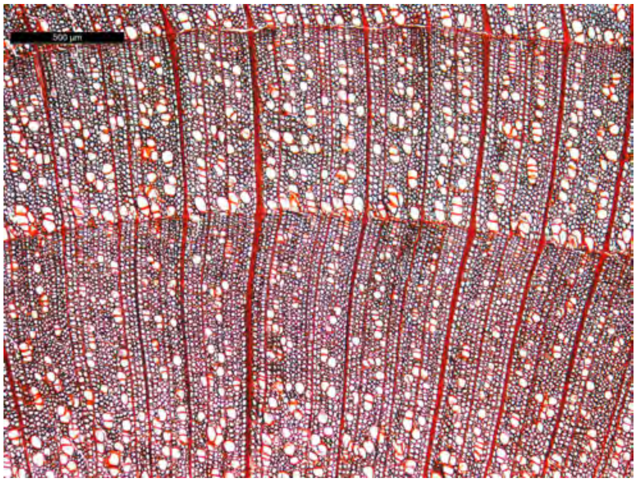


Figure 2.6 Image of a transverse thin section of *Tilia europaea* (lime) reference specimen wood seen in transmitted light in the optical microscope. The section has been stained in the laboratory to show the cellular details; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

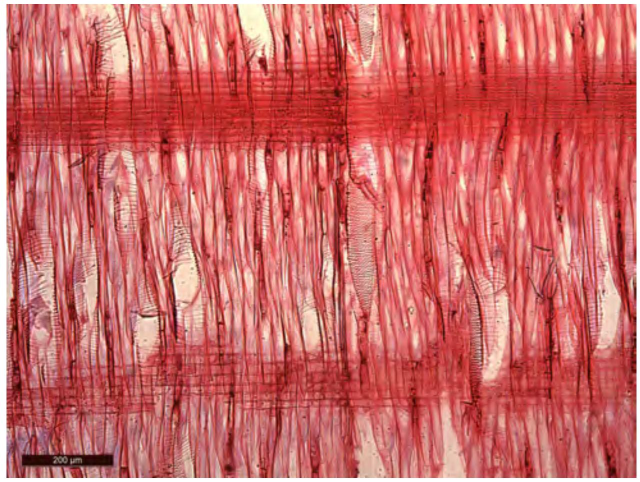


Figure 2.7 Image of a radial longitudinal thin section of *Tilia europaea* (lime) reference specimen wood seen in transmitted light in the optical microscope. The section has been stained in the laboratory to show the cellular details; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

Figure 2.7 shows a radial longitudinal thin section of *Tilia europaea* wood seen in transmitted (polarized) light in the optical microscope. The radial longitudinal plane of lime wood was the one most often selected for the prepared surface of the mummy portraits, onto which the ground and paint layers were applied. By examining the anatomical features, it is possible to appreciate (as it was for those features visible in the TS, as detailed above) why this even-grained wood was so popular. In some rays the ray parenchyma cells are all procumbent, while in others the body ray cells are procumbent with one row of upright and/or square marginal cells. Simple perforation plates with a single circular or elliptical opening are present in the vessels. The mean vessel element length can vary between 350 and 800 microns (μm). Intervessel pits are present in an alternate arrangement. Many of these vessel-to-vessel alternate pits are polygonal in shape and may be small (4–7 μm in diameter) or medium (7–10 μm) in size. Vessel-to-ray pits have distinct borders and are similar to intervessel pits in size and shape throughout the ray cell. Helical (spiral) thickenings—that is, ridges on the inner cell wall—are present in the vessels. The fibers have simple to minutely bordered pits, often found in both radial and tangential walls. These nonseptate fibers may be very thin walled, thin walled, or thick walled. The mean fiber length varies between 900 and 1600 microns.

Some anatomical features are visible in both the RLS and TLS, so for figure 2.8, which shows a tangential longitudinal thin section of *Tilia europaea* wood seen in transmitted (polarized) light in the optical microscope, the descriptions that follow are of only those characteristics discernible in detail in the TLS. Uniseriate rays (1 cell wide) are common, as are multiseriate rays between 4 and 10 cells wide. Ray height may exceed a millimeter. Some parenchyma strands are composed of 3 to 4 cells; others, 5 to 8 cells.

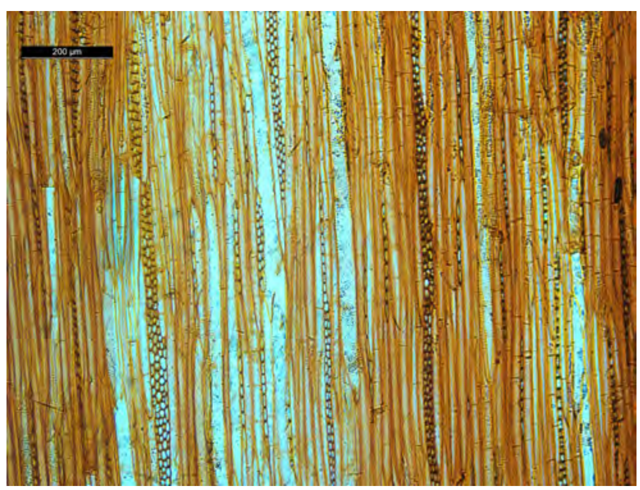


Figure 2.8 Image of a tangential longitudinal thin section of *Tilia europaea* (lime) reference specimen wood seen in transmitted light in the optical microscope. The section has been stained in the laboratory to show the cellular details; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

The combination of these anatomical features is the key to lime wood's popularity. The even distribution of ray parenchyma cells in their characteristic bricklike arrangement oriented at right angles to the equally evenly distributed vessels, fibers, and axial parenchyma cells results in a highly consistent and uniform cellular structure. These characteristics allow lime wood to perform predictably well when sawn or crosscut, which makes it an ideal timber for those mummy portraits that are fine, thin, light panels, curved to fit snugly in cartonnage wrapping over the face of the mummy.

Other Woods Imported from Europe or Western Asia: Why Choose Them?

Several species of oak are distributed across Europe and into western Asia. Characterized by its strength and sturdiness, oak is often considered to be an all-purpose carving wood, particularly for furniture, doors, and construction. It can be problematic to work on account of the large size of its vessels and the width of its multiseriate rays, which are often more than ten cells wide. Although wide rays may allow for easy radial longitudinal splitting of oak wood, its generally coarse grain means that using oak for mummy portraits required much thicker panels to be cut than those necessary when using lime wood.

Cedar of Lebanon wood had a long tradition of being imported into Pharaonic Egypt for use in high-status coffins and other funerary artifacts. It is often regarded as easy to carve, plane, and polish, although large knots and ingrowing bark can make woodworking difficult, and the wood may be rather brittle. Some cedar wood is renowned for being strongly aromatic and resinous (and therefore insect repellent); these may be useful properties for coffin wood planks but could cause problems for the painted areas of the mummy portrait and other painted panels if the resin seeped through to the surface. It is possible that the continued occasional use of cedar wood, even for portrait panels, reflected in some way its earlier prestige in Egypt. It is believed that cedar of Lebanon wood was traditionally sourced from mountainous forests in Lebanon, but it should be noted that Atlantic cedar, native to the Atlas Mountains in North Africa, is indistinguishable, anatomically speaking, from cedar of Lebanon wood. Closely related to cedars are firs. The most common species of fir tree in Europe is *Abies alba*, but from an anatomical perspective, the various *Abies* species cannot be distinguished. Although easy to work, fir tree wood is not durable and has little resistance to insect attack—not a prime choice for portrait panels, therefore.

Yew wood is dense, strong, and heavy but with remarkable flexibility, which makes it a good raw material for archery bows. Most yew wood has many knots and imperfections, so small turned, decorative objects are usually made from it. However, despite a high waste factor during preparation (and consequent higher costs), yew wood, on account of its quality, has been used for cabinetry, furniture veneers, carvings, and musical instruments. The use of yew wood for mummy portrait panels is unusual and may have a particular family or cultural significance.

Native Egyptian Woods: Why Were They Used?

As noted above, by far the most frequently used native Egyptian timber is the local fig wood (*Ficus sycomorus*), at 15.6 percent of the total number of mummy portraits and painted panels (fig. 2.9). Before discussing fig wood's properties, the issue of correct botanical taxonomic nomenclature must be addressed. It is important to insist on correct terminology and spelling of *Ficus sycomorus,* sycomore fig, as attested by international botanical taxonomic authority.[5] This type of fig tree, belonging to the Moraceae family, is completely unrelated botanically to the true sycamore tree, *Acer pseudoplatanus*, which is part of the Sapindaceae family and is mainly distributed across central Europe. It is only correct to write about ancient Egyptian sycamore timber if it has been scientifically identified as *Acer pseudoplatanus*—the inference being that the wood was imported into Egypt from Europe. It is incorrect to describe indigenous *Ficus sycomorus* wood as sycamore. *Sycamore*, spelled with an *a*, is not a fig tree; it refers to *Acer pseudoplatanus*, a completely different tree that is not present in Egypt and is anatomically distinct from fig. The spelling is not interchangeable: *Ficus sycomorus* is spelled with an *o*, and its common name is sycomore fig (not just “sycomore”).

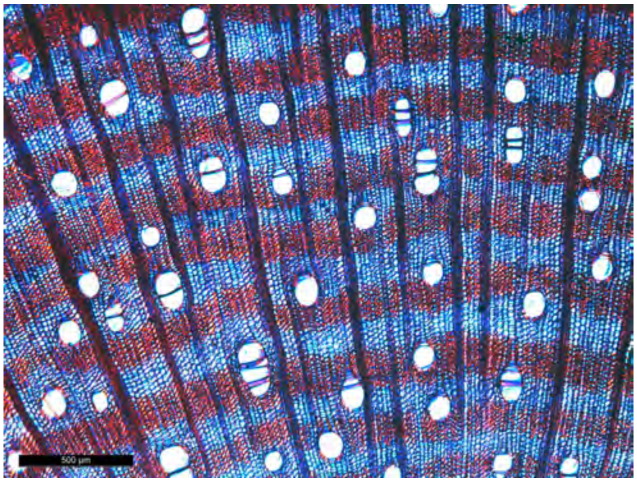


Figure 2.9 Image of a transverse thin section of *Ficus sycomorus* sycomore fig reference specimen wood seen in transmitted light in the optical microscope. The section has been stained in the laboratory to show the cellular details; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

Fig wood is light, not of high quality, and prone to insect attack. In Pharaonic Egypt thick layers of gesso and pigments covering coffin wood planks minimized these adverse properties to an extent. The popularity of native fig wood in the funerary tradition of Pharaonic Egypt was in part due to the fact that these trees were among the few to attain heights that allowed long coffin planks to be cut. In the Middle Kingdom period particularly, this type of fig tree had considerable religious significance, when it and its fruits (although much smaller than those of the cultivated fig, *Ficus carica*), were associated with the goddess Nut. Being such an important tree in Egyptian funerary practices of earlier periods, native fig wood's use for mummy portrait panels could be explained in terms of a fusion of old and new traditions in Roman Egypt. However, like those of imported oak, native fig wood panels would need to be much thicker than those of lime wood, and thus it would be very difficult to make them curve over the mummy head in the same manner as a thin lime wood panel. There may be no single reason for the choice of native fig wood for portrait panels; selection may have been reliant on money and status, or perhaps whether the panel was used as a domestic portrait rather than a funerary one—hence those examples of fig wood portraits in fig wood frames (such as the one from Hawara in the British Museum, 1889,1018.1).

The use of the native wood sidr (*Ziziphus spina-christi*; fig. 2.10) for painted panels is interesting. In Pharaonic Egypt it was unusual to choose woods for the joining elements, which are denser than the planks, and sidr was particularly sought after for creating tight carpentry joins. Sidr, found in tree and shrub forms, inhabits riverbanks, desert wadis, and scrubland thickets. Some of these more marginal habitats may restrict the straight growth of sidr, resulting in twisted or knotty (albeit very dense) timber, with wood suitable for planks or, later, painted flat panels, though the latter are more of a rarity.

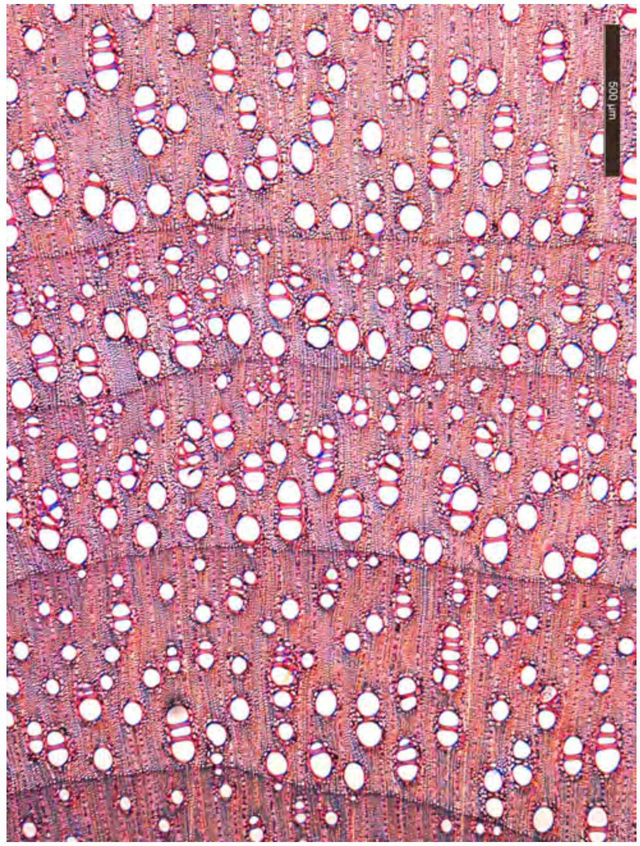


Figure 2.10 Image of a transverse thin section of *Ziziphus spina-christi* (sidr) reference specimen wood seen in transmitted light in the optical microscope. The section has been stained in the laboratory to show the cellular details; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

Tamarisk (*Tamarix aphylla*), another native Egyptian timber, is represented in small quantities for painted mummy portraits and panels. Tamarisk wood shows little resistance to attack by fungi and insects, although it is easy to work and would have been readily obtainable from the vegetation of the Nile bank. Its properties include medium bending and compression strength as well as moderate hardness, but its coarse and fibrous texture (fig. 2.11) makes tamarisk a more suitable wood for domestic articles or agricultural tools than for creating mummy portraits or painted panels, which, as with imported oak and native fig, would need to be much thicker than lime wood panels.

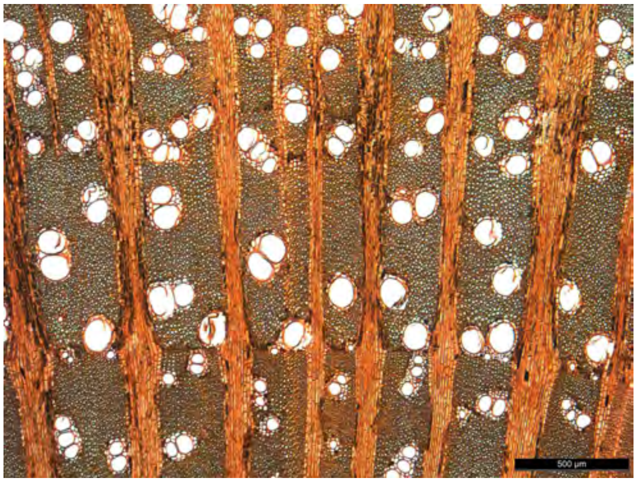


Figure 2.11 Image of a transverse thin section of *Tamarix aphylla* (tamarisk) reference specimen wood seen in transmitted light in the optical microscope. The section has been stained in the laboratory to show the cellular details; scale bar is in microns. Image: C. R. Cartwright. © Trustees of the British Museum

Where Are We Now, and What Research Lies Ahead?

In Roman-period Egypt, it is clear that despite maintaining the traditional practice of mummification, there was a fashion for funerary portraiture that echoed Greek and Roman traditions in the Mediterranean region. The excellent condition of preservation of the wood anatomy of these mummy portraits enabled an unexpected revelation from their identifications—the majority of these works are made from European timbers such as lime wood rather than native Egyptian woods. Over the last twenty-one years, the innovative use of high-performance SEM has facilitated the taking of microsamples from mummy portraits and other painted wood panels. The abundance of institutions participating in APPEAR has fostered and supported vital scientific consistency and comparability for the wood identifications. Although more types of woods are being identified as the research progresses, it is remarkable to see that the predominant choice, at around 70 percent, is still *Tilia europaea*, lime wood, imported from Europe. Currently (as of May 2018), the total of all imported European woods is 79.4 percent, whereas the total for all native Egyptian woods is 20.6 percent. The factors determining individual wood choices constitute intriguing and somewhat elusive elements framing this scientific research, but the search for enlightenment continues.

Interpretation remains the highest priority, preferably in collaboration with APPEAR colleagues. It remains to be seen how far cultural or even regional preferences can be documented, and from what type of evidence. Economic choices need to be evaluated in terms of which wood(s) people could afford to buy or commission. There is a general interest in trying to understand whether workshops, specialist artisans, and carpenters operated alongside or were employed by different stylistic schools of artists and, if so, how, when, and where. Of particular interest are the panels on lime wood and whether they were imported into Egypt as raw timber or prepared panels, or even whether some of the lime wood mummy portraits could have been entirely crafted in Europe.

Acknowledgments

I would like to thank all those in the APPEAR project who are actively supporting this research, including those institutions that have permitted microsampling of their mummy portraits and nonportrait painted panels. Thanks are due to British Museum colleagues who collaborated in the pre-APPEAR phases of the mummy portrait wood identification project.

NOTES

1. See Cartwright 1997a; Cartwright 1997b; Bierbrier et al. 1997; Cartwright and Middleton 2008; Cartwright, Spaabæk, and Svoboda 2011; Cartwright 2015; Salvant et al. 2018.
2. Cartwright 1997a.
3. Cartwright 2015.
4. Cartwright 2015.
5. See the International Plant Names Index (IPNI) at http://ipni.org and specifically *Ficus sycomorus* L. at [http://ipni.org/n/853797-1] (http://www.ipni.org/n/853797-1).

3

The Matter of Madder in the Ancient World

Richard Newman
Glenn Alan Gates

Madder, a lake pigment, may be one of the more common colorants used in Egyptian mummy portraits. As a pure pigment, it is pink or red, sometimes slightly purplish, and is most often noted as the major coloring in red and purple drapery and *clavi* (figs. 3.1 and 3.2). Madder has been found mixed with a blue pigment in purple drapery, and it is commonly noted on lips and highlights on faces.

Figure 3.1 Mummy Portrait of a Woman with Earrings, Romano-Egyptian, ca. AD 130–140. Encaustic on linden wood, 35.3 x 22.5 cm (13 7/8 x 8 7/8 in.). Cambridge, Harvard Art Museums / Arthur M. Sackler Museum, Gift of Dr. Denman W. Ross, 1923.60. Image: President and Fellows of Harvard College

Figure 3.2 Mummy Portrait of a Bearded Man, Romano-Egyptian, ca. AD 170–180. Encaustic on wood, 40.5 x 20 cm (15 15/16 x 7 7/8 in.). Baltimore, The Walters Art Museum, Acquired by Henry Walters, 1912, 32.6. Image: The Walters Art Museum

This paper will briefly review the nature of madder as well as methods by which it can be identified by noninvasive procedures and analyses of samples; a few specific instances of its use in mummy portraits will be described. Madder has been the subject of extensive research, from many points of view, and only a very few selected publications from this rich literature can be cited here.

The Rubiaceae family of plants, comprising more than thirteen thousand species in 617 genera,[1] includes many from which red colorants can be extracted. Colorants from Rubiaceae have been utilized in many parts of the world as textile dyes and pigments. In Europe and western Asia, perhaps a half dozen *Galium* species were likely to have been used as textile dyes.[2] In Europe, the dyes from this genus are commonly known as bedstraws and woodruffs; a related dye, *Asperula tinctoria* L. (often called dyer's woodruff), was also probably important. Although several *Rubia* species are found in many of the same regions as *Galium*, their range does not extend as far north as that of *Galium,* and they grow in regions farther south. *Rubia tinctorum* (often referred to as common madder or dyer's madder) is found in central and southern Europe, northern Africa, and central Asia. *Rubia peregrina* (wild madder) has a range mostly restricted to central Europe. *Rubia cordifolia* (Indian madder or munjeet) is found in central and eastern Asia, eastern Africa, and parts of Australia. Pliny the Elder suggested that by the first century AD at least, *R. tinctorum* was widely grown throughout Italy and the eastern Mediterranean, and it was a ubiquitous source of red dyes for textiles.[3] There is less certainty about the relative availability of the other madders.

The word *madder* is usually restricted to species in the *Rubia* genus. Because many of the same chemical compounds occur in *Rubia, Galium,* and *Asperula*, for the purposes of this paper *madder* will refer to red colorants extracted from any of these botanical sources.

The colorants are found in the cores of roots and rhizomes (underground stems). At certain times of the growing season, the roots exhibit a pink to strong red color, and it is easy to understand how they would have been attractive as potential color sources (figs. 3.3 and 3.4). Extracting the colorants is simple: dried roots are crushed and soaked in hot water. Simple water extracts, if used alone, would not have been fast to moisture if used as stains or dyes, and it seems likely that early in the historical use of madders as colorants, they were combined with inorganic mordants to attach them to textiles' fibers.[4] Inorganic ions, such as aluminum, form complexes with natural compounds found in the roots that facilitate strong bonds to textile fibers and also typically turn the roots' colors more reddish shades. For use as pigments, the extracts were probably prepared as lakes, as discussed below.

Figure 3.3 *Rubia tinctorum* roots (left) and rhizomes (right) before washing. Image: Ashley Walker, Naturesrainbow, Hitchen UK

Figure 3.4 *Rubia tinctorum* roots (left) and rhizomes (right) after washing and gentle brushing. Image: Ashley Walker, Naturesrainbow, Hitchen UK

The compounds responsible for the color are hydroxyanthraquinones (HAs). HAs found in Rubiaceae are derivatives of 9,10-anthraquinone, with hydroxyl (and sometimes other groups) substituted on ring A. In roots, many of these are present mostly in the form of glycosides, in which a HA (or aglycone) is bonded to a sugar molecule (a monosaccharide or disaccharide). Some common glycosides are primeverosides, in which the HA is bonded to the disaccharide primeverose. About three dozen different HAs have been identified in the roots of *Rubia tinctorum*, the most extensively studied of the madder-producing plants.[5] Structures of some common aglycones and glycosides in madders are shown in figure 3.5.

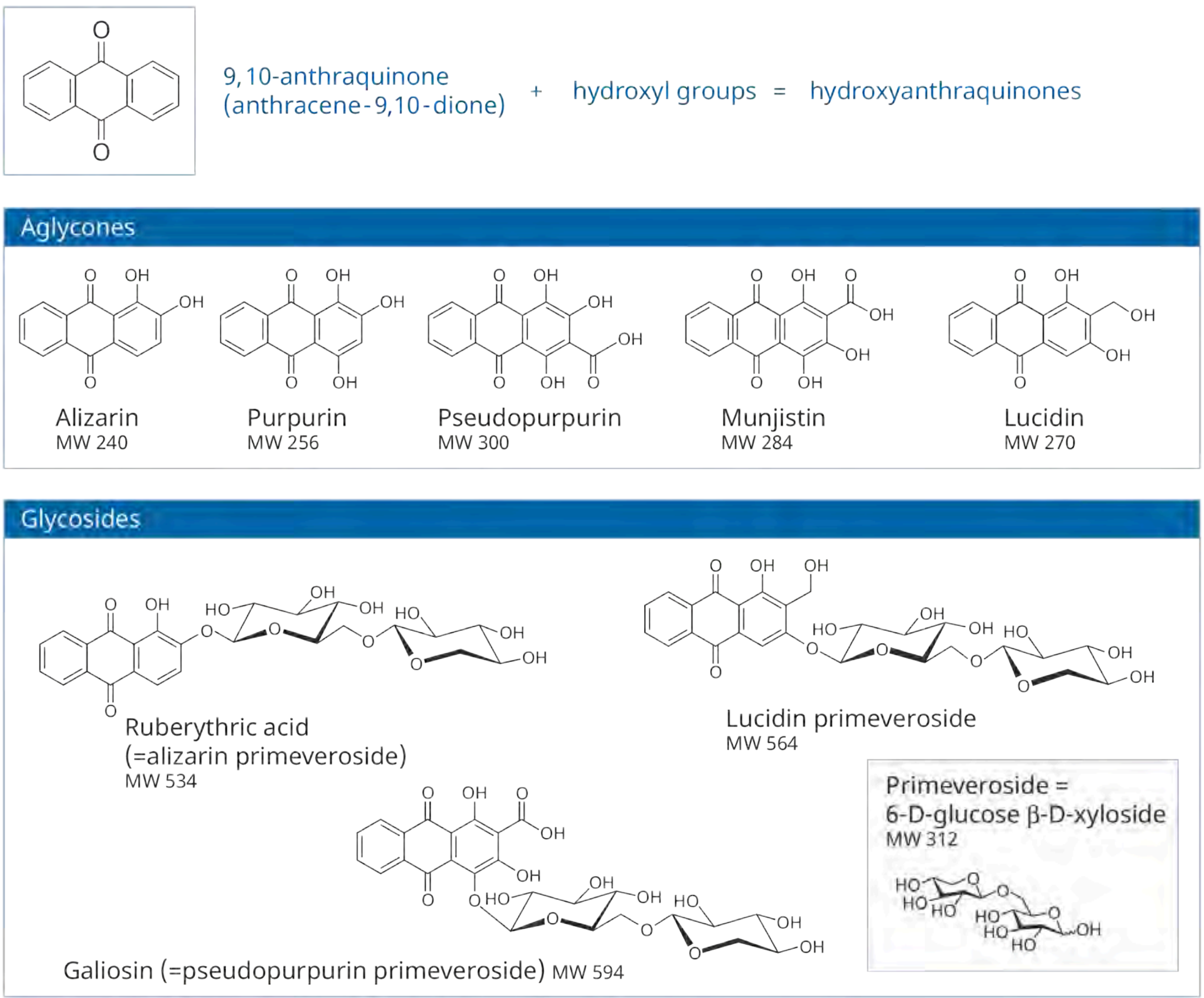


Figure 3.5 Structures (and molecular weights) of some common hydroxyanthraquinones and glycosides found in madder roots.

Air-drying of fresh roots leads to hydrolysis of the native glycosides by endogenous enzymes, although glycosides may be preserved if fresh roots are strongly heated, which destroys the enzymes.[6] Glycosides can also be easily broken down during other steps by which plant extracts are prepared and attached as dyes to fibers or prepared for use as pigments. As a result, samples of pigments or dyes extracted from textiles usually contain only aglycones. There can be considerable variations in the specific aglycones and their relative amounts found in the end products of their use—be it textile or pigments—even if they were prepared from only one species of plant.[7]

HAs can also be extracted from a number of types of scale insects, and at least four major types have or may have served as important historical sources of dyes in the ancient world: kermes (from *Kermes vermilio*), Armenian cochineal (*Porphyrophora hamelii*), Polish cochineal (*Porphyrophora polonica*), and lac (*Kerria lacca*).[8] The HAs in these sources, which contain substituents on rings A and C, do not overlap with any found in Rubiaceae.

Identification of specific HAs has been carried out by several techniques. Of them, the one that in principal requires the smallest sample is surface-enhanced Raman spectroscopy (SERS). It has been shown that three of the major HAs found in many Rubiaceae (alizarin, purpurin, and pseudopurpurin) can be identified by SERS; however, if more than one HA is present in a given sample, SERS may detect only one of them.[9]

Typically, techniques that can confidently identify two or more HAs simultaneously require larger samples than does SERS. (The actual sample size or weight required for any analytical technique depends on many factors, including the concentration of the compounds of interest in the sample.) Liquid chromatography (LC) is a proven workhorse, either with diode array detectors (LC/DAD), mass spectrometer detectors (LC/MS), or both (LC/DAD/MS). Successful applications of LC to Rubiaceae-based dyes and pigments are extensive.[10] Other mass spectrometric techniques, not combined with chromatography, have been less commonly utilized to date.[11] Noninvasive methods by which the presence of madder can be established or at least hypothesized are discussed later.

Alizarin, purpurin, and/or pseudopurpurin are the HAs most commonly detected in chromatographic analyses of madder pigments. Many researchers have used the types and relative amounts of these HAs, as indicated by peak heights or areas in chromatograms, to hypothesize the botanical source of madder in specific samples.[12] Of the various genera and species noted earlier, alizarin is the predominant HA only in certain extracts from *R. tinctorum*. If alizarin is absent or negligible, then *Galium*, *R. cordifolia,* or *R. peregrina* are the more likely sources. Conclusions can be problematic, as profiles of HAs are profoundly affected by processing of the raw materials, procedures used to prepare a dye or lake, and preparation of samples for analysis. In some instances, certain other HAs, present in minor amounts, may suggest specific botanical sources, but there is no general agreement on how useful the presence or absence of such minor components is for this purpose.[13]

The earliest published occurrence of a madder dye in a cultural artifact is in some (now unavailable or lost) fragments from Mohenjo-daro, an Indus valley site dated to about 3000 BC.[14] However, the analysis may not have been correct given techniques available at that time. The earliest confirmed identification of madder (from an analysis carried out by SERS) is on an Egyptian leather quiver fragment dated to the Middle Kingdom, Dynasty 11 (ca. 2124–1981 BC), excavated at Thebes.[15] The dye was rich in purpurin.

Some textiles excavated at a late second millennium BC site in the Tarim basin of western China were likely dyed with *R. tinctorum.*[16] This species has also been identified as the source of red dye for some textiles, dated to the eleventh and tenth centuries BC, excavated at Timna, Israel.[17]

Analyses of textiles, apparently discarded between the first and third centuries by Roman garrisons at eastern desert sites in Egypt, identified two “types” of madder,[18] likely from more than one type of plant. Dyers must have been aware of how different plants and manipulations in extraction and preparation procedures could affect the tint of the final product.

Textile dyeing and the making of lake pigments were separate operations, but lakes may have been made in some of the same workshops in which dyed textiles were produced. In later European history, the colorants used to make lakes were at least at times extracted from scraps of dyed textiles, and lakes in the ancient world could also have been made from such scraps.[19]

The earliest examples in a recent compendium of madder-based pigments in the ancient world are from Cypriot pottery of the eighth and seventh centuries BC; these works reportedly contained alizarin, purpurin, and possibly pseudopurpurin.[20] Some paint samples contained significant alizarin, while others contained little or no alizarin. A small bowl of pseudopurpurin-rich madder lake was among several that were excavated at Hawara, the region in which many mummy portraits are thought to have been created.[21]

Analysis by LC/MS of purple pigments from a Hellenistic sculpture identified an alizarin-poor madder mixed with Egyptian blue, but traces of insect dyes were also found: a type of cochineal and lac.[22] Lakes made exclusively from insect dyes may have been utilized in the ancient world, but there are few examples as yet.

Little is known about how lake pigments were made in the ancient world. Typical later procedures in Europe involved mixing the root extracts with a soluble aluminum sulfate salt (such as alum), then adding an alkali (such as plant ash) to precipitate the lake. The alkali can be used first, followed by addition of the soluble aluminum salt.[23]

Particles of lakes created by these procedures consist of HAs in complexes with aluminum (possibly also with smaller amounts of other elements, such as calcium) within particles of aluminum sulfate and mostly amorphous aluminum hydroxide.[24] Calcium carbonate, if used as an alkali, can result in a lake that contains calcium sulfate, which would be precipitated during the manufacturing process. After drying, a lake pigment can be ground like a mineral pigment, then mixed with the paint medium.

The substrates of ancient madder-type lakes have been identified as aluminum rich, clay containing, or based on calcium carbonate or calcium sulfate.[25] The possible presence of extenders (or white pigments) in samples makes precise identification of the lake substrate difficult, since most published analyses have not been carried out on isolated lake particles.

When paint cross sections containing lake particles are available, the substrates of the lake can be studied by scanning electron microscopy / energy-dispersive X-ray spectrometry (SEM/EDS) with little interference from other compounds present in the paint sample. Figure 3.6 is an image of a cross section from a purple *clavus* in a mummy portrait (see fig. 3.1). The purple paint contains gypsum, natrojarosite, indigo, and a red lake that fluoresces orange. The SEM/EDS spectrum from the largest lake particle in the image (fig. 3.7) is quite similar to spectra from madder lakes in later European paintings: aluminum is the major element, with some sulfur and smaller amounts of several other elements associated with the raw materials that had been used to make the lake. The particle encompasses several very small grains of lead white, perhaps an unintentional component of the lake. Lake-containing samples from mummy portraits examined at the Museum of Fine Arts often contain angular particles of calcium sulfate (usually gypsum) and finer-grained material that is rich in aluminum. The latter regions exhibit orange fluorescence. A chip of one pink paint sample is shown in figure 3.8. In this instance, the gypsum was likely added to the paints as a ground mineral after the lake was manufactured, rather than precipitating during manufacture.

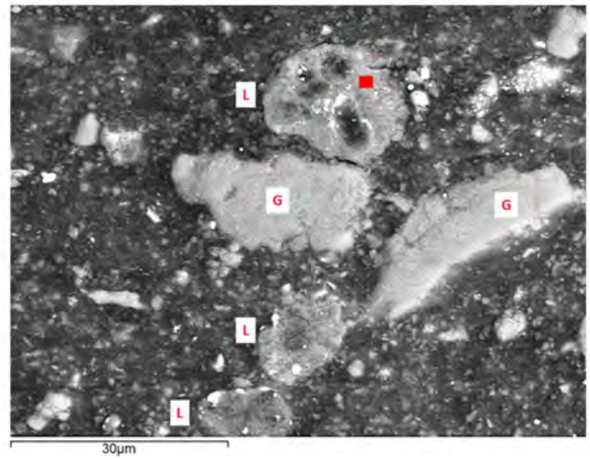


Figure 3.6 Detail of cross section from purple drapery in portrait shown in fig. 3.1. Backscattered scanning electron microscope image: L = lake particles, G = gypsum particles. Red square denotes region whose SEM/EDS spectrum is shown in fig. 3.7. Sample of fig. 3.1 courtesy of Katherine Eremin and Georgina Rayner

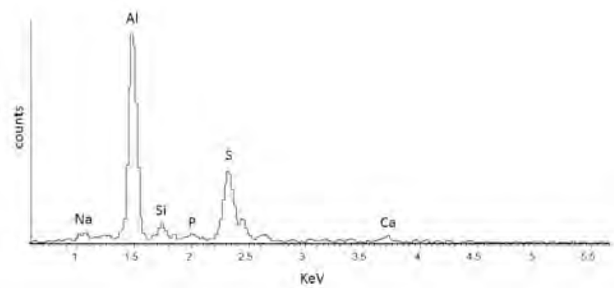


Figure 3.7 Energy-dispersive X-ray spectrum (SEM/EDS) from lake particle in upper middle of fig. 3.6; area analyzed is indicated by a solid red square in fig. 3.6.

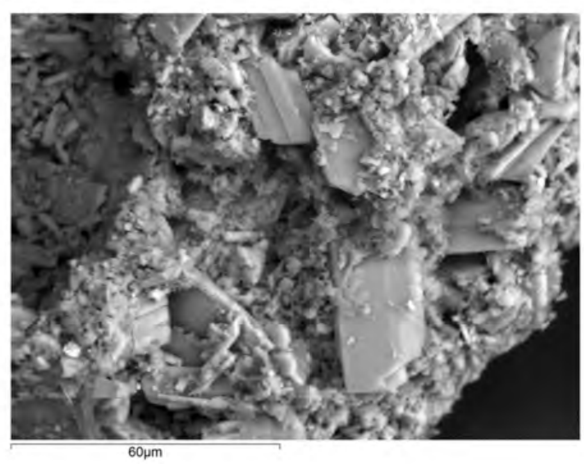


Figure 3.8 View of top of a small chip of pink paint from a mummy portrait, Romano-Egyptian, AD 100–200. Media not identified, 65 x 12.2 cm (25 9/16 x 4 13/16 in.). Copenhagen, Ny Carlsberg Glyptotek, ÆIN 686-687. Backscattered scanning electron microscope image; sample courtesy of Lin Rosa Spaabæk

A high-resolution transmission electron microscope study of a single, fairly large purplish pink lake particle from a purple *clavus* in a mummy portrait (see fig. 3.2) suggested that the lake particle, as in the other examples just mentioned, mainly consisted of aluminum compounds.[26] But lead-rich particles were detected—perhaps unintentional residues from a pot used in the manufacturing process.

In a mummy portrait from Tebtunis, lead white was found to be the predominant white pigment.[27] Drapery and *clavi* that contained substantial red lake were found to contain significant amounts of calcium sulfate and little or no lead white. It was speculated, quite reasonably, that calcium sulfate may have served as the lake substrate. As mentioned above, calcium sulfate could also have been added as a ground mineral to madder lake prepared on an aluminum-rich substrate, to adjust depth of color.

The ability to identify pigments without the need to take samples is important in all cultural heritage research. Some madder-based lakes strongly fluoresce orange or orange-pink under ultraviolet radiation (ultraviolet-induced visible luminescence [UVL]), which has long been utilized by conservators to tentatively identify such lakes on painted objects.[28] The pink or purple *clavi* and fabrics of mummy portraits and facial features (such as lips and cheeks) often exhibit such strong fluorescence, suggesting that madder was commonly used in these areas (figs. 3.9 and 3.10).

Figure 3.9 Funerary Shroud and Mask, ca. mid-third century AD. Excavated at Thebes, Deir el-Bahari, by Edouard Naville in 1897. Water-soluble medium on linen and stucco, H: 93.5 cm (36 13/16 in.). Boston, Museum of Fine Arts, Egypt Exploration Fund by subscription, 97.1100. Image: Jessica Arista © 2018 Museum of Fine Arts, Boston

Figure 3.10 UVL image of mummy shroud in fig. 3.9. Image: Jessica Arista © 2018 Museum of Fine Arts, Boston

Noninvasive instrumental analysis techniques that support identifications of madder include fluorescence spectroscopy and reflectance spectroscopy. The former can, in some instrumental setups, record excitation and emission spectra, permitting the excitation and the emission wavelength maxima to be determined—two fundamental properties of fluorescent compounds. Typical for madder lakes that have been studied to date are excitation maxima around 550 nanometers and emission maxima around 600 nanometers (fig. 3.11), but these wavelengths can vary by 10 or more nanometers, depending on plant source, preparation procedures, and other factors. Purpurin fluoresces considerably stronger than does alizarin,[29] and the most strongly fluorescing madders are probably those richest in purpurin (or pseudopurpurin, which has a fluorescence probably similar to that of purpurin).[30] Some current imaging techniques utilize light sources in the visible range, which are closer to the excitation maximum for the pigment than ultraviolet radiation, as well as filters on digital cameras that restrict the range of captured fluorescence emission.[31] Another fundamental property of fluorescent compounds is fluorescence lifetime (usually no more than a few nanoseconds), which has been applied noninvasively to a mummy portrait.[32]

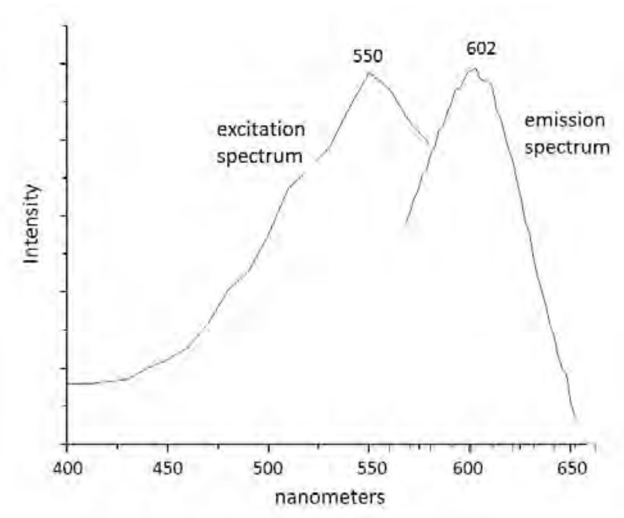


Figure 3.11 Fluorescence excitation and emission spectra from pink *clavus* of mummy shroud in fig. 3.9; analysis carried out noninvasively using a Cary Eclipse fluorescence spectrophotometer with an external fiber-optic probe.

Fiber optics reflectance spectroscopy (FORS) can distinguish between plant- and insect-derived HAs.[33] A spectrum typical for madder is shown in figure 3.12, from the *clavus* in the mummy shroud in figure 3.9. The valleys in spectra are usually (but not always) shifted to higher wavelengths for insect reds. The exact positions of the valleys can vary, depending on how a given lake was prepared.

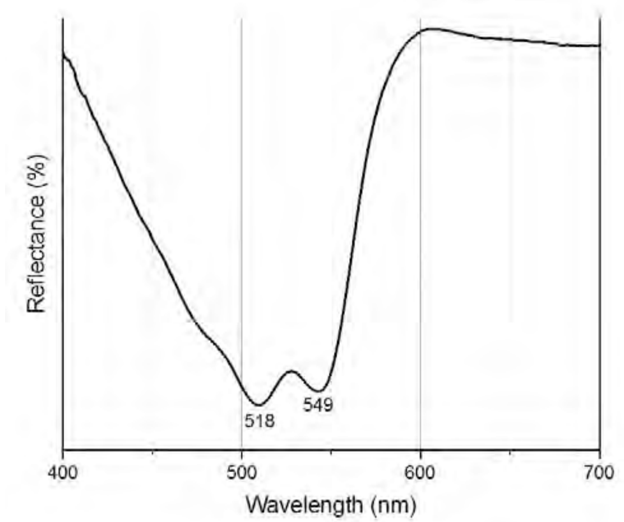


Figure 3.12 FORS from pink *clavus* of mummy shroud in fig. 3.9; analysis carried out noninvasively using an Ocean Optics FLAME visible–near infrared (400–1000 nm) spectrometer.

Fluorescence spectroscopy and reflectance spectroscopy can also be carried out on very small samples on the stage of a research microscope.[34] Although neither technique is routinely utilized at the moment, several publications attest to their value.

Relatively few identifications of the specific HAs in red lakes from mummy portraits have been published to date.[35] Thus far, madders appear to be purpurin or pseudopurpurin rich. A few analyses carried out by LC/MS for this paper are briefly discussed below. The analyses were performed on a capillary LC with an attached ion trap mass spectrometer, using a column and gradient elution program that is fairly standard for studies of dyes in cultural artifacts.[36] Using the most common form of ionization (electrospray ionization, or ESI), the most abundant ion detected by the mass spectrometer for a given compound is usually the pseudomolecular ion. In negative polarity, this ion has a mass of 1 dalton less than that of the molecule being analyzed; in positive polarity, the ion has a mass of 1 dalton more. In order to analyze dye-containing pigments, which are most often in the form of lakes, the lake first must be hydrolyzed, putting the dye molecules into solution. Analyses reported here use a sample preparation procedure (dissolution in boron trifluoride in methanol) first described in 1996.[37] Lakes are easily broken down, but acidic compounds are at least partially methylated, the result being that acidic compounds (such as pseudopurpurin and munjistin) may exhibit two peaks: one for the aglycone and one for the methylated aglycone.

Extracted ion chromatograms are the most sensitive means of detecting compounds present at very low levels when a mass spectrometer is used as a detector. The signal for the most abundant ion for a given compound (usually the pseudomolecular ion) is selected for display. If such an ion occurs at the expected retention time for a specific compound, that compound can be concluded to be present.

For the new analyses discussed here, it is required that a visible peak be apparent in the extracted ion chromatogram at the appropriate retention time. Extracted ion chromatograms for twenty-nine different compounds treated with the boron trifluoride reagent, including all common major and minor HAs in plant and insect sources, are examined. The reference materials were analyzed by the same procedures as the mummy portrait samples.

Results for two intentionally small samples (approx. 10 µg) of commercial madder lake pigments on aluminum-containing substrates are shown in figure 3.13. The solutions that were injected into the LC were diluted until nearly colorless, so that the concentrations of colorants would be similar to those encountered in actual samples taken from paintings. With the instrumentation employed, these samples showed no discernable peaks from either the diode array detector or the general displays of the mass spectrometer data (total ion chromatograms and base peak chromatograms). These analyses of very small reference samples reasonably reflect what can be expected from very small paint samples.

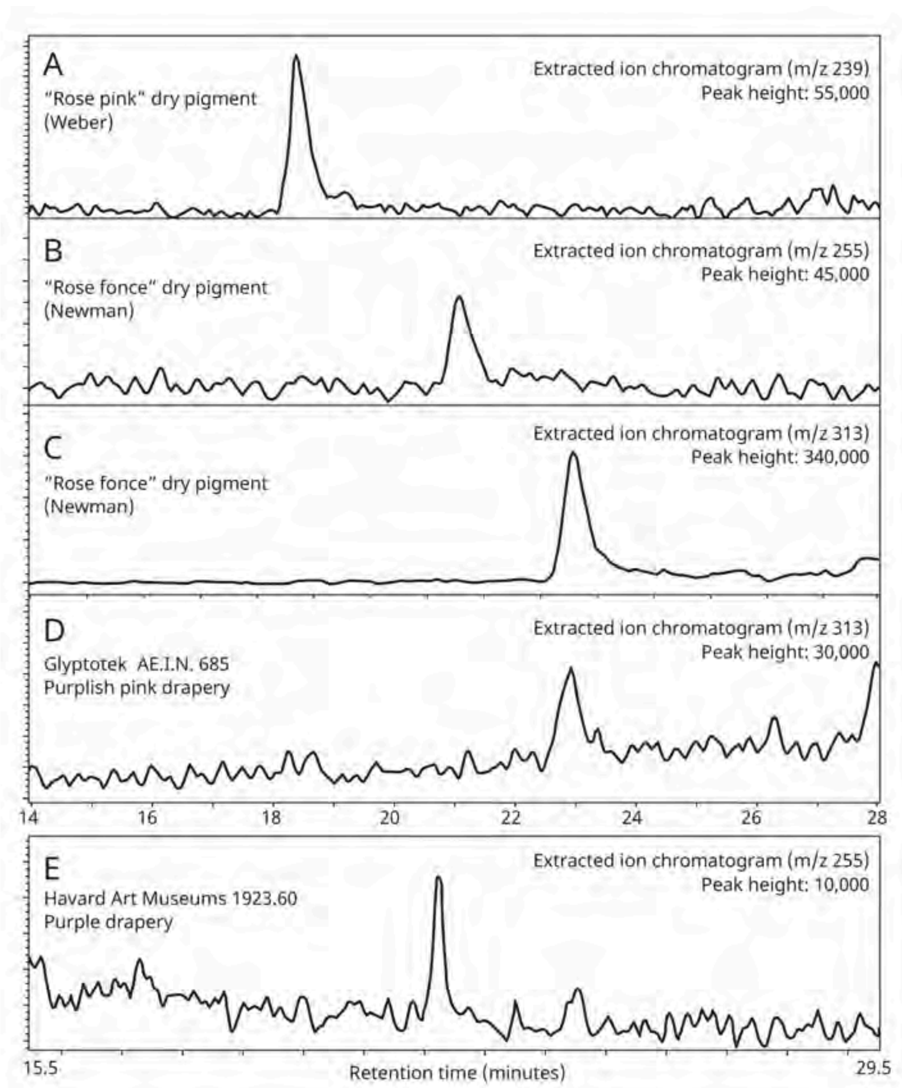


Figure 3.13 Details of extracted ion chromatograms from LC/MS analyses of reference pigments and samples from mummy portraits. All analyses carried out using electrospray ionization (ESI) in negative polarity.

- (A) “Rose pink” dry pigment, manufactured by Weber; Museum of Fine Arts, Boston, Forbes Collection 16
- (B) and (C) “Rose foncé” dry pigment, manufactured by Newman, Museum of Fine Arts, Boston, Forbes Collection 15
- (D) Purplish pink paint from drapery in Mummy Portrait, Romano-Egyptian, AD 100–200, media not identified, 50.2 x 22.4 cm (19 3/4 x 8 13/16 in.), Copenhagen, Ny Carlsberg Glyptotek, ÆIN 685
- (E) Purple paint from drapery on portrait in fig. 3.1

Samples prepared by reacting with approximately 5 percent boron trifluoride in methanol. Vertical scales adjusted individually; actual peak heights are indicated. Compounds plotted: alizarin (m/z 239), purpurin (m/z 255), methyl ester of pseudopurpurin (m/z 313). Instrumental conditions were different for (E), which resulted in shifted retention times.

Results for samples from two mummy portraits are included in figure 3.13. Purplish pink drapery in one was found by other analysis (SEM/EDS, FTIR microspectroscopy, and Raman microscopy) to contain a large amount of gypsum, relatively small amounts of red iron oxide, yellowish-brown natrojarosite, and probably some lead white, as well as an orange-fluorescing red lake on an aluminum-rich substrate; only pseudopurpurin was detected by LC/MS. Purple paint from a second painting (see fig. 3.1; see cross section in fig. 3.6) was found to contain contain gypsum, natrojarosite, some lead white, indigo, and an orange-fluorescing red lake; only purpurin was detected by LC/MS. The pink paint from the mummy shroud (see fig. 3.9) was found to contain gypsum, some calcium carbonate (calcite), small amounts of iron oxides, and red lake. LC/MS analysis (not shown) detected pseudopurpurin, with smaller amounts of alizarin and purpurin and, possibly, rubiadin.

Of the several samples from mummy portraits that have been successfully analyzed by this same LC/MS procedure, pseudopurpurin has most often been the only HA detected. Although it is only speculation, this result could indicate (as discussed above) that the source may not have been *R. tinctorum*.

In mummy portraits, madder appears to have been the major pigment used for pink draperies, just as the actual fabrics depicted were likely most often dyed with madder. Purple fabrics in mummy portraits were, it appears, often painted with a mixture of madder and indigo, the same mixture probably commonly used to dye fabrics purple. Given the ready availability and low cost of madder, it is not surprising that it was so prevalent in dyed fabrics and painted representations of those same fabrics.[38]

The APPEAR database contains more than fifty paintings in which madder is said to be present, and the vast majority of these identifications is based solely on UVL imaging.[39] In addition to serving as a major pigment in fabrics, madder also is frequently found in highlights on faces and hands; in some portraits, madder is also noted as a major pigment in flowers of wreaths and garlands, or representing wine in glasses.

Noninvasive analysis can add more certainty than observation of fluorescence; instrumental analysis of samples may provide specific identifications of HAs and provide more insight into the lake substrate. As analysis and noninvasive examination techniques continue to improve, so will knowledge about ancient lake pigments. The matter of madder (and other natural red colorants from insect or other plant sources) is a subject about which there is more to be learned.

NOTES

1. The Plant List, http://www.theplantlist.org/, accessed July 23, 2018.
2. Cardon 2007; Hofenk de Graaff 2004a; Schweppe 1993.
3. Pliny, *Natural History*, bk. XIX, ch. 17.
4. Hofenk de Graaff 2004a.
5. Derksen and Van Beek 2002.
6. Mouri and Laursen 2012.
7. Mouri and Laursen 2012.
8. Cardon 2007; Hofenk de Graaff 2004a; Schweppe 1993.
9. Rambaldi et al. 2015.
10. Hofenk de Graaff 2004a.
11. Wyplosz 2003; Selvius DeRoo and Armitage 2011.
12. Mouri and Laursen 2012.
13. Mouri and Laursen 2012. Certain varieties of Asian *R. cordifolia* contain some unusual HAs that permit their specific characterization (Han et al. 2016), but this does not seem to be the case with the variety of *R. cordifolia* available in the Mediterranean region.
14. Marshall 1931, 33.
15. Leona 2009.
16. Zhang, Good, and Laursen 2008.
17. Sukenik et al. 2017.
18. Wouters et al. 2008.
19. Kirby, Spring, and Higgitt 2005.
20. Daniels et al. 2014.
21. Cartwright and Middleton 2008.
22. Dyer, Tamburini, and Sotiropoulou 2018.
23. Kirby, Spring, and Higgitt 2005.
24. Kirby, Spring, and Higgitt 2005.
25. Daniels et al. 2014.
26. Gates et al. 2018.
27. Salvant et al. 2018.
28. La Rie 1982.
29. Miliani, Romani, and Favaro 2000.
30. Derrick, Newman, and Wright 2017.
31. See Mayberger et al., this volume.

32. Nevin et al. 2014.

33. Bisulca et al. 2008; Aceto et al. 2014.

34. Melo and Claro 2010.

35. Daniels et al. 2014; Salvant et al. 2018.

36. The LC/MS instrument and procedure are described in R. Newman, Kaplan, and Derrick 2015.

37. Kirby and White 1996.

38. Brøns and Sargent 2018.

39. The database currently combines “madder and kermes” into one category in its pigment listing, but kermes has not specifically been identified to date in mummy portraits and does not appear to have been a very common material in the ancient world, nor does it exhibit the strong fluorescence of (some) madders.

4

Green Pigments: Exploring Changes in the Egyptian Color Palette through the Technical Study of Roman-Period Mummy Shrouds

Caroline Roberts

This project began with a chance discovery: a saturated, soft blue-green background on a limestone funerary stela from the Roman Egyptian town of Terenouthis. Surprisingly, the color was not the same copper-based green found in a pigment bowl also excavated at the site; rather, it was celadonite, the green earth mineral (see fig. 4.1).[1] Most publications on Egyptian materials and techniques provided little information on the use of green earth in Egypt, focusing primarily on materials used during the dynastic periods, when green earth pigments were not employed. Only a small number of case studies cited the use of green earth on Egyptian artifacts. Curious to discover if there were other instances, I set out on a multiyear research project to study the use of green pigments in Greco-Roman Egyptian art. This work included an extensive review of existing literature on green pigments and a technical survey of artifacts in museum collections, including several shrouds at the J. Paul Getty Museum and the Metropolitan Museum of Art. The overarching goal of the research was to build a green pigment data set that was more inclusive of the Ptolemaic and Roman periods and to explore changes in pigment use in Egypt over time.

Figure 4.1 Green Pigments Characterized on Egyptian Artifacts

Possible Pigments	Chemical Formulas	Description
Malachite Verdigris	$CuCO_3$ $Cu(OH)_2$ $Cu(CH_3COO)_2$	Basic copper carbonate and copper acetate minerals
Chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4{\cdot}nH_2O$	A naturally occurring copper silicate mineral that often occurs with frit
Basic copper chlorides	$Cu_2Cl(OH)_3$	Described as synthetic pigments in some publications and elsewhere as the alteration products of Egyptian blue and Egyptian green
Organo-copper compounds	Cu-proteinate, Cu-carbohydrate, and Cu-wax pigments	Possible reaction between altered copper-containing pigments and binding media
Egyptian blue Egyptian green	$CaCuSi_4O_{10}$ Cu glass	Synthetic blue and green pigments produced by heating sand, natron, flux, and copper minerals
Green earth	$K(Mg,Fe^{2+})(Fe^{3+},Al)[Si_2O_{10}](OH)_2$ $(K,Na)(Fe^{3+},Al,Mg)_2(Si,Al)_4O_{10}$	A naturally occurring clay mineral—celadonite and glauconite are the two primary mineral species referenced
Mixtures	See description	Combinations of Egyptian blue ($CaCuSi_4O_{10}$), indigo, Egyptian green, orpiment (As_2S_3), yellow ochre ($Fe_2O_3{\cdot}H_2O$), and green earth

Literature Survey

The literature review focused deliberately on the Ptolemaic and Roman periods—at least initially. To compare pigment use during these periods to that of earlier times, the project eventually expanded to include studies focused on dynastic Egypt. A variety of published sources were consulted as well, as were analytical results reported in the APPEAR database. Artifact names and provenience, institutions and authors, and pigment characterizations were recorded. The review revealed that a wide range of materials had been used to create the color green in Egyptian art. Copper-based green pigments were reported most frequently and included minerals such as malachite and verdigris,[2] synthetic pigments such as Egyptian green,[3] and alteration products such as copper chlorides and organo-copper compounds.[4] Green earths and mixtures of blue and yellow pigments were also reported.[5] A summary of these pigments is provided in figure 4.1.

Technical Survey

With the help of many collaborators, a technical survey of funerary artifacts was conducted within several Egyptian collections. Artifacts included inscribed stelae, coffins, cartonnage fragments, and painted mummy shrouds. The goal of the survey was to characterize green pigments on artifacts from Ptolemaic and Roman Egypt in particular and, in doing so, increase the number of existing case studies. The results of this survey reflected what was reported in the literature—with two important exceptions. First, green earth appeared more frequently than copper-based greens on Roman-period artifacts. Second, a blue-yellow pigment mixture, which has been cited in two previous publications,[6] was found on at least two (possibly three) artifacts. These findings pointed to changes in pigment selection during the Ptolemaic and Roman periods—observations that will be discussed in the conclusions section below. Among the artifacts studied, it was the shrouds that yielded the most interesting results in terms of green pigments identified. The lack of copper greens, along with evidence of an expanded green palette, make the shrouds the most compelling case studies in terms of green color use.

Mummy Shrouds Case Study

The shrouds (figs. 4.2–4.8) are part of the collections of the J. Paul Getty Museum and the Metropolitan Museum of Art.[7] Like panel portraits, painted textile mummy shrouds were a form of burial dress for the dead. The shrouds functioned both as part of the mummy's encasement and as a surface for paint decoration. Sheets of linen textile were painted with portraits of the deceased; images, symbols, and writing from both Greek and Egyptian cultural traditions were also included. The portraits are at times naturalistic, depicting individuals as they were in life, but they can also be highly stylized, portraying the deceased as an embodiment of an Egyptian deity.[8]

Although the majority of shrouds in museum collections have been separated from the body, their overall shape, positioning of painted images and framing elements, wear patterns, and staining attest to their original use as mummy wrappings.[9] The shrouds discussed in this paper, although fragmented, represent a number of portrait formats. These include the bust-length vignette format, in which the portrait is limited to the individual's upper body; the full-length portrait; the three-figure format, in which the deceased is flanked by deities such as Osiris and Anubis; and shrouds in which the deceased is portrayed as a deity.[10] The sections that follow will briefly describe each shroud.

Figure 4.2 Mummy Shroud with Painted Portrait of a Boy, Romano-Egyptian, AD 150–250. Paint on linen, 62 x 52.5 cm (24 7/16 x 20 11/16 in.). Los Angeles, J. Paul Getty Museum, Gift of Lenore Barozzi, 75.AP.87

Figure 4.3 Mummy Shroud with Painted Portrait of a Youth, Romano-Egyptian, AD 220–250. Paint on linen, 49.5 x 35.5 cm (19 1/2 x 14 in.). Los Angeles, J. Paul Getty Museum, 79.AP.219

Getty Museum

Two vignette-type shrouds from the J. Paul Getty Museum were analyzed. The painted portrait of a boy depicts a young man with a falcon on his left shoulder (see fig. 4.2). The painting ends just below the youth's shoulders, indicating that the shroud would have been placed over the face of the deceased and secured with wrappings in the same manner as a portrait panel. The green of the leaves in the wreath is strikingly vivid, and upon close examination one can observe bright yellow pigment particles, indicating that the paint is some kind of mixture.[11]

The painted portrait of a youth features a boy holding a floral garland and a cluster of grapes (see fig. 4.3). A falcon and a mummiform figure appear over his proper right shoulder. Visible in the wing to the boy's left is a stripe of green; it appears to have been rendered by layering blue pigment over yellow pigment.

Metropolitan Museum

Four painted shroud fragments were analyzed at the Metropolitan Museum of Art. One example is a fragment of what was likely a full-length portrait shroud of a woman (see fig. 4.4). Only the woman's beringed hands and a pink floral garland remain. The leaves in the garland are rendered in dark blue or black, pale blue, and green.

Another example is a full-length portrait shroud of a young man who takes the form of Osiris (see fig. 4.5). The figure is enshrined within an architectural framework crowned by an uraeus. Six adjacent registers depict Horus, Anubis, Ra-Horakhty, and a portrait of the deceased.[12] The figure's crown and crook as well as two of the hieroglyph registers are rendered in a pale turquoise color.

Figure 4.4 Fragment of a Mummy Shroud with Painted Portrait of a Woman, Romano-Egyptian, late second to third century AD. Paint on linen, H: 28.5 cm (11 1/4 in.). New York, Metropolitan Museum of Art, Museum Accession, X.390 www .metmuseum.org, CC0

Figure 4.5 Painted Osiris Mummy Shroud, Romano-Egyptian, ca. AD 125. Paint on linen, 98 x 82 cm (38 5/8 x 32 1/4 in.). New York, Metropolitan Museum of Art, Gift of Mrs. S. W. Straus, 1925, 25.184.20 www .metmuseum.org, CC0

Figure 4.6 Fragment of a Painted Mummy Shroud, Ptolemaic or Romano-Egyptian, 304 BC–AD 364. Paint on linen, 25.3 x 18.3 cm (10 x 7 3/16 in.). New York, Metropolitan Museum of Art, Museum Accession, X.491A www.metmuseum.org, CC0

Figure 4.7 Fragment of a Painted Mummy Shroud, Ptolemaic or Romano-Egyptian, 304 BC–AD 364. Paint on linen, 14.8 x 18.8 cm (5 13/16 x 7 3/8 in.). New York, Metropolitan Museum of Art, Museum Accession, X.491B www.metmuseum.org, CC0

Two other fragments come from what appears to be an Osiris shroud. Fragment A (see fig. 4.6) shows the right shoulder of a mummiform figure covered with a bead net. The figure wears a broad collar and a *wadjet* eye amulet, and an unknown geometric form sits on the netting. Fragment B (see fig. 4.7) portrays a falcon head. The shroud fragments' backgrounds are a colorful display of checkered patterning. One checkered section is rendered in yellow-green and dark green—the same dark green seen in the upper portion of the broad collar, in the unidentified geometric form, and below the falcon. The yellow-green checkerboard appears to have been made by superimposing yellow squares over a dark green background.

Two painted shroud fragments (66.99.141 and 66.99.140—not pictured) were likely once part of a larger shroud (see fig. 4.8). The former depicts a female deity, possibly Nephthys, whose sheath dress appears to be green, making this shroud of interest to the study. The following sections discuss the techniques used to characterize the green pigments found on all the shrouds.

Figure 4.8 Fragment of a Painted Mummy Shroud, Ptolemaic or Romano-Egyptian, first century BC–first century AD. Paint on linen, 36.8 x 31 cm (14 1/2 x 12 3/16 in.). New York, Metropolitan Museum of Art, Purchase, Fletcher Fund and The Guide Foundation Inc. Gift, 1966, 66.99.141 www.metmuseum.org, CC0

Green Pigment Characterization

Egyptian green pigments are notoriously difficult to characterize—and visually identify—for several reasons. First, the aging and darkening of binding media can cause blue pigments to appear increasingly green over time. Another challenge is the fact that certain green pigments (such as malachite, copper chlorides, and organo-copper compounds) can be alteration products, making it difficult to conclude that an area was intended to be green at all. Finally, greens are often the result of pigment mixtures, meaning that multiple components must be characterized in order to make a full identification.

Technical Examination

Because of these challenges, a range of analytical techniques was used to investigate shroud paint surfaces and identify pigments in paint dispersions and cross sections: X-ray fluorescence (XRF) spectroscopy using Bruker Tracer III-V handheld XRF units with Rd tubes set to 40kV, 12.50μA at 30-second run times with S1PXRF software; Fourier transform infrared spectroscopy (FTIR) using a Hyperion 3000 FTIR spectrometer in transmission mode, with scans from 4000 to 600 inverse centimeters; Raman spectroscopy using a Renishaw system equipped with an He-Ne laser, with an emission line set at 633 nanometers; and finally, scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS) using a Philips XL30 environmental scanning electron microscope with Oxford INCA software. The analysis was made possible by the Getty Conservation Institute and the Metropolitan Museum of Art's Scientific Research Department.

As the research progressed, it became clear how different techniques could be used to answer specific questions about the greens. For example, XRF could narrow the possibilities based on elements present; SEM-EDS and Raman spectroscopy, thanks to their point-identification capability, were especially helpful for identifying the components of mixtures. It should be noted that, subsequent to my research at the Getty, additional analyses were carried out on shrouds 75.AP.87 and 79.AP.219 (see figs. 4.2 and 4.3). They included multispectral imaging, polarized light microscopy (PLM), XRF scanning,[13] combined XRF/XRD (X-ray diffraction) analysis,[14] and fiber optics reflectance spectroscopy (FORS) of many areas of color,[15] including green.

Multispectral Imaging

Multispectral imaging (MSI) was also used to investigate the shrouds' paint surfaces. Over the past decade MSI has emerged as a valuable tool for examining and characterizing paint surfaces.[16] This photographic technique captures the characteristic reflectance, absorption, and luminescence properties of pigments and other materials in an image. Because it can be carried out using a modified DSLR camera, MSI is also a relatively accessible tool in terms of cost.

The imaging method used to examine the shrouds was adapted from a technical imaging manual developed at the British Museum. This manual provides step-by-step instructions for capturing images in visible, ultraviolet luminescence (UVL) and reflectance (UVR), infrared reflectance (IRR), and visible-induced infrared luminescence (VIL) modes, as well as guidelines for image calibration.[17] A Nikon D70s UV/IR camera altered to record the electromagnetic spectrum between 250 and 1100 nanometers was used for image capture, as were light sources, lens filters, and calibration standards recommended in the British Museum manual. An open-source calibration workspace developed by the manual's authors was used to generate standardized multispectral images that can be more readily compared with those obtained under different conditions.

A set of reference paint-outs was created and imaged to provide a centralized visual record of the reflectance, absorption, and luminescence properties of known ancient pigments and binders. The paint-outs have been a useful tool for interpreting the MSI images of artifact paint surfaces and for isolating the particular imaging characteristics of copper-, earth-, and indigo-based green pigments in various binding media. Certain imaging techniques proved especially valuable in the investigation of the shrouds. For example, one could often differentiate between copper-based greens and green earths by the relative darkness of copper greens in UVL images,[18] compared with green earths. The presence of a red infrared false color, along with the absence of Egyptian blue luminescence in VIL images in green areas on shrouds X.491A and X.491B (see figs. 4.6 and 4.7), indicated that this pigment mixture included indigo. Used in this way, MSI provided important initial information that guided subsequent analysis and data interpretation.

Results

The results of the scientific investigation of the shrouds are summarized in figure 4.9. Information gathered by project collaborators and other scholars is cited in the text.

Figure 4.9 Green Pigment Analysis and Imaging Results of Painted Mummy Shrouds

Shroud	Analysis	Characterization
75.AP.87	XRF: Ca, Fe, Pb, As peaks XRF mapping: high As counts in leaves[19] SEM-EDS: Ca, Si, S, Pb, and As identified in individual pigment particles in green paint cross section Raman: indigo and orpiment identified in point ID of blue and yellow areas of sample cross section[20] PLM, infrared imaging confirm presence of indigo, orpiment in leaves[21]	Vergaut
79.AP.219	XRF: Fe, Pb, As peaks XRF mapping: high As counts in drapery above bird[22] FORS: indigo detected[23] Infrared imaging indicates presence of indigo in green section of drapery, suggesting that indigo and orpiment were layered to form green[24]	Indigo and orpiment, layered or in a mixture
X.390	XRF: n/a FTIR: calcite and celadonite[25] Imaging: pale blue areas of leaves contain Egyptian blue; green sample area has IRRFC similar to Cyprus green earth (celadonite)[26]	Green earth (celadonite?)
25.184.20	XRF: Ca, Fe, As, Pb (As may be Pb L alpha peak) FTIR: calcite and celadonite[27] Imaging: pale turquoise areas have muted blue IRRFC similar to Cyprus green earth (celadonite); low absorption of same areas in UVL image suggests that pigment is not copper based	Green earth (celadonite?)
X.491A–B	XRF: Ca, Fe, As FTIR: calcite, indigo, Egyptian green (?);[28] orpiment (peak at 800 cm^{-1})? Imaging: dark green squares are red in IRRFC, consistent with indigo; yellow-green squares painted over background have pale yellow IRRFC, consistent with reference orpiment paint-outs	Vergaut?
66.99.141	XRF: Ca, Fe, Cu, As, Pb (As may be Pb L alpha peak) FTIR: Egyptian blue[29] VIL imaging confirms that "green" dress is Egyptian blue	Darkened Egyptian blue

For the Getty objects, XRF analysis of leaves in shroud 75.AP.87 (see fig. 4.2) showed peaks for calcium, iron, lead, and—notably—arsenic, the results of which are confirmed in X-ray maps acquired from the shroud subsequent to this project.[30] SEM-EDS analysis identified both sulfur and arsenic in individual pigment particles in a green paint cross section taken from a leaf. An additional paint cross section from the same area revealed particles of orpiment and indigo,[31] confirming that the green pigment used in the wreath is vergaut, a mixture of the organic blue pigment indigo and the arsenic-sulfide mineral orpiment.[32]

Shroud 79.AP.219 (see fig. 4.3) was analyzed with XRF in the green-colored middle section of the wing to the boy's right (fig. 4.10). This analysis yielded XRF peaks for iron, lead, and arsenic. High levels of arsenic were also detected in XRF maps of both the yellow and green sections of the wing.[33] FORS analysis conducted subsequent to this research detected indigo in the lower section of the wing, indicating that a combination of indigo and orpiment was likely used to create the green color.[34] The green itself appears to be a result of overlap between a stripe of orpiment and a stripe of indigo, although it could also be a mixture of the two pigments; further analysis—such as Raman spectroscopy of a paint cross section—would be needed to confirm.

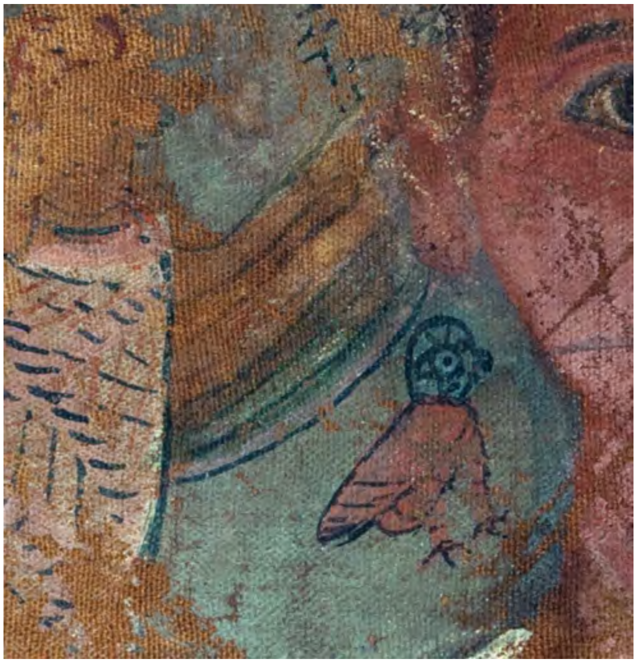


Figure 4.10 Detail of fig. 4.3, showing overlap of yellow and blue in wing.

At the Metropolitan Museum, a sample of green paint was taken from the garland on shroud X.390 (see fig. 4.4). FTIR analysis yielded a good match for green earth—particularly celadonite.[35] This match was further supported by the technical imaging results, in which the infrared false color of the sample area is similar to reference false colors of Cyprus green earth, which has been previously characterized as being predominantly celadonite.[36]

The Osiris shroud 25.184.20 (see fig. 4.5) was analyzed with XRF in one of several turquoise painted areas. Interestingly, no copper was found in the XRF spectra, which ruled out the possibility that this could be a green frit. FTIR analysis instead suggested that the turquoise color is green earth, a pigment that can carry a wide range of hues from olive green to pale turquoise. The best match to this shroud's sample was, as in the previous case, celadonite. The infrared-reflected false color (IRRFC) imaging supports this result, as does the relatively low absorption of the turquoise areas in the UVL image.

The results for shroud X.491A and B (see figs. 4.6 and 4.7) are less straightforward, but the materials present suggest that the artist used a mixture to produce green. The first clue was the significant arsenic peak in the XRF spectrum taken from a dark green area in the checkerboard pattern behind and to the right of the figure (see fig. 4.11). Multiple FTIR spectra were gathered from a sample taken from the same dark green square. Although one such square indicated a possible match for Egyptian green, the lack of copper in the XRF spectrum acquired in the same area likely rules out its presence. A second FTIR spectrum was generated from the same sample, one that indicated a match for indigo. Could this, in fact, be a mixture of indigo and a yellow pigment? The imaging supports this interpretation, as the green area in question is red (indicating indigo) in the IRRFC images; it also suggests that a layer of orpiment was applied over this dark green mixture to create the light green squares in the same checkerboard pattern. These areas appear bright pale yellow in the IRRFC image—as do other areas of bright yellow color on the portrait. Follow-up analysis with Raman spectroscopy would help to confirm this hypothesis.

Figure 4.11 Detail of fig. 4.6, showing dark and light green checkerboard background.

The FTIR results from shroud 66.99.141 (see fig. 4.8) strongly indicate that the goddess's “green” dress is, in fact, a discolored Egyptian blue. VIL imaging showed a strong infrared luminescence throughout the dress, helping to confirm the spectroscopic results.

Discussion

The technical investigation of the shrouds and of other artifacts included in the survey demonstrates how accessible imaging tools can optimize the investigative potential of traditional analytical techniques. In this study, multispectral imaging and analysis informed each other; together, they not only helped confirm ambiguous characterizations but also provided a broader impression of how pigments were used across an artifact's surface. These combined techniques were especially useful in analyzing the shrouds, where green, blue, and yellow pigments are often mixed and layered.

The conflicting results seen with fragments X.491 A and X.491B (see figs. 4.6 and 4.7) help illustrate the material and chemical complexity of green pigments and mixtures. Although the FTIR spectrum indicates a possible match for Egyptian green in the sampled area shown in figure 4.11, the lack of copper in the XRF spectrum acquired in the same area rules out its presence. Likewise, peaks at 1627, 1462, and 1076 inverse centimeters appear to be from indigo, while a peak near 800 inverse centimeters in spectra from both dark and light green squares could be from orpiment, the latter being consistent with the significant XRF peak for arsenic in the same area. Raman spectroscopy would be needed to confirm that this color is, in fact, a mixture of indigo and orpiment (vergaut).

While questions remain about the exact character of two of the shrouds' green pigments, it is noteworthy that the only copper-containing pigment found on the shrouds was a discolored Egyptian blue that appeared green. Although copper-based greens continued to be used after the dynastic periods, their absence on the shrouds is interesting and reflects a diversification in green pigment use during Egypt's Ptolemaic and Roman periods. This shift in pigment selection is suggested not only by the use of vergaut but also by green earth pigments—their best-known mineral deposits were located outside of Egypt,[37] and their use on these artifacts offers intriguing physical evidence of extensive pigment trade networks within the Hellenistic and Roman worlds.

Conclusions

The technical study of the painted mummy shrouds provides a small but meaningful addition to a growing Egyptian pigment data set. These and other studies are helping to create a more inclusive knowledge base on Egyptian materials and technology—one that focuses increasingly on the Ptolemaic and Roman periods. The research here demonstrates the sheer variety of greens that may be encountered on an artifact as well as the range of analytical tools that are required for green pigment identification. These analyses also show how pigment choices expanded during Egypt's Ptolemaic and Roman periods.

Plotting the results of this project's technical survey graphically (fig. 4.12), helps visualize this shift in green pigment use. In comparing the types of green found on Ptolemaic and Roman Egyptian artifacts with earlier uses of green, one can readily see an expansion in the types of green pigments and combinations of pigments used to achieve the color. Occurrences of green earth become much more common in the Roman period and at this time are found on artifacts more frequently than copper-based greens. Mixtures, likewise, occur more frequently, and mixtures of indigo and yellow occur exclusively during the Roman period.

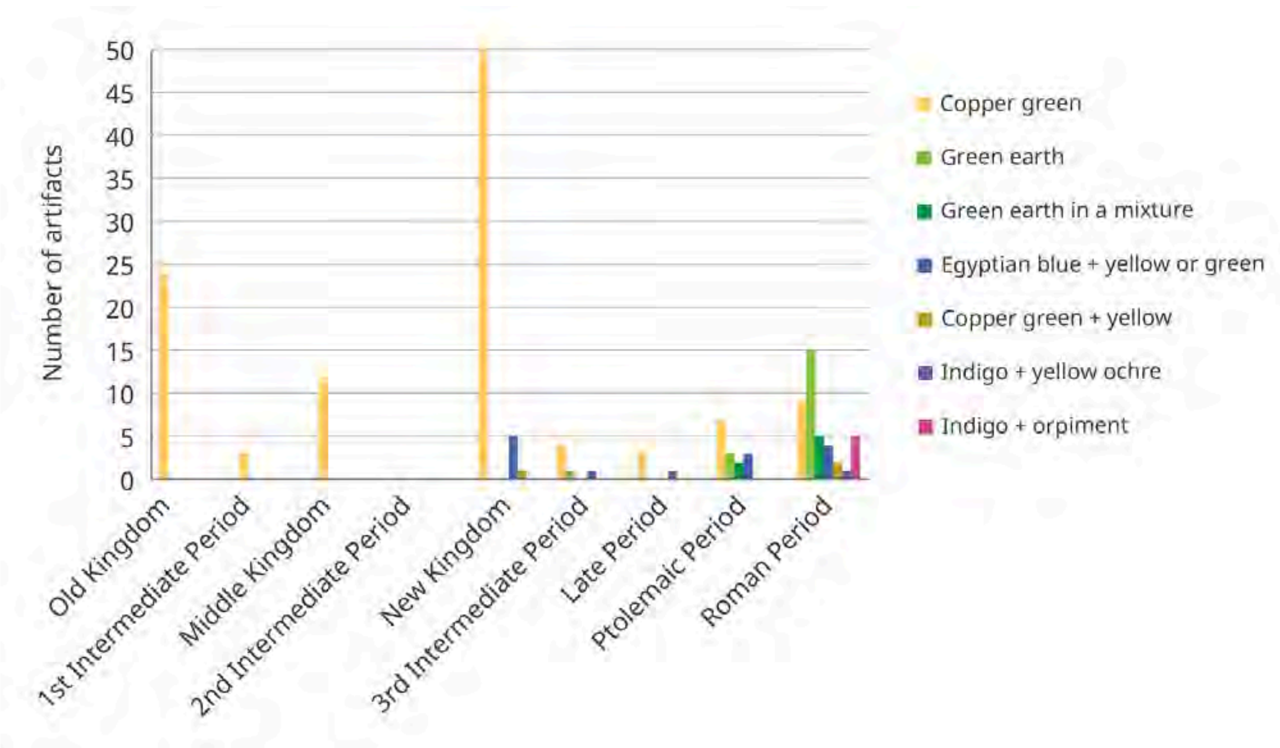


Figure 4.12 Confirmed characterizations of green pigments on Egyptian artifacts.

This expansion of the green pigment palette coincides with the introduction of traditionally Hellenistic and Roman pigments into Egypt, such as rose madder and red lead.[38] Green earth, too, originates in the Hellenistic paint tradition, and its use appears well established by the time portrait panels and shrouds were in demand.[39] The use of blue and yellow mixtures, although present in earlier dynastic Egyptian technical studies, appears to accelerate during the Ptolemaic and Roman periods. With an increasingly diverse palette came many possible green hues and shades and, as seen on a number of the shrouds, a propensity for mixing, layering, and experimenting with color. In portraiture in general, this nuanced use of color is reflected in both artists' painting techniques and choice of materials.[40]

The appearance of vergaut is also interesting (fig. 4.13). Perhaps best known for its use in Islamic and Western European illuminated manuscripts, vergaut is mentioned in Eraclius's tenth-century treatise *De coloribus et artibus Romanorum* and has appeared on many painted wooden artifacts and shrouds from Egypt and other Roman provinces.[41] More examples are sure to emerge as scholars continue to study artifacts from this syncretic period of Egyptian culture; making this evidence widely available is crucial to building complete pigment characterizations, understanding material choices and changes in artistic practice, and providing more, much-needed, technical information about Greco-Roman Egyptian art.

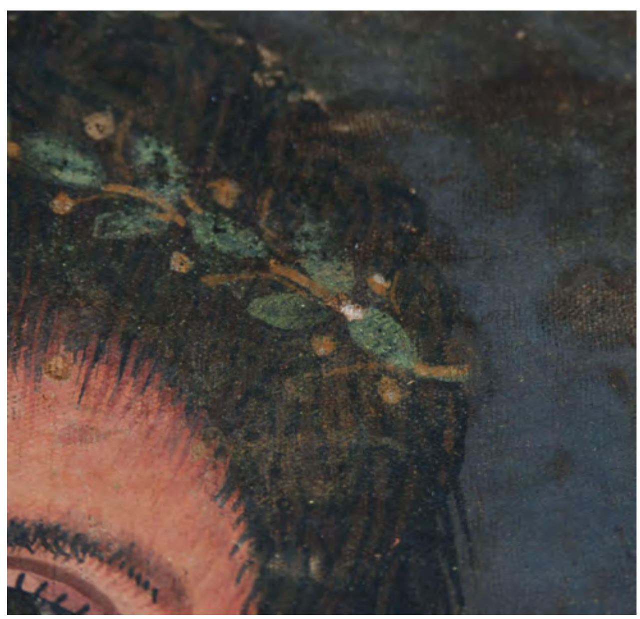


Figure 4.13 Detail of fig. 4.2, showing wreath painted with vergaut mixture.

Acknowledgments

This research is the product of the collaborative effort of many individuals who have lent their time, expertise, and support to the project over many years. For supervising my fellowship research on green pigments I would like to thank Suzanne Davis and Claudia Chemello at the Kelsey Museum of Archaeology; Marie Svoboda and Jerry Podany at the J. Paul Getty Museum; and Ann Heywood at the Metropolitan Museum of Art. I would also like to thank Emilia Cortes and the Metropolitan Museum's Egyptian Art Department and Greek and Roman Art Department for supporting my research on the shrouds. I am indebted to many scientists for their assistance and analysis at both the Getty Conservation Institute and the Metropolitan Museum's Department of Scientific Research, specifically Julie Arslanoglu, Federico Caro, Ilaria Ciancetta, Giacomo Chiari, Art Kaplan, Elisa Maupas, Adriana Rizzo, Karen Trentelman, and Marc Walton. Many thanks as well to Monica Ganio and David Strivay for making the results of their subsequent analyses of the Getty shrouds available. I must also thank Joanne Dyer for her MSI expertise, as well as Anna Serotta and Dawn Kriss for their ongoing collaborative support with reference standards, VIL methodology, and more. Finally, many thanks to J. P. Brown, Laura D'Alessandro, Emily Heye, and Tina March for accommodating my research at their museums.

NOTES

1. A sample of this pigment was identified as celadonite using a Rigaku Ultima IV X-Ray Diffractometer, at an angle of 2 to 70 degrees, 0.02-degree sampling width, and scan speed of 1, courtesy of the University of Michigan Earth and Environmental Sciences Department.
2. Lucas 1926; Lee and Quirke 2000; David 2001; Scott 2007; Pagès-Camagna and Guichard 2010; Pagès-Camagna, Guichard, et al. 2010.
3. Lucas 1926; Blom-Böer 1994; Scott 2007; Pagès-Camagna, Laval, et al. 2010.
4. El Goresy et al. 1986; Schiegl, Weiner, and El Goresy 1989; Scott, Dodd, et al. 2004; Scott 2007; Rowe, Siddall, and Stacey 2010; Liang and Scott 2014.
5. Edwards, Jorge Villar, and Eremin 2004; Scott 2007; Scott, Warmlander, et al. 2009; Dyer, O'Connell, and Simpson 2014.
6. Svoboda and Walton 2007; Passeri, Gunnison, and Mysak 2017.
7. See Jimenez 2014 for full bibliographies of the shrouds; Riggs 2005.
8. Riggs 2005.
9. Riggs 2005.
10. Riggs 2005; Jimenez 2014.
11. Cianchetta 2013.
12. Jimenez 2014.
13. Strivay 2013.
14. Chiari 2015.
15. Ganio 2016.
16. Verri 2009b; Cosentino 2014; Delaney et al. 2017.
17. Dyer, Verri, and Cupitt 2013.
18. A phenomenon also observed in Rowe, Siddall, and Stacey 2010.
19. Strivay 2013.
20. Cianchetta 2013.
21. C. Roberts 2013; images courtesy of the J. Paul Getty Museum, UCLA/Getty Program in Archaeological and Ethnographic Conservation, and the Los Angeles County Museum of Art.
22. Strivay 2013.
23. Ganio 2016.
24. Images courtesy of the J. Paul Getty Museum, UCLA/Getty Program in Archaeological and Ethnographic Conservation, and the Los Angeles County Museum of Art.
25. Arslanoglu 2014.
26. Kakoulli 2002.
27. Arslanoglu 2014.
28. Arslanoglu 2014.
29. Arslanoglu 2014.
30. Strivay 2013.
31. Cianchetta 2013.
32. Bioletti et al. 2009; Tanevska et al. 2014.
33. Strivay 2013.
34. Ganio 2016.
35. Arslanoglu 2014.
36. Kakoulli 2002.
37. Kakoulli 2002.
38. Svoboda and Walton 2007; Walton and Trentelman 2009; Kakoulli 2009.
39. Kakoulli 2009.

40. Delaney et al. 2017.

41. Braumüller 1873; Svoboda and Walton 2007; Passeri, Gunnison, and Mysak 2017.

5

Egyptian Blue in Romano-Egyptian Mummy Portraits

Gabrielle Thiboutot

Two blues were used in Romano-Egyptian mummy portraits: Egyptian blue, an artificial copper-based pigment, and indigo, a natural dye.[1] Research conducted by APPEAR project participants has demonstrated that at least 20 percent of the mummy portraits were made using one or the other (or both), shedding new light on the production process of mummy portraits. The discovery of significant amounts of Egyptian blue on the so-called Fayum Mummy Portrait of a Woman (figs. 5.1 and 5.2) at the Iris & B. Gerald Cantor Center for Visual Arts (Cantor Arts Center) confirmed trends visible in portraits from other collections and raised larger questions about patterns of use across find sites and time periods. This paper examines some of the results obtained by APPEAR participants and offers a preliminary discussion of how Egyptian blue was used in mummy portraits. The goal of this essay is to situate the use of the pigment in its broader artistic, social, and economic context(s), giving special consideration to its value and the range of meanings of blue in ancient sources. Such contextualization allows for a better understanding of Romano-Egyptian funerary portraiture and its place in the wider spectrum of ancient painting.

Figure 5.1 Visible light image of Fayum Mummy Portrait of a Woman, Romano-Egyptian, second to third century AD. Encaustic on wood panel, 34.6 x 20.3 cm (13 5/8 x 8 in.). Stanford, Iris & B. Gerald Cantor Center for Visual Arts, Stanford Family Collections, JLS.22225. Image: Art+Science Learning Lab, Cantor Arts Center

Figure 5.2 VIL image showing the presence of Egyptian blue on the tunic, gems, face, and hair of the portrait in fig. 5.1. Image: Art+Science Learning Lab, Cantor Arts Center

Production of Egyptian Blue

Egyptian blue, a copper calcium silicate ($CaCuSi_4O_{10}$), is a glassy blue pigment with a hue ranging from light to dark, depending on the size of its grains, that is made by firing quartz, sand, lime, natron or plant ash, and copper or bronze at 900 to 1,000 degrees Celsius for more than 24 hours, probably in a cylindrical open vessel.[2] It is the world's oldest synthetic pigment, dating from at least the First Dynasty in Egypt, although an even earlier instance was found on a predynastic alabaster bowl at the Museum of Fine Arts, Boston.[3] The latest production date of Egyptian blue is debated, but it has been found in Rome and Switzerland on wall paintings that date from the eighth to ninth centuries AD.[4] In terms of geographic distribution, Egyptian blue has been found on objects around the Mediterranean and beyond—even as far as the Arctic Circle in the north of Norway, where it was used on a shield of the Bo people made around AD 250.[5] The trade of the pigment is well attested in the Roman period, and it has been found with other pigments and goods in multiple shipwrecks, including Planier 3 and La Chrétienne M.[6] Archaeological evidence for the production of Egyptian blue was uncovered at Memphis and Amarna in Egypt, Cumae in Italy, and Kos in Greece, while early authors mention the pigment was also produced in Scythia, Cyprus, and Spain.[7] In ancient literature, three sources discuss Egyptian blue in detail: Pliny the Elder, Theophrastus, and Vitruvius, who refer to it as κύανος in Greek and *caeruleum* in Latin—two words that have broad semantic ranges and that should be translated carefully according to context.[8] For art historians, the enduring popularity of Egyptian blue and its wide-ranging distribution offer privileged insight into technical and stylistic changes, both at a local and at a pan-Mediterranean scale, as the pigment was used in idiosyncratic ways that can be tracked across different time periods and regions.

Egyptian Blue in the APPEAR Database

Many APPEAR project participants, including the Cantor Arts Center, the British Museum, and the Phoebe A. Hearst Museum of Anthropology, have detected Egyptian blue noninvasively on mummy portraits via several techniques, including visible-induced luminescence (VIL).[9] Developed by Giovanni Verri, this imaging technique relies on the fact that Egyptian blue has strong photo-induced near-infrared (NIR) luminescence; it displays a strong emission in the NIR range, with an emission maximum at 910 nanometers, when excited in the visible range.[10] VIL can detect particles of Egyptian blue even when it is mixed with other pigments, covered by substances such as varnishes, or otherwise invisible to the naked eye.[11] Beyond providing evidence for the presence and absence of luminescence, however, VIL images taken by APPEAR participants are usually not directly comparable because the equipment, capture conditions, and post-processing protocols of individual teams vary.[12]

At the time of writing (May 2018), approximately 284 panel paintings have been entered into the APPEAR database—a little less than 30 percent of the corpus of known painted mummy portraits from Roman Egypt.[13] Few of these portraits display blue hues, except to render blue gems in jewelry (see figs. 6.9a and 5.1). Some portraits depict individuals wearing blue garments, usually tunics or mantles (e.g., Berlin Antikensammlung 31161.26, Pushkin Museum 1a 5771). More rarely, portraits represent individuals with blue eyes (e.g., Pushkin Museum 1a 5771). It is therefore surprising that, so far, at least forty-four portraits in the APPEAR database have been found to display the VIL characteristic of Egyptian blue (fig. 5.3).[14] While this tally is much smaller than that of other pigments, such as ochre (found on at least seventy-two portraits) and lead white (found on at least sixty-six portraits), it is likely to rise in the future as institutions continue to analyze their portraits and share their results on the database.[15] In total, at least forty-seven mummy portraits are now known to have Egyptian blue—forty-four portraits in the APPEAR database and three portraits at the Egyptian Museum in Cairo (C.G. 33232, 33240, 33267).[16] Based on how the pigment has been used on the portraits, we can safely assume that its inclusion was deliberate. Because the APPEAR project is ongoing, and participating institutions hold the rights to their VIL images, the following section will discuss results in general and preliminary terms—individual publications must be consulted for more details.

Figure 5.3 Egyptian blue in the APPEAR database.

Date, Provenience, and Style

The forty-seven portraits with Egyptian blue vary in date, provenience, and style. In terms of date range, it is now clear that the pigment was used throughout the whole period of production of painted mummy portraits, from the mid-first century AD, as in the Menil Collection's late Julio-Claudian portrait (MFAH 2009.16) on which the pearl earrings are highlighted with Egyptian blue, to at least the mid-third century AD, as in the Cantor portrait (see figs. 5.1 and 5.2).

In terms of provenience, of the forty-seven portraits with Egyptian blue, fifteen are from Hawara, eleven from er-Rubayat, seven from Tebtunis, one from Antinoöpolis, one possibly from Saqqara, and one possibly from El-Hibeh; eleven have no known provenience. This distribution indicates that Egyptian blue was used on portraits found at all the major find sites and suggests that the pigment was used in all of the known production centers of funerary panel paintings.

All the portraits on which Egyptian blue was found so far were painted on wood panels, with the exception of a work from the Ashmolean Museum (AN1913.512). Interestingly, the portraits with Egyptian blue were more likely to be executed in encaustic: forty-one are made with a wax-based binder (87%), whereas only five are tempera (10.6%) and one is of unknown media (2%). In the known corpus as a whole, at least 618 portraits are in encaustic (59%), 398 are in tempera (38%), and 25 are unknown (2.4%); therefore, there seems to be a correlation between the use of Egyptian blue and wax binders (fig. 5.4). These preliminary observations warrant further investigation by APPEAR participants.[17]

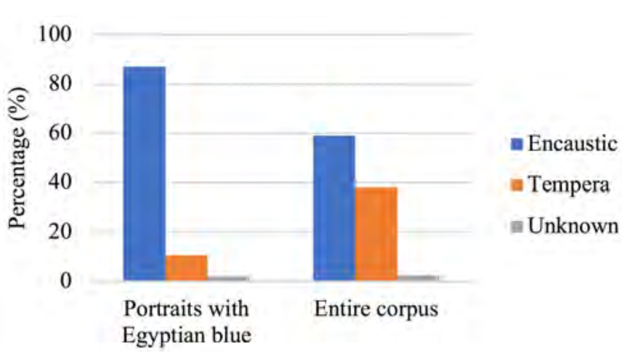


Figure 5.4 Blue pigments and paint binders in the mummy portraits.

Uses of Egyptian Blue in the Mummy Portraits

Figure 5.5 lists the ways, in order of frequency, that Egyptian blue is used in the forty-seven panel paintings that contain it. Three salient points emerge from this list.[18]

(1) Egyptian blue is most often mixed with other pigments and rarely achieves the hue we would consider blue, which, as mentioned above, is mostly absent from the portraits except in the few instances when blue gems, eyes, or garments are depicted.

(2) Egyptian blue is often mixed with pigments and lakes to create green, white, purple, pink, rosy beige, black, and brown, although the most frequently found hues are grayish and beige-hued white.

(3) Clear patterns of use are visible, whereby Egyptian blue is most often used in backgrounds and to model faces, both of men and women.

Figure 5.5 Uses of Egyptian Blue in the Mummy Portraits, in Order of Frequency

Uses of Egyptian Blue	Instances
Shading of cool flesh tones	31
Background (gray)	27
White/grayish white garments	13
White of eyes	10
Contour of the face	9
Dark hair highlights	9
Purple/pink garments	8
Pink of lips	5
White pearls	5
Purple *clavus*	3
Blue gems	2
Blue garment	2
Hazel irises	2
Green gems	2
Green leaves	1
Pupil highlight	1
Pink garland	1
Gray-white hair	1

Interpretation

The use of Egyptian blue in mixtures rather than on its own should not necessarily be taken as evidence that the artists or commissioners of the mummy portraits favored the classical / early Hellenistic tetrachromatic palette of red, yellow, white, and black, as has been proposed.[19] All the ways in which Egyptian blue is used on the mummy portraits have parallels in other artistic media from the Roman period, including painted statuary and wall paintings, which places the portraits firmly in a Roman artistic tradition and suggests that strong material, technical, and aesthetic ties united painting practices across the Mediterranean in this period.[20]

The popularity of Egyptian blue in the mummy portraits may partly be explained by its affordability. Despite frequent suggestions that the pigment was expensive because of its complex manufacturing process, the archaeological and literary evidence indicate otherwise. The pigment was often used to decorate objects of little monetary value, such as mass-produced terracotta figurines, confirming that the pigment was neither rare nor prohibitively expensive. In fact, Egyptian blue is the third most commonly found raw pigment in Pompeii, right behind red and yellow ochres and far ahead of other pigments.[21] Lucian uses the Greek word for Egyptian blue, κύανος, in a dialogue in which Lycinus admonishes Lexiphanes for his oratory style, telling him it resembles figurines sold in the agora, stained (κεχρωσμένος) with blue (κύανος) and red (μίλτος) and made of fragile (εὔθρυπτος) clay inside.[22] The comment is meant to be derogatory, likening blue and red pigments with cheap efforts to dress up a worthless core.

In the 70s AD, Pliny the Elder mentions a price range of eight to eleven denarii per pound of *caeruleum,* Egyptian blue, depending on the pigment's quality—almost exactly the same price as good red ochre, *sinopis*, which sold for twelve denarii per pound, and about half the price of indigo, *indicum*, which cost seventeen to twenty denarii per pound.[23] Naturally, these costs fluctuated according to demand, availability, and inflation. The price of Egyptian blue had increased tenfold by AD 301, when the Edict of Diocletian set a maximum price of one hundred fifty denarii for a pound of *cyanus vestorianus*, Vestorian or Egyptian blue.[24] Although this figure seems dramatically higher than Pliny's, inflation and the devaluation of currency over this 225-year period means that the actual value of the pigment had gone down by as much as 80 to 90 percent, making it quite affordable.[25] These prices are relatively consistent with the pigment bills found on papyri. It is interesting to note that the price ranges indicate there were degrees of pigment quality, and that the price varied accordingly. Although it has not been possible to detect variations in the quality of Egyptian blue used in the mummy portraits so far, the ancient sources cited above attest that it was relatively inexpensive during the period of production of mummy portraits.

Beyond the affordability of the pigment, there may have been material and cultural reasons for the use of Egyptian blue in the portraits. The results obtained by APPEAR participants demonstrate that in at least ten instances, Egyptian blue was mixed with other pigments to represent *clavi*, or purple tunics (e.g., Cairo Egyptian Museum C.G. 33240 and British Museum EA74832).[26] This trick is described by Pliny and Vitruvius, who claim that *caeruleum* (Egyptian blue) could be mixed with *purpurissum* (a red dye) to create purple.[27] Interestingly, indigo—despite its different optical properties—is also frequently mixed with organic red colorants to obtain similar results, as has been found in the *clavi* of three of the portraits at the Hearst Museum and in the garments of eight portraits at the Getty.[28] The choice of one blue pigment over the other in madder mixtures does not seem to indicate that the other pigment was unavailable; indeed, the Tebtunis portraits that have indigo in the *clavi* also have Egyptian blue in the backgrounds. The frequent use of indigo in *clavi* therefore seems deliberate, perhaps following a pattern whereby the artists tended to prefer painting materials that were close to the real-life objects they were meant to depict: gold leaf to represent gold jewelry, natural dyes for garments, Egyptian blue for gems, and lead white, which could be used for makeup, to model faces. This association between everyday materials and the choice of pigments is particularly visible in the use of madder lake, which in dye form is frequently used on textiles, to depict pink garments in the mummy portraits.[29] Choosing painting materials according to how closely they evoked their real-life counterparts may have been a strategy to heighten the portraits' mimetic impact.

The use of Egyptian blue in flesh tones is perhaps the most interesting of all. It is more often found in female portraits, where skin tones are traditionally ruddier (eighteen instances in female portraits to thirteen instances in male portraits). In his *Natural History,* Pliny tells us that a pigment named anularian white was used for giving a brilliant whiteness to female figures. According to him, this pigment was prepared from a chalk combined with the glassy paste "[that] the lower classes wear in their rings; hence it is, that it has the name *anulare*."[30] This passage is traditionally interpreted as referring to makeup that women would wear, similar to the lead-based ceruse Pliny describes in 34.54.[31] However, it is possible that this glassy paste may, in fact, be Egyptian blue, as its manufacturing process is very close to that of glass, and it could be molded to fit into jewelry instead of a gem.[32] In this case, Pliny's anularian white could be the white-and-blue mixture used to create highlights on the faces of some mummy portraits.[33] It is notable that mixtures of Egyptian blue and chalk (usually calcite and aragonite) were found in Pompeii; color merchants likely sold them pre-mixed on account of their popularity.[34]

The use of Egyptian blue in the flesh tones of mummy portraits may have something to do with the pigment's optical brightness, which had a special significance in an Egyptian funerary context. In the Pharaonic period, blue was associated with the sun, life, and immortality; in art, it was often used to depict the flesh of particular deities, such as Amun, while in literature, blue highlights in dark hair signified great beauty. Lorelei Corcoran notes that blue is associated consistently with “the scintillating effect” it produces, which “imbues an inanimate work of art with a sense of living presence,” and concludes that the glassy particles in Egyptian blue were probably appreciated for their ability to reflect light.[35] Classical authors also often refer to the shimmery quality of blue. For instance, in the *Timaeus*, Plato defines κύανος as a mix between black, white, and τον λαμπρόν (shininess).[36] The use of blue in flesh tones also had a symbolic meaning in classical literature, in which blue often refers to youth or to a divine-like appearance, as in Pharaonic art. Zeus, Poseidon, and other gods are described as having blue hair and beards, while their skin is often said to have a blue quality to it—probably referring more to the shimmery quality of blue than its actual hue. In the *Odyssey*, Athena alters Odysseus’ appearance upon his return to Ithaka, making his hair and skin κύανος (blue/shimmering), thereby elevating him above his mortal self and causing his son, Telemachus, to wonder if he is a god.[37]

Mixed with white, Egyptian blue also contributes to giving a “liquid” quality to the white of the eyes of certain mummy portraits, including British Museum EA74832, Phoebe A. Hearst Museum 6-21380, and Cairo C.G. 33232, a technique that has been observed in the eyes of polychrome statues from the classical period onward. The mixture of Egyptian blue and white may serve to achieve an effect akin to the epithet associated with Athena, γλανκῶπις, which is sometimes translated as “blue/gray/green-eyed” but most likely means “flashing/bright-eyed."[38] It is notable that the technique was frequently used on gorgoneia, including on a Campanian wall-painting fragment at the Allard Pierson Museum, considering that their eyes were notoriously fearsome (figs. 5.6a and 5.6b; figs. 5.7a and 5.7b). Eyes that are moist and luminous—two effects achieved by adding Egyptian blue—are extolled by ancient authors as signifying beauty and intelligence.[39]

Figure 5.6a Visible light image showing the presence of Egyptian blue in the peacock's feathers and Harpocrates’ eyes and headdress on Horus Harpocrates on Peacock, Romano-Egyptian, first century AD or later. Terracotta, H: 17.8 cm (7 in.). Amsterdam, Allard Pierson Museum, APM07232. Image: Courtesy Allard Pierson Museum

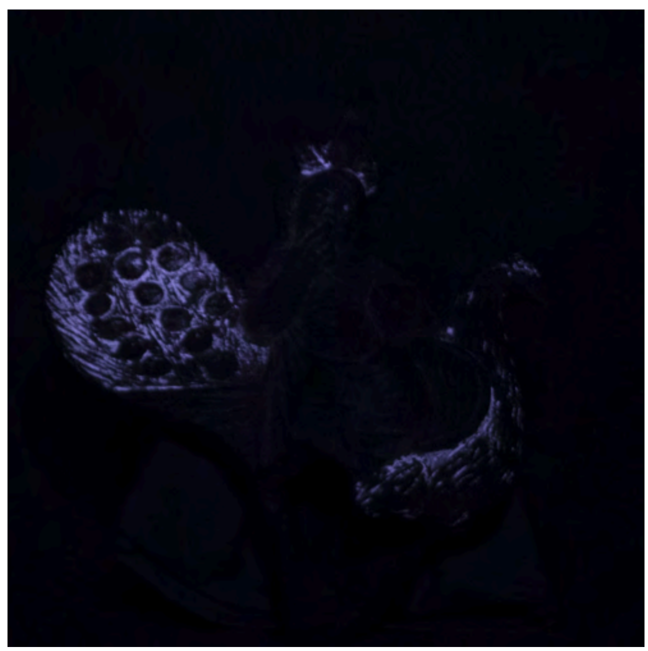


Figure 5.6b VIL image showing the presence of Egyptian blue in the peacock's feathers and Harpocrates’ eyes and headdress on fig. 5.6a. Image: Courtesy Allard Pierson Museum

Figure 5.7a Visible light image of a gorgoneion wall painting showing the presence of Egyptian blue in the flesh tones, eyes, and snakes of the gorgon. Amsterdam, Allard Pierson Museum, APM1670. Image: Courtesy Allard Pierson Museum

Figure 5.7b VIL image showing the presence of Egyptian blue in the flesh tones, eyes, and snakes of the gorgon in fig. 5.7a. Image: Courtesy Allard Pierson Museum

The naturalism achieved by using Egyptian blue in flesh tones and for the whites of eyes may have been an end in itself, as one of the primary goals of mummification was to make the body recognizable to the soul (the *ba* and the *ka*) of the deceased after death. The use of a blue pigment in flesh tones also finds strong echoes in literary and artistic depictions of both Greek and Egyptian gods as having blue/shimmering faces and eyes, which suggests that the pigment allowed the deceased to present an idealized version of themselves, ready for the journey to the afterlife and having already acquired the divine qualities of κύανος skin and hair. After all, in Egyptian beliefs, mummy masks served to protect the deceased, grant them the ability to see and speak in the afterlife, and make them "beautiful of face among the gods."[40] While the artists of the mummy portraits might not have had Pharaonic art or Homeric texts in mind when using Egyptian blue, their choice may have been influenced by certain subtle cultural constructs, which shaped their understanding of the symbolic properties of the pigment.[41]

Conclusion

The APPEAR project provides an extraordinary opportunity to reexamine mummy portraits and compare analytical results obtained by multiple institutions. The data gathered by APPEAR participants can then be interpreted through the lens of archaeological, literary, and documentary sources to better understand the use of individual pigments and also to reinterpret ancient sources through material evidence.

This close examination of the VIL results obtained by APPEAR participants has revealed that Egyptian blue was used in portraits that were found in all the major find sites and that date from the entire production period of mummy portraits. VIL results also confirmed that the pigment was used in idiosyncratic ways: in flesh tones, garments, and eyes. Ancient sources suggest that the pigment may have been popular on account of its affordability and optical properties, which allowed painters to obtain the cool shades characteristic of the naturalistic style of the portraits. A closer examination of literary sources reveals that it is also likely that the pigment was prized for its shining/shimmering quality, which possessed strong associations with the divine. In this context, the use of Egyptian blue in the mummy portraits allowed painters to reproduce reality more closely and brought a symbolic potency to the portraits, perhaps in an attempt to help the deceased access the afterlife.

Acknowledgments

This research was made possible thanks to the support of Susan K. Manganelli, Samantha Li, and Maria-Olivia Stanton-Davalos at the Cantor Arts Center Art+Science Learning Lab and to the staff at the Allard Pierson Museum, who allowed me to examine objects in their collection in 2017. Sincere thanks are also due to the editors and to the reviewers for their insightful comments and suggestions.

NOTES

1. Ganio et al. 2015.
2. Tite, Bimson, and Cowell 1984; Grifa et al. 2016.
3. Hatton, Shortland, and Tite 2008; Corcoran 2016.
4. Gaetani, Santamaria, and Seccaroni 2004. As early as the sixth century AD, authors display confusion as to how the pigment was made. Isidore of Seville mentions it was made of sand and natron with the optional addition of a Cypriot pigment called *cyprium* (Isid., *Etymologies* 19.17.14). Later instances include an eleventh-century wall painting in Spain and a 1524 painting of Saint Margaret by Giovanni Battista Benvenuto. These instances are generally explained as reuses of pigment samples, although some scholars believe the technology to make Egyptian blue was not lost, just extremely limited and localized. See Lluveras et al. 2010; Bredal-Jørgensen et al. 2011.
5. Scott 2016.
6. Tchernia 1968–70; Joncheray and Joncheray 2002.
7. Caputo and Cavassa 2009; Spurrell 1895; Petrie 1910; Kantzia and Kouzeli 1987; Pliny, *Natural History* 33.57.
8. Pliny, *Natural History* 33.57; Theophrastus, *De Lapidibus* 55.1–12; Vitruvius, *De Architectura* 7.11.
9. Ganio et al. 2015; Dyer and Newman, this volume.
10. Verri 2009a, 2009b; Verri and Saunders 2014; Accorsi et al. 2009.
11. Verri 2009a, 2009b; Verri et al. 2010, 220. For more examples, see Dyer, O'Connell, and Simpson 2014; Kakoulli et al. 2017.
12. The filters used by APPEAR project participants for VIL include the Hoya R72, Peca 904, Peca 908, Schott RG830 longpass filter, and XNite850—all of which have slightly different cutoffs. This, along with exposure time and the intensity of light sources, has an impact on the luminescence that can be detected by converted cameras. One step in the direction of standardization is the British Museum's 2013 CHARISMA protocol. See Dyer, Verri, and Cupitt 2013.
13. For an almost complete catalogue, see Parlasca 1969–2003.
14. The number of portraits that were tested but found to contain no Egyptian blue is unknown, since not all participants upload negative results to the database.
15. APPEAR database, as of November 2018.
16. The three portraits in Cairo were part of a group of ten portraits examined by the author in February 2017.
17. This correlation is also found in documentary evidence. A Ptolemaic-period bill for the painting of a house in the Fayum, P.Cair. Zen. 4 59763, mentions the price of beeswax (κηρός) and of pigments including lead white (ψιμύθιον), yellow ochre (ὤχρα), red ochre (μίλτος), and Egyptian blue (κύανος). A Hadrianic bill from Oxyrhynchus, HGV SB 14.11958, mentions fees to renovate a temple, including the prices of pigments, notably Egyptian blue, as well as sponges, pumice stones, and wax. This juxtaposition suggests that Egyptian blue was often used in conjunction with wax outside of mummy portraits, with wax used either as a binder or as a protective coating for wall paintings, as described by Vitruvius in *De Architectura* 7.9.3–4.
18. If Egyptian blue appears on a single portrait in multiple places—for instance, in a green gem and in a pink tunic—it is counted as two different instances. It is important to note that hues may have altered with time because of chemical interactions between pigments and binding media, substrate, or environmental pollutants.
19. Ganio et al. 2015, 820. For a discussion of the contradictions in the sources considering this palette, see Brecoulaki 2006.
20. Kakoulli 1997, 133; Guichard and Guineau 1990 and 2002; Verri 2009b, 1019.
21. See Delamare, Monge, and Repoux 2004, 92. Forty-seven samples of raw Egyptian blue in a wide range of saturation were found in Pompeii in three forms: blocks, balls, and powders.
22. Lucian, *Lexiphanes* 22.
23. Pliny, *Natural History* 33.162; for indigo, see 33.163, 35.46.
24. Price Edict of Diocletian, *De pigmentis* 34.
25. Delamare, Monge, and Repoux 2004, 90.
26. Verri 2009b, fig. 5.
27. Pliny, *Natural History* 35.45; Vitruvius, *De Architectura* 7.14.1–2.
28. Ganio et al. 2015.
29. Delaney et al. 2017; Brøns and Sargent 2018.
30. Pliny, *Natural History* 35.48.
31. Beckmann 1846, 260.
32. See, for instance, a number of blue frit bezel rings in the Fitzwilliam Museum and Egyptian blue beads found at

Amarna, Zawiyet Umm el-Rakham, and Tell Brak (Hatton, Shortland, and Tite 2008). For “glassy” substances being used to imitate gemstones, see Pliny, *Natural History* 37.22.

33. Anularian white is also described by Isidore of Seville, who says it brightens women's cosmetics and is made from clay and “glassy gems.” Isid., *Etymologies* 19.17.22.

34. Delamare 2008, 28.

35. Corcoran 2016, 42.

36. Plato, *Timaeus* 68c.

37. Homer, *Odyssey* 16.176.

38. Verri 2009a, fig. 4c; Salvant et al. 2018.

39. E.g., Pseudo-Aristotle 807b.19.

40. *Book of the Dead,* Spell 151.

41. Petrie found a mummified woman whose head rested on a papyrus scroll containing a carefully transcribed copy of part of the second book of the *Iliad* (the “Hawara Homer”). Petrie 1889, 24; Bodleian Library MS. Gr. class. a. 1 (P)/1-10.

6

Multispectral Imaging Techniques Applied to the Study of Romano-Egyptian Funerary Portraits at the British Museum

Joanne Dyer
Nicola Newman

The British Museum (BM) holds a collection of about thirty Greco-Roman funerary portraits from Egypt dating from the first to the third centuries AD.[1] Acquired between 1856 and 1994, they comprise eighteen female and twelve male portraits. Of them, two-thirds are classified as painted in encaustic (20) and just over a quarter in tempera (8), with the use of both encaustic and tempera identified in the remaining examples. To date, these classifications have mostly been made by visual inspection alone, as so far very little binding media analysis has been possible. In terms of supports, the portraits are mostly on *Tilia,* or lime wood, panels, which is in keeping with findings more generally, with a few painted on linen or linen cartonnage.[2] More than half of the portraits are from Hawara (16), excavated by Petrie; a third are from er-Rubayat (10) and reached the collection as a result of bequests by the Mond family to both the BM and the National Gallery, London; and the others (4) are from Thebes or Saqqara or of unknown origin.

In 2011 a condition survey of the BM's portrait collection led to an extensive conservation campaign during which four portraits that had sustained considerable damage, as a result of being fixed to rigid supports since the 1930s, were removed from these wooden "pseudo-cradles."[3] As part of this endeavor, analysis was carried out to understand past interventions, which were largely undocumented and made for surfaces that were particularly difficult to interpret, even under a microscope. Multispectral imaging (MSI) techniques were crucial to the understanding of these surfaces and in mapping the distribution of both restoration and original materials on the portraits.[4]

Since then, the BM has led in developing standardized methodologies for both the acquisition and the post-processing of multispectral images.[5] These practices ensure that the images produced not only are consistent but adhere to a series of internationally established standards. Such guidelines greatly facilitate the reproducibility of the methodology by the user, but more importantly, enable the images produced by different users to be compared with each other and exchanged with others adopting this systematic approach. Within the framework of the APPEAR project this consistency is of crucial importance: collaborative scholarship via the comparison of images and data is a key element of the aims of the project and central to the creation of a useful and sustainable database.

In this essay current MSI methods in use at the BM, some of which were pioneered in-house,[6] are described. In 2015 these techniques were applied to twenty-six portraits[7] from the BM collection as part of the museum's contribution to the APPEAR project. A summary of the results obtained is described using an innovative approach: the development of workflows that aid in the more standardized interpretation of these images and that enable new ways to interrogate the MSI data sets.

MSI Techniques

Multispectral imaging is a set of procedures used to observe an object by employing wavelength ranges that include and extend beyond the capabilities of the human eye. These techniques are increasingly being regarded as a powerful method with which to survey collections, as they allow the visualization and spatial localization of materials under different wavelengths of illumination. The resultant MSI sets often act as "maps" that highlight particular physical properties, allowing the objects to be viewed in a completely novel manner and emphasizing relationships between materials within the object and, often, between similar materials within a collection of related objects.

In contrast to hyperspectral imaging methods, which have recently been applied to the study of portraits[8] and that require specialized equipment, the procedures described here are based on readily accessible, inexpensive, broadband methods, which cover large sections within the wavelength range that can be observed using modified commercially available cameras. These devices typically employ silicon-based sensors and glass lenses, resulting in an available wavelength range for image acquisition between 350 and 1100 nanometers—that is, from the ultraviolet into the near infrared. The object is illuminated by two radiation sources symmetrically positioned at approximately 45 degrees with respect to the focal axis of the modified camera and at about the same height. The incoming radiation travels toward, and interacts with, the object. Following this interaction, the outgoing radiation travels from the object to the camera. A filter, or a combination of filters, is placed in front of the camera lens in order to select the wavelength range of interest. The experimental setup and the combinations of radiation sources and filter(s) used at the BM for each MSI technique are summarized in figures 6.1 and 6.2. The images are divided into two categories: reflected images and luminescence images.

Reflected images are defined as images in which the wavelength range of the incoming radiation and that of the outgoing radiation are the same (see fig. 6.1). They include:

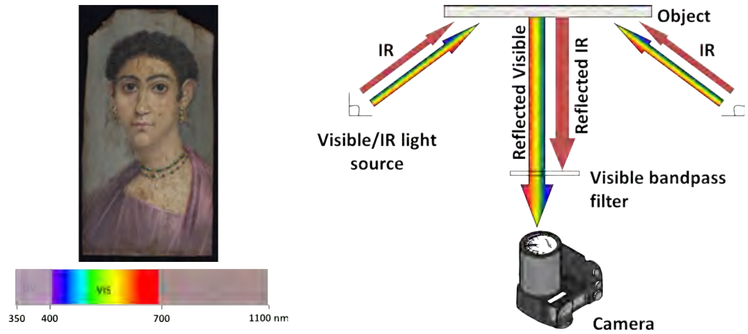
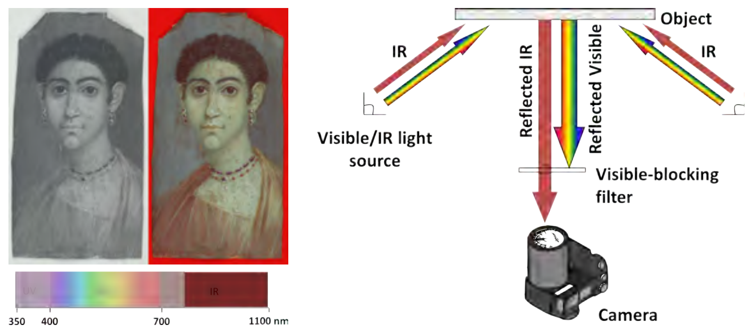
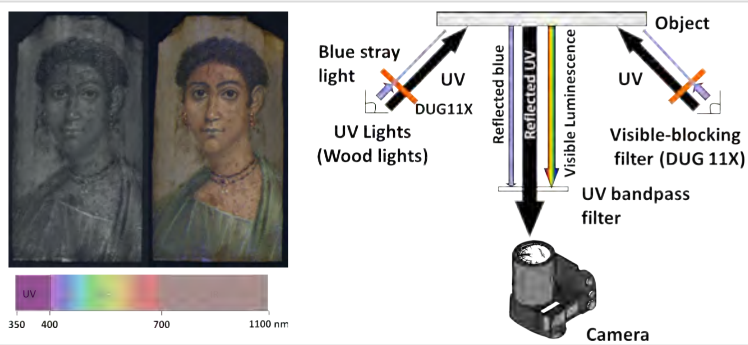
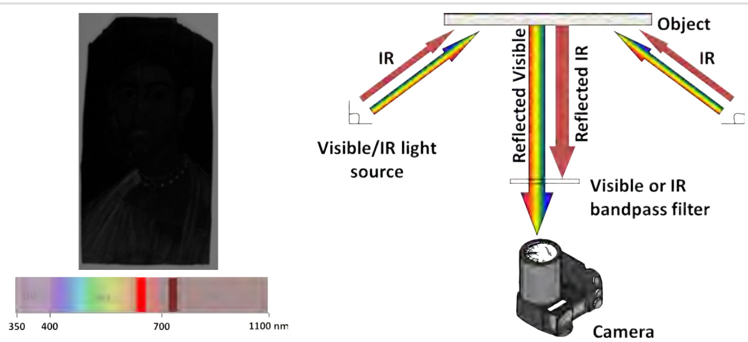
a) Visible (VIS) images, which correspond to standard photography and record the reflected light in the visible region (400–700 nm) when the object is illuminated with visible light.

b) Infrared-reflected (IRR) images, which record the reflected radiation in the infrared region (700–1100 nm) under infrared illumination. By combining components of the VIS and the IRR images, infrared-reflected false color (IRRFC) images are produced. As certain colorants can yield a characteristic appearance in false color, these IRRFC images can often be used for their tentative identification.[9]

c) Ultraviolet-reflected (UVR) images, which record the reflected radiation in the ultraviolet region (200–400 nm, depending on the camera lens used) when an object is illuminated with ultraviolet radiation. Components of the VIS and the UVR images can also be combined to produce ultraviolet-reflected false color (UVRFC) images.[10]

d) Multiband reflectance (MBR) images, which record reflectance images taken in two different bands or wavelength ranges—in this case, the red region of the visible and the near-infrared region—and subtracts them to give a map of the reflectance of one particular colorant: indigo.[11]

Figure 6.1 Schematic of the Experimental Setup for Reflected Images

MSI Technique and Experimental Setup		Radiation Sources	Filter(s)
a. VIS		2 x Classic Elinchrom 500 Xenon flashlights, each equipped with a softbox (diffuser)	IDAS-UIBAR interference UV-IR blocking bandpass filter (c. 380–700 nm)
b. IRR		2 x Classic Elinchrom 500 Xenon flashlights, each equipped with a softbox (diffuser)	Schott RG830 cut-on filter (50% transmittance at c. 830 nm)
c. UVR		2 x Wood's radiation sources (365 nm) filtered with a Schott DUG11X interference bandpass filter (280–400 nm)	Schott DUG11X interference bandpass filter (280–400 nm)
d. MBR		2 x Classic Elinchrom 500 Xenon flashlights, each equipped with a softbox (diffuser)	MidOpt BP 660 dark red bandpass filter (c. 640–680nm) then MidOpt BP735 infrared bandpass filter (715–780nm)

Mummy Portrait of a Woman, see fig. 6.9c.

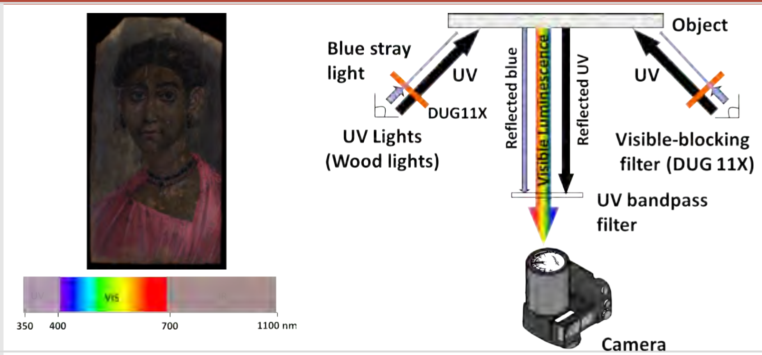
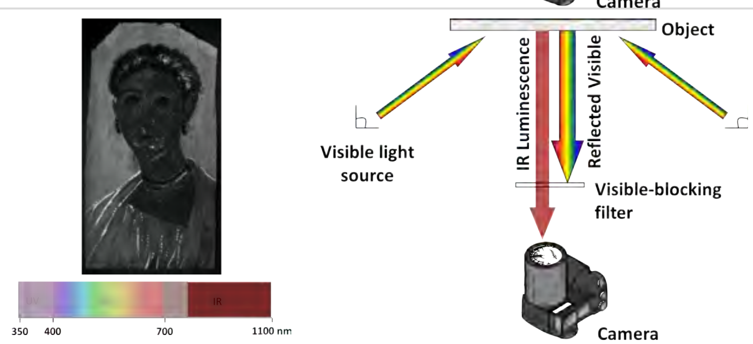
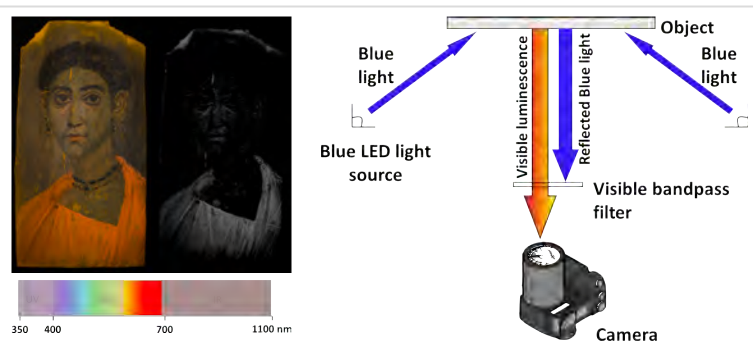
Luminescence images are defined as images in which the wavelength range of the incoming radiation and that of the outgoing radiation differ (see fig. 6.2). They include:

e) Ultraviolet-induced visible luminescence (UVL) images, which record the emission of light in the visible region (400–700 nm) when the object is illuminated with ultraviolet radiation. UVL images are used to investigate the distribution of luminescent materials—for example, organic binders and colorants, such as lake pigments—as well as varnishes, coatings, and adhesives.

f) Visible-induced infrared luminescence (VIL) images, which record the emission of radiation (luminescence) in the infrared region (700–1100 nm) when the object is illuminated with visible light. Very few materials display this property,[12] and in this context the only candidate is the pigment known as Egyptian blue, which appears bright white in VIL images.

g) Visible-induced visible luminescence (VIVL) images record the emission of light in a portion of the visible region (here, 500–700 nm) when the object is illuminated with visible light (here, blue light, 400–500 nm). A VIVL image is in many ways analogous to a UVL image, but the emission range makes it particularly useful in characterizing the spatial distribution of yellow and red lake pigments, such as madder. VIVL images can be processed to produce maps of the distribution of these pigments, in either color or grayscale.[13]

Figure 6.2 Schematic of the Experimental Setup for Luminescence Images

MSI Technique and Experimental Setup		Radiation Sources	Filter(s)
e. UVL		2 x Wood's radiation sources (365 nm) filtered with a Schott DUG11X interference bandpass filter (280–400 nm)	Schott KV418 cut-on filter (50% transmission at c. 418 nm) + IDAS-UIBAR bandpass filter (c. 380–700 nm)
f. VIL		2 x high power LED (red, green, and blue) light sources (Eurolite LED PAR56 RGB spots 20W, 151 LEDs, beam angle 21°)	Schott RG830 cut-on filter (50% transmittance at c. 830 nm)
g. VIVL		2 x high power LED (red, green, and blue) light sources (Eurolite LED PAR56 RGB spots 20W, 151 LEDs, beam angle 21°). Blue LEDs (λ_{max} = 465 nm)	IDAS-UIBAR bandpass filter (400–700 nm) + Tiffen Orange 21 filter (50% transmission at 550 nm)

Mummy Portrait of a Woman, see fig. 6.9c.

MSI techniques have increasingly become a part of the range of examination and analytical methodologies that conservation professionals have at their disposal, yet there are certain issues to be aware of with MSI techniques. In general, without standardization, the images obtained from these methods very much depend on the individual users and the setup employed, making cross-comparison between different institutions and researchers very difficult and decreasing the value of these data sets as documentation aids. This need for standardization was one that was identified by CHARISMA,[14] a recent European project, which strived to establish standards in areas that have traditionally lacked guidelines, such as MSI. Research was undertaken to develop new optimized methodologies for both the acquisition and the processing of images, to improve their reproducibility and comparability both within and between institutions. The outcomes of this research were distilled into a set of completely open-access user resources downloadable from the BM website.[15]

However, standardization does not end with producing these images—their interpretation also requires guidelines and a methodical approach to recording the information observed in order to derive useful data and objective comparisons. Workflows are a practical solution, as they provide a framework for systematically analyzing data and are already a familiar approach to conservation professionals who acquire and process images.[16] A workflow was thus devised, which could be followed for each portrait, allowing certain characteristic physical properties and their spatial distribution to be recorded and interpreted in an informed and impartial manner across the collection.

Workflows for MSI Interpretation

As a first approach, pigments were selected that are considered typical of the palette used in these portraits; the distinctive properties of these pigments—such as particular reflectance or luminescence in particular regions—can be used for their preliminary identification. Other materials related to conservation treatments and past restoration interventions, particularly those using modern materials, could also be addressed in this manner; however, it was initially decided to simplify the approach to this class of materials. The pigments selected were Egyptian blue, pink lake, carbon black, ochres, lead white, indigo, and copper-based greens.

In general, it was evident that the most useful approach involved compiling a combination of the photophysical properties observed into a signature behavior for each of the materials in question; this methodology was synthesized into a basic initial workflow, shown in figure 6.3. Although not a comprehensive list of every pigment known to occur in the production of these portraits, this inventory does represent a key subset, and the workflow was invaluable in assessing the presence or absence of these significant pigments. Their distribution and use were then documented according to a set of criteria optimized for each pigment. The results were tabulated and expressed as bar charts showing the key trends observed from portraits in the BM collection and the number of portraits that exhibit them. These trends, and the representative portraits that display them, are discussed in more detail below.

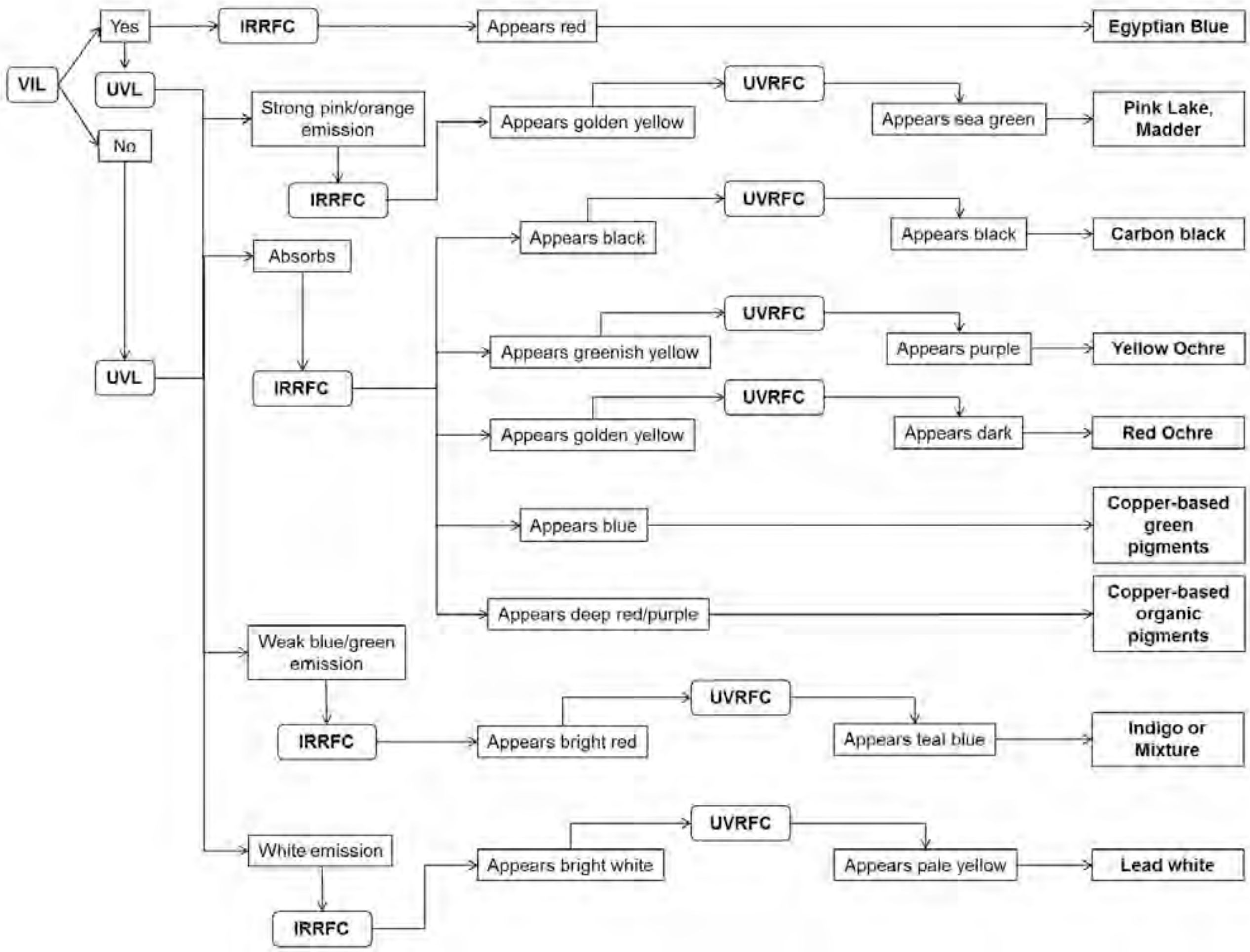


Figure 6.3 Workflow for assessing the presence of a selection of key pigments in the BM portrait collection by examining the response in the VIL, UVL, IRRFC, and UVRFC images. © Trustees of the British Museum

Egyptian Blue

As discussed, the pigment Egyptian blue produces signature visible-induced luminescence in the infrared region, but it also demonstrates characteristic behavior in IRRFC images (see fig. 6.3) due to its high reflectance[17] beyond the visible. Egyptian blue was identified in sixteen of the portraits imaged, with a fairly even spread chronologically and in its use for both male and female portraits. In addition, the pigment appears to be more prevalent in encaustic portraits, with only three of the tempera and one of the encaustic and tempera portraits containing it; however, what soon becomes evident from looking at the VIL images themselves is the diversity of usage of the pigment within these portraits. Use of Egyptian blue ranges from its presence in mixtures—for the backgrounds and in the depiction of garments and gemstones—to its use in a variety of subtle and highly painterly ways of modeling, contouring, and highlighting different aspects of the compositions. To systemically document this wide-ranging use of Egyptian blue pigment, a set of criteria was employed that considered not only how, but also where, it is being used within the portraits; this allowed key trends to be documented, as summarized in figure 6.4a, which plots the number of portraits displaying each identified use of the pigment.

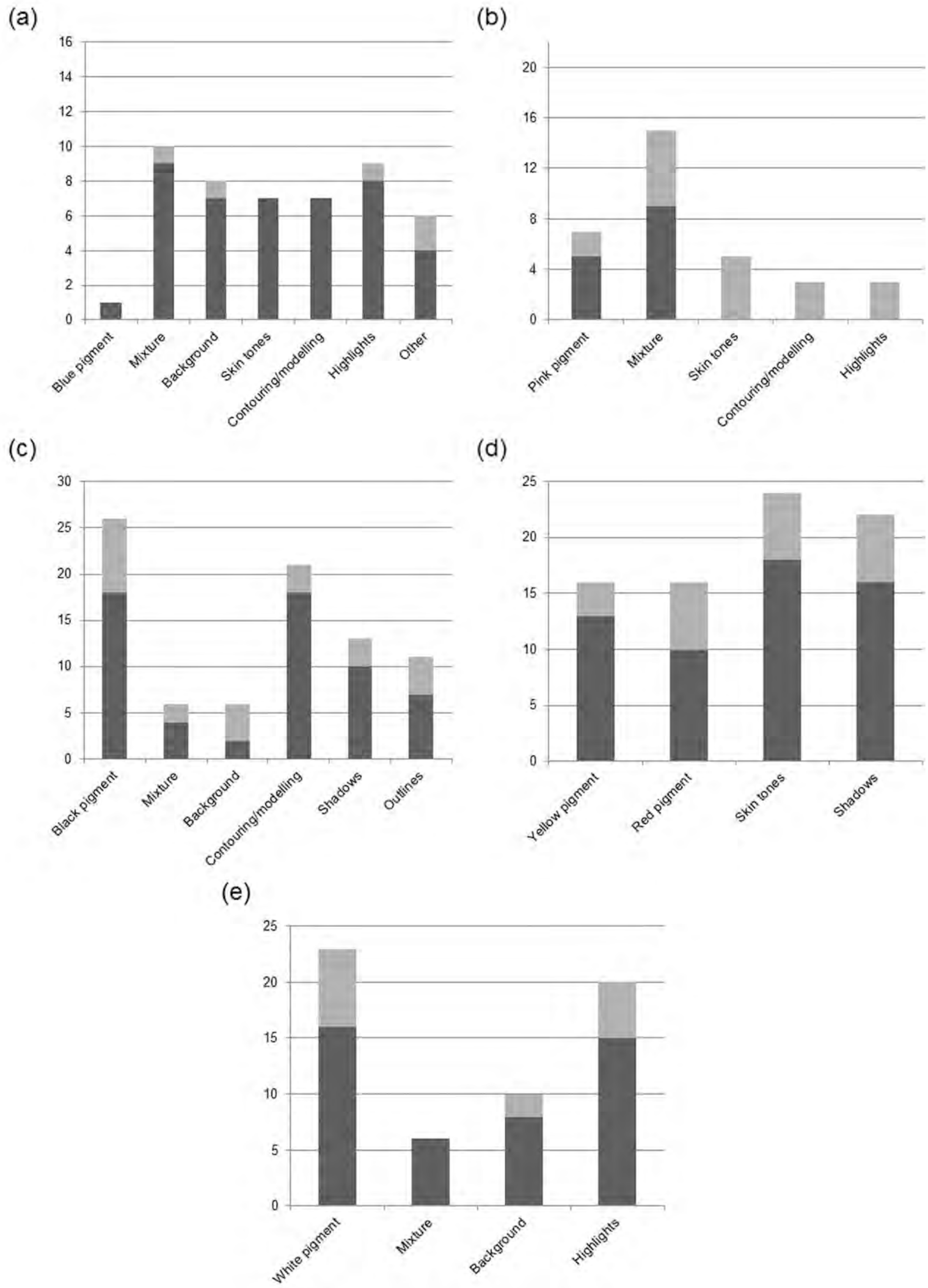


Figure 6.4 Bar charts showing the number of portraits exhibiting the identified uses of the pigments: (a) Egyptian blue; (b) pink lake; (c) carbon black; (d) ochres; and (e) lead white in the BM portrait collection (dark gray denotes portraits in encaustic; light gray, portraits in tempera). © Trustees of the British Museum

From this analysis, it was possible to deduce that within the BM portrait collection, Egyptian blue is only sparingly employed as a pure blue pigment and, in fact, can only be found in one portrait (see fig. 6.4a), in the garment of the so-called Portrait of a Lady, shown in figure 6.5a. In this same portrait, Egyptian blue was also used as a component of a mixture with yellow to depict the green jewels in the necklace and earrings. Mixtures were indeed found to be the most popular use of the pigment, identified in ten portraits (see fig. 6.4a). Mixtures with white were observed in the whites of the eyes and in areas of the drapery (as in fig. 6.5a) in several portraits, whereas mixtures with pink lake were less prevalent and observed in only two portraits: in the garment of a female portrait (fig. 6.5b) and in the *clavus* of a male portrait (EA74832, not shown).

Extensive use of Egyptian blue was also detected mixed into skin tones (see fig. 6.4a), as a means to create both light and shade (figs. 6.5c-1 and 6.5c-2). Additionally, widespread use of the pigment in mixtures was noted, to create highlights (see fig. 6.4a), in the treatment of garments, and to suggest volume and dimensionality (fig. 6.5d). Furthermore, Egyptian blue was found to have been used in a mixture in the colored backgrounds in eight of the portraits imaged (see fig. 6.4a).

Figure 6.5a VIS and VIL images showing Egyptian blue used as blue pigment in Mummy Portrait of a Woman, Romano-Egyptian, AD 160–170. er-Rubayat. Encaustic on lime wood with gilding, 44.4 x 16 cm (17 1/2 x 6 5/16 in.). London, The British Museum, 1939,0324.211 and EA65346. © Trustees of the British Museum

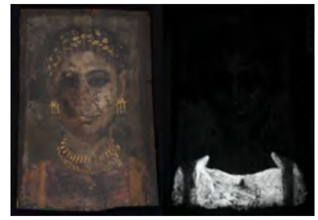


Figure 6.5b VIS and VIL images showing Egyptian blue used in mixtures with pink lake in Mummy Portrait of a Woman, Romano-Egyptian, AD 190–220. Hawara. Encaustic on fir wood with gilding, 32.1 x 22.7 cm (12 5/8 x 8 15/16 in.). The British Museum, 1994,0521.15 and EA74717. © Trustees of the British Museum

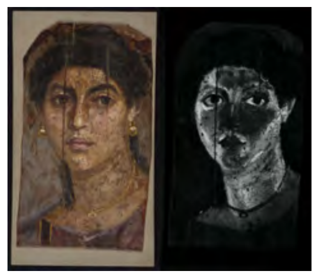


Figure 6.5c-1 VIS and VIL images showing Egyptian blue used in skin tones in Mummy Portrait of a Woman, Romano-Egyptian, AD 55–70. Hawara. Encaustic on lime wood, 35.8 x 20.2 cm (14 1/8 x 7 15/16 in.). London, The British Museum, 1994,0521.14 and EA74716. © Trustees of the British Museum

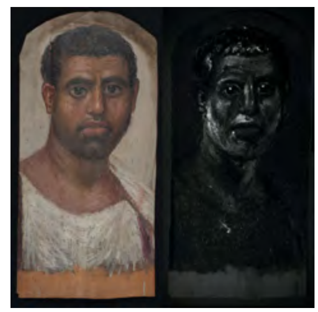


Figure 6.5c-2 VIS and VIL images showing Egyptian blue used in skin tones in Mummy Portrait of a Man, Romano-Egyptian, AD 80–100. Hawara. Encaustic on lime wood, 42.5 x 20.9 cm (16 3/4 x 8 3/16 in.). London, The British Museum, 1994,0521.16 and EA74718. © Trustees of the British Museum

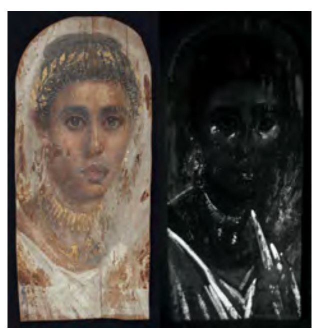


Figure 6.5d VIS and VIL images showing Egyptian blue used as a highlight in Mummy Portrait of a Woman, Romano-Egyptian, AD 100–120. Saqqara. Encaustic on lime wood with gilding, 37.4 x 17 cm (14 3/4 x 6 11/16 in.). London, The British Museum, 1856,0814.1 and EA29772. © Trustees of the British Museum

Pink Lake

Pink lake pigments, of which madder lake is the most emissive,[18] produce distinctive pink/orange luminescence under ultraviolet radiation. In addition, pink lakes such as madder appear golden yellow in IRRFC and sea green in UVRFC images (see fig. 6.3). This characteristic behavior was noted in twenty-two of the portraits imaged, again with an evenly spread chronology of use. Pink lake was detected more often in female portraits, and it is present in fourteen of the encaustic and all but one of the tempera portraits.

To document the distribution and use of the pink lake pigment, an approach similar to that described for Egyptian blue was employed; the results are summarized in figure 6.4b. This examination indicated that the major use of pink lake as a pink pigment (in eight portraits; see fig. 6.4b) is in the garments and lips, particularly in female portraits, as exemplified by that shown in figure 6.6a.

Mixtures of pink lake with various pigments constitute its most prevalent use (in fifteen portraits; see fig. 6.4b). In particular, it was used to modify the hue of garments to a dark red, as seen in the portrait in figure 6.6b, or to create purple shades in the *clavi* of several male portraits that evoke the Tyrian purple–dyed *clavi* worn by high-status Roman men.

Additionally, pink lake is observed in mixtures to both model and highlight skin tones (see fig. 6.4b), as seen in the portraits in figures 6.6c-1 and 6.6c-2. This practice was not as widespread in male portraits, except for the portrait of a youth shown in figure 6.6c; perhaps here it was employed to convey an age-appropriate freshness to his complexion. However, the use of mixtures to highlight certain areas (see fig. 6.4b), as in the portrait in figure 6.6d, was observed in a few male and female portraits. Another interesting use of the pigment is in the depiction of jewels (see below).

Figure 6.6a VIS and UVL images showing pink lake used as a pink pigment in Mummy Portrait of a Woman, Romano-Egyptian, AD 55–70. Hawara. Encaustic on lime wood, 41.6 x 21.5 cm (16 3/8 x 8 1/2 in.). London, The British Museum, 1994,0521.11 and EA74713. © Trustees of the British Museum

Figure 6.6b VIS and UVL images showing pink lake used in mixtures to produce dark red in Mummy Portrait of a Woman, Romano-Egyptian, ca. AD 200. er-Rubayat. Encaustic on oak, 38 x 23 cm (15 x 9 1/16 in.). London, The British Museum, 1939,0324.209 and EA65344. © Trustees of the British Museum

Figure 6.6c-1 VIS and UVL images showing pink lake used in mixtures to produce skin tones in Mummy Portrait of a Woman, Romano-Egyptian, AD 160–180. er-Rubayat. Tempera on wood, 29 x 16.6 cm (11 3/8 x 6 1/2 in.). London, The British Museum, 1931,0711.1 and EA63394. © Trustees of the British Museum

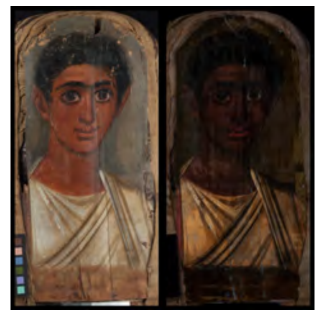


Figure 6.6c-2 VIS and UVL images showing pink lake used in mixtures to produce skin tones. Mummy Portrait of a Young Man, Romano-Egyptian, AD 140–180. Thebes (?). Tempera on wood. London, The British Museum EA6713. © Trustees of the British Museum

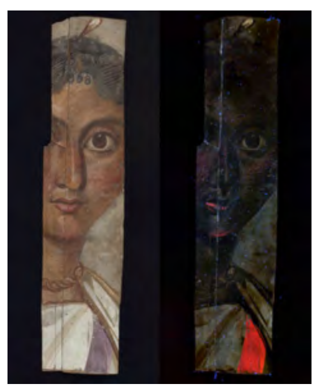


Figure 6.6d VIS and UVL images showing pink lake used in mixtures to produce highlights in Fragmentary Mummy Portrait of a Woman, Romano-Egyptian, AD 140–160. Tempera on lime wood, 30.5 x 7.4 cm (12 x 2 7/8 in.). London, The British Museum, EA5619. © Trustees of the British Museum

Carbon Black

Found on all the portraits imaged, carbon black was indeed the most ubiquitous of the pigments. As a result of its high absorbance across the range investigated, the pigment appears dark in all of the images recorded and, characteristically, remains dark in false color images (see fig. 6.3). This is particularly evident in the IRRFC images (figs. 6.7a and 6.7b) and is in contrast to areas that appear black in VIS images but are red (IR transparent) in IRRFC images.

Investigation of the distribution and use of carbon black showed that in all twenty-six cases, it was used as a pure black pigment (see fig. 6.4c) to depict the hair, eyes (particularly pupils), and eyebrows, as shown by the portrait in figure 6.7a, and, where present, facial hair and black *clavi*. An additional function, observed in eleven cases (see fig. 6.4c), was to outline facial features such as eyes and eyelids, pupils, irises, and noses. Jewelry was also often observed to be outlined in this manner.

Mixtures of carbon black with other pigments were noted (see fig. 6.4c): with white to produce a gray shade used to contour and model skin tones, adding definition to the face, neck, and jawline. Warmer shades were used to create shadows, particularly under the eyes, nose, and lips. These attenuate the appearance of the pigment in IRRFC to shades of gray, as in the portrait shown in figure 6.7b, while remaining quite dark (absorbing) in the UVL images.

In other cases, such as when carbon black and pink lake have been mixed to produce darker red tones in the garments, carbon black's presence is manifested by a darkening of pink lake's characteristic golden yellow and sea-green hues in IRRFC and UVRFC images, respectively, but the intensity of the luminescence from the lake is hardly attenuated.

In certain instances, areas appeared very dark or visibly black but did not remain black in the IRRFC images, as in the portrait in figure 6.7c. This behavior allowed the presence of carbon black to be distinguished from visually similar materials that are not carbon based, such as bituminous materials or organic colorants such as indigo (see below), which are infrared transparent and thus appear red in IRRFC.

Figure 6.7a VIS and IRRFC images showing carbon black used as a black pigment in Mummy Portrait of a Young Man, Romano-Egyptian, AD 80–120. Hawara. Encaustic and tempera on lime wood, 35.8 x 20.8 cm (14 1/8 x 8 3/16 in.). London, The British Museum, 1994,0521.9 and EA74711. © Trustees of the British Museum

Figure 6.7b VIS and IRRFC images showing carbon black used in mixtures to produce gray tones and evoke shadows in Mummy Portrait of a Young Man, Romano-Egyptian, AD 150–170. Hawara. Encaustic on lime wood with gilding, 42.7 x 22.2 cm (16 13/16 x 8 3/4 in.). London, The British Museum, 1994,0521.2 and EA74704. © Trustees of the British Museum

Figure 6.7c VIS and IRRFC images showing a case in which visually dark materials are IR transparent and hence not carbon based. Portrait of a Woman, Romano-Egyptian, AD 40–70. Hawara. Encaustic on linen shroud with gilding, 51.7 x 37 cm (20 3/8 x 14 9/16 in.). London, The British Museum, 1994,0521.7 and EA74709. © Trustees of the British Museum

Ochres

Twenty-five of the portraits imaged showed evidence for the presence of ochres, either as pure pigments or mixtures, establishing this as the second most commonly used class of pigments. Sixteen of the twenty-five showed use of yellow ochre as a yellow pigment (see fig. 6.4d), mostly to evoke the color of gold in the jewelry, *clavi,* and other adornments, especially on female portraits, such as that shown in figure 6.8a. Yellow ochre was identified by its distinctive set of characteristics, appearing very absorbing in UVL, dark greenish yellow in IRRFC, and purple in UVRFC images (see fig. 6.3). In three portraits, it was also employed as the bole layer for gilded areas.

Although also highly absorbing in UVL images, red ochre appears dark golden yellow in IRRFC and very dark in UVRFC images (see fig. 6.3). These characteristics allowed the identification of its use as a dark red pigment in sixteen portraits (see fig. 6.4d), most notably in the outlining and definition of facial features in both male and female portraits, but also in garments and lips, as in the portrait shown in figure 6.8b. In one case, it was also observed as a red bole beneath gilding.

The use of the red ochre in various shades for the depiction of skin tones and to produce shadows around the eyes, beneath the nose, under the chin, and along the neck and jawline was also noted by the attenuation to paler shades of (greenish) yellow observed in the IRRFC images (as in figs. 6.7a and 6.7b). The UVL images remain highly absorbing, as noted from the faces of the portraits in figures 6.6a, 6.6b, and 6.6d.

In six of the portraits, evidence for the use of yellow ochre in mixtures, via an attenuation of the purple tone observed in the UVRFC images, was also observed in the skin tones (fig. 6.8c).

Figure 6.8a VIS and UVRFC images showing ochres used as yellow pigment in the portrait shown in fig. 6.5c-1. © Trustees of the British Museum

Figure 6.8b VIS and UVRFC images showing ochres used as red pigment in Mummy Portrait of a Woman Holding an Unguentarium, Romano-Egyptian, AD 100–120. er-Rubayat. Stucco on linen, 37.5 x 18.2 cm (14 3/4 x 7 1/8 in.). London, The British Museum, 1931,0711.2 and EA63395. © Trustees of the British Museum

Figure 6.8c VIS and UVRFC images showing ochres used in mixtures to produce various shades for the depiction of skin tones. Mummy Portrait, Perhaps of a Priest, Romano-Egyptian, AD 140–160. Hawara. Encaustic on lime wood, 42.5 x 22 cm (16 3/4 x 8 5/8 in.). London, The British Museum 1994.0521.12 and EA74714. © Trustees of the British Museum

Lead White

Twenty-three portraits likely contain lead white present as a pure white pigment (see fig. 6.4e), as identified from its characteristic white emission in UVL images. The pigment is also highly reflective in the entire range, appearing white in IRRFC and pale yellow in UVRFC (see fig. 6.3). These observations are most discernible in white areas such as the garments (see figs. 6.7b and 6.8c) and eyes (see fig. 6.7a).

However, almost as important as the use of lead white as a white pigment, and observed in twenty portraits (see fig. 6.4e), is its use, often in mixtures, to represent how light naturally falls on facial features; lead white was similarly employed to suggest highly reflective surfaces, such as gold or gemstones, via the creation of highlights.

Further uses were noted: in mixtures with pink lake pigments; used as a counterfoil to mixtures of pink lake and black; to create volume, depth, and dimension in the depiction of garments; and in the backgrounds of ten portraits (see fig. 6.4e), particularly to produce a light gray, often in mixtures with Egyptian blue and/or carbon black. In these cases, the effect of the pigment on the false-color images is to lighten the hue observed.

Indigo

The presence of indigo, even in a mixture, is easily identified from its distinctive photophysical characteristics, appearing dark in VIL images, weakly emitting under ultraviolet irradiation, bright red in IRRFC, and teal blue in UVRFC images (see fig. 6.3). Only six portraits displayed these properties, revealing use of indigo both as a pure pigment and in mixtures, and in both encaustic and tempera portraits.

The clearest use of indigo as a blue pigment is observed in the portrait shown in figure 6.9a, where the blue necklace beads have been painted with it. Two uses of indigo in mixtures to create new hues were also observed: mixed with yellow, to depict the green jewels in the necklace of the portrait shown in figure 6.9b, and with pink lake in different proportions, to produce the purple-toned garment and deep red jewels observed in the portrait in figure 6.9c. In IRRFC images the appearance of mixtures, relative to that of the pure pigments, is modified according to the proportion of each pigment. The presence of a small amount of indigo thus attenuates the golden yellow appearance of pink lake areas to a more orange hue, as in the garment in figure 6.9c; whereas, with a larger proportion of indigo, the typical appearance of the latter is more prevalent and the presence of lake can be difficult to discern.

In this regard, using a combination of MBR and VIVL images (fig. 6.9d) can often be valuable to identify such mixtures, as each image isolates the signals from the respective pigments, thus allowing them to be compared more easily. The coexistence of these pigments—in this case, in the garment and the necklace beads—can then be more clearly visualized.

Figure 6.9a VIS and IRRFC images showing indigo used as a blue pigment in Mummy Portrait of a Woman, Romano-Egyptian, ca. AD 200. er-Rubayat. Encaustic on oak, 33 x 18 cm (13 x 7 1/8 in.). London, The British Museum, 1939,0324.208 and EA65343. © Trustees of the British Museum

Figure 6.9b VIS and IRRFC images showing indigo used in a mixture to produce a green pigment in the beads of the necklaces in Mummy Portrait of a Woman, Romano-Egyptian, AD 70–100, er-Rubayat. Tempera and encaustic on lime wood, 41.5 x 22 cm (16 3/8 x 8 5/8 in.). London, The British Museum EA74831. © Trustees of the British Museum

Figure 6.9c VIS and IRRFC images showing indigo used in mixtures to produce purple-toned pigments for the garment and beads of the lower necklace in Mummy Portrait of a Woman, Romano-Egyptian, AD 100–120. Hawara. Encaustic on lime wood, 38.2 x 20.5 cm (15 x 8 1/16 in.). London, The British Museum, 1994,0521.4 and EA74706. © Trustees of the British Museum

Figure 6.9d VIVL and MBR images showing the distribution of pink lake and indigo pigments in the garment and necklace beads in the portrait shown in fig. 6.9c. © Trustees of the British Museum

Copper-Based Greens

Seven distinctive uses of green were observed in the portraits imaged; all uses were to depict gemstones in jewelry, and four of the instances were found to be copper-based greens: one inorganic pigment (such as malachite or Egyptian green) and three organometallic pigments (copper fatty acid carboxylates). Both classes appear dark in the VIL and UVL images and are particularly absorbing in the latter. The main difference between inorganic and organometallic copper-based green pigments is the variation in their infrared transparency and, as a result, how they appear in the IRRFC images (see fig. 6.3). Thus, whereas mineral pigments are not very transparent in the infrared region[19] and appear blue (fig. 6.10a), the organometallic pigments have much higher infrared transparency and thus appear a deep red (fig. 6.10b). This behavior is also distinctive from that of other greens, such as iron-based silicate pigments (green earths), which usually appear absorbing under ultraviolet irradiation and a dull green in IRRFC images (fig. 6.10c), or mixtures of yellow and indigo or Egyptian blue, which also have particular characteristics, as previously described. Interestingly, within this fairly small sample of portraits, all of these available possibilities for green pigments discussed were represented, but the copper-based organometallic greens were observed only in encaustic portraits.

Figure 6.10a VIS and IRRFC images showing the use of copper-based inorganic pigments to depict green gemstones in the portrait shown in fig. 6.8b. © Trustees of the British Museum

Figure 6.10b VIS and IRRFC images showing the use of copper-based organometallic pigments to depict green gemstones in the portrait shown in fig. 6.9c. © Trustees of the British Museum

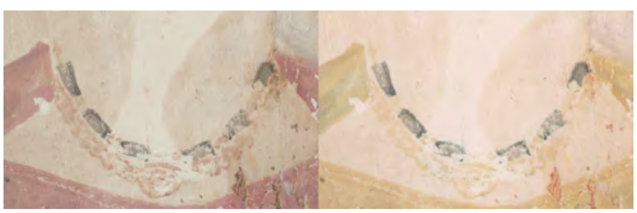


Figure 6.10c VIS and IRRFC images showing the use of green earth pigments to depict green gemstones in the portrait shown in fig. 6.6c-1. © Trustees of the British Museum

Conclusions

This work has described the application of current MSI methods in use at the BM to the study of its collection of Greco-Roman funerary portraits from Egypt. As with all noninvasive methods, the corroboration of the observations made from these investigations with other findings is important and will be considered in future work, but the results confirm that these technically accessible, relatively low-cost methods are a powerful tool for surveying such collections, providing a holistic overview that is invaluable in gauging the extent of distribution of particular materials and their mixtures. This more representative view is not always achievable with point analyses and is particularly significant when sampling is not possible. In addition, the approach can also aid decisions in terms of more focused and targeted invasive sampling, when this is permissible, resulting in less damage to these fragile objects.

In particular, this work has highlighted the importance of standardization—not only in the acquisition and processing of images but also in their interpretation—so as to provide a framework for systematically recording information. Observations resulting from this approach constitute an objective record of the presence, distribution, and use of pigments present in these portraits. It is hoped that through the contribution of this work to the APPEAR project, cross-comparisons with other collections will be stimulated, which will allow meaningful insights that can be used to further explore the painting practices of funerary portraiture of the period.

NOTES

1. Walker 2000.
2. Cartwright and Middleton 2008; Cartwright, Spaabæk, and Svoboda 2011.
3. N. Newman et al. 2013.
4. Verri 2009a.
5. Dyer, Verri, and Cupitt 2013.
6. Dyer and Sotiropoulou 2017.
7. Four of the portraits were not accessible, as they are on long-term loan to various institutions in the United Kingdom.
8. Salvant et al. 2018; Delaney et al. 2017.
9. Dyer, Verri, and Cupitt 2013, 4; Aldrovandi et al. 2005.
10. Dyer, Verri, and Cupitt 2013, 4; Aldrovandi et al. 2005.
11. Webb, Summerour, and Giaccai 2014.
12. Accorsi et al. 2009.
13. Dyer and Sotiropoulou 2017.
14. Cultural Heritage Advanced Research Infrastructures: Synergy for a Multidisciplinary Approach to Conservation/Restoration, funded under FP7-Infrastructures (grant agreement 228330).
15. Dyer, Verri, and Cupitt 2013.
16. Dyer, Verri, and Cupitt 2013.

17. Aceto et al. 2014, 1497.
18. Clementi et al. 2008.
19. Aceto et al. 2014, 1496.

7

Evaluating Multiband Reflectance Image Subtraction for the Characterization of Indigo in Romano-Egyptian Funerary Portraits

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The Brooklyn Museum (BKM) began acquiring Egyptian antiquities in 1902 and now boasts one of the largest holdings of Egyptian materials in the United States. This renowned collection contains six Romano-Egyptian funerary portraits on panel: Portrait of Demetrios (11.600, AD 95–100), Woman with Earrings (1996.146.9, AD 100–105), Mummy Portrait of a Man (ca. AD 120–130), Noblewoman (ca. AD 150), Boy with a Floral Garland in His Hair (ca. AD 200–230), and Portrait of a Young Person (ca. AD 200–230). Two of these portraits are characterized as tempera paintings with aqueous binding media and four as encaustic paintings with wax binding media. Aside from the Noblewoman portrait (fig. 7.1), which has been extensively restored, the portraits survive in remarkably good condition. All six portraits were documented and analyzed through visual examination, reflectance transformation imaging (RTI), X-radiography, infrared reflectography (IRR), X-ray fluorescence spectroscopy (XRF), fiber optics reflectance spectroscopy (FORS), Raman spectroscopy, and multiband imaging (MBI).

Figure 7.1 Noblewoman, Romano-Egyptian, ca. AD 150. Encaustic on *Tilia europaea* panel, 44 x 28.7 cm (17 5/16 x 11 5/16 in.). Brooklyn Museum, Gift of the Ernest Erickson Foundation, Inc., 86.226.18. Next to the portrait are the Spectralon 99 percent reflectance standard, X-Rite ColorChecker Passport, and unbound indigo pigment sample. Image: Brooklyn Museum Conservation Department

This paper focuses on multiband reflectance image subtraction (MBR) for the characterization of indigo. As few references to this technique exist in the literature, BKM conservators not only evaluated the information gained from its application to the study of Romano-Egyptian funerary portraits but also investigated the technique itself, refining variables in image capture and processing to optimize results. Protocols were developed for equipment setup and image capture using reflectance standards, color standards, and material samples as internal references. Spectral curves collected using FORS elucidated why materials other than indigo may be visualized in processed subtraction images. Selected data obtained from MBI, FORS, and Raman spectroscopy are discussed in this paper, along with relevant XRF results.

Indigo was detected exclusively in mixtures with a red lake pigment on three of the encaustic portraits; indigo, both in mixtures and alone, was found more widely on the two tempera portraits. Indigo was not found on the sixth portrait, also encaustic.

The use of indigo or woad on Egyptian textiles dates back to as early as the sixteenth century BC.[1] Woad (*Isatis tinctoria*) was more commonly used as a dye; indigo (*Indigofera tinctoria*), likely imported from India starting in the Ptolemaic era,[2] was more commonly employed as a pigment.[3] The term *indigo* is used throughout this paper to encompass indigotin-based colorants irrespective of plant source.

Pioneered by Webb and colleagues,[4] the MBR technique described in this essay combines one near-infrared image and one visible light image in digital post-processing. This noninvasive and nondestructive technique can visualize and localize materials, including indigo, producing a surface map.

To evaluate our modifications to and application of the imaging technique, analyses were carried out using a visible–near infrared fiber optics reflectance spectrometer and a handheld Raman spectrometer. In addition, samples were taken for analysis using a benchtop Raman instrument.

Paint-out boards created using historically consistent materials were imaged and analyzed with FORS, serving as simplified analogues of the portraits and providing references for known materials in mixtures with indigo.

Multiband Imaging (MBI)

MBI image suites—including visible, ultraviolet-induced visible fluorescence (UVF), ultraviolet reflectance (UVR), IRR, and visible-induced infrared luminescence (VIL) images—of each portrait and paint-out board were captured using a modified Nikon D610 DSLR camera with the UV/IR filters removed and a Jenoptik 60 millimeter UV-VIS-IR APO Macro lens (see fig. 7.2 for lighting and filter specifications). False-color ultraviolet reflectance (FCUV) and false-color infrared reflectance (FCIR) images were generated by combining reflectance captures via channel substitution in Adobe Photoshop.[5] A Spectralon 99 percent reflectance standard from Labsphere,[6] an X-Rite ColorChecker Passport, and an unbound indigo pigment sample[7] were included in all captures (see fig. 7.1). An unbound Egyptian blue pigment sample was included in all VIL captures. MBI suites of the paint-out boards included dry samples of the binding media and pigments used on each board (fig. 7.3).

Figure 7.2 Camera, Filter, and Illumination Sources Used for MBI Imaging

Light Source	MBI Type	Filters
Genaray Spectro LED-14 Lights (Output: 5600K)	Visible (VIS)	IDAS-UIBAR filter (375–700 nm bandpass)
UV Systems LW370 TripleBright II Lights (Output: 368 nm, 5750K)	Ultraviolet-induced visible fluorescence (UVF)	IDAS-UIBAR filter
		Kodak 2E pale yellow optical Wratten filter (410 nm longpass)
	Ultraviolet reflectance (UVR)	X-Nite BP1 filter (320–670 nm bandpass)
		X-Nite 330 filter (270–375 nm bandpass)
Solux Halogen MR-16 Lights (Output: 4700K)	Infrared reflectance (IRR)	X-Nite 830 filter (830 nm longpass)
	Captures taken to be processed for multiband reflectance image subtraction (MBR)	MidOpt BP660 filter (640–680 nm bandpass)
		MidOpt BP735 filter (715–780 nm bandpass)
American DJ RGB LED Lights, Model 64B LED PRO, Red Bulbs CL1 (Output: 629 nm)	Visible-induced infrared luminescence (VIL)	X-Nite 830 filter (830 nm longpass)

All captures taken using a UV-VIS-IR modified Nikon D610 DSLR camera with a Jenoptik 60mm APO Macro lens

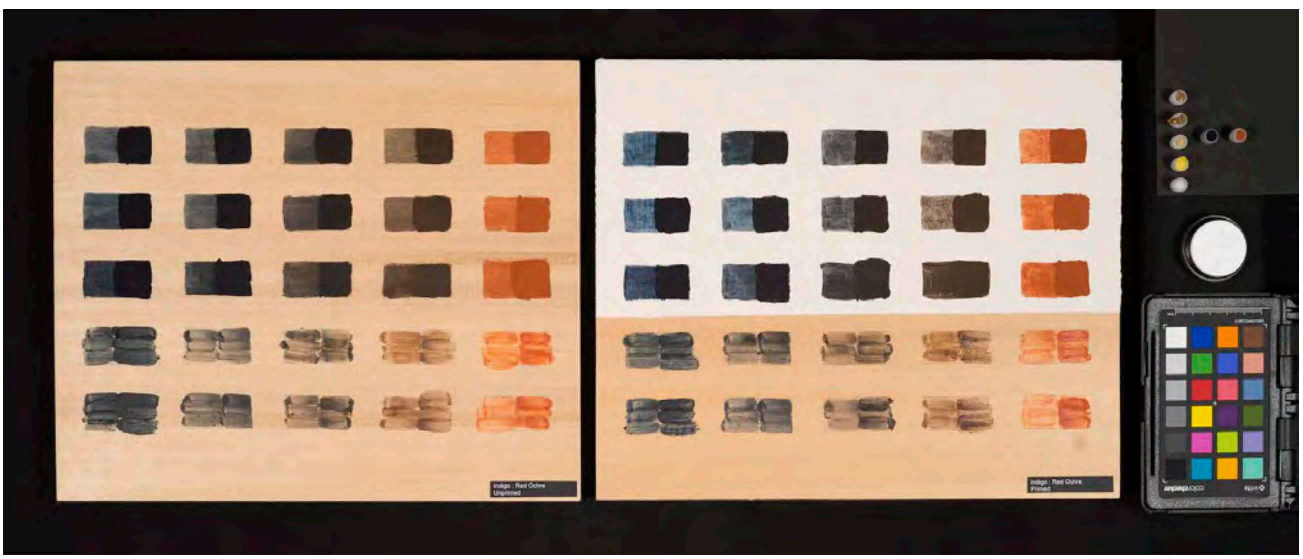


Figure 7.3 Paint-out boards made using indigo and red ochre, unprepared (left) and prepared (right), with reflectance and color standards, and pigment and binder references.

Multiband Reflectance Image Subtraction (MBR)

MBR to localize indigo was performed by illuminating the field with Solux MR-16 halogen bulbs, 4700 Kelvin output, and taking two captures: one with a MidOpt BP660 bandpass filter and one with a MidOpt BP735 bandpass filter. Captures were converted to grayscale in Adobe Photoshop's Camera Raw utility by setting the saturation to -100, and saved as TIFFs.[8] The desaturated TIFF images were then combined using the "Difference" Blend Mode in Photoshop to generate a subtraction image. Processing could alternatively be carried out using free and open-source software such as ImageJ and GIMP.

The “Difference” function takes the absolute value of the difference between two source images, pixel by pixel, to generate a new image. Corresponding source-image pixels with similar RGB values yield small numerical differences, while the combination of pixels with dissimilar RGB values creates large numerical differences. Differences of zero in each color channel result in a black pixel, while differences of increasing magnitude generate pixels approaching white as the values approach 255 in each channel. Materials with little change in reflectance across the spectral regions encompassed by the BP660 and BP735 filters result in small numerical differences and appear dark in the MBR image.

Characteristic reflectance spectra for indigo display strong absorbance around 660 nanometers and strong reflectance just under 800 nanometers. The pairing of narrow bandpass filters centered at 660 nanometers and 735 nanometers exploits the pronounced difference in indigo's reflectance in the visible and near infrared (fig. 7.4).[9] Indigo in various forms, including Maya blue, yields large numerical differences and appears bright in MBR images generated from captures made using these filters. Imaging performed at BKM indicates that other blue materials including lapis lazuli and ultramarine; cobalt-containing blues, such as cobalt blue, smalt, and cerulean blue; and, to a lesser extent, Egyptian blue, can also produce brightness in these images due to their reflectance behaviors.[10] MBR as a characterization technique is strengthened in combination with knowledge of an object's historical context and through corroboration by other imaging and analytical methods.

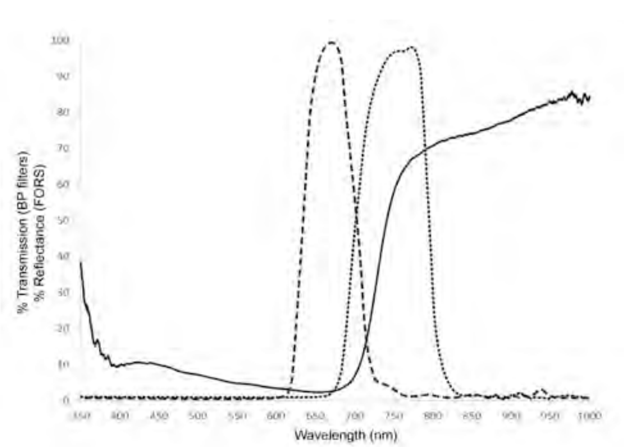


Figure 7.4 Transmission curves for the MidOpt BP660 (dashed line) and BP735 (dotted line) filters overlaid with a FORS spectrum for indigo in cowhide glue (solid line).

To achieve reliable and consistent MBR results, the measured exposure of the BP660 capture should be as close as possible to that of the BP735 capture without exceeding it.[11] Because the two bandpass filters pass different amounts of light, the BP660 capture typically requires a longer exposure time than that of the BP735 capture to result in a pair of images in which the BP660 capture is as close as possible to but still darker than the BP735 capture. Ensuring that the exposure gap between the two captures is as narrow as possible maximizes the specificity of the MBR technique, highlighting those materials with the largest differences in reflectance in this spectral region. The exposure of each capture was assessed using the RGB values of the Spectralon reflectance standard and the Neutral 8 gray square on the X-Rite ColorChecker Passport. The ColorChecker gray square was used because the American Institute for Conservation imaging guidelines already utilize this standard, recommending an RGB value of 200 in both visible and infrared photography.[12]

As with many imaging techniques, shifts in camera position or lighting between captures and uneven lighting can confound processing and undermine the usefulness of reflectance and color standards. Unlike with many other imaging techniques, suboptimal captures not only lower the quality of MBR results but can actually create misleading or erroneous images. Capture sets where one or both relative exposure values were higher in the BP660 shot were empirically found to produce erroneous results, in which some materials appeared bright or dark in ways not clearly related to each other or to known reflectance behaviors. Capture sets with the desired arrangement of exposures but larger exposure gaps produced MBR images with wider grayscale ranges, reducing the specificity of the technique. Adjusting exposures post-capture utilizes nonlinear functions and can also yield unrepresentative results.

Raman

Raman analysis of samples taken from the portraits was performed microdestructively using a benchtop Bruker Senterra Raman spectrometer equipped with a 50x microscope objective and a charge-coupled device (CCD) detector. A continuous-wave diode laser emitting at 785 nanometers was used as the excitation source, and two holographic gratings (1800 and 1200 rulings per mm) provided a spectral resolution of 3 to 5 reciprocal centimeters. The output laser power, number of scans, and integration time were adjusted based on the Raman response of the sample being analyzed.

In situ Raman analysis was conducted nondestructively using a handheld Bruker Bravo Raman spectrometer equipped with a CCD detector, featuring double laser excitation (785 nm and 852 nm) and providing a resolution of 10 to 12 reciprocal centimeters. The output laser power was approximately 50 milliwatts for both lasers, while the number of scans and integration time were adjusted based on the Raman response of the area being analyzed. Spectra were interpreted by comparison with the Metropolitan Museum of Art's library databases and with published literature.

Fiber Optics Reflectance Spectroscopy (FORS)

FORS readings were taken using an Ocean Optics FLAME-S-UV-VIS-ES spectrometer with an instrument range of 350 to 1000 nanometers, a cable range of 400 to 2100 nanometers, and a full-width, half-maximum optical resolution of approximately 1.5 nanometers. Spectra were recorded using OceanView software, and data were interpreted and plotted using Microsoft Excel. Three to five readings were taken for each color analyzed.

X-Ray Fluorescence Spectroscopy (XRF)

XRF readings were taken using a handheld Bruker Tracer III-V$^+$ instrument with a rhodium source, a beryllium sample window roughly 3 by 4 millimeters, and a SiPIN detector. Two readings were taken at each spot: one at 40 kiloelectron volts, 3 microamps, 60 seconds, and one at 15 kiloelectron volts, 32 microamps, 60 seconds under vacuum to improve sensitivity to lower-mass elements. Spectral data were acquired and interpreted using S1PXRF and Artax software.

Paint-Out Boards

A set of reference paint-out boards was made as a guide to better understand how indigo-containing paint films respond to MBR (see fig. 7.3). The materials used to make the boards were selected based on a literature review of Romano-Egyptian painting practices, on material characterizations in the APPEAR database, and on FORS and XRF analyses of the BKM portraits. Five binding media and seven pigments in addition to indigo, all unaged, were chosen.[13]

Linden (*Tilia americana*) panels were used as the support wood. In the APPEAR database, portraits described as having an aqueous binder usually have a white ground layer, while those described as wax commonly have no ground, or sometimes a black ground. The white ground on many aqueous portraits, including figure 7.5, is thickly applied with a visible brush texture.

Figure 7.5 Boy with a Floral Garland in His Hair, Romano-Egyptian, ca. AD 200–230. er-Rubayat. Tempera on *Tilia europaea* panel, 29.9 x 19.8 cm (11 3/4 x 7 13/16 in.). Brooklyn Museum, Charles Edwin Wilbour Fund, 41.848. Image: Brooklyn Museum Conservation Department

One set of panels was sized with two layers of cowhide glue followed by a partial ground layer of gypsum bound in cowhide glue, applied to mimic the brush texture observed on the portraits. The other set of panels was left unprepared as a comparative control.

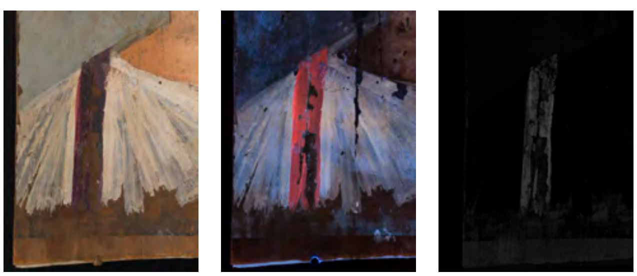
On each board, gradients between indigo and one other pigment were established using three aqueous binders—one cowhide glue and two rabbit-skin glues—and two beeswax binders—one yellow and one white. The pigments include Egyptian blue, orpiment, madder, red ochre, gypsum, lead white, and vine black. On the prepared boards, the aqueous paint-outs were applied over the gypsum ground and the wax paint-outs were applied directly on the sized wood. Each gradient step was divided into two halves. For the aqueous paint-outs, the halves comprise a single and a double layer of the same paint, while for the encaustic paint-outs, each half represents the same amount of wax combined with more or less pigment.

Indigo has a high tinting strength and was found on many of the BKM portraits in mixed pale purple hues that would have required only small amounts of colorant to create. To better represent the hues observed in the portraits, an additional pair of boards was made using minute quantities of indigo mixed with red ochre or madder.

Results

Indigo was identified on five of the six portraits in the BKM collection using FORS and Raman in combination with MBR images. On the three encaustic paintings in which it was identified, indigo was found exclusively in mixtures with a red lake pigment. On the two tempera portraits, indigo was detected more extensively throughout and in a broader range of color mixtures.

On the encaustic portraits of Demetrios and the Noblewoman (see fig. 7.1), the *clavi* were rendered using indigo-containing paints applied to different effects. On Demetrios, a rich, dark purple layer was applied over a lighter pink layer. On the Noblewoman, overlapping brushstrokes of purple and pink paints with varying opacities were used. Indigo was identified in the purple paints on both portraits, but not in the pinks (fig. 7.6).[14] A red lake pigment, most likely madder,[15] comprises the dominant pigment in the pink paint and is mixed with indigo to make the purple.



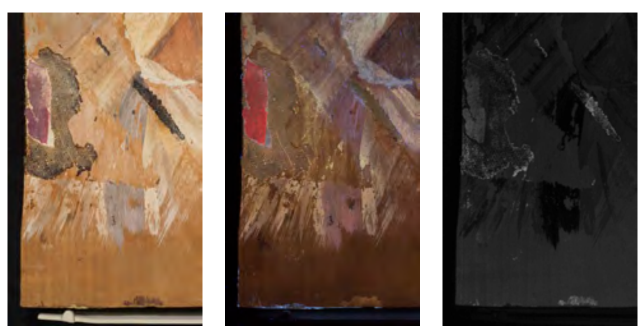
a. Normal light **b. UVF** **c. MBR**

Figure 7.6 Details of the *clavus* on fig. 7.1. Normal light, UVF illustrating the red lake pigment's characteristic pinkish-orange fluorescence, and MBR illustrating indigo's bright response. The brightness of the MBR image has been enhanced for legibility.

The Mummy Portrait of a Man is an encaustic portrait that retains remnants of funerary wrappings, including resin, textile, and white cartonnage painted with tempera (fig. 7.7). This portrait has two *clavi*: one rendered in encaustic and painted at the same time as the sitter's face, and one in tempera that was added on top of the cartonnage when the panel was integrated into the mummy bundle. The encaustic *clavus* was ultimately covered by wrappings.

Indigo was found only in the purple of the tempera *clavus* and was mixed with a red lake pigment (fig. 7.8). XRF, FORS, and Raman spectroscopy found no evidence of a blue pigment in the blue-gray encaustic *clavus*.

Figure 7.7 Mummy Portrait of a Man, Romano-Egyptian, ca. AD 120–130. Encaustic on *Cupressus sempervirens* panel, gold leaf, 43.8 x 19.7 cm (17 1/4 x 7 3/4 in.). Brooklyn Museum, Charles Edwin Wilbour Fund, 40.386. Image: Brooklyn Museum Conservation Department



a. Normal light **b. UVF** **c. MBR**

Figure 7.8 Details of fig. 7.7. Normal light, UVF, MBR showing the bright responses of indigo on the painted purple cartonnage and of the resin associated with the mummy wrappings. The brightness of the MBR image has been enhanced for legibility.

On the tempera portraits, indigo was identified in mixtures, creating both blue and purple colors. Indigo was used as the dominant pigment to paint bluish details including the rims of the cups and the bases of the garlands held by both sitters. On the Portrait of a Young Person (fig. 7.9), indigo was also detected in the dark blue decorative bands on the neckline of the undertunic. On the Boy with a Floral Garland in His Hair (see fig. 7.5), indigo was found in the leaves and flowers of the floral crown, as well as in the decorative bands and the *clavus*, where it was mixed with a red lake pigment to create a pale purple hue (fig. 7.10). These regions showed a very faint MBR response, appearing light pink in FCIR and light blue in FCUV. These false-color responses are similar to those observed on the paint-outs made as a reference for the pale purple hue using a small quantity of indigo mixed with madder.

Figure 7.9 Portrait of a Young Person, Romano-Egyptian, ca. AD 200–230. Tempera on *Ficus sycomorus* panel, 28.4 x 15.7 cm (11 3/16 x 6 3/16 in.). Brooklyn Museum, Charles Edwin Wilbour Fund, 54.197 Image: Brooklyn Museum Conservation Department

Figure 7.10 MBR detail of fig. 7.5, showing the bright response of indigo in the floral garland as well as the less pronounced responses of red ochre and of the panel wood exposed by paint loss. The brightness of the MBR image has been enhanced for legibility. Image: Brooklyn Museum Conservation Department

Discussion

The use of multiple techniques clarified what data each method can yield individually and what information can be gleaned when the results are considered together. FORS analysis, which essentially exploits the same reflectance phenomena as MBR, provided localized spectral information that corroborated the material responses observed in the MBR images and elucidated the circumstances under which the subtraction technique can yield misleading results. Raman analysis was used as a complementary technique to substantiate or challenge material characterizations made using MBI and FORS. The full MBI suite and XRF data were considered in combination with results of these analyses to further characterize the pigments present on the portraits.

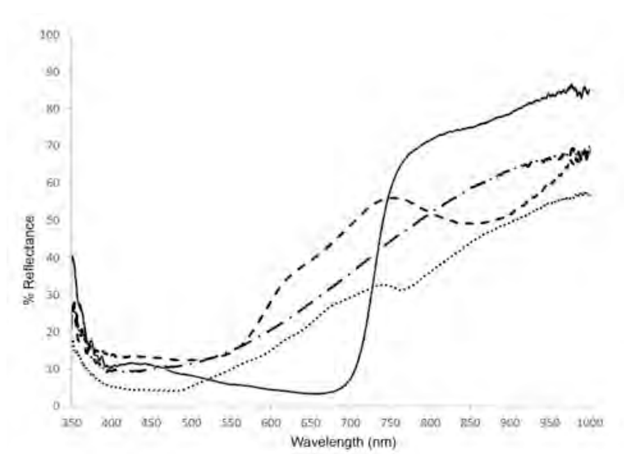


Figure 7.11 FORS spectra of wood (dot-dash line), resin (dotted line), and red ochre (dashed line), overlaid with an indigo spectrum (solid line).

Materials that have reflectance behaviors similar to those of indigo, in the range of 660 to 800 nanometers, can result in confounding MBR responses. In Romano-Egyptian mummy portraits, such materials include wood, resin, and red ochre (fig. 7.11). Wood yielded a consistent MBR response, both on unpainted areas of the reference boards and on the portraits where thin paint application or loss exposed the wood support (see fig. 7.10). On the Mummy Portrait of a Man (see fig. 7.7), translucent red-brown resin associated with the mummy wrappings appeared almost as bright as the indigo-containing paint (see fig. 7.8). Red ochre was faintly visualized on the reference paint-outs (fig. 7.12) and on the two tempera portraits in the dark red outlines surrounding the flesh tones and in the dark reds of the garlands (see fig. 7.10). Visual examination combined with MBR imaging could imply the dark purple-red color on the portraits was achieved through an admixture of indigo; however, XRF, Raman spectroscopy, and FORS indicated the color was achieved by red ochre alone.

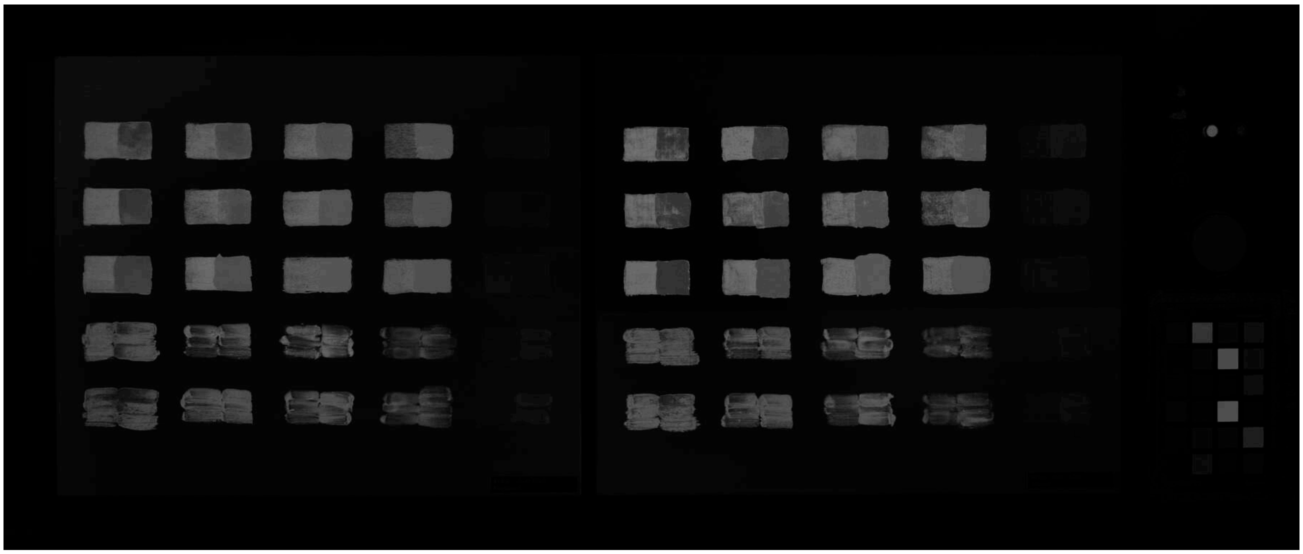


Figure 7.12 MBR of the paint-out boards made using indigo and red ochre pigments.

Using multiple images from the MBI suite in concert can elucidate the distribution of pigments across a painted surface. In the Boy with a Floral Garland in His Hair (see fig. 7.5), the floral crown was painted using white, blue, pink, and red. The blue leaves and bands on the flowers contain indigo and appear bright in the MBR image. The dark red paint surrounding the center of each flower contains red ochre and appears faintly visible (see fig. 7.10). The pink centers of the flowers appear dark and were painted using a red lake pigment, likely madder. In the absence of other analytical techniques, UVF and FCUV images can help characterize madder and red ochre (figs. 7.13 and 7.14). On the crown, the red lake pigment fluoresces brightly under ultraviolet radiation and appears blue in FCUV images, while the red ochre absorbs, appearing dark in UVF and dark purple in FCUV. These color responses and relationships proved consistent throughout this project, enabling comparisons across portraits, paint-out boards, and reference standards.

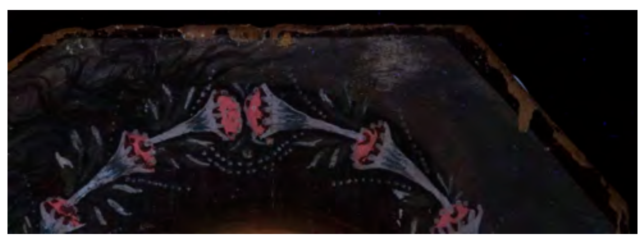


Figure 7.13 UVF detail of fig. 7.5, showing the characteristic pinkish orange fluorescence of the red lake pigment in contrast to the nonfluorescent red ochre. Image: Brooklyn Museum Conservation Department

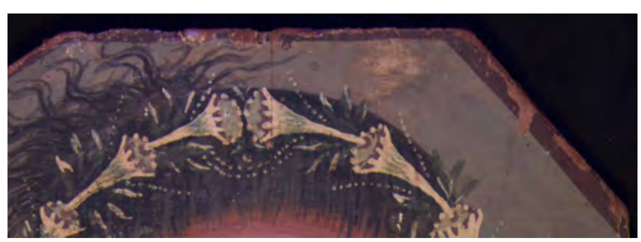


Figure 7.14 FCUV detail of fig. 7.5, showing the blue color of the red lake pigment in contrast to the dark purple color of the red ochre. Image: Brooklyn Museum Conservation Department

Synthesizing the results of multiple techniques provides a richer understanding of material usage and distribution. On the Noblewoman (see fig. 7.1), the hair was rendered by applying an unmodulated layer of paint over the black ground; the hairstyle was then defined by adding a central part and tightly coiled curls at either ear in addition to short, directional highlights. FORS and handheld Raman identified indigo in the curls and highlights; however, MBR yielded no visible response. Images of the reference boards suggest that minute amounts of indigo are difficult to visualize via MBR. The painted details in the hair appear somewhat degraded under magnification; aging of the pigments and/or binding media may be affecting indigo's MBR response. The hairstyle details fluoresce strongly under UV, consistent with madder (fig. 7.15). Considering the FORS and Raman data together with the UVF image strongly suggests the brushstrokes comprise an indigo-madder mixture. Additionally, the blue-green color of these brushstrokes in FCUV (fig. 7.16) is similar to the FCUV color of the unbound indigo standard included in all images and of indigo mixed with madder on the paint-out boards. Although FCUV alone is not diagnostic for indigo, within this suite of images it is notably corroborative.

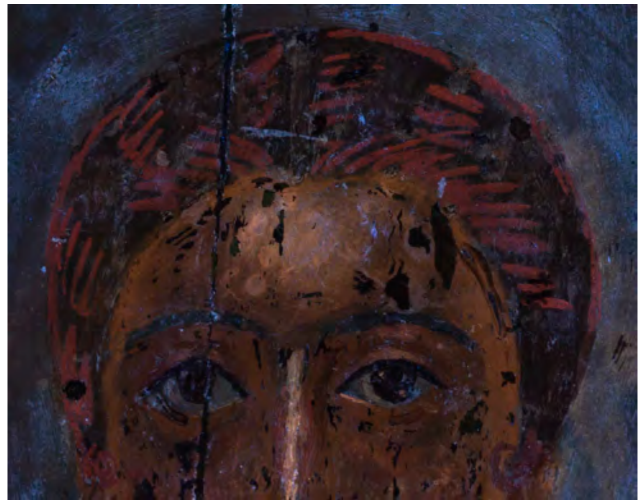


Figure 7.15 UVF detail of fig. 7.1, illustrating the characteristic fluorescence of the red lake pigment in the highlights in the hair. Image: Brooklyn Museum Conservation Department

Figure 7.16 FCUV detail of fig. 7.1, showing the blue-green color in the highlights, consistent with indigo. Image: Brooklyn Museum Conservation Department

Conclusion

The setup and capture protocols developed during this investigation generate consistent MBR images using accessible tools and software. MBR is a relatively straightforward and low-tech method for characterizing and mapping materials, such as indigo, across the surface of an object, which can inform further analysis or enable extrapolation from spot assays. MBI image suites can help clarify material responses by considering behaviors across different wavelengths and bands.

Further research could advance the noninvasive characterization and mapping of materials in cultural heritage objects.[16] MBR performed with the filters discussed here could be used to investigate the effectiveness of imaging indigo-containing paint that has been covered as a result of conservation treatment. Additional imaging and analysis of Romano-Egyptian portraits and reference paint-outs could address questions about how aging impacts indigo's MBR response. Future MBR studies could investigate new combinations of filters to target other materials with pronounced changes in reflectance within the ultraviolet, visible, and infrared spectral regions.

Acknowledgments

The authors would like to thank Anna Serotta for advising and helping to carry out the imaging; Sylvana Barrett and Marie Svoboda for sharing their expertise with historical painting practices; Caroline Cartwright for generously performing wood identification on the BKM portraits; BKM curators Edward Bleiberg and Yekaterina Barbash and curatorial assistant Kathy Zurek Doule for enabling this research; BKM interns Colleen Watkins, Natasha Kung, Meredith Menache, Josephine Ren, Ariana Smith, Anneliese Holmes, and Heather Hodge for their assistance in making the paint-out boards; Nathan Griffith for sharing his understanding of image processing softwares and functions; and the BKM conservation department along with Anne Pasternak, Shelby White and Leon Levy Director of the Brooklyn Museum, for supporting this project. Raman analysis was carried out at the Department of Scientific Research of the Metropolitan Museum of Art, as part of the Network Initiative for Conservation Science (NICS). Support for NICS was provided by a grant from the Andrew W. Mellon Foundation.

NOTES

1. Schweppe 1997.
2. Peacock 2000.
3. Hofenk de Graaff 2004b.
4. Webb, Summerour, and Giaccai 2014.
5. Kushel 2011, sections 6.4.7, 6.5.8.
6. This Spectralon exhibits 99 percent reflectance from 400 to 1600 nanometers, decreasing to a minimum of approximately 95 percent reflectance from 250 to 400 nanometers and from 1600 to 2500 nanometers. “Spectralon® Diffuse Reflectance Standards,” Labsphere, accessed December 21, 2018, https://www.labsphere.com/site/assets/files/2628/pb-13058rev01_standards.pdf.
7. Indigo, Indian, powder, *Indigofera tinctoria*, Kremer Pigments item 36000.
8. Post-processing desaturation is not included in the MBR technique performed at the Smithsonian Museum Conservation Institute, which used a camera modified to capture monochrome images. The system used for this paper was based on modifications to BKM's existing MBI kit, which does not include a monochrome camera but is more accessible.
9. MidOpt bandpass filter transmission curves from “BP600 Dark Red Bandpass Filter” and “BP735 Near-IR Bandpass Filter,” MidOpt, accessed January 11, 2019, http://midopt.com/filters/bp660/; and http://midopt.com/filters/bp735/.
10. Presentation delivered on May 16, 2019, American Institute for Conservation, 47th Annual Meeting, “Materials Characterization with Multiband Reflectance Image Subtraction at the Brooklyn Museum: A New Tool for the Multiband Imaging Kit.”
11. This may seem mathematically arbitrary, but it follows the optical behavior of indigo, as it absorbs at 660 nanometers and appears dark in the BP660 capture and reflects at 735 nanometers and appears light in the BP735 capture.
12. Warda 2011.
13. Materials list:

    Indigo (see note 7)

    Linden wood (*Tilia americana*), Woodworkers Source

    Cow hide glue, cubes, Kremer Pigments item 63020

    Rabbit skin glue, cubes, Kremer Pigments item 63025

    Rabbit skin glue, undated historical BKM lab materials

    Beeswax, natural, bright yellow beads, Kremer Pigments item 62200

    White beeswax, white beads, Natural Pigments

    Gypsum, food-grade calcium sulfate, LD Carlson

    Egyptian blue, Kremer Pigments item 10060

    Red Moroccan ochre, Kremer Pigments item 116430

    Orpiment, Kremer Pigments item 10700

    Madder lake, made from natural roots, Kremer Pigments item 37202

    Lead white, undated historical BKM lab materials

    Vine black, Kremer Pigments item 47000
14. All MBR images in this paper have been slightly enhanced for print.

15. The red lake pigment is most likely madder, based on the characteristic pinkish orange fluorescence observed in UVF and on the well-documented use of madder in this part of the classical world; see Daniels et al. 2014.

16. Dyer et al. 2018.

8

Invisible Brushstrokes Revealed: Technical Imaging and Research of Romano-Egyptian Mummy Portraits

Evelyn (Eve) Mayberger
Jessica Arista
Marie Svoboda
Molly Gleeson

Little is known about the techniques or materials employed for underdrawings in Romano-Egyptian mummy portraits. Preliminary sketches are not typically observed on painted funerary portraits; however, during recent technical investigations on three distinct mummy portraits at three different institutions, conservators using technical imaging revealed previously undetected brushstrokes. Under the auspices of the APPEAR project, the Penn Museum (Penn), J. Paul Getty Museum (Getty), and Museum of Fine Arts, Boston (MFA) independently discovered formerly unobserved brushstrokes by using visible-induced visible luminescence (VIVL) imaging on certain mummy portraits in their collections. The "invisible brushstrokes," or fluorescence,[1] are not visible to the naked eye, but they are present on three very distinct portraits ranging in temporal periods (AD 100–250), painting techniques (e.g., tempera versus encaustic), and substrates (e.g., wooden panel versus linen textile). Although all the portraits depict young men, these invisible brushstrokes appear to have been employed for different stylistic effects. Uniting these observations is the fact that the brushstrokes were undetected until the portraits were imaged under a narrow band of visible light (535–555 nm).

The principal application for VIVL imaging in the conservation field has been to visualize fluorescent pigments (or other materials) on painted surfaces. Materials that exhibit luminescence (emitted radiation) can be excited by a wide range of wavelengths, but optimum excitation occurs within a narrow range of wavelengths. For this paper, various methods of observing VIVL on mummy portraits were compared, and we found that detecting the invisible brushstrokes required specific setups and access to specialized equipment. Because VIVL fluorescence can be weak and easily quenched, a careful evaluation of materials must occur before interpreting VIVL imaging results.

The collaborative nature of the APPEAR initiative facilitated connections and exchange of expertise across disciplines, which was essential for this paper. Without this framework, the independent discoveries of these invisible brushstrokes could have been attributed to specific mummy portraits rather than interpreted collectively as a new phenomenon. A goal of this paper is to encourage institutions to continue to undertake basic research on mummy portraits in their collections and share findings. The discovery of the invisible brushstrokes at the Penn, Getty, and MFA happened within the research priorities of each institution, and we are indebted to colleagues in conservation science, imaging, and curatorial for their valuable input. The research is ongoing, and this publication strives to present the initial findings.

Imaging and Analysis Background

The VIVL imaging that revealed this phenomenon was possible because each institution had access to a SPEX CrimeScope unit, a tunable radiation source used for forensic applications.[2] The wavelength of the emitted light is controlled by filter wheels that enable objects to be examined under lighting conditions ranging from ultraviolet (UV) to infrared (IR). When each portrait was imaged specifically with the CrimeScope at 535 nanometers and 555 nanometers, previously unobserved brushstrokes became visible. The brushstrokes exhibited a response similar to that of madder lake, which has a known fluorescence excitation maximum of approximately 550 nanometers and an emission maximum of approximately 600 nanometers.[3] The unexpected detection of these invisible brushstrokes prompted further questions about the artists' materials, intentions, and working techniques. Madder lake was identified on other areas of the paintings, such as the purple tunic on the MFA portrait and the purple *clavi* on the Getty shroud.[4] The similar behavior of the areas of confirmed madder and the invisible brushstrokes, when imaged with the CrimeScope, prompted the hypothesis that the fluorescent brushstrokes could be a madder-based material (e.g., an organic lake pigment.) The facts that the brushstrokes could not be detected through the standard diagnostic methods using ultraviolet (UV) radiation (300–400 nm), are not readily evident on the surface in visible light, and cannot be identified through nondestructive surface analyses indicate that they may be present as a mixture or underlayer; however, the extensive sampling needed to confirm this hypothesis was not possible at this time.

To investigate these invisible brushstrokes, conservators, conservation scientists, and imaging specialists carried out thorough examination, imaging, mock-ups, and both nondestructive and destructive technical analysis on the three mummy portraits. Techniques employed included optical microscopy (OM), polarized light microscopy (PLM), reflectance transformation imaging (RTI), standard multispectral imaging (MSI), (portable) X-ray fluorescence (pXRF, XRF), fiber optics reflectance spectroscopy (FORS), fluorescence excitation-emission matrix spectroscopy (EEM), Fourier transform infrared spectroscopy (FTIR), gas chromatography/mass spectroscopy (GC/MS), liquid chromatography/mass spectroscopy (LC/MS), and Raman spectroscopy.[5] An important goal of this Penn-Getty-MFA collaborative project is to replicate the CrimeScope VIVL images at the narrow bandpass of 535 to 555 nanometers without the use of this expensive and proprietary instrument. The hope is to present a possible imaging alternative, making this type of investigation more accessible to a greater number of institutions. Given that this phenomenon was discovered on three distinct portraits, it is likely that this unexplained fluorescence could be found on additional Romano-Egyptian mummy portraits.

Discovery of the Brushstrokes

The Penn Museum has been actively collecting technical data on three Romano-Egyptian mummy portraits in its collection. The painting pivotal to this research, Portrait of a Young Man (fig. 8.1), depicts a youthful man with dark curly hair, large eyes, and facial hair; he wears a white tunic. Executed on a white background, the painting was painted in encaustic on a wooden panel; based on style, the work has been dated to approximately AD 100. Records indicate that the portrait was discovered in er-Rubayat.[6] It entered the Penn Museum in 1894, when the portrait was purchased from the collection of Theodore Graf. Initial examination of the panel revealed nothing unexpected;[7] however, when the work was imaged with the CrimeScope at specific wavelengths of light (535 nm and 555 nm), cursory brushstrokes outlining the figure became clearly visible (fig. 8.2). The brushstrokes appear to have been executed quickly, perhaps serving to roughly sketch out the composition. The exact location of the lines within the paint stratigraphy, however, could not be confirmed. Given the fluorescence range, a madder-based pigment was suggested early on as a potential material known to have been used on mummy portraits.

Figure 8.1 Portrait of a Young Man, Romano-Egyptian, ca. AD 100. Encaustic on wooden panel, 25 x 18 cm (9 7/8 x 7 1/8 in.). Philadelphia, University of Pennsylvania Museum of Archaeology and Anthropology, Purchased from Theodor Graf, 1894, E16213. Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

Figure 8.2 VIVL image of fig. 8.1. Camera: Canon EOS D5 Mark III (unmodified); SPEX Mini CrimeScope® MCS-400 (535 nm); Tiffen 23A red filter (grayscale). Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

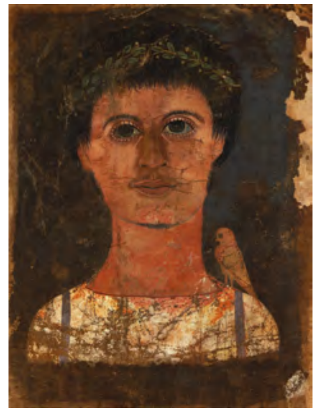


Figure 8.3 Mummy Shroud with Painted Portrait of a Boy, Romano-Egyptian, AD 72–213. Tempera on linen, 62 × 52.5 cm (24 7/16 x 20 11/16 in.). Los Angeles, J. Paul Getty Museum, Gift of Lenore Barozzi, 75.AP.87.

Figure 8.4 VIVL image of fig. 8.3. Camera: Nikon D90 (modified); SPEX Mini CrimeScope MCS-400 (555 nm); PECA 916 and red long pass filters (grayscale). Courtesy of the UCLA/ Getty Program in Archaeological and Ethnographic Conservation

The Getty's sixteen Romano-Egyptian mummy portraits were also examined and imaged using the CrimeScope.[8] Only one portrait revealed an unexpected fluorescence: Mummy Shroud with Painted Portrait of a Boy (fig. 8.3), which shows a dark-haired, large-eyed young boy wearing a white tunic with purple *clavi*. He has a wreath with green leaves and yellow berries, and a hawk perches on his proper left shoulder. The shroud, painted with tempera on linen, dates to approximately AD 72 to 213.[9] Although the exact findspot in Egypt is unknown, the mummy shroud entered the Getty Museum in 1975 as a gift from Lenore Barozzi. Following a systematic approach in the study of the Getty portraits, extensive analysis and imaging were carried out on the shroud.[10] Imaging the portrait with the CrimeScope revealed invisible brushstrokes restricted to the area just under the eyes, at the same 535 nanometers and 555 nanometers narrow bandpass (fig. 8.4). The fluorescence was not detected with any other analytical or imaging technique, and FORS analysis identified only red ochre (hematite) on the surface. The young boy's *clavi*, confirmed to be madder lake,[11] exhibited a fluorescence similar to that of the area under the eyes, which suggests that a madder-based pigment could have been used within the stratigraphy of the paint layers. The highly specific use of a pinkish tone under the eyes implies that the artist may have been attempting to create dimension and a fleshlike effect—a sophisticated approach to painting by the ancient artist.

In 2016 the British Museum hosted the interim APPEAR meeting, where speakers presented their preliminary research. Researchers from both the Penn and Getty discussed their independent findings of these invisible brushstrokes, initiating discussion and establishing research collaborations between museum participants. In subsequent months, the MFA would also discover previously undetected brushstrokes with VIVL imaging, after using the CrimeScope on one of its mummy portraits, and join the partnership.[12]

The MFA has twelve Romano-Egyptian mummy portraits in its collection. Funerary Portrait of a Young Man (fig. 8.5) depicts a young man against a dark gray background. He has dark curly hair and a beard as well as large eyes, and he wears a purple tunic; a coating is present on the surface. The portrait was painted in tempera on a wooden panel and based on its painted style is dated to the early third century AD. The work was acquired from an individual in São Paulo, Brazil, in 1959. In late 2016, the MFA briefly had access to a CrimeScope unit. Imaging performed on the portrait clearly revealed similar brushstrokes around the hairline and on the beard when the same 535-nanometer and 555-nanometer narrow bandpass filters were used (fig. 8.6).[13] Under magnification, select brushstrokes are slightly visible as hazy areas on the surface; without VIVL imaging via the CrimeScope, these marks could not be identified through visual examination alone. Analysis of the portrait by EEM positively identified madder on the highly concentrated purple of the tunic.[14] Likely due to the surface coating, it was not possible to detect madder in any of the areas of the brushstrokes.

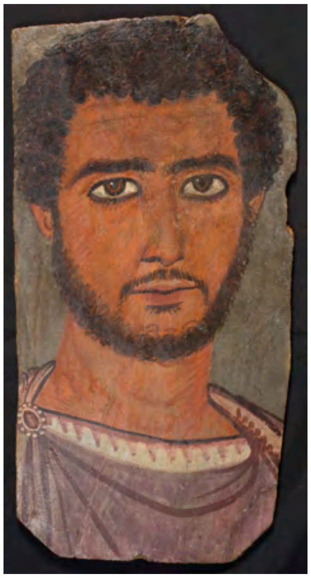


Figure 8.5 Funerary Portrait of a Young Man, Romano-Egyptian, early third century AD. Tempera on wooden panel, 31 x 16.5 cm (12 3/16 x 6 1/2 in.). Boston, Museum of Fine Arts, Abbott Lawrence Fund, 59.340. Photograph © Museum of Fine Arts, Boston. Image: E. Mayberger and J. Arista

Figure 8.6 VIVL image of fig. 8.5. Camera: Canon EOS D5 Mark III (unmodified); SPEX Mini CrimeScope® MCS-400 (535 nm); B+W UV-IR-Cut (486 MRC) and Tiffen 23A red filters (grayscale). Photograph © Museum of Fine Arts, Boston. Image: E. Mayberger and J. Arista

Contextualizing the Brushstrokes

Although the purpose of these enigmatic brushstrokes may never be fully understood, it is clear that ancient artists intentionally employed material in ways more sophisticated than previously known. Underdrawings, although uncommon, made from carbon-based media have been found on other mummy portraits.[15] Egyptian blue was also used imperceptibly for underdrawings and highlights, and it was added to white pigment to enhance or brighten select details (e.g., eyes and tunics).[16] Although the invisible brushstrokes on these three portraits are neither a carbon-based medium nor Egyptian blue, their presence is purposeful. They appear to have been used to create sketchy outlines or underdrawings around the figure on the Penn portrait, to give fleshlike warmth and dimension to the Getty figure's face, and to add vibrancy, depth, and radiance to the MFA figure's hair. We hypothesize that the brushstrokes contain madder, an organic material known to fade over time. As such, it is possible that the visual effect of these brushstrokes originally would have been more readily apparent.

The root of the madder plant has been used for textile dyeing and pigment making for millennia, and madder-derived dyes and pigments were available widely in antiquity. As madder is an organic pigment, its appearance and fluorescence are affected by several different factors, ranging from the method of pigment extraction and manufacture to binding media selection. The one material that exhibits a similar fluorescence to madder is safflower; however, it was not commonly used as a colorant on cultural artifacts in the ancient world, and no published occurrences confirming the use of safflower on painted objects from the Romano-Egyptian period exist.[17] Unlike many inorganic pigments, madder can be produced to create a range of colors from oranges to reds to purples.[18] Madder was a known material in ancient Egypt and frequently incorporated into the palette of funerary mummy portraits, as Newman and Gates discuss in this volume.

The excitation and emission spectra (fig. 8.7) collected from an MFA mummy shroud depict characteristic examples of madder curves.[19] Madder, known to fluoresce strongly when excited and imaged with UV radiation, can often be identified by its characteristic light orange or bright pink fluorescence. Because many materials fluoresce with UV radiation, limiting the radiation to blue or green light closer to madder's peak excitation wavelength (~550 nm) can reduce the fluorescence noise of other materials and prioritize madder fluorescence. VIVL imaging can achieve this by using narrow bands of visible light to excite the material and a filtered camera system to restrict the range of emission captured.[20]

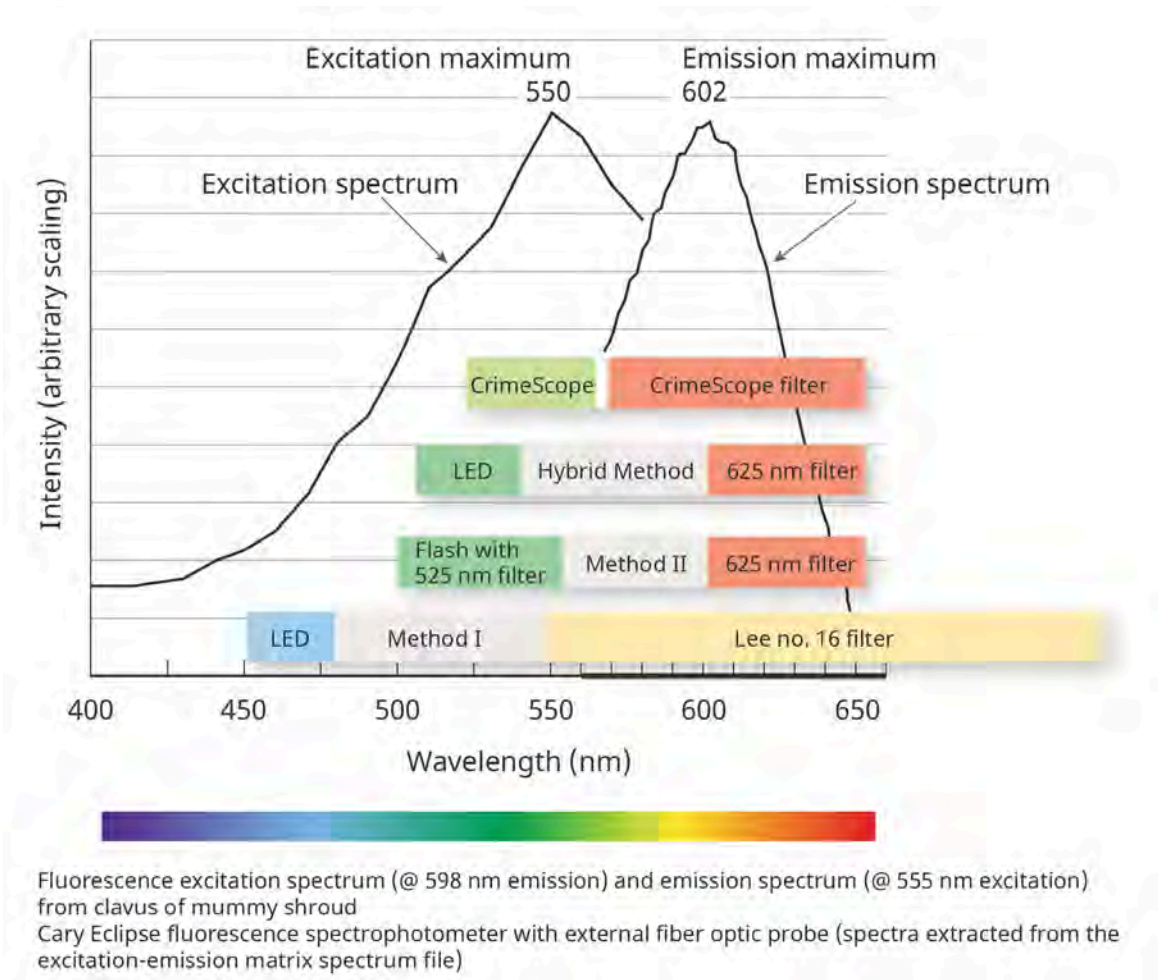


Figure 8.7 Fluorescence of Madder-Type Pigments. Image © Museum of Fine Arts, Boston. Image: R. Newman (spectra) and J. Arista (annotations)

Imaging Research Considerations

All three portraits were the subject of extensive analytical research and imaging. The project brought into focus issues of reproducibility and other challenges involved in MSI. The data collected relied on sophisticated techniques executed by experienced users and were discussed with outside experts. Because of the collaborative nature of the project, participants employed precise and internationally recognized terminology. For imaging, the *CHARISMA User Manual for Multispectral Imaging*[21] was adopted. Although some methods of imaging are routinely used and familiar to most conservators, others are not, so all approaches should be clearly documented to assist with their replication and reproducibility.

For this paper, some VIVL images were rendered in grayscale (see figs. 8.2, 8.4, and 8.6) to facilitate the visualization of the invisible brushstrokes for publication.

One colored VIVL image (fig. 8.8) displays the expected orange fluorescence of madder. Different lighting systems, distance from and intensity of radiation source, filter combinations, and choice of camera can significantly alter VIVL images—consistency even within one institution can be challenging. Carefully reviewing image metadata before directly comparing VIVL images is paramount.[22]

Figure 8.8 VIVL image of fig. 8.1. Camera: Nikon D5200 (modified); SPEX Mini CrimeScope MCS-400 (535 nm); Tiffen 23A red filter. Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

VIVL imaging offers exciting possibilities for material characterization as a noninvasive technique utilizing different radiation sources, filter combinations, and digital cameras. More important than suggesting a prescriptive protocol for studying materials with VIVL imaging is to understand the underlying principles. Specific knowledge of spectral curves for radiation sources and filters is crucial. This schematic (see fig. 8.7) indicates the color of visible radiation and filters placed on the camera to illustrate the process. A gap between the excitation radiation source and emission capture window is required to prevent overlap, which can complicate interpretation. Like most analytical techniques, VIVL imaging produces results that should be corroborated with a second imaging or scientific technique.

Although the APPEAR database does not include technical information from all extant mummy portraits, it provides a statistically relevant framework from which to begin evaluating portraits. The discovery of the invisible brushstrokes alone does not challenge the authenticity of the three portraits even if the phenomenon was completely undetected with all other analysis and imaging techniques. More research needs to be conducted with VIVL imaging to contextualize and accurately identify the invisible brushstrokes discussed in this paper and to see if they are present on other portraits. It is important to note that many factors (e.g., coatings, binders) can affect the fluorescence of a material, and one should avoid making definitive statements about objects based solely on material fluorescence.

VIVL Imaging Methods

The goals of this research were to determine the effectiveness and limitations of the CrimeScope and to test comparable, relatively low-cost and user-friendly setups, to enable other institutions to search for similar features on mummy portraits in their own collections. To better understand the appearance of the invisible brushstrokes, different VIVL testing methods were explored. The methods are illustrated here with images of the Penn mummy portrait.[23] Additionally, two mock-up boards were created and imaged in order to explore the fluorescence behavior of madder below and through paint layers. The results are discussed in the subsequent sections.

CrimeScope Method

The SPEX CrimeScope is a portable instrument equipped with a high-intensity xenon light that can be tuned to specific narrow bands of light (20–30 nm wide) in the UV and visible ranges (some models have attachments for the near IR). The spectral curves are narrow and steep—ideal for VIVL imaging.[24] In addition to the radiation source, the manufacturer provides colored glasses (yellow, orange, red) to facilitate the differentiation of materials.[25] Conversations with the manufacturer resulted in identifying comparable camera filters based on the Wratten numbering system. Understanding the spectral curves for both the radiation source (narrow bands at 535 nm and 555 nm) and camera filters (Tiffen 23A filter 50% transmittance ~580 nm) made it possible to target material fluorescence. As a result, the image captured with this setup has a red-orange cast (see fig. 8.8). A regular, nonmodified camera can be used for VIVL imaging; however, to capture a set of MSI images, a modified camera should be used with additional filters so resulting images can be overlaid. Despite the advantages of the CrimeScope, this proprietary instrument has some drawbacks. Given the intensity and the handheld source of the xenon beam, illumination consistency between images can be difficult to achieve. Small discrepancies in the distance between the radiation source and object have a great effect on the strength of the fluorescence emission, and the single strong beam can also flatten images when photographed; however, the most limiting factor of the CrimeScope is the cost, which is generally well beyond the budget of most cultural heritage institutions. That said, the CrimeScope method proved to be the most successful technique to detect the invisible brushstrokes on all three portraits.

Experimental Method I

A recently published article[26] presents a new VIVL imaging approach for madder-based pigments using blue LED lights. This method was tested on the Penn and MFA mummy portraits to determine if the invisible brushstrokes could be detected. The excitation source was provided by two American DJ–brand LED lights (dominant wavelength 461 nm). Although the prevailing wavelength is much lower than the peak excitation of madder (~550 nm), the spectrum has a long shoulder. Using camera filter Lee no. 16 (50% transmission at 540 nm) provided a larger acquisition window and gave the images a blue cast with madder fluorescence appearing pink.[27] Although the LED lights do not have the same intensity as the CrimeScope, adjustments can be made to the aperture and exposure settings to maximize fluorescence emission capture.

Method I imaging results on the MFA portrait were mixed. Although madder fluorescence was clearly visible on the large, thickly applied blocks of purple paint, such as on the tunic, the painterly invisible brushstrokes were difficult, if not impossible, to detect without prior knowledge of their location. This may be due to the surface coating or to the nature of the brushstrokes themselves. Method I proved much more effective on the uncoated Penn portrait (fig. 8.9). Comparison of imaging results for the CrimeScope method (fig. 8.10) and Method I (fig. 8.11) on the same area of detail of the Penn portrait illustrates that Method I can be used to detect the invisible brushstrokes.

Figure 8.9 VIVL image of fig. 8.1. Camera: Canon EOS D5 Mark III (unmodified); American DJ–brand 64 LED Pro (blue light); Lee no. 16 filter. Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

Figure 8.10 VIVL image of fig. 8.1 (detail). Camera: Canon EOS D5 Mark III (unmodified); SPEX Mini CrimeScope® MCS-400 (535 nm); Tiffen 23A red filter (grayscale). Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

Figure 8.11 VIVL image of fig. 8.1 (detail). Camera: Canon EOS D5 Mark III (unmodified); American DJ–brand 64 LED Pro (blue light); Lee no. 16 filter. Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

Experimental Method II

The Penn-Getty-MFA partnership led to many conversations with conservation scientists and imaging specialists, which led to another VIVL imaging method (unpublished) being explored.[28] The excitation source was a Speedlite 580 EX II flash with an XNite 525-nanometer bandpass filter (490–560 nm peak width) attached to the light source.[29] An XNite 625-nanometer bandpass filter (590–670 nm peak width) was placed in front of the camera lens. Although both the CrimeScope and Speedlite flash use a xenon bulb, the CrimeScope illumination is continuous and a more powerful light source. Method II lacked sufficient light intensity.

It is unlikely that the invisible brushstrokes would have been detected with Method II alone. The Penn portrait (fig. 8.12) was much easier to image, although the results were dark and the invisible brushstrokes difficult to discern without post-processing enhancement. Potentially, Method II could be improved if a second flash or stronger light source were incorporated. Additional experimentation has yielded mixed but promising results that warrant further investigation (fig. 8.13).[30]

Figure 8.12 VIVL image of fig. 8.1 (detail). Camera: Canon EOS D5 Mark III (unmodified); Speedlite 580 EX II flash; XNite 525 nm bandpass and XNite 625 nm bandpass filters. Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

Figure 8.13 VIVL image of fig. 8.1 (detail). Camera: Canon EOS D5 Mark III (unmodified); American DJ–brand 64 LED Pro (green light); XNite 625 nm bandpass filter. Image: E. Mayberger and M. Gleeson, Courtesy of the Penn Museum

Mock-Up Boards

To test if madder could fluoresce through layers of umbers, ochres, and lead-based pigments when photographed with different VIVL imaging methods, a mock-up board was created at the MFA. Imaging (UV, VIVL) and analysis (EEM) confirmed that a weak madder fluorescence could be detected when present under layers of umbers and ochres, but lead-based pigments quenched any observed fluorescence. Another mock-up board was made at the Getty to explore the different paint-layer possibilities (fig. 8.14) around the eyes of the Getty portrait. Although visible with the VIVL imaging methods tested, the madder fluorescing through one (#3 on mock-up) and two (#4 on mock-up) layers of hematite is most readily apparent when using the CrimeScope method (fig. 8.15). This trial confirms that the observed fluorescence can penetrate through certain paint layers (e.g., ochres, umbers, hematite) and may suggest a possible paint-layering sequence for the area around the eyes on the Getty portrait. The imaging results of these mock-ups indicate that the CrimeScope, with its powerful light source, is the most effective method of those tested for revealing madder under paint layers.

Figure 8.14 Getty Eyes Mock-Up Board, created by E. Adamian. Image: E. Mayberger and M. Gleeson

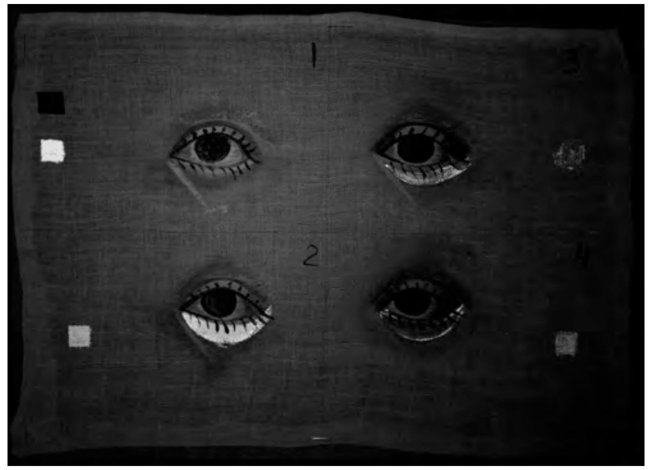


Figure 8.15 VIVL image of Getty Eyes Mock-Up Board. Camera: Canon EOS D5 Mark III (unmodified); SPEX Mini CrimeScope MCS-400 (535 nm); Tiffen 23A red filter. Image: E. Mayberger and M. Gleeson

Conclusions

The Penn-Getty-MFA collaboration enabled the shared discovery of the previously undetected brushstrokes on Romano-Egyptian mummy portraits. Notably, it was possible to detect the brushstrokes only with VIVL imaging; a range of traditional imaging and analytical techniques failed to identify them. VIVL imaging with the CrimeScope produced the best results, due to its continuous xenon-bulb illumination with specific narrow radiation bands. Despite the discussed drawbacks of the forensic instrument, discovery of the brushstrokes would not have been possible without it. Although we had hoped to present Methods I and II as potential, more affordable options for VIVL imaging of the invisible brushstrokes, these alternative VIVL imaging methods produced mixed results; the LEDs and xenon flash did not appear to be strong enough illumination sources to reveal the brushstrokes consistently.

The mock-ups demonstrated that the characteristic fluorescence of madder can be observed even underneath other paint layers if sufficiently excited by an appropriate radiation source. This possibility depends on the thickness of overlying paint and absorbance of the materials in that paint. There must be an adequate amount of both the excitation radiation to an underlying layer containing madder and the emission radiation from the madder for the fluorescence to become apparent to the camera. Other materials in the paint layers (pigments, binders) or coatings present on the surface may affect the ability to observe underlying madder-rich brushstrokes. The condition and materials of the portraits themselves affect the effectiveness of VIVL imaging. Some materials may also fluoresce under the particular excitation wavelengths, and it could conceivably occur (at least in part) in the same region as madder. As such, the invisible brushstrokes described in this paper are not definitively identified as madder (FORS or EEM fluorescence proved inconclusive on the delicate invisible brushstrokes); however, madder was confirmed on other areas of the portraits. It was not possible to sample the invisible brushstrokes in order to confirm the presence of madder at this time.

Given that these invisible brushstrokes were found on three distinct portraits, it is likely that this unexplained fluorescence could be identified on additional examples. Material characterizations and uses may provide evidence for a technique used by specific artists or workshops. We hope that other institutions will be alerted to this unique discovery and incorporate targeted VIVL imaging into their imaging procedures as a means to explore and better understand these arresting and enigmatic portraits.

Acknowledgments

The authors are grateful to a number of individuals for their contributions to this paper, especially Yosi Pozeilov, Richard Newman, Joanne Dyer, Michele Derrick, David Saunders, Pam Hatchfield, Mei-An Tsu, Monica Ganio, Giacomo Chiari, Roxanne Radpour, Christian Fischer, Elmira (Ellie) Adamian, Lydia Vagts, Caitlin Breare, Louise Orsini, Larry Berman, Laure Marest-Caffey, Lynn Grant, Angela Chang, and Walter Hill. The authors would also like to thank the following entities for their support: the APPEAR community; Penn Museum; J. Paul Getty Museum; Museum of Fine Arts, Boston; Andrew W. Mellon

Foundation; the Conservation Center; Institute of Fine Arts, New York University; and the UCLA/Getty Program in Archaeological and Ethnographic Conservation.

NOTES

1. While the VIVL imaging technique refers in its name to luminescence, the phenomenon of interest in this paper is fluorescence.
2. See Fischer and Kakoulli 2006; Kakoulli et al. 2017.
3. Published luminescence research on madder roots, aluminum complexes, and madder lakes (solids mainly involving aluminum complexes) shows a range of excitation and emission maxima. Excitation maxima for madder lakes are around 550 nanometers, which corresponds to green light. The intensity of fluorescence will be at its maximum at excitation wavelengths close to the excitation maxima; however, shorter wavelengths also excite the characteristic fluorescence. Narrow bands of other visible wavelengths, shorter than green wavelengths, also can be used to excite madder fluorescence.
4. The purple-colored areas (e.g., tunic and *clavi*) on both the Getty and MFA portraits have a similar fluorescence to that of the invisible brushstrokes when imaged with the CrimeScope. Madder lake was identified in these concentrated purple-colored areas by UV examination and confirmed with nondestructive FORS (Getty) and fluorescence EEM spectroscopy (MFA) analyses; see the APPEAR database.
5. Unpublished reports containing these results are in the APPEAR database.
6. This archaeological site has several acceptable spellings; this spelling was chosen because it is used in the Penn records.
7. APPEAR research at the Penn Museum focused on imaging (radiography, standard MSI, RTI) and the noninvasive analytical technique of pXRF.
8. We would like to thank the UCLA/Getty Program in Archaeological and Ethnographic Conservation for the use of their Mini CrimeScope (from Horiba Scientific) in imaging the Getty portraits.
9. Carbon-14 date of linen shroud recorded at AD 72–213; see the APPEAR database.
10. APPEAR research at the Getty Museum focused on analysis (pXRF, LC/MS, GC/MS, FORS, Raman, XRD, PLM) and imaging (standard MSI, electron emission radiography).
11. Pseudopurpurin, a component of madder, was confirmed on the *clavi* using LC/MS analysis (APPEAR report by R. Newman); this was corroborated by FORS analysis (APPEAR report by C. Fischer).
12. Change in institutional affiliation by one of the authors (E. Mayberger) brought the knowledge of this phenomenon directly to the MFA.
13. Because of the nature of initial testing with the CrimeScope, many objects were examined in an expedited manner. The pertinent VIVL image captured was unfortunately inadvertently cropped.
14. Museum of Fine Arts, Boston, Scientific Research Report 2016-72.
15. Knudsen 2017.
16. See Ganio et al. 2015, 813.
17. Personal communication with Richard Newman, MFA, March 23, 2018; Vogelsang-Eastwood 2000, 279.
18. Daniels et al. 2014.
19. Madder was identified by EEM on a funerary shroud and mask (97.1100) in the MFA's collection; the pigment was used exclusively to create highlights and volume in areas of the figure's skin.
20. Organic pigments have no significant known fluorescence in the infrared (IR) region; however, it has been published by E. René de la Rie (1982) that a minute tail of the madder fluorescence does extend to the very near IR region.
21. Dyer, Verri, and Cupitt 2013.
22. Images need to be color balanced, and the incorporation of imaging standards (e.g., AIC PhD Targets, Labsphere Spectralon) is essential.
23. The Penn portrait was selected to illustrate the VIVL imaging methods in this paper because the results were the most successful on this uncoated portrait.
24. Exact spectra curves for each filter setting were obtained from the manufacturer; however, a nondisclosure agreement was required.
25. The filter settings and colored glasses were produced for the forensic field and maximized for common materials of interest.
26. Dyer and Sotiropoulou 2017.
27. If an unmodified camera is used, an additional camera filter limiting the capture region to the visible is needed.
28. This method of imaging was developed by Yosi Pozeilov, senior conservation photographer at the Los Angeles County Museum of Art.
29. To attach the bandpass filter to the flash, matte board and black tape were used to make a temporary mounting system.
30. At the MFA, the authors experimented with using American DJ–brand LED lights set on green light (dominant wavelength 526 nm) instead of the blue light used for Method I, and the

same XNite 625 nm bandpass filter used for Method II was placed on the camera lens. It was theorized that green light, which is closer to the excitation maxima, would be more effective. The resulting images were not as successful as those obtained from the CrimeScope, but in some areas the brushstrokes were visible. The Penn portrait imaging results with this hybrid method allow the brushstrokes to be readily discernable.

9

Framing the Heron Panel: Iconographic and Technical Comparanda

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The four painted panels of gods in their original frames known from antiquity were all found in the Fayum and date to between the first and fourth centuries AD, most likely to the second century.[1] A framed panel depicting Sobek and Amun, formerly in Berlin, was destroyed during World War II.[2] Only three survive today: one of Sobek and Min in Alexandria,[3] one of Heron and a god with a double ax, in Brussels (fig. 9.1),[4] and one of Heron alone (fig. 9.2), in Providence, the subject of this paper.

The precise archaeological context of the Providence panel—which was discovered still mounted in its original eight-point frame—is unknown. Likely unearthed in the 1930s, the work was in Maurice Nahman's collection in Cairo by 1938 and appeared in the sale of Nahman's collection at the Hôtel Drouot, Paris, in 1953. The Rhode Island School of Design (RISD) Museum in Providence purchased it from Mathias Komor Fine Arts, New York, in 1959.[5]

Figure 9.1 Heron and Lycurgus, Romano-Egyptian, late second century AD. Tempera on wood, with frame: 33.3 x 29.1 cm (13 1/8 x 11 7/16 in.); without frame: 24.2 x 19.4 cm (9 1/2 x 7 5/8 in.). Brussels, Musées royaux d'Art et d'Histoire, E 7409 © RMAH

Figure 9.2 The God Heron, Romano-Egyptian, late second to third century AD. Tempera on wood, with frame: 58.1 x 48.7 cm (22 7/8 x 19 3/16 in.); without frame: 52.4 x 42.5 cm (20 5/8 x 16 3/4 in). Providence, Museum of Art, Rhode Island School of Design, Museum Works of Art Fund, 59.030. CC0 1.0

The RISD panel (see fig. 9.2) depicts the god Heron wearing a cuirass, *pteruges*, a fringed mantle, greaves, and laced boots. His feet are oriented in the same direction, in the Egyptian convention of depicting standing figures. Bearded and dark haired, his head crowned with a laurel wreath and surrounded by a halo, Heron stares ahead with large eyes. Holding a scroll in his proper left hand, he pours a libation on to the ground from a patera in his right hand, below which is a thymiaterion. Although dressed as a Roman soldier, Heron carries no weapons. To his left a small figure wearing a wreath and a short white tunic offers a rose garland in his right hand and a bouquet in his left. The griffin of the goddess Nemesis, shown beside her wheel, crowns a column farther to Heron's left.[6] Beside the column is a Greek inscription that translates to "On behalf of Panephremmis, for a favor," naming the person for whom the painting was offered but not the actual donor.[7]

Although only a few of these framed panels of gods survive, many more examples must have existed in antiquity.[8] The unpainted edges of other painted panels suggest that they were also originally framed. Among them are a panel of Heron in Berlin; one of Heron and a god with a double ax in a private collection in Étampes; one of a goddess, possibly Isis, in Asyut; and one of Harpocrates/Dionysos in Cairo.[9] However, not all framed panels portray images of gods, as evidenced by a portrait of a woman found in a grave in Hawara, now in the British Museum (fig. 9.3),[10] and a portrait of a man in the Getty.[11]

Figure 9.3 Portrait of a Woman, Romano-Egyptian, ca. AD 50–70. Excavated by Sir William Flinders Petrie at Hawara in 1888. Tempera on wood with twisted rope for hanging, with frame: 45.5 x 41 cm (17 15/16 x 16 1/8 in.); without frame: 25.9 x 20.4 cm (10 3/16 x 8 1/16 in.). London, British Museum, 1889,1018.1.

In construction, the RISD Heron panel, the largest of the extant framed panels, resembles the panel in Alexandria and the now-lost Berlin panel.[12] All three have been constructed of multiple slats of wood held together by an enclosing eight-point frame. The Alexandria panel is composed of three slats of wood, while both the RISD and lost Berlin panels are composed of five slats. It appears that most framed panels were made from multiple slats, though smaller, single-panel examples did exist.[13]

The figure of Heron has been studied extensively in recent years, especially by the French scholar Vincent Rondot. In his book *Derniers visages des dieux d'Égypte* and in articles, Rondot reviewed past scholarship on Heron, explored his origins, and gathered and analyzed all known representations of him to date.[14] Thomas Mathews explored images of Heron and other Romano-Egyptian panel paintings of gods as precursors to Christian icons in his book *The Dawn of Christian Art in Panel Painting and Icons* and in previous work.[15]

Most scholars agree that Heron was not a native Egyptian god, but his origins are still debated. Some believe that he came from Thrace, where he was worshipped by soldiers, and that Thracian settlers brought him to Egypt in the Ptolemaic period.[16] Others, like Rondot, believe that Heron originated in the Near East, where he protected travelers along caravan routes.[17] Heron gained popularity as a protector god in Egypt during the first centuries AD[18] and was featured in wall paintings in various sites in the Fayum. In Karanis he appears dressed as a Roman soldier with a smaller figure by his side,[19] while in Magdola, wall paintings depicting Heron adorn a temple dedicated to him.[20] His images guard the entrance of the temple of Sobek in Theadelphia: in wall paintings flanking the entrance Heron is depicted both next to a horse and offering incense at an altar in one painting, and on horseback and pouring a libation in the other.[21]

Although Heron is the sole subject in the RISD panel, save for the much smaller figure beside him, the other painted panels featuring Heron invariably show him standing beside a god wielding a double ax.[22] Stylistic details and a similar palette link the RISD Heron to a fragmentary panel in Berlin (no. 15979) that shows Heron with dark curly hair and beard, large eyes, a halo, and a cuirass decorated with a gorgoneion.[23] An armed deity, suggested by the upright spear visible next to the tree to Heron's right, once stood beside Heron in the Berlin work.

A purported shared origin associates the RISD panel with two other Heron panels. The framed panel in Brussels (see fig. 9.1; see note 4), purchased by Franz Cumont in Paris in 1938, came from the same findspot (unfortunately not recorded) as RISD's panel, according to the seller.[24] The Brussels Heron holds both a sword and a spear, in contrast to his unarmed representation in the RISD panel. Next to him is a scowling god, clad in a patterned, belted tunic, checked trousers, and fringed cloak, who raises a double ax in his right hand and grasps a spear in his left. A small figure of a woman wearing a wreath, chiton, and himation stands to the god's right. Although this deity's identity remains elusive, Rondot has proposed that he is Lycurgus.[25] Heron and Lycurgus entered the Egyptian pantheon in the Roman period and became a frequently represented pair in the Fayum. In the Brussels panel, both wear haloes and wreaths, with the leaves enlarged and emphasized, perhaps to indicate that in this context they are also associated with the Fayum's bountiful harvests.[26] Although the figures' proportions are similar in the RISD and Brussels framed panels, the painting styles differ. The figures in both panels are outlined, but the details in the Brussels panel are rendered in a flat, decorative manner within the bold outlines; this style stands in contrast to the attempt at modeling and suggestion of volume evident in the RISD panel.

A fragmentary panel in Étampes has also been linked with the RISD and Brussels panels. Believed to have come from the same site, all three were in Maurice Nahman's collection before 1938. Both the Étampes and RISD panels appeared in the 1953 Paris auction of Nahman's collection.[27] Depicting the same subject as the Brussels panel, the Étampes panel portrays Heron younger, with a lighter beard. Heron and Lycurgus are rendered in a more painterly style, with shading achieved through delicate hatching rather than blocks of color. Instead of the predominantly warm brown tones of the RISD and Brussels panels, the Étampes image features light purples and pinks as well as browns. Like the RISD panel, it bears an inscription, which translates as "Pathevis, son of Erieus, is the one who [dedicated this work], for a favor."[28] The divergent painting styles employed in these framed panels appear to reflect the variety of styles in contemporary mummy portraits.

The inscription on the RISD and Étampes panels—*ep' agatho*, meaning "for a favor"—indicates that these works were votive offerings. Inclusion of the donor's name in the RISD inscription would not have been necessary if both panels had been offered together; one mention of the donor's name, Pathevis, would have sufficed.[29] In both panels, the inscriptions are placed next to Heron's left ear so he can hear the donor's appeals. The size and prominence of his ears are believed to allude to his special powers of hearing, and associate him with Egyptian gods who hear petitions.[30] In these paintings, Heron seems to model the proper way to honor him: worshippers should offer libations and incense.

Another *ep' agatho* inscription offers a clue to the donor of these paintings. A partially preserved inscription on a fragmentary panel in London likely reads: "[missing name] the *dekanos* dedicated this painting [for a favor]."[31] Although not a high-ranking official, the *dekanos* belonged to the elite of the Roman administration in Egypt. Thus, the local elite, who were memorialized in mummy portraits, likely also commissioned framed panels of gods.[32]

Archaeological contexts for certain panel paintings aid in determining their function. The panel of Soknebtunis and Min now in Alexandria (no. 22978) was excavated in the temple of Soknebtunis in Tebtunis, in the second court of the temenos, an area that had become a glass workshop in later Ptolemaic times but maintained some religious function after the temple was abandoned.[33] The now-missing framed panel depicting Sobek and Amun (no. 15978)[34] and the Berlin fragmentary Heron (no. 15979)[35] were found in a house in Tebtunis. When the structure was abandoned in the third century AD, the panels were left on the site, along with the hemp cord and the peg in the wall from which the now-lost panel was hung.[36] Framed painted panels in religious and domestic contexts are depicted in many mosaics and wall paintings that have been found outside Egypt.[37] A mosaic from a Roman villa in Antioch depicts a man gazing at a framed panel while reclining at home,[38] and another from Hadrian's Villa in Tivoli shows a framed panel left in front of a statue of a god in an outdoor shrine.[39] The various depictions of framed panels suggest that they were much more common than the handful of surviving examples would indicate.

The evidence provided by these different types of archaeological finds suggests that the framed panel paintings of Heron now in Providence, Brussels, and Étampes were likely installed within a house or a neighborhood chapel.[40] These rare surviving religious images from Egypt provide insight into some of the ways that Egyptians conceived of and worshipped their gods in Roman times.

Technical Analysis

Since the time of acquisition in 1959, the RISD Heron panel has undergone three recorded conservation treatments: the first at the Museum of Fine Arts, Boston, in 1971, a second treatment at RISD in 1999, and a third at the Metropolitan Museum of Art in 2000.[41]

The five individual wooden slats that compose the Heron painting were analyzed, as was the attached eight-point frame; all are *Ziziphus spina-christi,* or sidr wood,[42] a hard and durable wood native to Palestine and to north and west Africa. This tree is known to be on the small side, growing only to five meters high. There are many recorded examples of this type of wood being utilized in Egypt; it was used to manufacture both large items, such as boats and coffins, and small objects, such as dowels.[43]

The eight-point frame is constructed of four overlapping individual members that are joined by mortise and tenon with square shoulders, reinforced by wooden pegs that are raised at each corner (see fig. 9.2). Great care was taken in the arrangement of these wooden frame members; the wane edges, meaning those that would have originally possessed protective bark, were placed with the smooth side facing toward the inside of the frame—seen here on the panel reverse. Thus, it would appear that the maker intended to prevent the imperfections in this scarce wooden resource from being visible along the edge of the outer frame (fig. 9.4).[44]

Figure 9.4 Detail of fig. 9.2, showing wane edge and tool marks. Photo: I. Neuman, RISD Museum

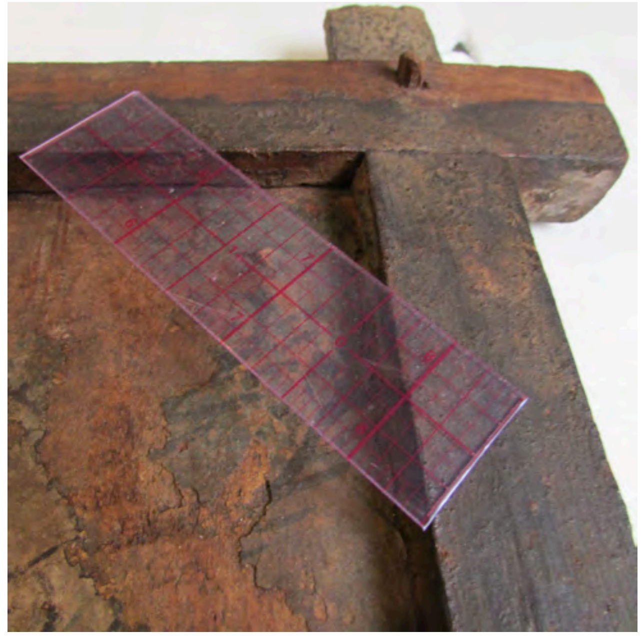

Figure 9.5 Detail of upper proper left corner of fig. 9.2, showing raised peg and Egyptian blue. Photo: I. Neuman, RISD Museum

Although great attention was paid to hiding imperfections of the frame members, some tool marks, however, were left quite visible—such as the saw marks on the lower tenons and on the reverse of the individual panels. The lack of visible plane marks on the reverse attests to the high skill of the handsaw operator.[45]

Regarding joinery, the pegs located in the proper left corners of the frame are raised off the surface (fig. 9.5). The raised nature of these pegs suggests that either they may have functioned for display purposes, being used to hang cordage, or they were intended to be accessible and tapped out on occasion, thereby making the frame more easily removable. An alternative theory proposes a deliberate choice by the maker: because these raised pegs would have been an encumbrance or an inherent vulnerability prone to breakage, they might have been an intentional aesthetic choice on the part of the frame maker.[46]

Curiously, in the proper upper right corner of the RISD frame, two pegs are side by side; the other corners possess only one. This second peg most likely served as a point of attachment to an auxiliary support (fig. 9.6). Another detail supporting this theory of attachment to an auxiliary support involves the two additional holes, located at the center of both horizontal members, that also possess wooden pegs. These pegs differ from those located at the corners, as they are flush, as opposed to raised. The upper central peg is placed at the midpoint above the middle slat of the painting (fig. 9.7). In contrast, the lower central peg lies along a seam between two of the painted slats. Therefore, the placement of these two central pegs does not appear to be related to stabilizing the painting itself; rather, these central pegs could have been used as a functional mechanism to attach the framed panel to an auxiliary surface.

Figure 9.6 Detail of upper proper right corner of fig. 9.2, showing two pegs. Photo: I. Neuman, RISD Museum

Figure 9.7 Detail of fig. 9.2, showing the central peg along the top frame member. Photo: I. Neuman, RISD Museum

The painting was executed once the slats were inserted via tongue and groove into the frame, as pigment dripped from the upper proper left-hand corner onto the inside of the adjacent frame member (see fig. 9.5), which suggests that the frame is original to the painting. This pigment has been analyzed as Egyptian blue by visible-induced luminescence (VIL) and can be seen clearly fluorescing on almost the entire background of this image, except for the portion of the panel that is a modern replacement (fig. 9.8). Paint also extends up the interior surface of the frame members of the Brussels panel, but this does not appear to be the case with the framed portrait panel from the British Museum.

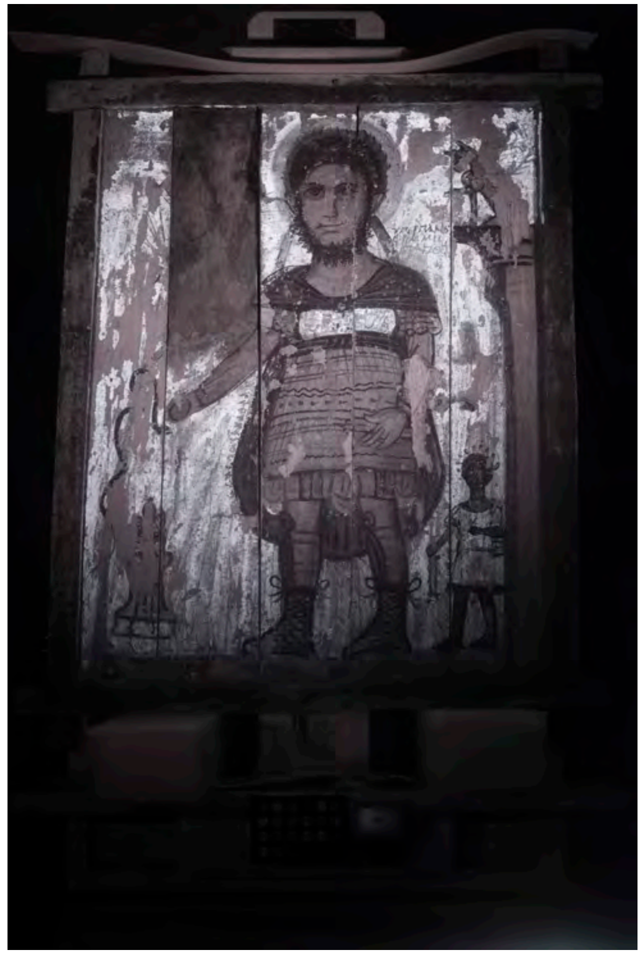

Figure 9.8 VIL image of fig. 9.2, showing Egyptian blue. Photo: J. Arista, © Museum of Fine Arts, Boston

What is particularly interesting about the construction of the RISD panel, as compared with the other two paintings, is that it is composed of five narrow slats of wood. This arrangement of multiple slats differs from the single-panel construction of both the British Museum and the Brussels panels. The presence of a mitered wooden liner also differentiates the British Museum panel painting (see fig. 9.3) from the other two examples.

The five slats on the RISD panel are arranged in an irregular pattern of nonparallel boards with straight edges but not of equal widths; they are not actually rectangular. These irregularly shaped slats reflect the narrow sidr tree boughs, which would have been in limited quantity and therefore a valuable commodity. The alternation of wide- and narrow-ended slats is indeed a sound idea from a woodworking perspective, as the slats are more dimensionally stable in this arrangement. It is clear that all of the edges of the panels have been planed to be straight and that they originally fit tightly with no perceptible gaps. The two slats on the viewer's right appear to be book-matched, derived from the same tree bough. Based on the wood grain pattern, the center wooden slat might also originate from the same tree bough, albeit from a slightly different location (fig. 9.9).[47] These individual slats also contain many knots, one of which appears to be a bark “inclusion,” where bark has grown into a knot and has left a smooth surface when viewed on the reverse.[48]

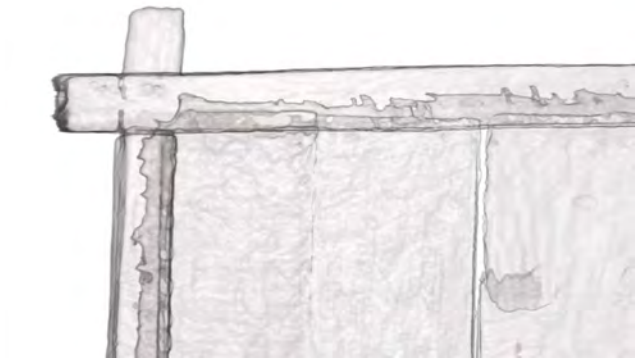

Figure 9.10 3-D volume rendering of fig. 9.2, showing perimeter voids. Image: S. Collins, Rhode Island Hospital

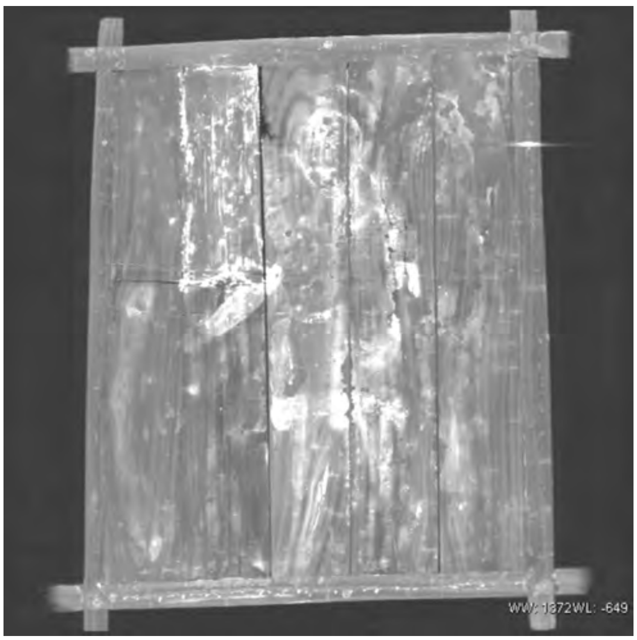

Figure 9.9 CT scan of fig. 9.2, showing the book-matching arrangement. Image: S. Collins, Rhode Island Hospital

Three-dimensional volume rendering, undertaken at the Rhode Island Hospital, revealed an irregular void along the interior perimeter of the frame (fig. 9.10). Material present in the void may have been an adhesive; however, it is not physically possible at this time to obtain a sample from the interior groove.

In addition to the Egyptian blue pigment, other pigments were identified by means of two rounds of X-ray fluorescence (XRF) spectroscopy in 2016 and 2017 (fig. 9.11).[49] The semiquantitative data are consistent with other analyses that we have completed to date. The presence of calcium and sulfur in all samples is consistent with a gypsum binder or, alternatively, could indicate calcium carbonate, frequently used as a substrate for madder lake. Silicon and aluminum were found in all samples, indicating the presence of a clay. Some interesting findings from the XRF data are the high levels of lead in the lips, indicating lead white, potentially mixed with madder lake. Copper was found in several areas of the painting, including the gray background, the altar, the small figure's robe, Heron's breastplate, and even Heron's red halo. We are confident about identifying the copper as consistent with the presence of Egyptian blue because these areas also fluoresce during VIL analysis.

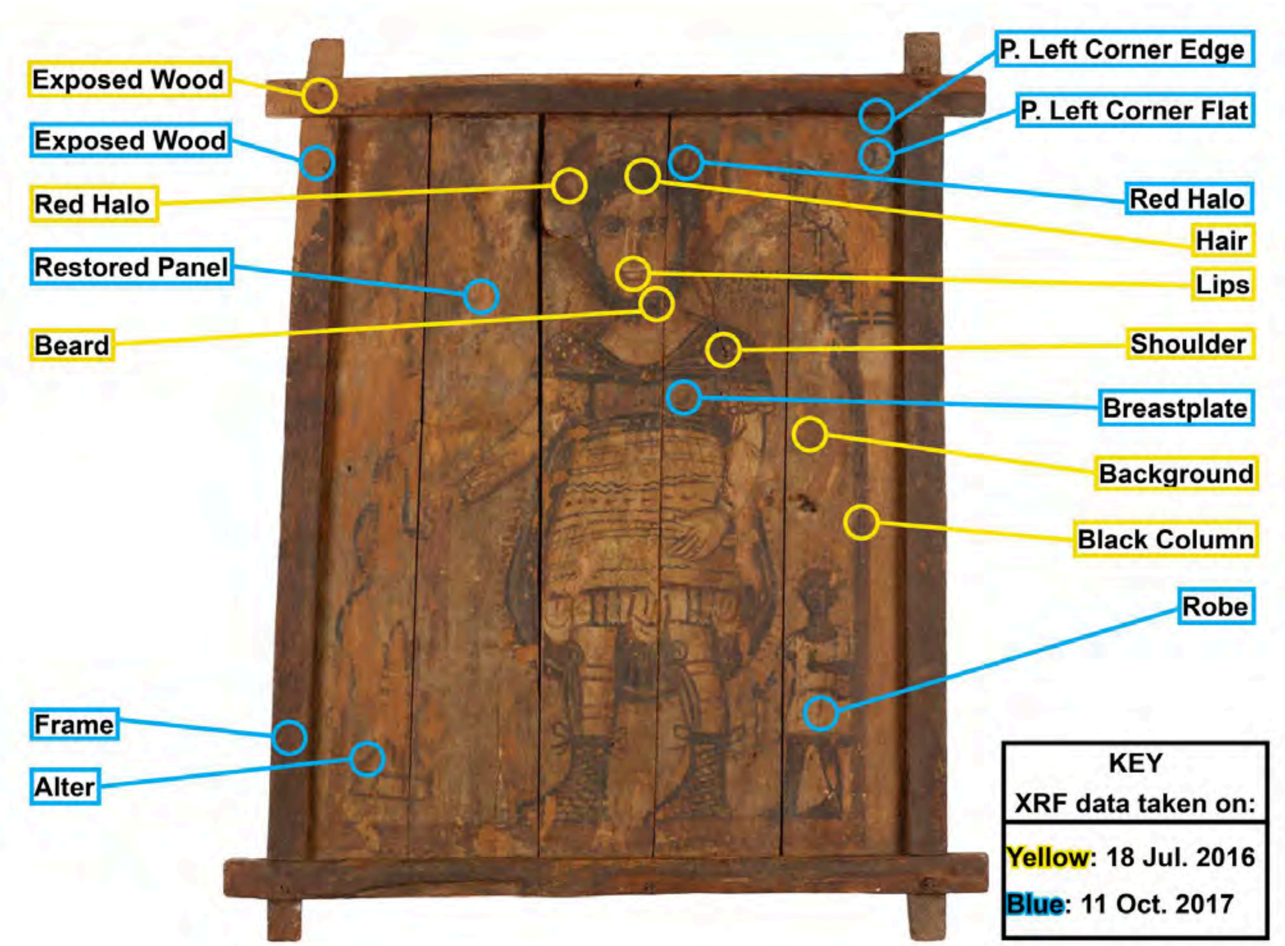

Figure 9.11 XRF sample sites of fig. 9.2. Diagram by C. Cooper

The characterization of the binding medium by means of infrared microspectroscopy was also conducted.[50] The paint sample taken from below the proper right foot produced spectra that indicate that one particle primarily contains gypsum and an oxalate. Another particle primarily contains a stearate compound. An additional organic material, such as an oil, may also be present, but identification by IRR was uncertain. Analysis of a second sample indicates the presence of many inorganic compounds and a water-soluble binder with a reasonable resemblance to plant gum.

There are notable differences in the wood and the style of frame between the RISD panel (see fig. 9.2) and the small Portrait of a Woman in the British Museum (see fig. 9.3).[51] While the RISD panel is composed of five slats of sidr wood, the British Museum panel is much smaller in scale and is composed of a single piece of *Ficus sycomorus,* sycomore fig wood.[52] The fact that the British Museum panel is a single plank speaks to the relatively larger size of sycomore fig wood, whereas the more diminutive scale of the sidr wood corresponds with the narrow slats of the RISD panel. The Brussels painting is also composed of a single panel, but the analysis of its wood has not been undertaken.

Another difference among these three panels is that the British Museum frame exhibits two parallel grooves, whereas the RISD and Brussels frames have only one groove into which their painted panels have been inserted. The British Museum frame appears to have been cut from prefabricated frame stock, as both grooves extend past the mortise and tenon (fig. 9.12).

Figure 9.12 Detail of fig. 9.3, showing double groove. Photo: I. Neuman, RISD Museum

What would the function have been of the empty uppermost groove, measuring 0.7 centimeters in width, on the British Museum frame? If there were some sort of protective cover, such as a hinged wooden door panel on either side, the existing wooden liner could have served as a spacer to keep the protective doors from abrading the surface of the painting. Interestingly, a wooden hinge does survive from Saqqara in the collection of the Birmingham Museum and Art Gallery (fig. 9.13).[53] Could a similar hinge originally have served this purpose for the British Museum frame?

Figure 9.13 Hinge, Egyptian, 600–100 BC. Saqqara. Wood. Birmingham, UK, Birmingham Museums and Art Gallery, 1969A547. Photo © Birmingham Museums Trust

An additional difference among the three panels is that the frames for the smaller, single-plank British Museum and Brussels panels do not possess the wooden pegs that are so prominent in the corners of the RISD frame; however, the British Museum frame is the only example of the three that possesses the braided cordage with which to hang the framed panel. According to the APPEAR website, this cordage has been identified as palm (fig. 9.14).[54] Visual inspection reveals that the cordage has been repaired in the modern era with Japanese paper.

Figure 9.14 Detail of fig. 9.3, showing palm-fiber hanging device. Photo: I. Neuman, RISD Museum

Unfortunately, the painted surface of the British Museum panel itself does not survive in good condition. Its surface appears to have a paraffin consolidant, possibly present from the time of excavation.[55] In contrast, the painted surface on the Brussels panel is in very good condition. Its surface possesses a matte and lean paint layer similar to that on the RISD panel.

As a midsize institution with a collection of one hundred thousand objects, the RISD Museum was able to contribute to and benefit from this international exploration in a valuable, symbiotic way. The APPEAR project has allowed us to dig deeper within our own collection and explore others located across the globe. Closer to home, it has helped us create new connections and strengthen collaborations with the geologists at Brown University as well as image specialists at Rhode Island Hospital, both of which are only footsteps away from our institution. In summer 2017, an undergraduate conservation intern funded by the Andrew W. Mellon Foundation created a digital reconstruction of the RISD panel as her final project (fig. 9.15). On behalf of the RISD Museum, we are very grateful to the Department of Antiquities at the Getty Villa for the opportunity to participate in this unique and educational project.

Figure 9.15 Color reconstruction of fig. 9.2. Reconstruction by Macy Nobles, RISD Museum

NOTES

1. Rondot 2013, 12; Rondot 2015.
2. Soknebtunis and Amun, Berlin, Staatliche Museen, Ägyptisches Museum 15978; Rondot 2013, 122–27.
3. Sobek and Min, Alexandria, Greco-Roman Museum 22978; Rondot 2013, 75–80.
4. Heron and Lycurgus, Brussels, Musées royaux d'art et d'histoire E 7409; Rondot 2013, 141–45.
5. Heron, Providence, RISD Museum, Museum Works of Art Fund 59.030, accession card and curatorial files; Cumont 1939, 5; Antiquités de Maurice Nahman 1953, no. 286; Parlasca 1966, 69n66, 243, no. 236; Winkes 1973; Winkes 1982, 68–69, cat. no. 37; Friedman 1989, 188–89, cat. no. 98; Rassart-Debergh 1991; Nachtergael 1996; Mathews 2000; Mathews 2001; Sörries 2003, 146–48, no. 34; Rondot 2013, 208–12 (with a full bibliography up to 2013 on 208), 283–85; Rondot 2015; Mathews 2016, 62–68; Spier, Potts, and Cole 2018, 244.
6. According to Rondot 2013, 285, this is the only image of Heron with Nemesis, the goddess of divine justice.
7. For a discussion of the inscription, see Nachtergael 1996, 138–42.
8. A painted sarcophagus from Kerch shows a painted panel on an easel and another hanging on the wall of an artist's workshop; see St. Petersburg, State Hermitage Museum P-1899.81; Goldman 1999; Knudsen 2017; Corcoran and Svoboda 2010, 36, fig. 17; Squire 2015, 178–79, fig. 9.2.
9. 1. Heron [with Lycurgus], Berlin, Staatliche Museen, Ägyptisches Museum 15979; Rondot 2013, 128–31.
   2. Heron and Lycurgus, Étampes, France, private collection; Rondot 2013, 152–56.
   3. Goddess, Asyut, Egypt, Asyut College Museum 82; Rondot 2013, 81–83.
   4. Harpokrates/Dionysos, Cairo, Egyptian Museum; Rondot 2013, 84–88.

   Some of these gods are native to Egypt, some come from the Greco-Roman pantheon, and others, such as Heron, have unclear origins.
10. Portrait of a Woman, London, British Museum 1889,1018.1; Walker and Bierbrier 1997, 121–22, cat. no. 117.
11. Portrait of a Bearded Man, Los Angeles, J. Paul Getty Museum 74.AI.20; Thompson 1978–1979; Sörries 2003, 146–48, no. 34; Hart 2016, pl. 7.
12. See notes 3 and 2, respectively.
13. See notes 4 and 10 (portrait), respectively.
14. Rondot 2015; Rondot 2013; Rondot 2001.
15. Mathews 2016; Mathews 2001.
16. Will 1990; Seyrig 1970, 102.
17. Cumont 1939, 1–9; Rondot 2013, 298–300.
18. Rondot 2013, 282–300.

19. Wall painting of Heron with Lycurgus, from Karanis, exact findspot unknown; Rondot 2013, 58–59, fig. 23, note 58.

20. Rondot 2013, 49–52, figs. 17–18.

21. Rondot 2013, 52–56, figs. 19–21.

22. Heron is often depicted in the company of an armed god in wall paintings; Rondot 2013, 52–56, figs. 19–21.

23. Rondot 2013, 128–31; Mathews 2016, 35, 37.

24. Cumont 1939, 1–2.

25. Rondot 2001; Rondot 2013, 283–300; Rondot 2015, 152–53.

26. Mathews 2016, 36.

27. Rassart-Debergh 1991, 350–52; Rondot 2013, 25–26.

28. Nachtergael 1996, 138–40; Rondot 2013, 208–12; Mathews 2016, 60.

29. Nachtergael 1996, 140, even believes that both inscriptions were written by the same hand; Mathews 2016, 60, 65.

30. Mathews 2016, 37.

31. London, Petrie Museum of Egyptian Archaeology, University College 16312; Rondot 2013, 160–61.

32. Mathews 2016, 65.

33. Mathews 2016, 48–52.

34. See note 2.

35. See note 9 (1).

36. Mathews 2016, 33–37.

37. See Sande 2005 for a list of wall paintings and mosaics showing framed panels in sacred landscapes.

38. Princeton, New Jersey, Princeton University Art Museum 1937-264; Mathews 2016, 8, fig. 1.

39. Vatican Museum, mosaic from Hadrian's Villa in Tivoli; Sande 2005, 89, fig. 2; Mathews 2016, fig. 2.10.

40. Cumont 1939, 5–6, suggests that the panels were installed in Theadelphia, where Heron had a cult presence; Mathews 2016, 65.

41. Curatorial file, RISD Museum.

42. Identification of the wood used for four mummy portraits from the Rhode Island School of Design Museum, Caroline R. Cartwright, senior scientist and wood anatomist, Department of Scientific Research, British Museum, November 22, 2016.

43. Nicholson and Shaw 2000, 347.

44. Personal communication, John Dunnigan, professor, Department of Furniture Design, Rhode Island School of Design, February 15, 2018.

45. Ibid.

46. Ibid.

47. Ibid.

48. Ibid.

49. XRF performed by Dr. David Murray, Brown University, using a Delta Professional Olympus Handheld XRF analyzer with an Ag mini X-ray tube excitation source, using two 30-second scans at 40 kV.

50. SR Lab project number 2016–243, “IR Microspectroscopy over the Mid-IR Range of 4000–650 Wavenumbers,” Richard Newman and Michele Derrick, Scientific Research Department, Museum of Fine Arts, Boston, October 26, 2016.

51. See note 10.

52. Cartwright 1997a.

53. Killen 1994, 18; Mathews 2001, 171.

54. APPEAR database, https://www.getty.edu/museum/conservation/APPEAR/index.html.

55. Personal communication, Lin Rosa Spaabæk, paintings conservator, Copenhagen, September 6, 2017.

10

A Study of the Relative Locations of Facial Features within Mummy Portraits

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Olivia Dill
Marc S. Walton
Andrew Shortland

This paper explores the positioning of facial features depicted in mummy portraits of various different styles and dates, as drawn from the APPEAR database, by bringing together two parallel studies that were undertaken by the Ashmolean Museum in Oxford and Cranfield University in Shrivenham, United Kingdom, and Northwestern University in Evanston, Illinois, United States.

Mummy portraits, also referred to as Fayum portraits and often described as Greco-Roman or Romano-Egyptian, date from the first to the third centuries AD. These painted faces were inserted or incorporated into the wrappings of embalmed human remains, although many portraits now exist without their associated mummies. Discussions of their cultural influences often include references to the Greek ancestry of some of the Fayum residents;[1] Greek painting styles and techniques;[2] the importance of Roman identity, as reflected in the deceased's appearance; and the traditional Egyptian techniques of preparing and presenting the dead. As such, mummy portraits are often seen to "stand at the meeting point of Egyptian, Greek and Roman worlds."[3] The depicted likenesses are often near life-size and represent a human face. At their most realistic some of these portraits are readily recognizable as the faces of real people who once lived, and yet they still have a group identity that connects them to other, more stylized examples.

The most obvious similarity among the mummy portraits as a group is the general presentation of the face. The deceased almost always assume a similar pose, in which the shoulders and the head are slightly rotated, by different measures, in the same direction. Together with an almost invariably calm reserve reflected in his or her expression, this posture gives the impression of a formal process of image making; however, it could also be an indication that the faces are conforming to a predetermined and generally accepted form. This idea that many different faces can share a group identity under certain conditions of presentation was succinctly described by John Berger as "pictures from a photomat."[4] In the context of photographs for official identification, it is certainly true that rigorous control of particular aspects of presentation can enable individual facial features to be clarified and more easily scrutinized. For an image of identity to be successful there clearly must be a balance between repetition (facilitating comparison yet risking anonymity) and features that convey individual differences; however, in the case of a painted portrait, it is a person—and not a photographic process—who creates the image. According to Prag, in his comments on a male mummy portrait,[5] "the artist cannot have painted it without a model somewhere along the line, for one cannot create such a countenance out of thin air.... It lacks the personality that an individual skull with its own individual proportions would have given it."[6]

Prior to the period when it is generally believed mummy portraits were painted, several proportional systems were in place and could have been influential. They vary from the Egyptians' evolving use of proportional grids and measurements[7] to the apparently mathematical-based Greek models of ideal beauty, attributed to sculptors such as Polykleitos.[8] Arguably the simplest of approaches for the proportions of a human head was noted by Marcus Vitruvius in his *Ten Books on Architecture* (30–10 BC).[9]

In terms of generally locating horizontal reference lines in the facial features of mummy portraits, a system based on ten equally spaced divisions is readily apparent (fig. 10.1). This spacing seems consistent on all mummy portraits studied to date (with only a few exceptions showing discrepancies in the upper limit of the hair, possibly due to a lack of height with certain hairstyles). At the time of writing, no other painted portraits outside of those characterized as mummy portraits have been found to possess the same regular, horizontal spacing of facial features, suggesting this format could be unique to mummy portraits.[10] The uniform, repeating spacing down the face makes it possible to quickly and reliably locate the hairline, the fringe or forehead lines, the eyebrows, the eyes, the nostrils, the top lip/mouth, and the top of the chin. For an artist painting portraits to a consistent standard, a repeating unit of horizontal distance between facial features would be very useful.

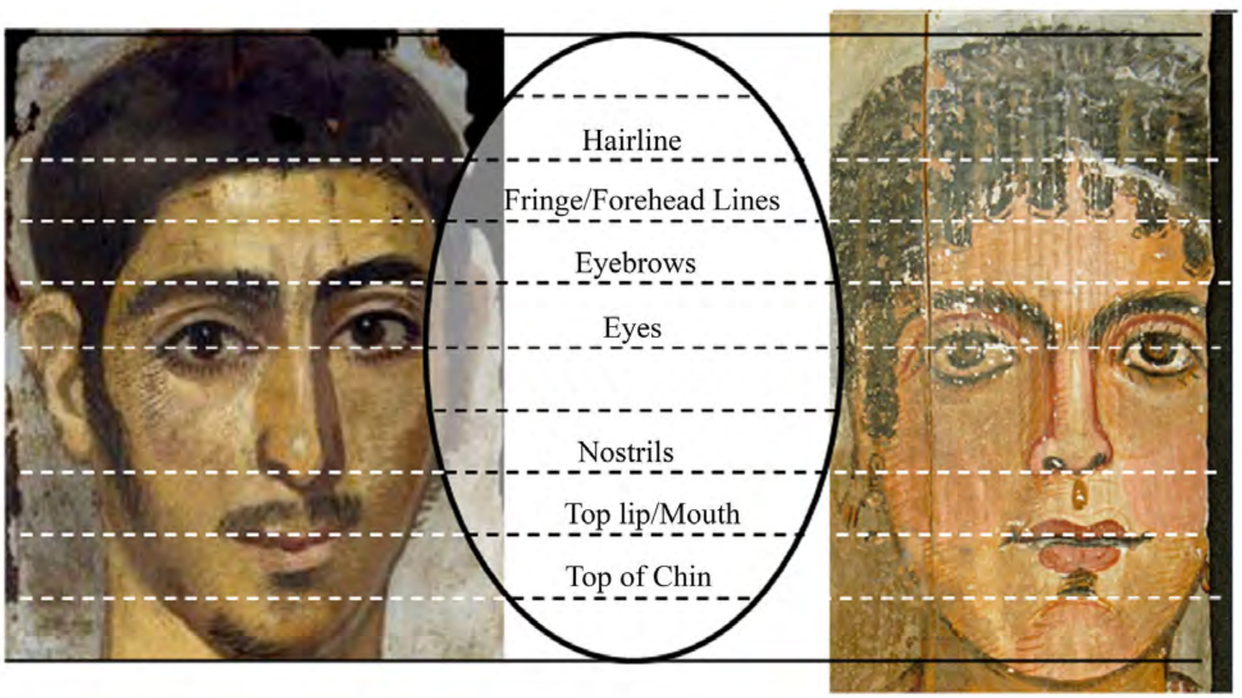


Figure 10.1 The division of mummy portraits into ten equally spaced, horizontal bands. Left: Portrait of a Young Man, Romano-Egyptian, AD 193–235. Uncovered at Tanis by Grenfell and Hunt in 1902. Encaustic paint on a lime wood panel with traces of linen, 39.2 x 19.1 cm (15 7/16 x 7 1/2 in.). Oxford, Ashmolean Museum of Art and Archaeology, Egypt Exploration Fund, AN1896-1908.E.3755. Right: Portrait of a Woman, Romano-Egyptian, AD 90–110. Fayum. Tempera paint on a lime wood panel, 38.2 x 14.5 cm (15 x 5 11/16 in.). Oxford, Ashmolean Museum of Art and Archaeology, John Davidson Beazley (ex–Graf Collection), AN1966.1112 © Ashmolean Museum of Art and Archaeology, University of Oxford

To explore mummy portrait faces further, an open-source software library module, DLIB,[11] was implemented in the programming language Python and used to examine and compare the location of facial features on a set of seventy-two mummy portraits.[12] The algorithms underlying DLIB first employ a histogram of oriented gradient (HOG) filter to find the face in a given image and then deep learning to locate sixty-eight reference points for each face. These sixty-eight reference points are a standard set of features that make up the Multi-PIE set[13] and are sufficient for many machine-learning tasks, including distinguishing individual human faces in photographs. The exact procedure was applied to the same number of photographs of real faces taken in a variety of positions. The database from which these photos were selected at random includes more than thirteen thousand faces taken from news articles online; the database is appropriate here because the photos it contains were not taken in controlled settings for machine-learning purposes. As such, the faces it contains boast a wide range of poses and expressions.[14] A smaller subset was selected randomly for comparison here, by sorting photos alphabetically by the sitter's last name and selecting the first seventy-two entries, excluding duplicates. Compatibility with DLIB was a constraint that resulted in the exclusion of five images of faces with widely opened mouths, for which facial recognition was unsuccessful. As an indication of uniqueness of pose, the normalized standard deviation in the location of these reference points was calculated for real faces selected randomly as described above; real faces that appeared to have a frontal or slightly rotated pose; and the faces depicted on mummy portraits (fig. 10.2). As expected, different poses present a source of variation; however, on natural faces, this variation decreases when faces adopt a similar orientation. It is thus striking that mummy portraits, as a group, demonstrate even lower variation than do real faces with similar poses. This greater similarity than just having the same pose suggests that when compared with each other purely in terms of locating and scaling facial features, most mummy portraits exhibit a strong underlying format.

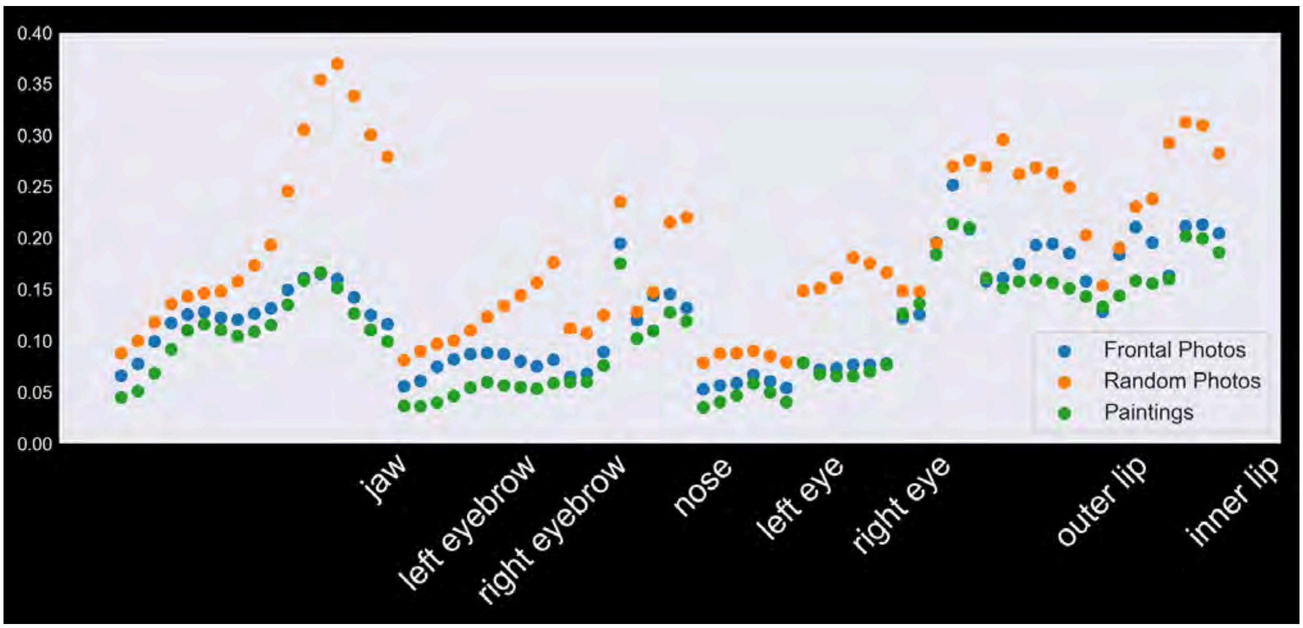


Figure 10.2 Chart illustrating the mean normalized standard deviation for radius values of facial reference points. Northwestern University

The average locations of facial features in all mummy portraits taken from the study data set were recorded and plotted, as were the average locations of facial features in the sample set of photographs of real faces (fig. 10.3). Overwhelmingly, in mummy portraits, eyebrows, eyes, lower lips, and chins are consistently positioned higher up on the face than expected when compared with data on images of real faces. Furthermore, those facial features located farther away from the lower edge of a mummy portrait show a greater upward displacement from their expected natural position; however, this shift does not extend to the hairline, which suggests a systematic elongation of the face, extending from the chin to the eyebrows, and a countering compression in the forehead.

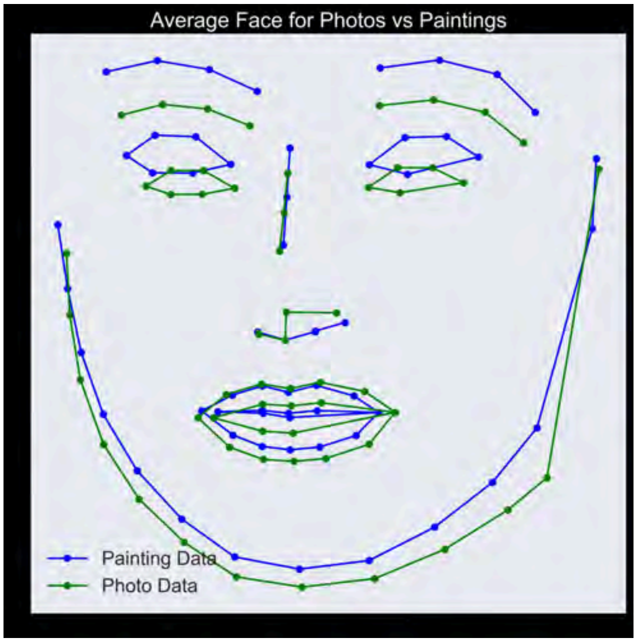


Figure 10.3 Average human face compared with that of a mummy portrait. Northwestern University

The average facial feature locations on the mummy portraits also draw attention to the large eyes, a striking characteristic.[15] In particular, the distance from the top to the bottom of both eyes in all but two of the mummy portraits examined was larger than the average distance found in photographs of real faces.[16] Closer comparison of the eyes from mummy portraits of different styles and dates suggests that they also seem to have an underlying correlation in shape and size (fig. 10.4). In contrast, mouths appear slightly smaller than expected—possibly as a counterbalance to the larger eyes.

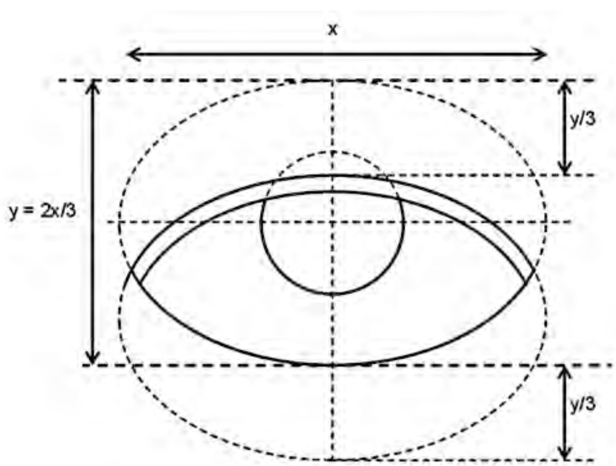


Figure 10.4 Diagram showing the general proportions of the eyes of mummy portraits. © Ashmolean Museum of Art and Archaeology, University of Oxford

Each mummy portrait was compared with the image of a real face that was angled and rotated in increments of 15 degrees. As a means of measuring similarity between faces at different tilt and rotation angles, each painted portrait was assigned to the photograph of a face for which the sum of differences between corresponding features (the Euclidean distance between vectors containing all coordinates of facial features) was the smallest. This was repeated three times for three different human faces and the results averaged. The majority of mummy portraits compared most favorably with images of human faces that have been tilted both down and to the right or left by 15 degrees (fig. 10.5). However, this effect is, evidently, subtle enough that some other portraits match most closely with faces that are not tilted or rotated. Furthermore, the comparison is relative in that one portrait may be very far or very close on a baseline level from every face with which it is compared, and the comparison still selects only the best fit. This interpretation attempts to understand favorable or less favorable comparisons in terms of tilting of the face.

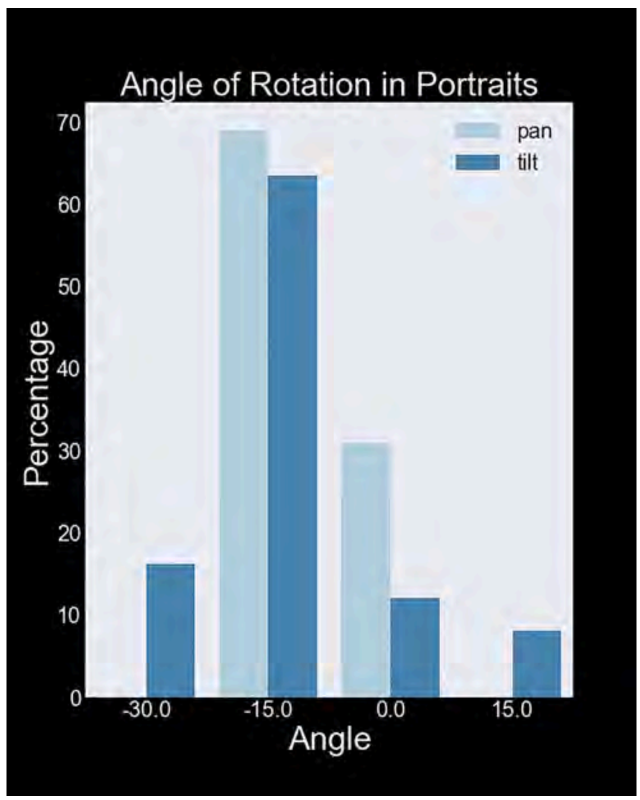


Figure 10.5 Images of mummy portraits compared with images of real faces, which are tilted forward and backward, and panned left and right. Northwestern University

During the embalming process, there are very practical reasons to elevate the head of the deceased at a slight angle by placing it on a headrest. Both the disfiguring effects of blood pooling in the head and an unsightly mouth gaping wide open as the head rolls back at an unnatural angle are best avoided if you respect the dead.[17] It is likely that there were also ceremonial reasons for the protection of the neck—and thus the use of a headrest behind it—during the journey to the afterlife. Although little discussed, it is highly likely that most X-ray images or CT scans of related mummified remains will support this notion that heads within mummified remains are often to be found with the skull angled slightly. For example, analysis of a mummy portrait from the Garrett-Evangelical Theological Seminary, Evanston, Illinois, by Northwestern University[18] revealed that the head would have been tilted by about 15 degrees during mummification, based on a residue of resin found inside the skull, and that the mummy's skull as it remains today is still rotated forward (figs. 10.6 and 10.7). Likewise and more relevant perhaps, the mummy portraits themselves, in the context of being attached to a mummified body, should not necessarily be assumed to be lying flat and parallel to the ground; more likely, they too were somewhat tilted forward in line with the positioning of the head and the shape of the mummified body beyond the shoulders.

Figure 10.6 Portrait of a Young Girl attached to the Hibbard Mummy, or Hawara Portrait Mummy no. 4, Romano-Egyptian, second to late first century BC. Found in Hawara by Petrie in 1911. Encaustic on lime wood panel, approx. 19.1 x 11.4 cm (7 1/2 x 4 1/2 in.). Evanston, Garrett-Evangelical Theological Seminary, Gift of Lydia Beekman Hibbard. Northwestern University

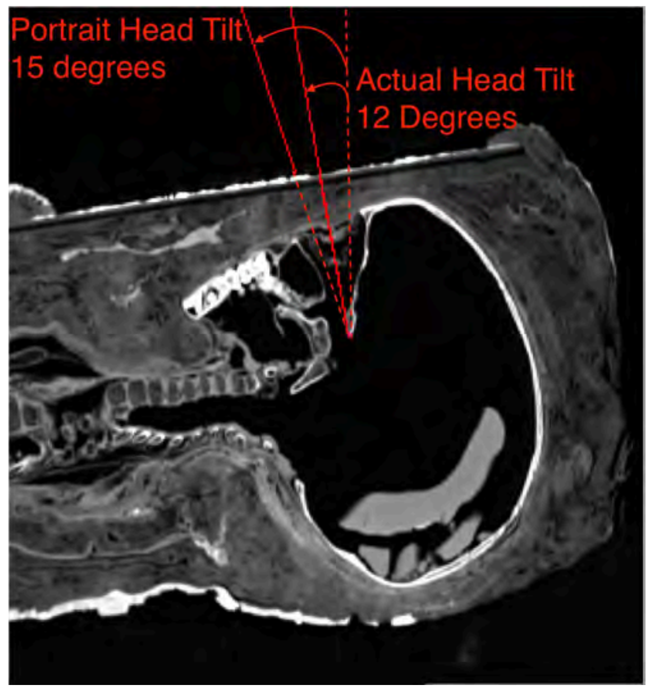


Figure 10.7 CT scan through the side of the head of the Hibbard mummy (fig. 10.6). Northwestern University

The effect of viewing a mummy portrait that is angled forward or backward is an alteration in the perceived proportions of the deceased's face (fig. 10.8). If the lower edge of the portrait is assumed to be the center of rotation, then tilting forward or backward will cause the relative horizontal positions of facial features to move toward the center in relation to their distance from it. So, features farther away from the lower edge of the portrait will experience greatest displacement toward it. It is therefore apparent that the deviations of a mummy portrait from the expectations of a real face can be temporarily removed by changing the angle of presentation.

Figure 10.8 Drawn face with the principal horizontal lines of a mummy portrait, viewed at different angles. © Ashmolean Museum of Art and Archaeology, University of Oxford

Citing ancient sources (which are not usually specifically identified),[19] authors such as Cennino d'Andrea Cennini (ca. 1360–before 1427),[20] Dionysius of Fourna (ca. 1670–after 1744),[21] and Johann Joachim Winckelmann (1717–1768, citing Anton Raphael Mengs)[22] have given guidance on the classical proportions of a human head. With regard to the vertical spacing of facial features, the simplest and most common guide is often based on a division of fifths, with one-fifth equal to the width of an eye. Not only does this help produce a recognizably human face, it also allows an artist to position the eyes and, by extrapolation, the length of the eyebrows and the widths of the nose, mouth, and chin. When heads are turned slightly to one side, the central three-fifths relationship remains true with the nose moved off-center to allow it to be seen in slight profile. To support the illusion of rotation, the outer-fifth spacing on the receding edge of the face is reduced and the cheek and jawline emphasized. This vertical-fifths relationship is likewise evident in the mummy portraits examined (fig. 10.9). There also appears to be a relationship between the relative widths of the ears: the nearest ear generally occupies a whole-fifth division, while the receding ear often accommodates a half-fifth division. In practical terms, the width of the face is effectively four and a half times the width of an eye or the space between the eyes.

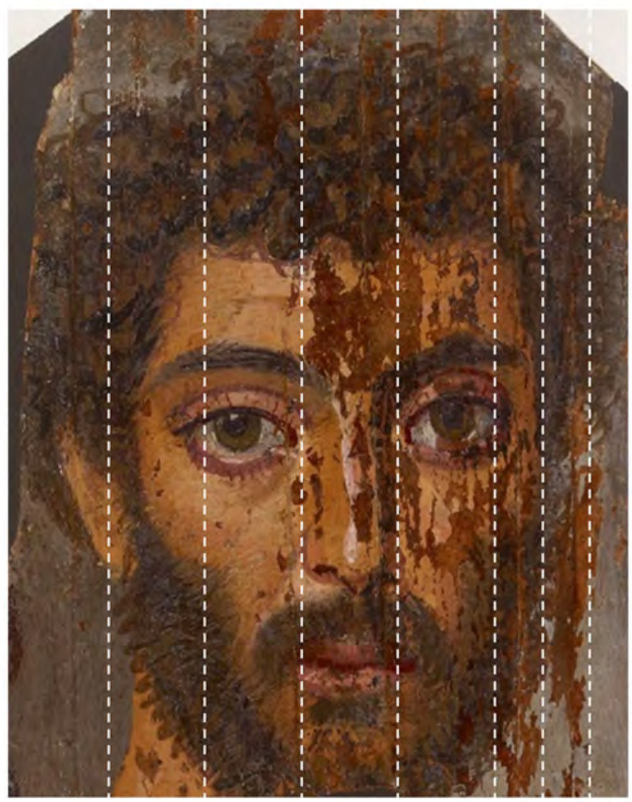


Figure 10.9 Face of a mummy portrait, with vertical reference lines based on the distance between the eyes. Portrait of a Bearded Man, Romano-Egyptian, AD 150–160. Encaustic on lime wood panel, 41 x 20.5 cm (16 1/8 x 8 1/16 in.). Oxford, Ashmolean Museum of Art and Archaeology, John Davidson Beazley (ex–MacGregor Collection), AN1922.240. © Ashmolean Museum of Art and Archaeology, University of Oxford

When the mummy portraits were compared with images of a real face in rotation, facial recognition software identified the majority of the mummy portraits examined as achieving a 15-degree turn (see fig. 10.5). However, some were identified as looking directly forward despite having the reduction in facial width. This is possibly because in addition to the foreshortening on the receding side of the face, facial features also have to move slightly when the head turns. If we look at the centers of vertical symmetry for features in front of and behind the face, we would expect the nose and lips to move away from the center of the face, toward the receding half. Likewise, the center of the back of the head should move in the opposite direction (fig. 10.10). For most mummy portraits examined, this movement is in small and equal amounts; however, there are some portraits in which this movement is not apparently successful, and these works may register as forward-facing heads. This identification could indicate a mistake in technical understanding, or it is possible that we do not fully understand the intended angle of viewing for some mummy portraits. For example, were there situations in the context of viewing a portrait on mummified remains when viewing directly from the front was not possible or intended?

Figure 10.10 Face of a mummy portrait, shown at left in fig. 10.1, with vertical centers of symmetry for the head (yellow, center), nose (red, right) and top of the hair (blue, left). © Ashmolean Museum of Art and Archaeology, University of Oxford

If we combine the horizontal and vertical reference lines extrapolated so far, we see that mummy portraits can often align neatly to a system of ten horizontal divisions and four and a half vertical divisions. If we simplify the number of horizontals to five, then we are left with a five-by-four-and-a-half grid. This arrangement is similar to a grid depicted in an image of a portrait painter on a sarcophagus dating from the first century BC in the State Hermitage Museum Collection (figs. 10.11 and 10.12).[23] Although we do not suggest that an identical grid was used, it is possible that a similar idea could have been initially used to plot the facial features of mummy portraits. It is not inconceivable that, with practice, an artist could master gridlike spacing without an actual grid. The grid on the sarcophagus would suggest equal height and width spacing in the subsequent face depicted; however, the underlying framework of mummy portraits that has been proposed suggests a height-to-width spacing at a ratio of three to two. This discrepancy could be deliberate to allow for subsequent tilting, or it could be a by-product of the angle from which the deceased's head, or a drawing grid, is viewed.

In conclusion, mummy portraits appear to share a remarkably similar arrangement in terms of the relative size and locations of their facial features. There seems to be a consistent underlying facial format that is unique to these portraits. When the angle at which this format is presented is changed, the facial feature locations and proportions likewise change—and conform more closely to those expected in a real face. Mummy portraits include simple foreshortening and shifting centers of symmetry to achieve the illusion of a turning head. This illusion does not always seem to be successful; however, some of the mummy portraits examined have curved panels and others are flattened. Without fully understanding the original intent—or not—it is difficult to be certain if curvature is now a missing viewing factor in some of these portraits.

Figure 10.11 Sarcophagus, Bosporan Kingdom, first century BC. Crimea. Limestone, 81 x 215 cm (31 7/8 x 84 5/8 in.). Saint Petersburg, State Hermitage Museum, П.1899-81

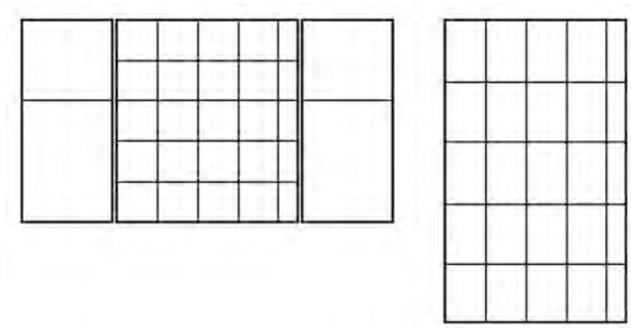


Figure 10.12 Copy of a grid depicted on a sarcophagus dating from the first century BC (fig. 10.11) compared with a grid deduced from the mummy portraits (right). © Ashmolean Museum of Art and Archaeology, University of Oxford

NOTES

1. See Walker and Bierbrier 1997, 15, 18–19; Lydakis 2004, 282; P. Roberts 2008, 7; Bagnall 1997.
2. Doxiadis 1995, 84–86; Doxiadis 2007, 144–45.
3. Geoffroy-Schneiter 1998, 16–17.
4. J. Berger 2002, 56–57.
5. Identified in the article as a portrait of a bearded man, said to be from er-Rubayat, ca. AD 150–180 (London, National Gallery 3932).
6. Prag 2002, 58.
7. Robins 1994.
8. Tobin 1975.
9. "For the human body is so designed by nature that the face, from the chin to the top of the forehead and the lowest roots of the hair, is a tenth part of the whole height; the open hand from the wrist to the tip of the middle finger is just the same; the head from the chin to the crown is an eighth.... If we take the height of the face itself, the distance from the bottom of the chin to the underside of the nostrils is one third of it; the nose from the underside of the nostrils to a line between the eyebrows is the same; from there to the lowest roots of the hair is also a third, comprising the forehead."
10. Indeed, could this be an additional way to assess those mummy portraits identified as later fakes or forgeries?
11. https://github.com/davisking/dlib/blob/master/python_examples/face_landmark_detection.py; King 2009.
12. This is the number of mummy portraits for which DLIB was successful, and there were many more for which it was unsuccessful.

13. Sagonas et al. 2016.

14. Huang et al. 2007.

15. Ebers 1893, 93: “When I just now used the word *startling*, it was with reference not only to the encaustic method of painting but also to the apparent disproportionate size of the eyes, which in many even of the male portraits are almost obtrusive.”

16. Two mummy portraits with eyes that were not taller are Mummy Portrait of a Bearded Man (32.6) in the Walters Art Museum and Portrait of a Woman (17.060) in the RISD Museum.

17. Dr. Richard Lloyd, e-mail message to authors, November 3, 2017.

18. Stock et al., forthcoming.

19. See Panofsky 1955.

20. Thompson 1954, ch. 70.

21. Hetherington 1978, 12.

22. Winckelmann 2006, 209.

23. Inventory number П.1899-81, https://www.hermitagemuseum.org/wps/portal/hermitage/digital-collection/25.+archaeological+artifacts/19421.

11

From All Sides: The APPEAR Project and Mummy Portrait Provenance

Judith Barr

When the APPEAR (Ancient Panel Paintings: Examination, Analysis, and Research) project was launched in 2013, provenance was not preeminent among its ambitious research aims. But no artwork is absent of history, from the time when it was made until its current circumstance. In this regard, the APPEAR project—which seeks to "increase the understanding of [ancient panel painting] materials and manufacture"—is perfectly situated to consider the role of provenance when undertaking a comprehensive study of these works of art.[1] This paper will focus on select case studies drawn from the corpus of the APPEAR project in order to examine them within the historical context of mummy portrait collections and to explore the role provenance can play in furthering the collaborative objectives of the project itself.

Provenance: A Time Line?

For museums, *provenance* often signifies a discussion of an artwork's history of ownership. In this way provenance is a kind of ownership pedigree, and historically, it was a way of championing particular excavators or owners whose inclusion could confer status or authenticity. But the emphasis on these few constituents has often meant the elision of a great deal of history, and for many objects bought on the art market, including mummy portraits, provenances are rarely complete. Traditional object provenances are also often implicit but not explicit—in other words, what is known about an object's history is emphasized, but not what is absent.[2] But provenance has other meanings: instead of ownership history, it can document the place where an artwork was created or the time at which an artwork was first known.

To the scholar Rosemary Joyce, provenance can stretch back to the sources for an artwork's material components as well as forward through the litany of the artwork's owners.[3] For mummy portraits, perhaps provenance should then be considered not merely in terms of an artwork's pedigree but in terms of the age of the wood used for its panel, the species of tree from which it was hewn, the traces of prior use, the origin of the pigments, the source for the wax. All of these elements are brought together by the APPEAR project, where provenance and conservation data sets can be considered concomitantly. A mummy portrait's provenance situated within this broader framework is more like a tree than a straight line, comprising centuries of data points that converge into a single object that then may be transferred, bought, stolen, sold, or even divided into separate fragments.

To many archaeologists, the superseding issue is not an object's ownership history but an excavation history or at least a secure findspot. This distinction is often delineated by the use of the term *provenience* to make clear that an object comes from a known, documented context. An unexcavated portrait cannot be fully recontextualized by comparison with excavated material; it must remain, to borrow a concept from the archaeologist Elizabeth Marlowe, on shaky ground.[4] But even portraits excavated together may have divergent collecting histories, in which they were displayed, mounted, or sold in different ways, leaving unanswered conservation and provenance questions alike. Mummies bereft of portraits—such as that of a teenager now in the collection at Durham University—are a reminder of the complicated history behind the collection of mummy portraits and of what has been lost.[5] Although some portraits undoubtedly were victims of pests, poor burial conditions, or ancient vandalism, other portraits were deliberately extracted from discarded mummies, perceived more salable as artworks without the physical reminder of their origin.[6]

The distinctions between provenance and provenience are often blurred, and they remain a particular challenge with mummy portrait records, where art-historical attributions to a site based on style or materials have often been conflated with a secure findspot or provenience.[7] The APPEAR database allows for the opportunity to reconsider provenance and conservation as essential partners. What provenance alone cannot provide, conservation and material analyses can help reconstruct and retrace. Through interrogating provenance and conservation data together, commonalities in treatment, materials, and composition can be revealed—or old assumptions about a portrait's history disproven.

Mummy Portrait Collections: A Brief History

The history of mummy portrait and panel painting collections is one rich in both provenances and proveniences, and the rediscovery and later collecting of mummy portraits and panel paintings is well documented in the literature. Egyptian funerary portraits and shrouds began gaining a greater prominence within European private collections only in the early nineteenth century, centuries after the arrival of two portrait mummies bought by Pietro della Valle in Saqqara in 1615.[8] Two influential figures among the collectors of the early nineteenth century were Henry Salt and Robert Hay, who amassed huge collections of Egyptian material that were largely devoid of provenience. These assemblages were later sold and dispersed to institutions from Europe to North America, informing the development of public collections around the world. Portrait mummies and shrouds from the Salt and Hay collections represent some of the earliest documented examples from the APPEAR corpus.

Perhaps the most formative figure in the collecting of mummy portraits was Theodor Graf, an Austrian carpet dealer with establishments in Alexandria and Cairo. His agents turned toward the fertile burial grounds of the Fayum in the 1880s as a source for funereal textiles and ancient papyri.[9] Precisely how and from whom Graf acquired all of his portraits remains opaque, although records include names of some local dealers like Ali (Abd el-Haj el-Gabri) and Farag (Ismail).[10] In 1887 the discovery of hundreds of mummy portraits, which Graf then exported en masse and promptly exhibited in major cities across Europe and America, ignited both artistic imaginations and art-historical fervor. Despite media attention from displays in venues such as the World's Columbian Exposition, the commercial market for Graf's portraits was perhaps less than desired, as hundreds of portraits remained unsold at the time of his death in 1903.[11] Graf's portrait collection, which is relatively well documented through sale catalogues, dealer photographers, and exhibition publications, provides crucial data points for exploring the emergent market for mummy portraits at the turn of the century.

Concurrent with the mummy portrait exhibitions mounted by Graf from 1888 to 1893 were the discovery by the archaeologist William Flinders Petrie of portrait mummies at Hawara in 1888 and his own subsequent exhibitions in the Egyptian Hall at Piccadilly in London.[12] Graf was not alone as a purveyor of mummy portraits, as the public could view these images through a growing number of collections, like that of Augustus Pitt-Rivers, whose acquisition ledger includes mummy portraits acquired from Petrie in 1888 and from Greville John Chester in 1889.[13] This display was notable enough that the Baedeker guide singularly listed “some Greco-Egyptian mummy-portraits from the Fayoum” as among the paintings on view at Rushmore in 1890.[14] That Pitt-Rivers’ portraits reached rural England only a short while after the arrival of Graf's collection in Vienna is again testimony to the rising celebrity of mummy portraits within the art world and to the tightly linked networks of funders, excavators, and diggers between Egypt and Europe.[15]

By the end of the nineteenth century and the beginning of the twentieth, the systematic excavations at Hawara, Antinoöpolis, Tebtunis, and other sites added hundreds of portraits and their essential documented contexts to the growing corpus of panel paintings.[16] As always, Klaus Parlasca's monumental study of more than a thousand mummy portraits remains a fundamental resource for provenance research.[17] This paper would not be possible without Parlasca's careful cataloging of the movements of these portraits, especially those on the art market, which are otherwise poorly documented. Given this complicated history, it seemed appropriate to consider the composition of the APPEAR project entries in terms of their provenance.

The potential of a partnership between provenance and conservation—by presenting the data of both disciplines together as part of the same database—is what first drew me to the APPEAR project. But in order to start looking for commonalities, I needed to determine what data existed on the provenance of these portraits currently (May 2018) in the APPEAR database. To create this preliminary assessment, I collected data from a wide number of sources: provenances in individual entries, online museum collection pages, publications by Parlasca, exhibition catalogues, dealer advertisements, auction catalogues, dealer archives, and information provided by colleagues both at the Getty and throughout the APPEAR project.[18] As a caveat, the provenance information for some portraits remains incomplete, unpublished, or both, and future studies may incorporate new information not available at this time.

Of the 278 individual portraits, paintings, and fragments currently entered into the APPEAR database, just over one hundred come from documented excavations. Two others are likely to have been owned if not excavated by Petrie but cannot be connected to specific records; five portraits had no provenance information available from the APPEAR project or from publications that would confirm their categorization. That leaves 166 portraits, or just under 60 percent of the portraits in the database without a secure documented provenience. Of them, four have been described as forgeries. This set of 166 unprovenienced portraits is split almost evenly between ex-Graf and non-Graf groups.

Although the Graf collection was historically associated with er-Rubayat, the burial ground for the ancient city of Philadelphia, more recent scholarship has challenged this assumption; the diversity among ex-Graf portraits preserved within the APPEAR database alone warrants caution.[19] The eighty-four Graf portraits currently make up roughly one-third of the APPEAR database, and one-quarter of the suggested total of 330 portraits and fragments once owned by Graf, making the APPEAR database an unparalleled resource for understanding the composition of his collections. These portraits constitute significant portions of both Graf's initial collection, often referred to as Graf I, and the collection revealed only after his death, Graf II.[20] The celebrity nature of Graf as an owner has often overshadowed later collecting histories accrued by ex-Graf portraits, even for portraits still on the art market more than a century later; in this way, the APPEAR project also allows for the dispersal of the Graf collection to be more critically examined. It should be noted that more than thirty additional portraits and mummies are a part of APPEAR institution collections but are not currently a part of the database, so future analyses will lead to different breakdowns across all categories of provenance and provenience data.

To return to the excavated material, the APPEAR database contains portraits from at least eight sites: Hawara, Tebtunis, Kafr Ammar, Fag el-Gamus, Thebes, El-Hibeh, Tanis, and Karanis. Excavated material from at least six additional sites—Marina el-Alamein, Saqqara, Abusir el-Melek, Antinoöpolis, Akhmim, and Aswan—is not currently represented, although several portraits within the database have been stylistically attributed or ascribed through market provenances to some of these sites.[21] The excavated portraits represent a narrow array of early excavations, from Hawara in 1887 to the Karanis excavations of 1926. Understanding and confirming the overall geographical distribution of the portraits within the APPEAR corpus is critical so that any limitations on the data available can be understood within the appropriate context.

The portraits acquired on the art market are, as expected, a far more heterogeneous group. They represent both the earliest and the latest acquisitions in the APPEAR database: from an intact portrait mummy in the British Museum, acquired from Henry Salt by 1821, to a portrait acquired in 2009 by the Museum of Fine Arts in Houston.[22] As referenced above, the unexcavated portraits include stylistic attributions to or market provenances suggesting connections to a wide variety of sites, including Hawara, Antinoöpolis, er-Rubayat, Akhmim, Kerke, Thebes, El-Hibeh, and Saqqara. Unlike the excavated portraits in APPEAR, which overwhelmingly entered into museum collections soon after excavation, the portraits acquired on the art market have histories that are often complex and nonlinear. For example, C. Granville Way donated two shrouds to the Museum of Fine Arts, Boston, in 1872, but they were documented decades before, in 1836, as part of the Robert Hay Collection in Scotland.[23]

Given the large percentage of Graf portraits in the database, it follows that the acquisition dates of many APPEAR portraits reflect the dispersal of that collection in the early decades of the twentieth century; however, Graf portraits continued to move into and out of private collections and museums, and the APPEAR corpus includes additional acquisitions by museums throughout the twentieth century of mummy portraits with no known connection to Graf or his agents. As a whole, the APPEAR project represents close to two centuries of mummy portrait collection, excavation, display, and treatment.

Unsurprisingly, two names dominate the provenances of the APPEAR portraits: William Flinders Petrie and Theodor Graf, the two figures associated with both the largest group of excavated portraits and the largest private collection of portraits, the latter group all unprovenienced. The word cloud in figure 11.1 excludes Petrie and Graf for the purposes of illustrating more clearly the other constituents identified as involved with the APPEAR portraits. To create this image, a tally was included for every figure identified as part of a portrait's history, including a site's excavators, patrons, dealers, and donors. Within this framework, some portraits are associated with multiple figures and others with very few. The discrepancy in available information means that this compilation is not intended as a complete plot of every provenance for every portrait, but it serves as a beginning toward mapping emergent patterns. The negative space documents the unknowns: the names of the anonymous people who first found and handled the portraits that formed many early collections; the intermediary agents and dealers whose own preferences for and treatment of the portraits is also undocumented; and the amorphous category of “private collection,” which elides so much of the combined collecting histories of ancient panel paintings. Although Graf's singular collection is often treated as a metonym for the art market trade in portraits, Graf operated within a far broader constellation of dealers extending into the twentieth and even twenty-first centuries. By acknowledging and considering the wider circulation of portraits on the art market, other connections may be drawn in the future between portraits across the APPEAR project.

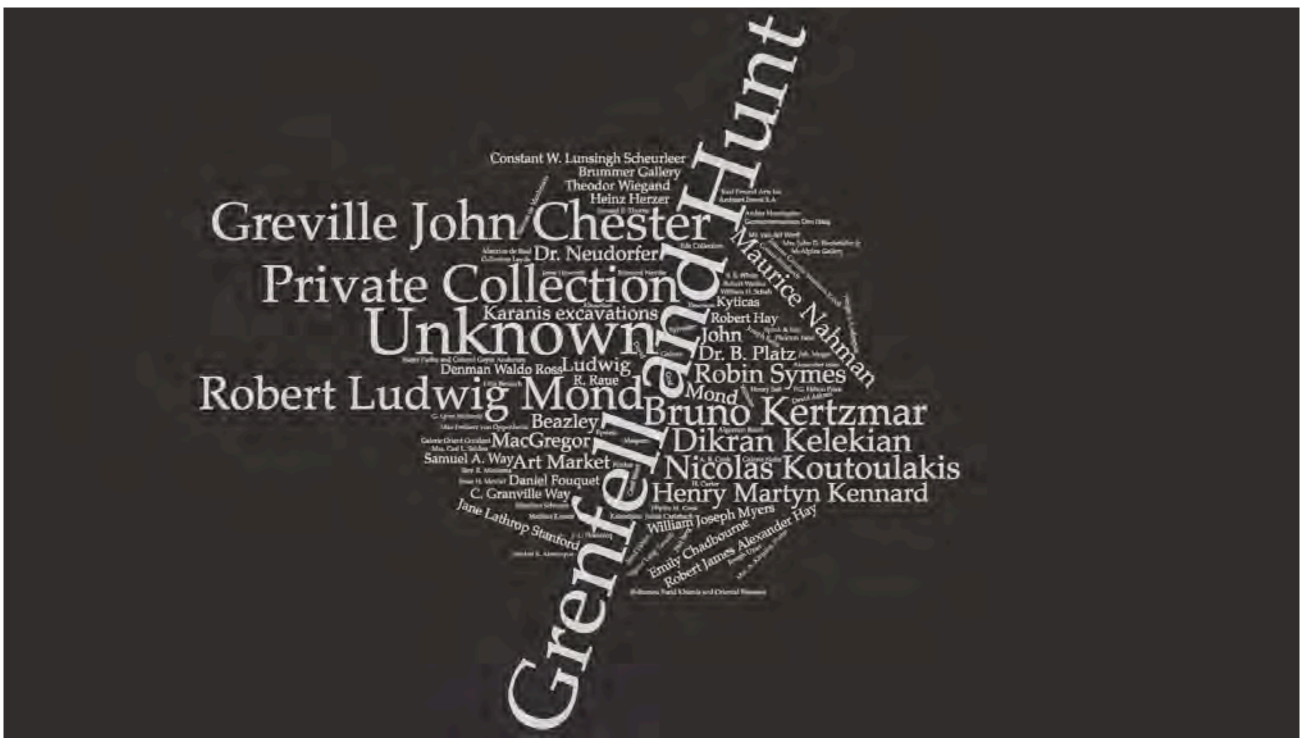


Figure 11.1 Word cloud of constituents associated with portraits in the APPEAR database, excluding William Flinders Petrie and Theodor Graf

Tracing Provenance: A Museum Collection as Case Study

To return to the Getty's own collection, the APPEAR project arrived at an opportune moment. Over the past five years, a small team of researchers has worked on the provenance of the forty-six thousand objects and fragments in the antiquities collection, so the APPEAR project was a welcome chance to reassess what information was known about the provenances of the Getty's portraits. The recent reinstallation of the Villa's collection provided further opportunities to photograph and analyze the mummy portraits traditionally on permanent display. All sixteen of the panels, portraits, shrouds, and portrait mummy were acquired by the museum or donors through the art market between 1971 and 1991; none of the works are known to have been archaeologically excavated.

In beginning to assess their histories, one primary tool was the portraits themselves. It is no surprise that the reverses of ancient panel paintings, like those of their modern counterparts, have been infrequently discussed and rarely published. The relative rarity of ancient panel paintings has also meant that post-acquisition, many portraits have been on near-constant display, precluding any comprehensive documentation of marks, stickers, stamps, or labels on their reverses. To date, these markings, often themselves of unknown provenance, are seldom referenced in museum publications or catalogues.[24]

Because so many portraits in the APPEAR project were part of the Graf collection, the APPEAR database serves in particular as a repository for Graf-related ephemera of all kinds.[25] Graf once owned at least two of the Getty's portraits, Mummy Portrait of a Woman (79.AP.129) and Mummy Portrait of a Young Woman (81.AP.29), although their respective provenance histories include many detours between their departure from Egypt and their final acquisition by the Getty (figs. 11.2 and 11.3).[26] Although Mummy Portrait of a Young Woman was never published as part of the Graf collection prior to Graf's death, the portrait's provenance is clear from the reverse, where a round purple stamp with the legend “SAMMLUNG THEODOR GRAF” is preserved (fig. 11.4). This stamp indicates that the portrait was part of Graf's second collection, as it was only applied to those portraits handled by the art dealer Bruno Kertzmar by 1930.[27] Even fragmentary portraits were stamped, as seen in a narrow fragment in the Allard Pierson Museum, where the stamp overlies an artificial backing.[28] This stamp is often accompanied by paper labels with photo negative numbers, visible on numerous other APPEAR portraits (see fig. 11.6), but no other labels are extant on Mummy Portrait of a Young Woman, indicative of differential preservation.

Figure 11.2 Mummy Portrait of a Woman, Romano-Egyptian, AD 175–200. Tempera on wood, 28.2 × 14.5 cm (11 1/8 × 5 11/16 in.). Los Angeles, J. Paul Getty Museum, 79.AP.129

Figure 11.3 Mummy Portrait of a Young Woman, Romano-Egyptian, ca. AD 170–200. Tempera on wood, 34.9 × 21.3 cm (13 3/4 × 8 3/8 in.). Los Angeles, J. Paul Getty Museum, 81.AP.29

The portrait 79.AP.129, Mummy Portrait of a Woman, was instead sold to Alfred Emerson at some point before 1922; the reverse preserves multiple export stamps from the Bundesdenkmalamt of Austria (fig. 11.5).[29] Because the sequence of twentieth-century Austrian export stamps can be dated, they offer an underexplored avenue for documenting the dispersal of Graf's collections.[30] This portrait has other unexplained markings, including a number in pencil beginning with “AV” (repeated twice) and another set of numbers—“109/167”—perhaps relating to its sale in 1942 at the Kende Galleries, where it was lot 167.

One unusual example of an unknown stamp, found on the reverse of a portrait from the Rhode Island School of Design Museum, is a square with scalloped edges, perforated in a cross pattern, with an elaborate design in blue and traces of ink (fig. 11.6).[31] Although uncommon, this stamp is also identifiable on more modern works of art, including at least one painting by Lucas Cranach the Elder.[32] Although the date and purpose of the stamp remain opaque, additional examples may help clarify its identity.

Figure 11.4 Reverse of fig. 11.3. Photo: Marie Svoboda, J. Paul Getty Museum

Figure 11.5 Reverse of fig. 11.2. Photo: Marie Svoboda, J. Paul Getty Museum

Figure 11.6 Reverse showing square stamp in center, Portrait of a Man, Romano-Egyptian, ca. AD 150–160. Probably tempera on wood, 34.3 x 19.7 cm (13 1/2 x 7 3/4 in.). Providence, RISD Museum, Mary B. Jackson Fund, 39.025

Analyses conducted as part of the APPEAR project suggest other pathways of research that may connect the Getty's portraits to others on the art market. One is the presence of lithopone, seen in four of the Getty's panel paintings: the three panel paintings once identified as a triptych (74.AP.20–.22) and a portrait of a man (73.AP.94).[33] All four were acquired in 1973 or 1974, and the dates and purposes of any prior restorations were unknown at the time of purchase. Lithopone, a pigment invented in 1874, is a mixture of barium sulfate and zinc sulfide.[34] At least two additional portraits in the APPEAR database preserve evidence of lithopone, including a modern forgery and a portrait now in Chicago.[35] Is lithopone use indicative of restorers working in a particular time, place, or firm? Additionally, all three panels of the “triptych” have detectable levels of bromine on both sides, suggesting residue from a methyl bromine application for pest control. Future research may help clarify the history of pesticide treatment for ancient panel paintings over the past few centuries.

Given that so many portraits entered into collections over the past century without excavation reports or publication histories, tracing mummy portraits on the market is challenging. Illustrations of mummy portraits in early auction catalogues are rare; terse descriptions—“Three ancient Portraits painted on wood panels, from the Fayum”—paired with unphotographed lots are not uncommon.[36] Studies on the reception of mummy portraits are a boon to provenance research, as they aid in tracking changes over time to mummy portrait lot descriptions, which range from Byzantine to Hellenistic, Egypto-Roman, Greco-Egyptian, Greco-Alexandrian, or Coptic, rarely with any specified provenience.[37] The ways in which these portraits were and are categorized within market settings reflect changes in contemporary scholastic debates as well as consumer preferences in selecting and ultimately purchasing these objects. Tracing a mummy portrait requires a consideration of how it *may have been* described, not only how it would be labeled today.

Provenance research has also been aided in recent years by the growing number of dealer and collector archives now available in libraries across the world. Dealer files can help document provenance as well as changes in a portrait's appearance, its mounting, and more. Among the most relevant for mummy portrait research are the records of the Brummer Gallery and the Kelekian Archives, both housed within different departments at the Metropolitan Museum of Art.[38] Dealer advertisements in trade publications, also increasingly available as a digitized resource, can serve as early publications for portraits on the art market. Further, considering historic display choices makes clear the desire to literally reframe mummy portraits within the painting tradition of the European canon. That so many portraits have now been removed from these older frames and mounts for contemporary displays is a further reminder of the changing reception that has greeted mummy portraits over the past two centuries: Are they artifacts? Are they human remains? Are they works of art? These shifting categories are, in turn, reflected in dealer stock books and academic publications, which then affect provenance research.

Reconstructing a History: An APPEAR Case Study

The value of approaching a portrait's history through both provenance research and conservation analyses can be illustrated by an APPEAR portrait donated to the Los Angeles County Museum of Art (LACMA) in 1971 by Phil Berg, a local art collector and talent agent (fig. 11.7).[39] The portrait had arrived at LACMA with no prior provenance information, but Marie Svoboda of the Getty was able to identify a Graf stamp on the portrait's reverse while it was being imaged for the APPEAR project (fig. 11.8). Another stamp was later determined to be an Austrian export stamp, as faint letters reading “Bundesdenkmalamt, Wien” are visible; this stamp probably dates to between 1923 and 1934, congruent with the dispersal after 1930 of the group of portraits owned by Kertzmar. Research for this paper led to an earlier catalogue of Berg's collection; in this volume the portrait's photograph shows evidence of an earlier phase of restoration by that time.[40]

Figure 11.7 Funerary Portrait, Romano-Egyptian, late third to fourth century AD. Tempera on wood, 30.5 x 15.2 cm (12 x 6 in.). Los Angeles County Museum of Art, Gift of Phil Berg Collection, M.71.73.62 © Museum Associates / LACMA

Figure 11.8 Reverse of fig. 11.7. Image: Yosi Pozeilov © Museum Associates / LACMA

With confirmation of a Graf provenance, the portrait could then be matched to one published by Parlasca, where a historical photograph of the portrait showed it in a different state of conservation, with dark patches occluding much of the face.[41] The portrait's move to Los Angeles was unknown to Parlasca, who had listed it as unpublished. Additional labels on the reverse of the portrait do not correspond exactly to any others in the APPEAR database, and they may relate to the panel's conservation history.

An examination of the portrait's ultraviolet flourescence (UVF) results indicates the presence of zinc white in the clothing and in the hair, a sign of overpainting (fig. 11.9).[42] But there are no obvious signs of overpainting or restoration in many of the darkened areas extant in 1930; delicate pigments, like the madder used to indicate the veins in the corner of the eyes, are evident in the UVF results. Although diagnosis is difficult through photographs, perhaps the blackened areas were the result of burial residue or adhesives; additional research into the panel's surface is needed to understand the sequence of historical photographs. Research stemming from APPEAR has added decades of evidence about the portrait's history, but the provenance recovered would not be as valuable without the conservation data, which allow us to begin to understand the changes the portrait has undergone throughout this time.

Figure 11.9 UVF results for fig. 11.7. Image: Yosi Pozeilov © Museum Associates / LACMA

Conclusion

While provenance may not have been the original goal of the APPEAR project, it allows for the opportunity to explore the multiple, complicated histories of these portraits in collections around the world. Just as understanding the taphonomic processes that artifacts have undergone in archaeological contexts is important for later interpretation of these objects, the physical processes that affect artworks after excavation are imperative to understand as well. Projects such as the APPEAR database underscore the need for dynamic collaborations on provenance as much as on material analyses.

Provenance, as a part of art-historical investigations, can help unravel where a portrait was created or who owned it. Provenance alone does not capture when a portrait was framed, fractured, or restored, although it provides a scaffold on which these data can be pieced together. Likewise, conservation and material analyses are a part of provenance; they contribute toward a greater, holistic understanding of an object's past. The history of mummy portraits is also inextricably tied to the extraction and marketing of other Egyptian artifacts from the same burial grounds. The provenance documentation in the APPEAR database better contextualizes the broader market for Egyptian antiquities throughout the past two centuries. Every portrait in APPEAR has the potential to inform another: that is the premise and the promise of this project. The continued shared interrogation of the provenances and conservation histories of these portraits around the world is an essential component toward this end.

Acknowledgments

I am indebted to Marie Svoboda and Mary Louise Hart for their encouragement and assistance with this paper, to the Los Angeles County Museum of Art (LACMA) for use of its image and data, and to the Andrew W. Mellon Foundation for its support of the conservation science fellow who performed some analytical work on the LACMA portrait.

NOTES

1. “The APPEAR Project,” accessed November 28, 2018, https://www.getty.edu/museum/conservation/APPEAR/index.html.
2. My thanks to David Newbury for this phrase.
3. Joyce 2012, 48–49.
4. Marlowe 2013.
5. Mummies (Organic Material) Child Mummy, Durham University Oriental Museum: DUROM 1985.61; the mummy was previously sold as part of the dispersal of the Pitt-Rivers family collection. For an example in Munich of a once intact, excavated portrait mummy for which only the portrait survives, see Grimm-Stadelmann 2016, 6.
6. Corcoran and Svoboda 2010, 18.
7. The association of style with a presumed findspot is further complicated by the evidence for the transport of portrait mummies prior to burial. Corcoran 1995, 38–39.
8. On the early history of mummy portrait collecting, see Parlasca 1966, 18–22; Bierbrier 2000; Grimm-Stadelmann 2016, 4–5.
9. Bernhard-Walcher 1998; on the history of Graf's varied collections, see Merz 2000 and Hagen and Ryholt 2016, 217.

10. Freccero 2000, 2; Hagen and Ryholt 2016, 192–95, 214.

11. Parlasca 1966, 27–28; Graf 1893.

12. On Petrie's excavations, see Trope, Quirke, and Lacovara 2005, xvi–xvii; on his mummy portrait finds, see Picton, Quirke, and Roberts 2007.

13. Allen 2012. In addition to the fragments published here, a male portrait, acquired in July 1888 from Petrie, can be added to those works probably on display at Rushmore.

14. Baedeker 1890, 102.

15. Pitt-Rivers' own guide notes that one or more of the portraits on view were "obtained by Mr. Flinders Petrie in Egypt," while omitting any additional provenance or excavation information. See Pitt-Rivers 1894, 8.

16. Thompson 1982, 5; Corcoran 1995, 35–37.

17. Parlasca 1966, 1969–2003.

18. I would like to thank all involved for their invaluable contributions.

19. Walker 2000, 69.

20. Freccero 2000, 29.

21. Corcoran 1995, 35–36; Bernhard-Walcher 1998, 28–29.

22. "EA6713," British Museum, accessed July 21, 2018, http://www.britishmuseum.org/research/collection_online/collection_object_details.aspx?objectId=129371&partId=1&searchText=henry+salt+6713&page=1; "Mummy Portrait of a Young Woman," 2009.16. Museum of Fine Arts, Houston, accessed July 21, 2018, https://emuseum.mfah.org/objects/96231/mummy-portrait-of-a-young-woman. Additional portraits in the database are on loan to APPEAR institutions from private collections.

23. "Funerary Shroud," 72.4723 and 72.4724, Museum of Fine Arts, Boston, accessed May 20, 2017, https://www.mfa.org/collections/object/funerary-shroud-136783 and https://www.mfa.org/collections/object/funerary-shroud-136779.

24. It is hoped that APPEAR entries will include these whenever possible, especially for stickers or stamps no longer extant but visible in archival photographs.

25. Freccero 2000, 29.

26. For their complete provenances, "Mummy Portrait of a Woman," 79.AP.129, J. Paul Getty Museum, accessed May 1, 2018, http://www.getty.edu/art/collection/objects/8633/unknown-maker-mummy-portrait-of-a-woman-romano-egyptian-ad-175-200/; "Mummy Portrait of a Young Woman," 81.AP.29, J. Paul Getty Museum, accessed May 1, 2018, http://www.getty.edu/art/collection/objects/9400/unknown-maker-mummy-portrait-of-a-young-woman-romano-egyptian-about-ad-170-200/.

27. Bernhard-Walcher 1998, 34; for the use of this stamp on collections beyond mummy portraits, see Merz 2000, 125–27.

28. Fragment of a Portrait, APM 8654, Amsterdam, Allard Pierson Museum.

29. This distinctive triangle stamp dates from April 1939 to November 7, 1940 or 1942; many thanks to Anita Stelzl-Gallian of the Bundesdenkmalamt for this information and her assistance.

30. These are rarely noted in museum catalogues; Freccero 2000, 88, is a notable exception.

31. "Portrait of a Man," 39.025, Providence, Rhode Island School of Design Museum, accessed July 22, 2018, https://risdmuseum.org/art-design/collection/portrait-man-39025?return=%2Fart-design%2Fcollection%3Fsearch_api_fulltext%3D39.025%26field_type%3DAll%26op%3D.

32. Lucas Cranach the Elder, *Portrait of Christiane of Eulenau*, 1534, Bayerische Staatsgemäldesammlungen, accessed April 21, 2018, http://lucascranach.org/DE_BStGS_13706. As with the mummy portrait, this painting also passed through the Galerie Fischer in Lucerne, one possible but unconfirmed connection.

33. For an in-depth treatment of 74.AP.20–.22 and their histories, see Hart 2016.

34. "Lithopone," Conservation and Art Materials Encyclopedia Online, Museum of Fine Arts, Boston, accessed August 1, 2018, http://cameo.mfa.org/wiki/Lithopone.

35. Art Institute of Chicago, 1922.4799; Sabino 2016, para 76.

36. Sotheby's, London, 18 October 1949, p. 19, lot 214.

37. E.g., the Sotheby's sale of July 27, 1931, at which both mummy portraits and textiles from the Graf collection were sold. The portraits are described by their provenance ("from the Graf Collection") and the textiles by a vague provenience ("from Egyptian burial grounds"), as if the portraits alone were dissociated from their original context.

38. "The Brummer Gallery Records," Cloisters Library and Archives, accessed April 12, 2018, http://libmma.contentdm.oclc.org/cdm/landingpage/collection/p16028coll9. The Kelekian Archive is held by the Onassis Library for Hellenic and Roman Art at the Metropolitan Museum of Art.

39. "Phil Berg, a Pioneer Talent Agent…," UPI Archives, February 3, 1983, accessed July 28, 2018, https://upi.com/6058577.

40. Los Angeles County Art Institute Galleries 1959, 32A.

41. Parlasca and Frenz 2003, no. 915.

42. Eng and Maccarelli 2016.

12

Painted Mummy Portraits in the Museum of Fine Arts, Budapest

Kata Endreffy
Árpád M. Nagy

The Collection of Classical Antiquities of the Museum of Fine Arts in Budapest owns five painted mummy portraits from Roman Egypt; this essay aims to discuss them in light of recent examinations carried out as part of the APPEAR project.[1] Over the past few years, valuable new information has been revealed via both restoration and technical analyses performed in cooperation with the Kunsthistorisches Museum, Vienna, under the direction of Bettina Vak, and through research on the collection history of the five pieces—as well as a sixth portrait from a private collection that for a short while was deposited in the museum. This paper concentrates on collection history, which sheds light on important aspects of the portraits—such as provenance, condition, and the date of their reworking—and also deals with specific features of private and, subsequently, public collecting. These concerns may be quite different from those encountered in larger museums and as such are lesser discussed perspectives in the highly topical debate on "who owns antiquity."[2]

The provenience of the five Budapest portraits is not known: we have presumed findspots for all of them but no information on their archaeological contexts. All have been stripped of their immediate contexts—that is, the mummy casings into which they were presumably inserted. We do not know to whose burials they once belonged, and we have scant information on where the patrons lived as well as when and how the deceased were buried. Without their names, an essential part of their identity, what survives is a constructed image—one that is heavily altered through the removal of layers of bandages and linen and through the addition of modern layers of paint that may completely obscure the original image. In evaluating the five mummy portraits, we are left with the objects as they are today and can rely on few outside sources to complement our findings.

The paintings themselves are funerary portraits in the Greco-Roman sense, constituting a pictorial record of the deceased with a focus on their position within contemporary society: the panels commemorate their subjects as members of the Romanized Egyptian elite.[3] It is the Greco-Roman aspect that dominates the appearance of the Budapest portraits today: save for barely noticeable hints, like traces of linen and resin,[4] little evokes the context of the paintings within Pharaonic burial practices. In the Egyptian funerary religion, however, the portraits are detached accessories of mummified figures, which, once fitted closely above the face, served as substitutes for the head, aiding the returning spirit in identifying the body and enabling it to partake of the funerary offerings.[5] Through the sacred wrappings, the gilding, and the wreaths, the paintings did not so much represent the deceased as humans but signaled their transformation into gods. Like the wrapped bodies themselves, the mummy portraits inserted within the linen bandages were meant to be hidden inside the tomb, safe from desecration—being locked away and covered ensured their preservation. To the ancient Egyptian mind, the paintings in Budapest, like hundreds of other mummy portraits similarly detached and dispersed around the world today, would represent failures in the process of self-preservation.[6]

With little awareness of this loss, the public and the scholarly community have been fascinated by these remarkably lifelike and vivid representations since the large-scale discovery of the corpus in the late nineteenth century. Given the cross-cultural context of their creation in Roman Egypt and the complexity of their function within that culturally variegated milieu, the paintings are open to several complementary investigative approaches and multiple layers of interpretation, which also allow for various possibilities in their display. In the new permanent exhibition *Classical Antiquities* at the Museum of Fine Arts, Budapest, we chose to display two paintings (figs. 12.1 and 12.2) in a room focused on concepts that may offer direct points of connection to visitors today.[7] The paintings appear together with funerary portraits from other periods and cultures, illustrating how people of antiquity perpetuated the memory of their loved ones. No attempt is made at reconstructing the lost Egyptian context of the mummy portraits, and there is a conscious refraining from pretending that such a reconstruction could make up for the loss of that context. The paintings are not presented as extensions of the body, in their aspect of *soma*, to paraphrase Jan Assmann,[8] but in their quality as *sema*—as signs or records of the lives of people of the past.

Prior to this installation, all five Budapest portraits underwent cleaning and stabilization. This restoration was performed by Bettina Vak at the Kunsthistorisches Museum in Vienna, where the paintings were transported in late 2015. Also carried out were technical studies that enabled pigment, binding media, and wood identification, and that complemented art-historical investigations.[9] Brief references to the results will be made below as the portraits are discussed in the light of their collection history. The five portraits have not only lost their ancient context—we are also in the dark about most of their modern history. In the following sections, we attempt to reconstruct the little that we could gather about the fate of the paintings at the end of the nineteenth century and into the twentieth century. Information on the lives of their three collectors offers new insights on the objects themselves and also outlines three different paradigms in the social history of modern Hungary.

Mummy Portraits from the Collection of Bernát Back

The two portraits now on display were purchased by the Museum of Fine Arts from Bernát Back, a Hungarian art collector, in 1948.[10] Back was born in 1871 into a Moravian Jewish family that had settled in Hungary in the mid-nineteenth century.[11] The family quickly became integrated into Hungarian society, with Back's father receiving noble titles and Bernát himself entering the political elite as a member of the Upper House of the Parliament. He lived in the city of Szeged in southern Hungary as a successful businessman and a prominent art patron, amassing a large and valuable collection of mostly sixteenth- to seventeenth-century paintings and sculptures.[12] Back sought to make his collection accessible to the public, a goal that was eventually realized in 1917 with an exhibition at his Szeged home; a subsequent show of his later acquisitions was also mounted there two decades later, in 1938. Back, having moved to Budapest, used what was left of his political influence and connections with the Catholic Church to survive the Second World War unharmed, a rare exception in the shared destiny of Hungarian Jews. He stayed in Budapest until 1951, when he was forced to flee to avoid retaliation by the Communist government for his earlier support of the right-wing regime that had propelled Hungary to its grim role in the war and that was largely responsible for the fate of Hungarian Jews. He spent his last years with his daughter's family in Gyón, a small town near Budapest, where he died in 1953.[13]

Like other members of the contemporary Hungarian elite, Back had little interest in ancient works of art: it was the Middle Ages, the era of a great, independent kingdom, that was generally elevated to the mythical status of a golden age in Hungarian cultural memory.[14] But Back had a particular enthusiasm for Egypt: in 1914, he sponsored as well as took part in a scientific expedition to the Monastery of Saint Catherine on the Sinai Peninsula with a team that included the renowned Coptologist Carl Schmidt and the orientalist Bernhard Moritz.[15] The outbreak of the First World War interrupted the mission, and much of the scientific documentation was lost.[16] Back's photographs and meticulous notes, however, survived, and he continued to work on this material up until his death four decades later.[17]

We have only one source concerning Back's antiquities that may shed light on his attitude toward ancient art. His correspondence from 1905 shows that he owed his collection of antiquities, including a group of stucco funerary masks, to his friend the painter and art collector

Sigmund Röhrer, who purchased the pieces from Theodor Graf for an unusually low price. Röhrer was quick to acquire the masks—in the hopes of Back's subsequent approval—before the German Egyptologist Friedrich Wilhelm von Bissing could make an offer.[18] This turned out to be more than just a good business opportunity, as Back decided to keep the pieces; the masks were only purchased by the Museum of Fine Arts from his grandson in the 1970s.[19] Interestingly, the items then numbered twenty-two, though Röhrer's letter from 1905 mentions only twenty-one, which means that Back must have bought antiquities, including the two painted mummy portraits, on other occasions as well. The stamps on the backs of the portraits clearly show that they too come from the Graf Collection.[20] It is probably because of this Graf connection that the two portraits are presumed to have come from er-Rubayat in the Fayum; in Back's documents there is no indication about their origin. The two portraits actually look quite different.

The first one is an encaustic painting on a thin panel of lime wood. The image shows an elderly woman with graying hair; she wears a purple tunic with black *clavi* and no jewelry (see fig. 12.1). Based on the hairstyle, the portrait has been dated to the Hadrianic period.[21] The other portrait[22] was painted in tempera on a thick sycomore fig panel; resin stains are found on the perimeter of the painting on both sides (see fig. 12.2). Against a blue background there is a woman wearing an off-white tunic with purple *clavi*, a pair of hoop earrings with three pearls each, and a necklace with a gorgoneion pendant.[23] In many ways this portrait is strongly Hellenized, with effects of foreshortening, eyes gazing off to one side, and right shoulder raised slightly higher than the left. At the same time, the execution does seem rather hurried, as if the artist did not entirely feel comfortable in this visual language.

Figure 12.1 Mummy Portrait of a Woman, Romano-Egyptian, second quarter of the second century AD. Presumably from er-Rubayat. Encaustic on lime wood, 29.5 x 14.1 cm (11 5/8 x 5 9/16 in). Budapest, Museum of Fine Arts, Collection of Classical Antiquities, 8901. Image: Szépművészeti Múzeum, Budapest. Photo: László Mátyus

Figure 12.2 Mummy Portrait of a Woman, Romano-Egyptian, second half of the second century AD. Presumably from er-Rubayat. Tempera on sycomore fig, 32 x 18.4 cm (12 5/8 x 7 1/4 in). Budapest, Museum of Fine Arts, Collection of Classical Antiquities, 8902. Image: Szépművészeti Múzeum, Budapest. Photo: László Mátyus

The *clavus* on the left shoulder seems a bit too thick, whereas on the right shoulder the tunic's neckline actually cuts into the *clavus*. There is a thick blue-gray line next to the right side of the neck, which suggests either a misunderstanding of the garment or an attempt to make the neck look thinner without changing the outline of the tunic. Similarly awkward is the right earring, which appears as if it did not actually pierce the ear; rather, it floats directly in front of it. Much of the left earring is covered by hair. The coiffure itself is problematic: with its short, free locks and lack of a parting, it does not conform to typical styles of the period. The portrait was dated to the third quarter of the fourth century by Klaus Parlasca and to the Antonine period by Barbara Borg; the latter dating is generally accepted today.[24] We have no close parallels for the piece;[25] the unique hairstyle may perhaps be explained by the possibility raised by Susan Walker at the Getty conference—that the painting was reworked in antiquity, turning the portrait of a man into that of a woman when the need arose.

Mummy Portraits from the Collection of Bonifác Platz

Three other portraits entered the Museum of Fine Arts only two years after the Back pieces, in 1950, but their collection history outlines an entirely different situation.

The works were purchased in Egypt by a Cistercian monk and scholar, Bonifác Platz.[26] Platz was born into a German artisan family in 1848, in the city of Székesfehérvár in central Hungary. He was a first-generation intellectual who became a priest, a teacher and theologian, and an ardent critic of the theories of Charles Darwin. Platz published widely on the age, origin, and history of mankind, and some of his works even appeared in German and Polish.[27] Fascinated by ancient Egypt, he traveled to the Nile valley six times between 1896 and 1908. The first excursion was an official one: together with Ignác Goldziher, the eminent orientalist of the time, he led a six-week study trip, visiting the Nile valley from Alexandria to Philae. On his later trips during the first years of the twentieth century, Platz purchased several Egyptian antiquities, which he later deposited at the Cistercian abbey at Zirc. After his death in 1919, the objects disappeared for decades, then resurfaced in the 1950s and were obtained by the Museum of Fine Arts in subsequent years. Many key pieces in the museum's Collection of Egyptian Antiquities come from Platz's purchases, and the museum's classical collection also includes many different artifacts from his acquisitions.

An amateur Egyptologist, Platz compiled a detailed manuscript catalogue of his collection of more than 150 pieces, and this record contributes considerably to what we know about the portraits.[28] The catalogue gives a thematic arrangement of the objects, but the numbers follow an approximate order of their acquisition between 1896 and 1908. This sequence suggests that the three portraits were purchased on two separate occasions.

The earlier acquisition bears the number 73 in the catalogue and purports to be from Akhmim in Upper Egypt (fig. 12.3).[29] We do not know if this should be taken as a place of purchase or as information Platz obtained from the seller; the phrasing suggests that the latter is more likely, because otherwise Platz seems to have carefully marked what he bought on-site and what he found in situ. The information may still be important as an independent source that could be compared with the archaeological data. Like all the Platz portraits, the image is painted on a thin lime wood panel in the encaustic technique, and it shows a woman wearing a purple tunic with a black *clavus*, adorned with a pair of simple hoop earrings; the turbanlike hairstyle would suggest a second-century date. This painting's authenticity has never been questioned, even though large-scale retouching is quite visible. X-ray fluorescence (XRF) analysis confirmed the modern retouching as well as indicated the presence of small traces of the original ground and pigments. Recent X-ray images have revealed the extent of modern retouching even more clearly, by outlining an entirely different face beneath the modern layer.[30]

Figure 12.3 Mummy Portrait of a Woman, Romano-Egyptian with modern retouching. Akhmim. Encaustic on lime wood, 39.3 x 16.7 cm (15 1/2 x 6 9/16 in). Budapest, Museum of Fine Arts, Collection of Classical Antiquities, 51.343. Image: Szépművészeti Múzeum, Budapest. Photo: László Mátyus

Heavy retouching is also evident in the case of another painting from the Platz collection. The Mummy Portrait of a Man (fig. 12.4)[31] was dismissed by Parlasca as a modern forgery, but XRF analysis has here too demonstrated traces of the original ground and pigments in the area of the right eye. The portrait bears the number 117 in the Platz catalogue and is said to be from the Fayum. It is important to note that Platz himself lamented that the value of the painting was reduced by the heavy retouching, which suggests that these considerable restorations were carried out by trained painters in Egypt prior to his purchase at the turn of the nineteenth century.

Figure 12.4 Mummy Portrait of a Man, Romano-Egyptian with modern retouching. Fayum. Encaustic on lime wood, 28.5 x 15.6 cm (11 1/4 x 6 1/8 in). Budapest, Museum of Fine Arts, Collection of Classical Antiquities, 51.342. Image: Szépművészeti Múzeum, Budapest. Photo: László Mátyus

Figure 12.5 Mummy Portrait of a Woman, Romano-Egyptian, first quarter of the second century AD. Fayum. Encaustic on lime wood, 36.5 x 12.7 cm (14 3/8 x 5 in). Budapest, Museum of Fine Arts, Collection of Classical Antiquities, 51.344. Image: Szépművészeti Múzeum, Budapest. Photo: László Mátyus

The third portrait from Platz's collection is reassembled from seven fragments of lime wood, which have been fastened on to a wooden board (fig. 12.5).[32] It shows a young woman, her head turned slightly to the right, wearing a purple tunic and a gold necklace threaded with red beads and dark, rectangular stones. Microscopic images and XRF analyses have shown what was only suspected before: that there is gold foil on the jewelry, lips, and eyes. The hairstyle suggests a Trajanic date.

Whereabouts Unknown: A Mummy Portrait from the Collection of Oszkár Hillinger

At present, we are still in the dark about the fate of the sixth mummy portrait that surfaced in Hungary in the mid-twentieth century. The portrait was owned by Oszkár Hillinger, whose biography can only be partially reconstructed.[33] He was born in 1887, in the city of Eger in northeastern Hungary, into a Jewish family. He went on to become a successful businessman and a high-ranking bank clerk in Budapest, and he survived the Second World War only to be relocated to the small town of Jászkisér in the early 1950s as an “enemy of the working class.” He later emigrated to London, where he is presumed to have died in 1962. Not much is known about the artworks in his possession, though they included sculpture, furniture, and a collection of about five thousand ex libris created for him by artists from Hungary and abroad. Apart from the mummy portrait in question, we do not know of ancient works of art in his possession; like Back, Hillinger did not focus on collecting antiquities.

We owe both the information on and the photograph of this portrait to an exhibition organized in fall 1947 at the Museum of Fine Arts, Budapest, which was still partly in ruins after World War II.[34] The exhibition brought together antiquities in Hungarian private collections: approximately five hundred items, including Hillinger's painting, were displayed in the museum's entrance hall. The 35-centimeter-tall portrait, painted in tempera on a panel that was obliquely cut along all corners, shows a young woman with a serious expression; she faces front and wears a red tunic with large *clavi*, a gold necklace with a small pendant in an inverted T-shape, and gold earrings with four pearls each (fig. 12.6). The portrait is also from Theodor Graf's collection and was auctioned in Vienna in 1932; thus, the work is presumed to come from er-Rubayat.[35]

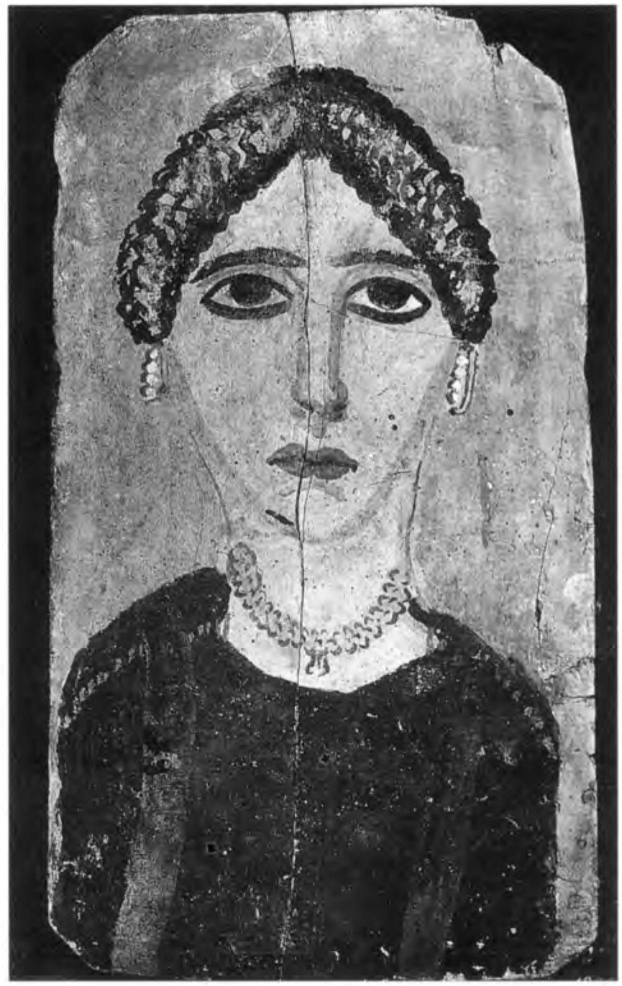


Figure 12.6 Mummy Portrait of a Woman, Romano-Egyptian, second century AD (?). Presumably from er-Rubayat. Tempera on wood, 32 x 18.4 cm (12 5/8 x 7 1/4 in). Whereabouts unknown. Image: Szépművészeti Múzeum Archives

Museum archives attest that when Hillinger was relocated to Jászkisér in the 1950s and his art collection confiscated by the Hungarian government, the mummy portrait was deposited in the Museum of Fine Arts for safekeeping. Before Hillinger left the country, he bequeathed his collection—or, more precisely, the task of reclaiming his objects from the state—to his sister, Erzsébet Hillinger. It was a lengthy process that dragged on for a decade: the portrait was only returned in 1963. János György Szilágyi, keeper of the Collection of Classical Antiquities at the Museum of Fine Arts then and for the next three decades,[36] made several attempts at acquiring the portrait from Hillinger's heirs, but to no avail. Neither Szilágyi nor Parlasca could later locate the piece, which thus remains inaccessible to both scholars and the wider public.

The primary means for enlarging the Collection of Classical Antiquities in the Museum of Fine Arts, Budapest, has always been the acquisition of objects from private collections in Hungary.[37] The three stories outlined above—that of the philanthropist art collector Bernát Back, the scholar and traveler Bonifác Platz, and the art lover Oszkár Hillinger—are emblematic examples of antiquities collecting in Hungary. They represent a tradition in antiquities collecting that resists the labels of both nationalism and colonialism, reflecting instead a humanist attitude that sees Hungarian culture within a shared European tradition and that is driven not by politically motivated institutions but by individuals who recognize the role that antiquity plays in their own culture. In this way, they offer what may be a third approach to the question of who owns antiquity.

These private collections have played a fundamental role in the formation of today's public collections. At the same time, the story of Oszkár Hillinger also shows the dangers of loss associated with private collecting; perhaps renewed research and the possibilities offered by the APPEAR database will prove helpful in locating the portrait in the future. Once commissioned, painted, wrapped, remembered, and forgotten, then rediscovered, unwrapped, traded, stored, and restored, the portraits continue their long history.

NOTES

1. See the APPEAR project's webpage at https://www.getty.edu/museum/conservation/APPEAR/index.html. The APPEAR database gathers information retrieved from portraits dispersed in museums around the world. It encourages joint research and rescues lesser-known pieces from oblivion by placing them into mainstream scholarship, both of which are important factors in the case of the Budapest portraits. We thank the editors for inviting us to read this paper at the conference and for publishing it in the present volume.
2. The question naturally echoes the title of James B. Cuno's monograph *Who Owns Antiquity?* (2008).
3. For an approach of "deconstructing" the Roman element in mummy portraits, see Walker 1997. Portraiture in Roman Egyptian funerary art is discussed in detail in Riggs 2005, esp. 95–174.
4. Resin stains appear on fig. 12.1; linen is attached to the board of fig. 12.3.
5. Much of what the ancient Egyptians would have considered essential for a continued existence after death is thus lost: besides the qualities and the knowledge necessary to navigate the underworld and to prove victorious before the netherworld tribunal, as well as the provisions from the world of the living, the central element would have been a burial that kept earthly remains and funerary equipment intact so as to accommodate the needs of the transfigured spirit. For a starting point in the vast literature on ancient Egyptian mortuary religion, see Assmann 2001; for an analysis of funerary beliefs in Roman Egypt, see Riggs 2005.
6. On the significance of textile wrappings in ancient Egyptian culture, and on approaches of the modern West that tend to focus on the (all too literal) unwrapping of that tradition, see the recent, pioneering study by Christina Riggs (2014).
7. The room is entitled *"Introite et hic dii sunt"*: Eros, Dionysos, Thanatos. It focuses on the spheres of these three deities, whose presence people today may also experience in an elemental way—just like the people of antiquity.
8. Discussing ancient Egyptian portraiture, Assmann differentiated between the portraits' focus on the "body" (*soma*) and the "sign" (*sema*), arguing that some Egyptian statue types, such as reserve heads from Old Kingdom burials, were not meant to communicate or commemorate something as signs but instead served as extensions of the mummified body itself; compare Assmann 1996, esp. 61–63. In their Egyptian context, painted mummy portraits would also have been seen as extensions of the body.
9. Multispectral imaging was conducted by conservation scientist Roberta Iannaccone, complementing the images taken by András Fáy (Museum of Fine Arts, Budapest). Pigments were identified through micro X-ray fluorescence analysis by Katharina Uhlir (Kunsthistorisches Museum, Vienna); wood samples were collected and analyzed by wood scientist Caroline Cartwright (British Museum, London); X-ray images were later taken by Mátyás Horváth (Hungarian University of Fine Arts, Budapest). We are grateful for the cooperation and assistance of all researchers involved.
10. On the acquisition, see Nagy 2013, 160–61, 161n473.
11. A brief biography is given in Verő 2017, 87. The article, which has a German summary on page 113, provides a comprehensive overview on the history of Back's collection.
12. Many of these today constitute highlights in the Galleries of Old Master Painting and Sculpture at the Museum of Fine Arts, Budapest: some of them were donated by Back, others were later acquisitions (see Verő 2017).
13. On Back's final years, see Valentyik 2017.
14. On medievalism in Europe in the nineteenth century, see the studies in Geary and Klaniczay 2013.
15. On the Sinai expedition, see Verő 2017, 108–12.
16. Besides two brief reports by Carl Schmidt and Bernhard Moritz, only one scientific publication survives by the latter: Moritz 1918.
17. See Verő 2017, 112. The unpublished manuscript is preserved in a private collection.

18. Sigmund Röhrer's letter to Bernát Back on February 8, 1905, mentioned by Verő 2017, 108n164.

19. Budapest, Museum of Fine Arts, Collection of Classical Antiquities, inventory nos. 74.2.A–.19.A, 74.45.A, 79.7.A–.9.A. For a recent analysis of the stucco masks, see Müller 2017.

20. This was not the first attempt to bring the Graf portraits to Hungary. Graf made an offer to sell some of his portraits to Hungary, and consequently, in March 1891, the director of the National Picture Gallery in Budapest made a proposal to the Hungarian minister of religion and education asking him to consider that the gallery widen its scope of collection to include paintings from antiquity. In the case of a positive decision, three male and three female portraits would have been purchased from Graf's collection, selected from a list of fifteen items. In the end, the acquisition did not go through. See the Museum of Fine Arts archives 64/1891.

21. Budapest, Museum of Fine Arts, inv. no. 8901, 29.5 x 14.1 cm, lime wood. All wood identifications are by Caroline Cartwright. Zaloscer 1961, 60; Parlasca 1977, 34, no. 269, pl. 65.2; Doxiadis 1995, 30, 191, no. 27; Borg 1996, 46–47, pl. 64.1; Frenz 1999, 175, no. 75.

22. Budapest, Museum of Fine Arts, inv. no. 8902, 32 x 18.4 cm, sycomore fig. Zaloscer 1961, 60; Parlasca 1980, 59, no. 642, pl. 152.1; Frenz 1999, 195, no. 99; Borg 1996, 55.

23. On this type of pendant and its apotropaic function, see Borg 1996, 169n147, as well as Michaelis 2015.

24. See Parlasca 1980, 59, followed by Frenz 1999, 195 versus Borg 1996, 55, and similarly Michaelis 2015.

25. It is not entirely unlike a painting in the Getty Museum (inv. no. 81.AP.29), also from the Graf Collection and also tempera on a thick sycomore fig panel, in which the execution of the mouth, the eyelashes, and the strong contour of the upper eyelid are perhaps comparable, but otherwise the similarities are not very strong.

26. For a brief biography, see Győry 2002 (in Hungarian).

27. See, for instance, Platz 1887, 1891. Platz was not averse to classifying the race of the patrons of his mummy portraits based on their facial features.

28. The manuscript is preserved in the Zirc-Pilis-Pásztó and Szentgotthárd Abbey Archives of the Cistercian Order, no. VeML XII. 2/i, manuscripts of Bonifác Platz 9/b. We are grateful to Katalin Anna Kóthay for providing us with a copy of the manuscript.

29. Budapest, Museum of Fine Arts, inv. no. 51.343, 39.3 x 16.7 cm, lime wood. Platz manuscript, 23, no. 73; Zaloscer 1961, 60; Parlasca 1977, 41, no. 297, pl. 71.1; Borg 1996, 48.

30. The X-rays were taken by Mátyás Horváth (Hungarian University of Fine Arts) shortly before the closing of this manuscript; the question needs further examination and study.

31. Budapest, Museum of Fine Arts, inv. no. 51.342, 28.5 x 15.6 cm. Platz manuscript, 24, no. 117; Zaloscer 1961, 60; Parlasca and Frenz 2003, 119n5, pl. 201.3.

32. Budapest, Museum of Fine Arts, inv. no. 51.344, 36.5 x 12.7 cm, allegedly from the Fayum. Platz manuscript, 24, no. 118; Zaloscer 1961, 60; Parlasca 1969–2003, 55, no. 105, pl. 25.3; Doxiadis 1995, 181, 223, no. 121; Geoffroy-Schneiter 1998, 59, 79.

33. For a brief discussion of Hillinger's life and his collection, see Horváth 2017.

34. Dobrovits and Oroszlán 1947, 15, pl. 3.

35. Parlasca and Frenz 2003, 70, no. 803, pl. 177.6 (dated to the mid-fourth century AD). Based on the sole archival photo, the piece can only tentatively be dated to the second century AD.

36. See Bellelli 2016.

37. See Nagy 2013, 208.

Part Two

13

Scrutinizing “Sarapon”: Investigating a Mummy Portrait of a Young Man in the Michael C. Carlos Museum, Emory University

Renée Stein
Lorelei H. Corcoran

In 2004 the Carlos Museum of Emory University acquired a mummy portrait that depicts a young, beardless man wearing a white tunic (fig. 13.1). He has dark curly hair, thick eyebrows, and full lips. Within a red, tabula ansata–shaped label at the subject's right, an inscription in Greek provides his name, patronymic, and age at death. He is identified as “Sarap[i]on,"[1] son of Haresas, 25 (or 29) years.[2] Little more than 3 percent of the approximately one thousand mummy portraits worldwide include texts with the deceased's name,[3] making this example both rare and significant.

The portrait's modern history began in the early twentieth century, when Philadelphia art collectors Vera and Samuel Stockton White III purchased the work from the Dikran Kelekian galleries. The Whites’ substantial art collection was donated to the Philadelphia Museum of Art in 1967; however, the mummy portrait was not included in that gift and instead was sold by Parke-Bernet Galleries, New York, presumably to its last private owner, businessman Jonas Senter.[4]

Figure 13.1 Mummy Portrait of Sarap[i]on, Romano-Egyptian, ca. second century AD. Wood, pigments, wax, and glue, 33.7 x 41.9 cm (13 1/4 x 16 1/2 in.) Atlanta, Michael C. Carlos Museum, Emory University, Mohamed Farid Khamis / Oriental Weavers Fund, 2004.048.001. © Michael C. Carlos Museum, Emory University. Photo: Bruce M. White, 2008

Upon acquisition by the Carlos Museum, the painting was treated to stabilize loose fragments, remove a historical but inappropriate frame, and minimize its fragmentary appearance by selectively inserting toned fills. The report from that treatment confirmed earlier observations: the portrait was assembled from more than one painting.[5] The APPEAR project motivated this present reconsideration, which also benefits from improved technology.

The Carlos painting consists of more than fifty fragments of varying lengths and widths. The woods range in color, and their painted surfaces differ in thickness, ground, and brushwork. While the fragments can be differentiated by close visual inspection, this study also employed materials analysis and multispectral imaging to associate the fragments into groups.

Gas chromatography/mass spectrometry analysis of representative paint samples identified traces of aged beeswax on some fragments and animal glue on others; an egg coating might have been selectively applied. Analysis and examination are complicated, however, by the presence of modern animal glue used to secure the fragments to the plywood backing. Overpainting created most of the proper left eye and cheek, reshaped the proper right shoulder, and produced the highlights on the tunic's folds. Additional media samples along with wood identifications may further differentiate fragment groups.

A complex puzzle emerges from combining close visual examination and media analyses with multispectral imaging and elemental mapping. Individual fragments and brushwork are highlighted by differences in radio-opacity in X-ray images. Fragments can be further distinguished and associated by their appearances under ultraviolet induced visible fluorescence (fig. 13.2) and false-color infrared imaging, revealing modern interventions. The distribution of elements present in various paints also suggests relationships among fragments. Elemental mapping by scanning X-ray fluorescence spectroscopy showed lead to be present in some whites as well as some reds, while iron is present in retouching on the face (fig. 13.3). Calcium is concentrated in the group of fragments above the ear, which have a visible, thick, white ground. Zinc is associated with modern reworking; the absence of zinc in the fragments that constitute the inscription is noteworthy. Scanning electron microscopy and energy dispersive X-ray spectroscopy analysis of a sample from the white letters revealed a highly crystalline compound of oxygen, aluminum, sulfur, and sodium, with trace inclusions of lead. Raman spectroscopy confirmed the presence of a sulfate compound, indicating that the letters are painted with (sodium-?) aluminum sulfate.

Figure 13.2 UVF image of Mummy Portrait of Sarap[i]on. © Michael C. Carlos Museum, Emory University

Figure 13.3 Scanning XRF map showing lead on Mummy Portrait of Sarap[i]on. Map obtained on a Horiba XGT-5000 at Georgia Electron Microscopy.

The inscription fragments are smoothly painted, probably in glue tempera, on dark wood with no visible ground layer. Those fragments and others adjacent to them appear similar by visual examination, multispectral imaging, and elemental mapping. Some fragments associated with this group depict carefully delineated black curls, indicating that the named deceased had dark hair with wiry curls. It is unlikely, however, that the face presents Sarap[i]on's likeness. Examination and analysis reveal that the face fragments were instead painted in wax encaustic, and although probably ancient, they have been reworked. Thus, the fragments that now compose the Carlos portrait were likely taken from three or more ancient portraits, perhaps from among those found at Antinoöpolis, er-Rubayat, and/or Hawara.

In 1966, while it was still in the White collection, the portrait was described by Klaus Parlasca as "a heavily overpainted pastiche,"[6] and in 1993 Dominic Montserrat pronounced that it was of "dubious authenticity."[7] Despite these reservations, however, Parlasca and Frenz did *not* list the Carlos portrait in the forgeries section of their most recent volume of the *Repertorio*—perhaps because they acknowledged that it "incorporates original fragments."[8]

It could be argued that as a modern assemblage, retouched and intended to present a unified whole, the Carlos portrait constitutes a fake. Yet, there is historical accuracy to both the depiction and the object. The text and the image record and evoke the life of a young man who died in Roman Egypt and was memorialized according to contemporary religious practices and regional stylistic preferences. The Carlos portrait is, therefore, a modern construct that is representative of both the named deceased and the genre of ancient painting to which mummy portraits belong. In its re-presentation of ancient fragments, this object underscores the subtle distinctions that affect the assignment of "authenticity."

Acknowledgments

We thank Melinda Hartwig for permission to publish. We acknowledge the contributions of Jessica Betz Abel, Madeline Beck, Ann Brancati, Miriam Cady, Caroline Cartwright, Claire Fitzgerald, Eric Formo, Stacey Gannon-Wright, Joy Mazurek, Brian P. Muhs, Tanya Olson, Michaela Paulson, Tina Salguero, Morgan Webb, Terry Wilfong, and the Andrew W. Mellon Foundation.

NOTES

1. The name is written in the text without an iota, but *Sarapion* was the more common spelling in antiquity; see as corrected in Montserrat 1996, 184n27.

2. Parlasca (1966, 82) initially proposed the text be read as "25 years [of age]"; then later, Parlasca and Frenz (2003, 65), hesitated between 25 and 29 because the final letter—whether epsilon, 5, or theta, 9—is unclear. Montserrat (1996, 184n27) read the age as lambda epsilon, 35. It is only in an archival

photo of Sarap[i]on that the kappa (2) is clear, whereas the final letter is still not clearly legible. Regardless, the young Sarapion died, therefore, in his mid- to late twenties.

3. Montserrat 1996, 184n27.

4. Michael C. Carlos Museum records for Inv. 2004.048.001.

5. Parlasca 1966, 81, 259.

6. Parlasca 1966, 81, 259.

7. Montserrat 1996, 184n27.

8. Parlasca and Frenz 2003, 65, 120.

14

Defining a Romano-Egyptian Painting Workshop at Tebtunis

Jane L. Williams
Caroline R. Cartwright
Marc S. Walton

The collections of the Phoebe A. Hearst Museum of Anthropology, University of California, Berkeley, include eleven mummy portraits excavated between 1899 and 1900 from Tebtunis, Egypt.[1] This group constitutes one of the largest assemblages of Roman-period mummy portraits to remain both together and unrestored since excavation; as such, it presents a rare opportunity to explore the local practices of an ancient painting workshop. The group also contains, on the back of an effaced portrait, direct evidence of painting practice: a sketch with annotations detailing how the image should be completed (fig. 14.1).[2] The APPEAR project inspired the collaborative technical study of the eleven Tebtunis portraits as well as a single, additional portrait purchased from Theodor Graf for the University of California (PAHMA 5-2327; fig. 14.2), which provides a comparative example of a stylistically different portrait attributed to the site of Kerke.[3]

Figure 14.1 Sketch, shown in NIR illumination, with instructions in Greek for completing the portrait, found on the reverse of a nearly effaced portrait, Tebtunis, Egypt, second century AD. Encaustic paint and ink on sycomore fig panel, 34.8 x 22.5 cm (13 11/16 x 8 7/8 in.). Berkeley, University of California, Phoebe A. Hearst Museum of Anthropology, 6-21378a. Courtesy of Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California. Photo: M. Walton

Figure 14.2 Mummy Portrait, Romano-Egyptian, second century AD. Attributed to Kerke, Egypt. Glue tempera paint on linden panel, 35 x 19 cm (13 3/4 x 7 1/2 in.). Berkeley, University of California, Phoebe A. Hearst Museum of Anthropology, 5-2327. Courtesy of Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California

A multimodal approach based on noninvasive analytical techniques—including in situ X-ray fluorescence spectroscopy, Fourier transform infrared spectroscopy, hyperspectral imaging, and photometric stereo imaging—was used to compare the portraits and determine whether the use of materials and techniques across the group defines a local workshop.[4] Noninvasive analyses then targeted the selection of a limited number of paint microsamples to confirm material identifications and provide information about pigment distribution within the layers.[5] Wood substrates were identified via scanning electron microscopy of tiny samples from the panels.[6]

Distinctive features of nine of the Tebtunis portraits (PAHMA 6-21374, 6-21376, 6-21377, 6-21378a [see fig.14.1], 6-21378b [see fig. 14.3], 6-21379, 6-21381, 6-21382, and

6-21383) set them apart from the rest of the paintings currently in the APPEAR corpus. As the corpus grows, these attributes may identify related paintings in other collections. These portraits are unique in the APPEAR corpus, as they have gypsum chalk white preliminary sketches on the obverse and/or Greek script on the reverse. Additionally, these nine Tebtunis portraits are on thick (1.2–1.5 cm) sycomore fig panels; thick panels and the use of sycomore fig are less common within the APPEAR corpus. Sycomore fig was used for fewer than 20 percent of the panels identified for the APPEAR project, including this group of nine.[7] Finally, two pairs of portraits within this group of nine share features that are identical in both appearance and execution and are unlike any portraits outside the group. Two male subjects (PAHMA 6-21377 and 6-21378b [see fig. 14.3]) wear gilded wreaths that were painted first with an indigo-based paint, and two female subjects (PAHMA 6-21381 and 6-21383) wear on their third fingers gold bands rendered in yellow ochre and gold leaf.

Figure 14.3 Mummy Portrait, Romano-Egyptian, second century AD. Tebtunis, Egypt. Encaustic paint on sycomore fig panel, 34.8 x 22.5 cm (13 11/16 x 8 7/8 in.). Berkeley, University of California, Phoebe A. Hearst Museum of Anthropology, 6-21378b. Courtesy of Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California

Although additional features unite these nine paintings, none are unique to the Tebtunis portraits. The paint on all eleven Tebtunis portraits has a beeswax-based binder that was applied with brushes and metal tools. Lead white is a component of most colors, and nearly all tones are based on a mixture of iron earth pigments, including hematite, goethite, jarosite, and a manganese-rich “umber.” Egyptian blue has been identified within the APPEAR corpus in the shading and outlines of faces, the backgrounds, and in blue and blue-based colors. Among the tighter group of nine Tebtunis portraits, Egyptian blue appears only in the neutral background color.[8] Blue, purple, and pink shades are all based on the organic pigments indigo and madder. Certain pigments detected on other mummy portraits—namely, orpiment, realgar, and cinnabar—were not detected on these nine images.

Marked differences between the Tebtunis portraits and the portrait purchased from Graf (PAHMA 5-2327; see fig. 14.2) show the range possible in materials among known mummy portraits.[9] The Graf example is painted on a thin (0.3 mm) sycomore fig panel with an animal glue–based paint[10] over a white, calcium sulfate foundation layer; it has no discernible underdrawing. Its palette relies even more heavily than the Tebtunis portraits on iron earth pigments. No lead white, madder, indigo, Egyptian blue, cinnabar, orpiment, or gold leaf was detected.

APPEAR project participants are finding that the portrait painters, wherever they worked, had a similar range of materials available to them. Workshop practice within the Tebtunis portraits is defined and differentiated from the rest of the APPEAR corpus not by unique materials, but by specific choices the painters made from readily accessible tools and the subtle differences in how these artists employed the materials. With the possibility not only to identify materials but also to map how and where they are used in a painting, we can begin to distinguish the practice of a workshop.

NOTES

1. O'Connell 2007.
2. Fournet 2004.
3. Hearst Museum ledgers attribute the portrait, purchased by Alfred Emerson in 1900 from Theodor Graf, to Kerke.
4. The methodology and results are detailed in Salvant et al. 2018.
5. Paint sample analyses are detailed in Salvant et al. 2018.
6. Cartwright 2015.
7. See Cartwright, this volume.

8. Ganio et al. 2015.
9. Salvant et al. 2018.
10. Using gas chromatography/mass spectrometry, Joy Mazurek, of the Getty Conservation Institute, analyzed two samples from the paint and identified a protein binder with amino acids most closely correlating to those of animal glue.

15

Nondestructive Studies of Ancient Pigments on Romano-Egyptian Funerary Portraits of the Kunsthistorisches Museum, Vienna

Bettina Vak
Roberta Iannaccone
Katharina Uhlir

Introduction

In 2014 the conservation department of the Kunsthistorisches Museum, Vienna (KHM), joined the APPEAR project by adding ten mummy portraits to the collaborative study. Preliminary scientific investigations of these works began at the KHM in 1999.[1] Conservation treatment was completed on all ten portraits as well as on five examples from the collection of antiquities of the Museum of Fine Arts, Budapest, to learn more about the acquisition history of the Budapest funerary portraits.[2]

Conservation scientist Dr. Roberta Iannaccone implemented noninvasive multispectral imaging (MSI) for preliminary pigment identification. Dr. Caroline Cartwright, a wood anatomist, identified the tree species used for all fifteen panels; for the KHM examples, the results confirmed that six were sycomore fig, three were linden, and one was tamarisk.

Methods

MSI is a set of techniques based on photography at various wavelengths; every range of wavelengths (from ultraviolet to near infrared) can reveal different characteristics.[3] Ultraviolet-reflected (UVR), ultraviolet-induced visible luminescence (UVL), ultraviolet-reflected false color (UVRFC), visible (VIS), visible-induced infrared luminescence (VIL), reflected near-infrared (NIR) photography, and infrared-reflected false color (IRRFC) imaging were used to characterize pigments and shed light on modern retouches.

To acquire the images two cameras were used: a Nikon D80 with a resolution of 10 megapixels and a 23.5-by-15.7-millimeter sensor dimension, and a modified Nikon D3200 with a resolution of 24.2 megapixels with removed IR filter and a 23.5-by-15.7-millimeter sensor dimension. Both cameras were equipped with a Nikkor AF 28–105-millimeter, f/3.5–4.5D lens as well as specific filters for every technique.[4]

Noninvasive portable micro-X-ray fluorescence analysis (μ-XRF) was performed using the KHM's PART II instrument.[5] The spectrometer, equipped with a vacuum chamber to reduce the absorption of low energetic radiation in air, possesses a low-power X-ray tube with molybdenum (Mo) target (excitation parameters used: 40 kV, 0.4 mA, 100s). The primary beam is focused via a polycapillary lens (spot size ~150 μm). The measuring point is placed 1 millimeter outside of the chamber, thus minimizing absorption losses in the excitation and μ-XRF radiation paths.

Results

For all fifteen investigated portraits the common use of earth pigments was confirmed. Additionally, lead white, orpiment or realgar, copper green, Egyptian blue, madder, and gold were detected. Also identified were three different types of ground layers: calcite, gypsum, and lead white.

For the purpose of this publication, the studies of two portraits—visually classified as encaustic and tempera based—are described below.

The Portrait of a Lady (fig. 15.1) is encaustic based. The characteristic pink luminescence attributed to a red lake pigment is visible on the tunic but not on the lips; there μ-XRF confirms the presence of iron, suggesting the use of red ochre. The NIR image does not show an underdrawing; however, on the lips the outlining pigment seems mixed with a substance that strongly absorbs infrared radiation, suggesting the presence of charcoal in the admixture.

a. UVL

b. VIS

c. VIL

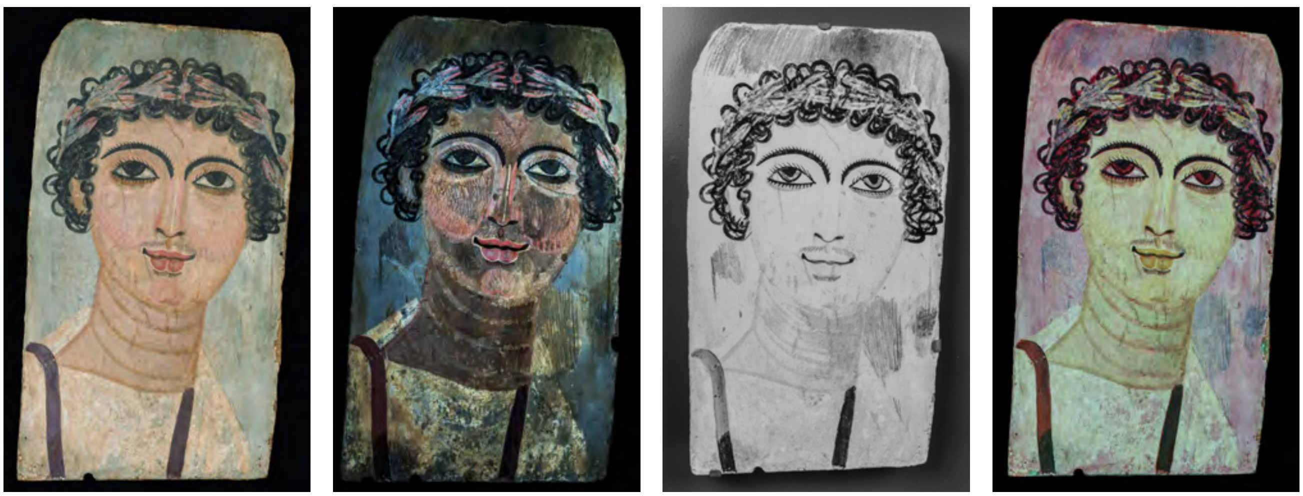
Figure 15.1 Portrait of a Lady, Romano-Egyptian, AD 117–138. er-Rubayat. Encaustic on wood, 40 x 20 cm (15 3/4 x 7 7/8 in.). Vienna, Kunsthistorisches Museum, Antikensammlung, X 297. KHM-Museumsverband

The violet tunic seems to partially absorb infrared radiation, with IRRFC showing a green/grayish response. Aluminum, typically associated with the lake substrate, together with a strong pink luminescence suggests the presence of red lake. Usually, when a red lake paint layer is superimposed on or mixed with red ochre or cinnabar, it appears yellow/orange in IRRFC. The VIL image shows the typical luminescence of Egyptian blue in areas of the tunic. μ-XRF measurements confirm this observation, revealing some copper. Most likely, the red lake was combined with

Egyptian blue, lead white, and red ochre (detected by μ-XRF) to obtain the purple tint. Egyptian blue was mainly used to render the face and create shadows (fig.15.1c).

Identification of the dark blue *clavus* on the left side of the tunic was inconclusive. XRF analysis did not identify any characteristic elements, and UVRFC and IRRFC imaging techniques did not indicate the presence of indigo. Furthermore, a pale blue fluorescence can be observed on top of the painted surface, in areas not covered by the mummy wrappings.[6] Classification and origin of this material will be a matter of further investigation.

The Portrait of a Young Man with Wreath (fig. 15.2) is tempera based. The UVL image shows some areas with bright pink fluorescence (likely due to a red lake) mainly on the wreath, cheeks, and lips; a bright yellow luminescence can be observed on the bridge of the nose, the lip outlines, and the eye. μ-XRF analysis in the area of yellow luminescence identified the presence of lead (lead white) and iron (earth pigments). Lead white typically fluoresces light blue; therefore, this particular yellow fluorescence could be related to the binder or a pigment mixture.[7]



a. VIS **b. UVL** **c. NIR** **d. IRRFC**

Figure 15.2 Portrait of a Young Man with Wreath, Romano-Egyptian, AD 125–150. er-Rubayat. Tempera on wood, 32.5 x 18 cm (12 13/16 x 7 1/16 in.). Vienna, Kunsthistorisches Museum, Antikensammlung, X 432. KHM-Museumsverband

The μ-XRF spectrum of the irises indicates the presence of iron (earth pigment). The unexpected red color visible in the IRRFC image of the dark hair, the original portion of the *clavi*, the irises, and the light blue background is attributable to the spectral response of a blue pigment, probably an organic blue (indigo) partly mixed with an earth pigment.[8]

Our understanding of the materials and painting process of the mummy portraits described above has been much enhanced by the scientific identification of the woods and by the use of two nondestructive methods (μ-XRF and MSI) for identifying the pigments.

NOTES

1. Pitthard et al. 2007.
2. See Endreffy and Nagy, this volume.
3. For similar methods applied on Attic ceramics, see Vak 2013.
4. Iannaccone 2015; Dyer, Verri, and Cupitt 2013.
5. Buzanich et al. 2010; Uhlir et al. 2012.
6. For further information about the material, see Pitthard et al. 2007.
7. See La Rie 1982; Roy 1993, 67–81.
8. Indigo has been identified in the pupil, hair, *clavi*, and beads of a comparable portrait in the Getty collection: Mummy Portrait of a Woman (79.AP.129). The paintings are similar in both their execution and their response to MSI.

16

Painted Roman Wood Shields from Dura-Europos

Anne Gunnison
Irma Passeri
Erin Mysak
Lisa R. Brody

On Friday, January 18, 1935, Clark Hopkins, field director of excavation at Dura-Europos, in present-day Syria, wrote in his notes: "Just after breakfast, three painted shields were found one right a top of the other.... Herb and I spent all morning removing them. Most of the wood was strong enough to move easily and much of the painting is visible."

Now in the collection of the Yale University Art Gallery (YUAG), these three shields—dated to shortly before AD 256, when Dura-Europos was sacked by Sassanians and abandoned—were quickly recognized as rare examples of painting on wood from antiquity. They depict scenes of the Trojan War from the *Iliad* (fig. 16.1): the battle between the Greeks and the Amazons, and a warrior god.

Figure 16.1 Shield Painted with Two Scenes from the *Iliad*, Greco-Roman or Parthian, mid-third century AD. Dura-Europos, Syria. Pine planks and pigment. New Haven, Yale University Art Gallery, 1935.551. Image: Yale University Art Gallery

Constructed of multiple thin slats of wood joined along the long edges and painted, the oval shields—all approximately four feet high by three feet wide—were cleaned in the field after excavation and consolidated with polyvinyl acetate by the expedition artist Herbert (Herb) Gute. He also painted faithful watercolor reproductions (also now in YUAG's collection; fig. 16.2) of the shields' imagery. Enthusiasm for the discovery prompted an official press release from Yale University in 1935 and publications of Gute's watercolors in the *Illustrated London News* in 1935 and *Fortune* in 1936.

Figure 16.2 Herbert J. Gute (American, 1908–1977), *Wooden Shield Painted with Scenes from the Trojan War*, commissioned by Yale University, 1935 or 1936. Watercolor on paper, 79.9 x 64.9 cm (31 7/16 x 25 9/16 in.). New Haven, Yale University Art Gallery, 1936.127.26. Image: Yale University Art Gallery

When the shields were brought to Yale University in 1935, conservator George Stout and scientist Rutherford Gettens from the Harvard University Fogg Art Museum analyzed them and produced a comprehensive report. Also at that time, Yale School of Forestry professor Samuel Record investigated the wood and identified it as pine. There was, however, little further comprehensive study or conservation treatment of the works until 2011, when the warrior god shield was conserved for display at YUAG.

The shields were fragile at the time of excavation and have only deteriorated in the eighty-five years since. The scenes are obscured by dirt and shiny, discolored polyvinyl acetate; the paint is lifting and tenting; and the wood substrate has buckled and warped. Though outliers in the APPEAR project in both place of origin and type of object, these shields serve as opportunities to examine similarities and differences in techniques and materials across regions. Since it was examined in 2011, the Trojan War shield has been the subject of an ongoing collaborative research project among conservators, conservation scientists, and curators at Yale.

Based on analysis with ultraviolet-induced visible fluorescence (UVF), X-ray fluorescence (XRF), scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM-EDS), Fourier transform infrared spectroscopy (FTIR), and Raman spectroscopy, the painted surface appears to include carbon black; calcium-based whites including gypsum and chalk; lead white; orpiment; organic red (likely rose madder); vermilion; indigo; and red and yellow iron oxide pigments.

A cross section (fig. 16.3) was taken from the edge of a plank and analyzed with FTIR, Raman spectroscopy, and SEM-EDS. The results are as follows:

4 – A thin reddish preparatory layer, composed of vermilion, small quantities of lead white, and rose madder on a gypsum substrate, in a matrix of aluminosilicates; likely rose madder, based on strong orange UVF.

3 – Pink layer, containing an organic red dye precipitated on a gypsum substrate, in a matrix of aluminosilicates.

2 – S-twist bast fiber, possibly flax.

1 – A ground layer of white calcium carbonate, likely chalk, in a matrix of aluminosilicates with S-twist bast fibers mixed in.

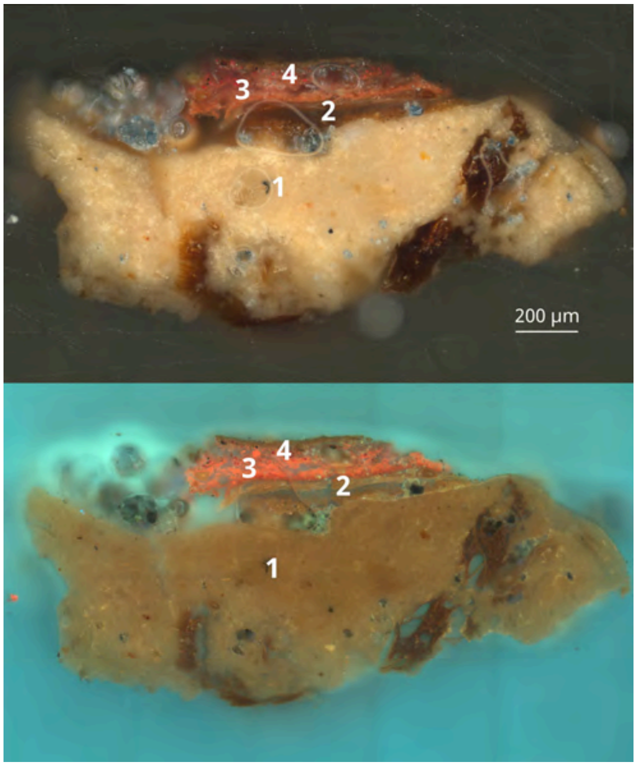


Figure 16.3 Cross section removed from the edge of a wood slat: in visible light (above) and exhibiting UVF (below). Image: Yale University Art Gallery

Of particular interest to our study is the identification of the paint's binding media. Visual analysis of the uppermost painted surface indicates the application of tempera paint. Gettens and Stout analyzed flakes of the paint film in a microchemical study. Although they did not arrive at a definite conclusion, they observed the presence of nitrogen and phosphorous, indicating an organic medium of either egg or casein; they were inclined to believe that the substance was casein.

In our study, surface scrapings of paint layers and residual glue on the edge of the wood slats were analyzed with FTIR and gas chromatography/mass spectrometry (GC/MS). FTIR detected proteins in the glue sample, which indicates that animal glue was used to join the slats; however, both FTIR and GC/MS identified wax as the binding medium of the paint layers. Proteins were not detected in the paint samples.

Dr. Brandon Gassaway of the Rinehart Lab in the Department of Cellular & Molecular Physiology and the Systems Biology Institute at Yale analyzed surface scrapings of paint layers and glue from the edge of wood slats with mass spectrometry–based proteomics. In both samples, casein, β-lactoglobulin, and serum albumin were found, attesting to the presence of bovine milk.

Joy Mazurek at the Getty Conservation Institute also studied GC/MS scrapings of a blue paint layer and red preparation layer. Proteins, likely animal glue, as well as degraded beeswax were identified. Mazurek (see this volume) believes this finding suggests that animal glue was used in the preparation layer, and that the paint layer includes a beeswax binding medium.

Cleaning and stabilization of the shields has been a priority in our project. Treatment has focused on removing surface dirt and the polyvinyl acetate, which has been reduced with 1:1 acetone and ethanol, as well as consolidating lifting paint.

Acknowledgments

Some of the analysis using SEM-EDS was carried out by Anikó Bezur, Wallace S. Wilson Director of Scientific Research, Technical Studies Laboratory, at Yale's Institute for the Preservation of Cultural Heritage. We thank Carol Snow, deputy chief conservator and Alan J. Dworsky Senior Conservator of Objects, YUAG; Ian McClure, Susan Morse Hilles Chief Conservator, YUAG; Debora Mayer, head of the paper conservation laboratory at the Weissman Preservation Center, Harvard Library, Harvard University; Brandon Gassaway and Jesse Rinehart of the Rinehart Lab in the Yale Systems Biology Institute; and Joy Mazurek, assistant scientist at the Getty Conservation Institute.

17

Characterization of Binding Media in Romano-Egyptian Funerary Portraits

Joy Mazurek

Introduction

The identification of binding media in funerary portraits is inherently complicated due to various factors such as restoration history, microbial deterioration, and environmental conditions (which are not always known). Gas chromatography/mass spectrometry (GC/MS) protocols were developed to identify waxes, oils, fatty acids, and proteins in forty-seven Romano-Egyptian funerary portraits. Analytical protocols utilized three separate derivatization techniques. The first analysis identified free fatty acids, wax esters, and fatty acid soaps; the second, oils and plant resin; and the third, proteins. The identification of plant gum required a separate paint sample. Figure 17.1 shows the museums that participated in this study, the number of portraits tested, and the types of binding media identified. What follows is a brief summary of the binding media survey; further information—including GC/MS analytical data, protocol details, painting technique, and sample locations—is the subject of another article.[1]

Figure 17.1 Summary of GC/MS Binding Media Results

Museum	Beeswax	Beeswax and Oil		Animal Glue	
J. Paul Getty Museum	81.AP.42 73.AP.94	73.AP.91 79.AP.141 [4] 78.AP.262	71.AP.72 74.AP.11	79.AP.219 [1] 81.AP.29 79.AP.129 91.AP.6 [3] 79.AP.142 [6]	74.AP.20 [3] 74.AP.21 [3] 74.AP.22 [3] 75.AP.87 [1, 3]
Santa Barbara Museum of Art				VL.2015.5	
Ny Carlsberg Glyptotek	AEIN 680	AEIN 681 [3] AEIN 682 AEIN 683 AEIN 684 [3]	AEIN 1425 [1] AEIN 1426 [2] AEIN 1473 [2]		
National Museum Denmark	AS 3891	AS 3892		AS 8940	
Museum of Fine Arts, Houston, and the Menil Collection	2009-16 TR:184-2013	CA 7124	CA 7013		
Los Angeles County Museum of Art				M.71.73.62	
Walters Art Museum	32.6	32.4			
Ashmolean Museum	AN 1888.342 [5]				
Phoebe A. Hearst Museum		6-21377		5-2327	
Petrie Museum	UC 19607 [2] UC 30081 [2] UC 33971 [2]	UC 19608 UC 19610	UC 19612	UC 14768	
Cantor Arts Center		JLS.22252		JLS.22226 [2]	
Total Portraits (47)	**11**	**21**		**15**	

[1] shroud; all other portraits are on wooden panels

[2] paraffin wax

[3] egg coating

[4] *Acacia* sp. plant gum in ground

[5] animal glue in ground

[6] animal glue and *Acacia* sp. plant gum

Tempera

Tempera portraits were tested by GC/MS amino acid analysis, as this method allowed for the identification of proteinaceous binding media. The portraits' samples were compared with common media, such as egg, animal glue, and casein. Results show that animal glue was the preferred tempera paint, as attested by a glue tempera portrait from the Petrie Museum (UC 14768; fig. 17.2a). The amino acids detected matched colllagen, the protein that makes up animal glue (fig. 17.2b). An earlier publication identified egg tempera in paint from UC 14768; however, this result was inaccurate due to interpretation error. It was based on fatty acids that are used to identify lipids and drying oils.[2]

Figure 17.2a Mummy Portrait, Romano-Egyptian, AD 160–180. Kafr Ammar, Egypt. Wood and animal glue, 31.2 x 18.0 cm (12 1/4 x 7 1/8 in.). London, Petrie Museum of Egyptian Archaeology, University College London, UC 14768. Courtesy of the Petrie Museum of Egyptian Archaeology, UCL

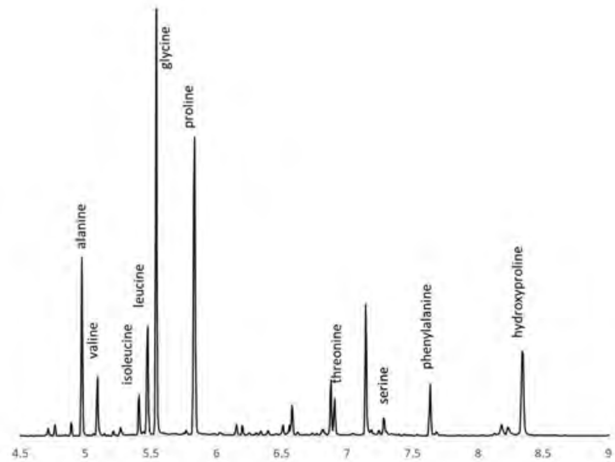


Figure 17.2b The GC/MS chromatogram of figure 17.2a shows that the amino acids closely match animal glue (99 percent).

Enzyme-linked immunosorbent assay (ELISA) detected egg on the surface of four panel portraits from the Getty Museum (JPGM 74.AP.20–22, 91.AP.6). Egg coatings were also detected by GC/MS amino acid analysis on the surface of two portraits from the Ny Carlsberg Glyptotek.[3] Future proteomic studies may help to determine the type of bird used to manufacture the egg coatings. Recently, cow skin (*Bos taurus*) was identified in JPGM 74.AP.20 with mass spectrometry, or peptide mass profiling, by comparing a sample from the portrait with different species of collagen.[4]

Plant gum was identified in the black ground from a beeswax mummy portrait (JPGM 79.AP.141), based on carbohydrate analysis. Animal glue was identified in the black ground of a similar encaustic portrait from the Ashmolean (AN 1888.342). *Acacia* sp. gum was identified in a gray paint sample from a glue-and-gum-tempera mummy portrait (JPGM 79.AP.142).

Encaustic

Thirty-two encaustic portraits were identified as beeswax portraits; they were analyzed for fatty acids, hydrocarbons, and wax esters by GC/MS. The investigation showed similar beeswax profiles for the majority of portraits, with considerable amounts of palmitic acid (C16)—likely present as palmitic acid lead soap—reduced alkanes (hydrocarbons), and decreased wax esters as compared with fresh beeswax. Results show that paint from the dark background of a beeswax mummy portrait (UC 19610; fig. 17.3a) had altered chemically, when compared with fresh beeswax (fig. 17.3b). The wax esters and alkanes had decreased substantially, while palmitic acid (C16) had increased.

Figure 17.3a Portrait of a Young Man, Romano-Egyptian, AD 140–160. Hawara, Egypt. Wood and beeswax, 39.6 x 27.8 cm (15 5/8 x 10 15/16 in.). London, Petrie Museum of Egyptian Archaeology, University College London, UC 19610. Courtesy of the Petrie Museum of Egyptian Archaeology, UCL

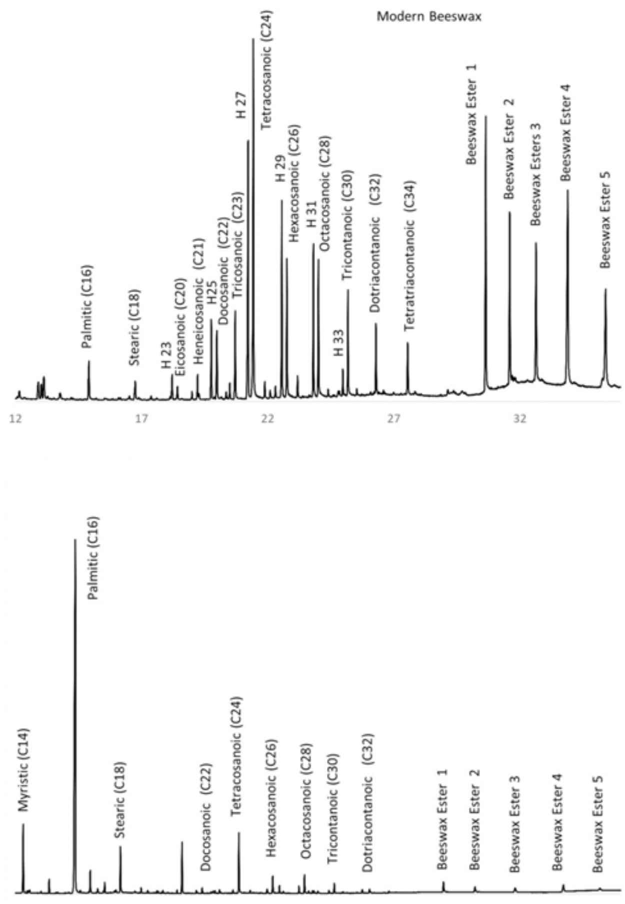


Figure 17.3b The bottom chromatogram shows the beeswax compounds identified in figure 17.3a. When compared with fresh beeswax (top chromatogram), an increase in palmitic acid (C16) and a decrease in hydrocarbons (H) and beeswax esters are evident.

Beeswax was likely applied melted, and little is known about the intentional modification by the artist in order to apply it while cold; this formulation is also called Punic, or emulsified, wax.[5] Previous publications have described intentionally modified wax based on changes in chemistry—for example, low relative amounts of fatty acids, decreased alkanes and wax esters, and the presence of metal soaps.[6] An early paper identified a modified wax, or “Punic wax,” in a beeswax mummy portrait (UC 19612), based on brushstrokes and decreased wax esters and alkanes.[7]

GC/MS analysis of UC 19612 shows that it was similar to most portraits tested; it had significant amounts of palmitic acid (as lead soap) and a decreased occurrence of wax esters and alkanes. The decreased content of wax esters (in comparison with fresh beeswax) does not necessarily mean it was intentionally modified, as similar wax profiles were observed in most portraits tested. Future research may shed light on the chemistry behind the decrease in wax esters and the subsequent reaction between palmitic acid and lead pigment.

Oil Identification

GC/MS fatty acid analysis identified oil in twenty-one beeswax portraits (two on linen) and one glue tempera portrait on linen (JPGM 75.AP.87; fig. 17.4a). Considered biomarkers for an oxidized oil, dicarboxylic fatty acids in paint are more likely to form in dry and arid climates. Figure 17.4b shows a chromatogram of JPGM 75.AP.87; it contains dicarboxylic fatty acids, indicating the presence of an oxidized oil. Brassicaceae (mustard, crucifers, and cabbage family) seed oil has been positively identified in Egyptian artifacts, based on similar dicarboxylic fatty acids.[8] Further research and corroborative findings will help determine if these oils were intentionally added.

Figure 17.4a Mummy Shroud with Painted Portrait of a Boy, Romano-Egyptian, AD 150–250. Unknown, Egypt. Tempera on linen, 62 x 52.5 cm (24 7/16 x 20 11/16 in.). Los Angeles, J. Paul Getty Museum, Gift of Lenore Barozzi, 75.AP.87

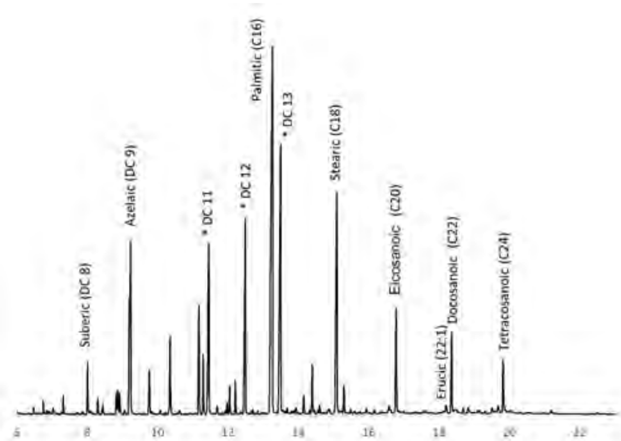


Figure 17.4b Chromatogram of white paint from the background of figure 17.4a shows the presence of an oxidized oil, based on the detection of azelaic acid, undecanedioic acid (*DC11), dodecanedioic acid (*DC12), and tridecanedioic acid (*DC13). Erucic acid (C22:1) was identified, indicating Brassicaceae oil (mustard or cabbage family).

Conclusions

The GC/MS protocols were capable of identifying beeswax, fatty acids, soaps, oils, and proteins in one paint sample. Analysis of beeswax from mummy portraits showed a decrease in wax esters and hydrocarbons, while palmitic acid intensified—most likely present as fatty-acid lead soap. Animal glue was identified as the preferred medium in tempera portraits. Egg coatings were detected on two beeswax mummy portraits and three glue tempera panel portraits. Twenty-one beeswax portraits contained oxidation products of an unknown oil, based on the presence of dicarboxylic fatty acids. Future research may enable a better understanding of possible connections between the portraits' provenance and restoration history.

NOTES

1. Mazurek, Svoboda, and Schilling 2019.
2. Ramer 1979.
3. Mazurek et al. 2014; see also Spaabæk and Mazurek, this volume.
4. Mazurek et al. 2014.
5. See Sutherland, Sabino, and Pozzi, this volume.
6. Stacey 2011, 1749; Freccero 2000.
7. Mills and White 1972.
8. Colombini et al. 2005.

18

Binding Media and Coatings: Mummy Portraits in the National Museum of Denmark and the Ny Carlsberg Glyptotek

Lin Rosa Spaabæk
Joy Mazurek

Introduction

The authors analyzed via gas chromatography/mass spectrometry (GC/MS) eleven Romano-Egyptian mummy portraits—ten encaustic and one tempera—from the National Museum of Denmark and the Ny Carlsberg Glyptotek to identify their binding media. GC/MS can distinguish between modern and ancient beeswax and can characterize the presence of oils, plant resins, and proteins.[1]

X-ray fluorescence (XRF) analysis of the painted surfaces was used to identify the presence of lead pigments and their effect on the beeswax composition. Lighter-colored areas with high concentrations of lead pigments were compared with darker areas (results not shown) to complement the GC/MS findings.

Binding Media

Two samples from the tempera portrait (AS 8940) were identified as animal glue, based on the presence of amino acids; samples from the ten encaustic portraits were classified as beeswax, based on a discernable pattern of hydrocarbons, fatty acids, and wax esters (see Mazurek, this volume). Figure 18.1 provides a summary of the paint samples tested for each encaustic portrait. Five encaustic portraits contained, in addition to beeswax, unknown proteins, and two encaustic portraits contained animal glue: in a flesh-area sample (AEIN 681) and in a gray background (AS 3891). More research is needed to determine the sources of the proteins and the animal glue, as they could be from the ancient preparation layer or from contamination during (undetected) conservation treatments.[2]

Figure 18.1 Summary of GC/MS Results of Encaustic Binding Media

Encaustic Portrait ID	Paint Sample	Additional Oil/Protein	Surface Coating
AEIN 680	yellow tunic	ND	ND
	gray background	ND	
	black hair	ND	
AEIN 681	flesh	oxidized oil, animal glue	egg
	black hair	ND	
	gray background	oxidized oil, unknown protein	
AEIN 682	black hair	oxidized oil	ND
	flesh	oxidized oil, unknown protein	
AEIN 683	yellow jewelry	ND	ND
	black hair	ND	
	flesh	oxidized oil	
AIEN 684	black hair	oxidized oil	egg
	background	oxidized oil	
AEIN 1425	flesh	oxidized oil	ND
	gray background	oxidized oil	
AEIN 1426	black	ND	paraffin
	white tunic	oxidized oil, unknown protein	
	gray background	oxidized oil	
AEIN 1473	white tunic	ND	paraffin
	black hair	ND	
	gray background	oxidized oil	
AS 3891	green tunic	unknown protein	ND
	gray background	animal glue	
AS 3892	dark hair	oxidized oil, unknown protein	ND
	white tunic	unknown protein	

Paint samples from encaustic portraits are described by color and/or location. Beeswax was identified in all paint samples described here. In addition, unknown proteins (protein detected but did not match content in our database), animal glue, oxidized oil, and egg or paraffin coatings were also identified. Samples without additional oils, proteins, and coatings are reported as ND (not detected). AEIN 1425 and AEIN 1426 are on linen supports; all others are on wooden panels.

Beeswax and Oils

Portrait AEIN 682 (fig. 18.2a) was analyzed via GC/MS for beeswax and oils. The upper chromatogram in figure 18.2b shows results typical for ancient beeswax, confirming significant amounts of palmitic acid compared with wax esters. The lower chromatogram attests to the detection of azelaic acid, a dicarboxylic fatty acid used to identify oxidized oils. Other dicarboxylic fatty acid markers were found that may indicate Brassicaceae—that is, mustard, rapeseed, or radish—oil. Dicarboxylic fatty acids were identified in paint samples from portraits thought to have been discovered at Hawara and er-Rubayat and that date from AD 25 to 200, indicating that oxidized oil is present regardless of provenance.[3]

Figure 18.2a Portrait of a Woman, Romano-Egyptian, AD 140–160. Linden wood and beeswax, 25 x 11 cm (9 7/8 x 4 5/16 in.). Copenhagen, Ny Carlsberg Glyptotek, AEIN 682. © Ny Carlsberg Glyptotek, Copenhagen. Photo: L. Spaabæk

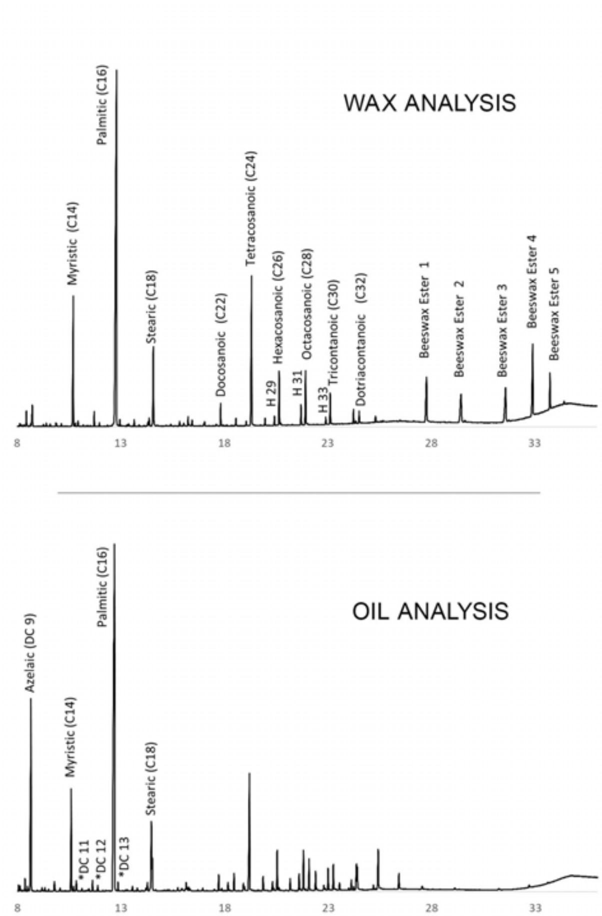


Figure 18.2b The GC/MS chromatograms for figure 18.2a show a sample containing aged beeswax, soaps, and oil. The top chromatogram presents the wax analysis; the bottom chromatogram displays the oil analysis of the same sample.

The oxidized oil may attest to an intentionally modified encaustic, contamination, or a past restoration campaign. The relatively high concentrations of palmitic acid are likely due to the hydrolysis of wax esters and the subsequent formation of a fatty acid metal soap (i.e., lead palmitate). This soap was identified in the lighter-colored samples, which possess a greater amount of lead.

Egg Coating

Visual examination shows that the two encaustic portraits, AEIN 681 (fig. 18.3) and AEIN 684, have unpigmented, deteriorated surfaces. Both works entered the Ny Carlsberg Glyptotek from the Theodore Graf Collection in 1892, and they likely originate from er-Rubayat. Amino acid analysis by GC/MS revealed that both coatings matched egg protein (fig. 18.4); however, they differ in their visual appearance and response to ultraviolet-induced visible fluorescence (UVF), in their thickness, and in the method of application. The coating on AEIN 681 exhibits a bluish-yellow fluorescence, is very thin and glasslike, and has cracked into tiny “islands” with sharp edges. Although now only in scattered areas, the coating likely covered the entire portrait at one time. In contrast, AEIN 684's coating shows a brighter bluish yellow fluorescence under UVF illumination, is thicker and more translucent, and has a yellow tone, presumably due to aging/deterioration. Numerous tiny, lightly curled fibers are observed embedded in the coating.

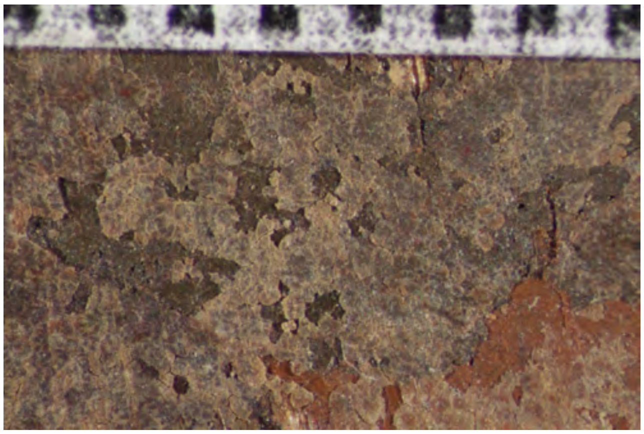


Figure 18.3 Photomacrograph (40x) of the thick, transparent top coating on AEIN 681. Photo: L. Spaabæk

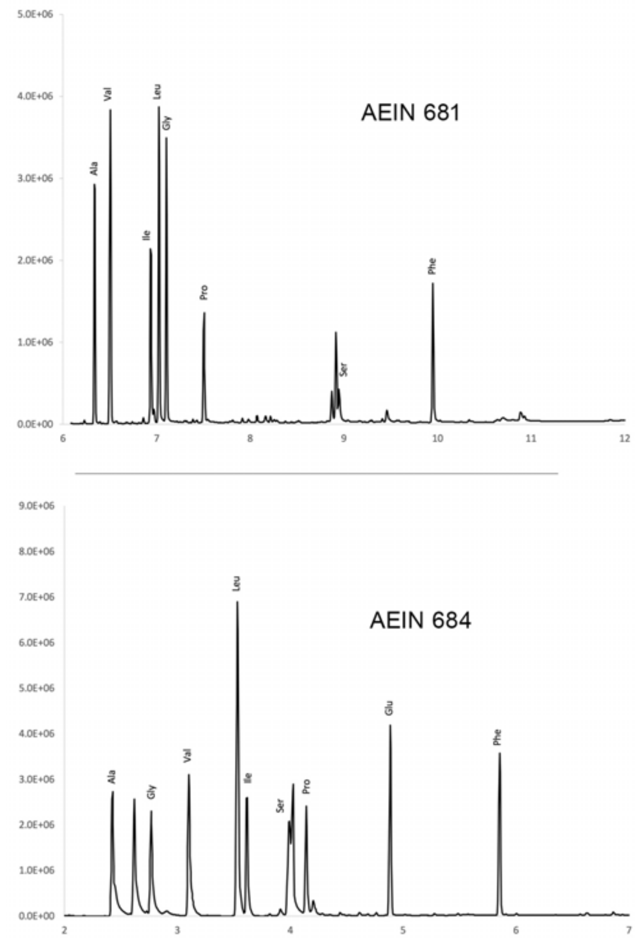


Figure 18.4 GC/MS chromatograms showing the presence of amino acids found in surface coatings isolated from AEIN 681 and AEIN 684. The protein identified most closely matches egg due to the characteristic pattern of amino acids: Ala = alanine, Val = valine, Ile = isoleucine, Gly = glycine, Pro = proline, Ser = serine, Phe = phenylalanine, Glu = glutamic acid. Photo: L. Spaabæk

Due to the locations of surface deposits and incrustations, these egg coatings are presumed to be original. Remains of resin from mummification, superficial layers of sand or dirt (burial material), and a lack of this coating within the more recent surface cracks support this hypothesis. Under UV light the egg coating on AEIN 684 (see fig. 18.5) reveals a distinct fluorescent border at the bottom of the portrait and a faint one at its top. The coating is not present where the mummy wrappings would have covered the panel; therefore, we suggest that the coating was applied after attaching the portrait to the mummy, perhaps as a votive act. Further research is necessary to identify other portraits with similar coatings and to compare them with later egg coatings and varnishes applied to icons, medieval paintings, and sculptures.[4]

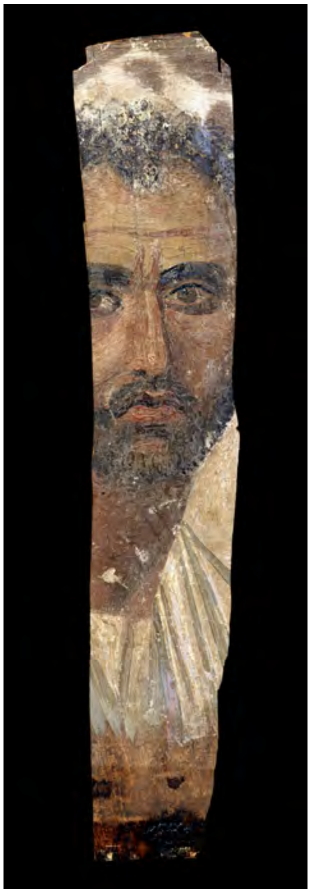


Figure 18.5a Visible light image of Portrait of a Man, Romano-Egyptian, AD 140–200. Linden wood and beeswax, 41 x 8 cm (16 1/8 x 3 1/8 in.). Copenhagen, Ny Carlsberg Glyptotek, AEIN 684. © Ny Carlsberg Glyptotek, Copenhagen. Photo: O. Haupt

Figure 18.5b UVL image of figure 18.5a. The egg coating has a bright bluish yellow luminescence with a clear demarcation of where the coating ends at the bottom of the panel. Photo: M. L. Sargent

Acknowledgments

We thank the National Museum of Denmark (NM) and the Ny Carlsberg Glyptotek for their kind permission to examine and take samples from their mummy portraits. We also thank the staff at both museums; Michelle Taube (NM) and David Buti, Centre for Art Technological Studies, for the XRF examination; and the Carlsberg Foundation and the Getty Conservation Institute for their generous support.

NOTES

1. Stacey et al. 2018.
2. Cartwright, Spaabæk, and Svoboda 2011.
3. AEIN 1425, 1426, and 1473 were excavated at Hawara; the remaining portraits belonged to the Graf Collection and are presumed to be from er-Rubayat.
4. Woudhuysen-Keller and Woudhuysen-Keller 1994.

Glossary

Animal glue. A collagen-based adhesive made by boiling animal skin, bones, or tendons in water. The proteinaceous glue is used as a binding medium that is mixed with pigments for painting; it can also be used for sizing or sealing wood, for applying gilding, and for joining or bonding. Glues can be made from many types of animals including cow, rabbit, horse, or fish.

Antinoöpolis. An ancient Roman city south of Cairo and the Fayum basin, on the east bank of the Nile. The mummy portraits believed to have been discovered at this site exhibit a characteristic austere style and the wooden panels a unique stepped shape. The city was founded in AD 130 when the emperor Hadrian named it in honor of Antinoüs, his lover who drowned in the Nile.

Antonine period (AD 138–192). The era that encompasses the reigns of the emperors Antoninus Pius (AD 138–161), Marcus Aurelius (AD 168–180), and Commodus (AD 180–192). In the Antonine period provincial elite populations flourished. The distinctive, Hellenized hairstyles of members of the imperial court were seen on coins and in widely disseminated portraits, largely of stone and bronze. For women, a bun of braids coiled at the crown of the head and gradually draped to the nape of the neck; men adopted a bearded appearance with long, tousled hair. These closely imitated, specific hairstyles help scholars propose a rough chronology of Roman portraiture and art.

Balteus. A sword strap, typically depicted on painted portraits as a diagonal red band, sometimes with gold or silver studs, worn over the tunic. Its presence suggests that the deceased was in the military.

Beeswax. A natural wax produced by honeybees (*Apis* sp.) that is primarily composed of esters of various fatty acids and long-chain alcohols. Egyptians used beeswax for the mummification process, in cosmetics, to retain the permanency of wig curls, and to create painted portraits (encaustic).

Binding media. Organic materials that hold pigments together, enabling them to be applied as a cohesive film. Ancient binding media are based on natural materials, including wax, plant gums, and proteins, such as animal glues. The physical properties of the medium strongly influence the handling and visual characteristics of the paint.

Bulla (pl. *bullae*). A type of amulet, similar to a locket, worn around the neck of a boy. An indication of free birth, a bulla was used for protection as well as an official status symbol.

Calcium carbonate (chalk, lime, calcite). A chemical compound used to create a stable white pigment with limited hiding power (opacity); this pigment is used to make grounds (preparation layers) for painting. Chemical formula: $CaCO_3$

Carbon black. A pigment made by charring wood or other organic materials in a reducing environment (a restricted air supply). It is also known as vine black (charred, desiccated grape vines and stems) or lamp black (soot collected from oil lamps). Infrared imaging can be used to reveal artists' sketches and underdrawings made in carbon black that may not otherwise be visible beneath the painted layer, due to the pigment's tendency to absorb infrared radiation.

Cauterium (cautarium). Similar to a spatula or a palette knife, a metal tool that, after being heated, was used to blend the wax colors in encaustic painting.

Cestrum. A pointed graver, possibly metal, used for adding incised details in encaustic. The cestrum would have been heated and used to draw into wax.

Chiton (tunic). A simple garment that covered the upper body, starting at the shoulders and ending at a length somewhere between the hips and the ankles. The English word *chiton* originates from the Latin *chiton*, which means "mollusk"; that, in turn, is derived from the Greek word *khitōn*, meaning "tunic." The tunic was a basic garment worn by both men and women in ancient Rome. Citizens and noncitizens alike wore chitons (usually white for men and red for women). Citizens might wear a chiton under the toga, especially on formal occasions. The length of the garment and the presence or lack of stripes (*clavi*), as well as their width and ornamentation, indicated the wearer's status in Roman society.

Cinnabar. An orange-red pigment with excellent hiding power (opacity) and good permanence. It has been used from antiquity to the present. Chemical formula: Mercuric sulfide, HgS

Clavus (pl. *clavi*). A vertical stripe or ribbonlike ornament, placed in pairs, that adorned the shoulders of a tunic. In Rome some *clavi* of specific width and/or color distinguished members of particular rank or status, but the significance of the *clavus* in an Egyptian context remains undetermined.

Consolidate. To strengthen or stabilize a material by adding another impregnating material, such as an adhesive (consolidant). For example: *The paint on the surface was consolidated using gelatin.*

Earth pigments. Naturally occurring minerals that contain metal oxides, principally iron and manganese, and that have been used since prehistoric times as pigments. The primary types are ochre, sienna, and umber.

Egyptian blue (cuprorivaite). A pigment that was manufactured and used by Egyptians possibly as early as 3100 BC. Considered to be the first synthetic pigment, Egyptian blue was made by mixing a calcium and copper compound with silica/quartz and a flux, heating the mixture to a very high temperature (900°C), and then grinding the glassy product to a powder. Chemical formula: Calcium copper silicate, $CaCuSi_4O_{10}$ or $CaOCuO(SiO_2)_4$

El-Hibeh (el Hiba). An archaeological site on the east bank of the Nile, south of Cairo. Remains at the site date from the late Pharaonic, Greco-Roman, Coptic, and early Islamic periods—approximately 1100 BC to roughly AD 700.

ELISA (enzyme-linked immunosorbent assay). An analytical technique that employs antibodies to identify proteins in binding media such as animal glue, egg, and milk, as well as polysaccharides in plant gums. ELISA can also characterize the biological source of the protein (e.g., rabbit-skin glue vs. fish glue).

Encaustic. A wax-based painting technique. From the Greek word *enkaustikos* ("burned in"), the term in its most literal sense refers to the use of molten beeswax combined with pigments; once solidified, the paint can be further manipulated by the use of heated tools. The term is often used in a more general sense to describe any painting technique in which wax is the major component of the medium.

er-Rubayat (er Rubayyat, er Rubiyat, er Rubayet, el Rubiyat). An archaeological site on the west bank of the Nile within the Fayum basin, also known as the cemetery near ancient Philadelphia. This location is where many portraits acquired by the Viennese art dealer Theodor Graf were found.

False-color infrared (FCIR) / infrared-reflected false color (IRRFC). Images created through digital post-processing by combining visible and near-infrared images. The false colors produced can help in characterizing materials or in distinguishing between visually similar substances.

False-color ultraviolet (FCUV) / ultraviolet-reflected false color (UVRFC). Images created through digital post-processing by combining visible and ultraviolet reflectance (UVR) images. The false colors produced can help in characterizing materials or in distinguishing between visually similar substances.

Fayum (Faiyum, El Faiyûm, Al-Fayoum, Fayyum). A fertile desert basin immediately to the west of the Nile River, south of Cairo. Roman mummies were discovered there in several ancient cemeteries and archaeological sites, including Hawara and er-Rubayat. The Fayum was a very prosperous region and a vibrant cultural center during the Greco-Roman and Roman periods.

Fiber optics reflectance spectroscopy (FORS). An analytical technique for identifying pigments and dyestuffs. This technique uses two fiber optics: one to expose the sample to light and the other to collect a diagnostic reflectance spectrum.

Fibula. A decorative pin or brooch, usually made of metal such as bronze, silver, or gold, used to gather and secure the folds of a garment.

Flavian period (AD 69–96). The era that encompasses the reigns of Vespasian (AD 69–79) and his sons Titus (AD 79–81) and Domitian (AD 81–96). Although Vespasian encouraged a return to traditional Roman values of austere modesty, the rule of Domitian saw new levels of extravagance, especially in the dress and coiffure of imperial women. As imperial fashions became known through the dissemination of coins and sculptured busts and statues, the elaborate hairstyles were imitated, with tiers of curls requiring hairpieces to achieve the required height and mitered shape above the brow; men copied the look of balding emperors Vespasian and Titus.

Fourier transform infrared spectroscopy (FTIR). An analytical method used for the characterization and identification of organic and some inorganic materials, based on the excitation of specific vibrational modes of functional groups in the infrared region.

Galena. A natural mineral form of lead sulfide used as a gray/black pigment and as a cosmetic in antiquity. Chemical formula: PbS

Garland. A floral necklace used in religious rituals and for festive occasions. The Egyptians placed garlands on their mummies as a sign of celebration in entering the afterlife; this practice developed at the beginning of the New Kingdom and continued into the Roman period. The rose was specifically associated with the goddess Isis.

Gas chromatography/mass spectrometry (GC/MS). An analytical technique used for the precise identification of organic binding materials such as oils, waxes, resins, and gums. The gas chromatograph separates complex mixtures of organic compounds using a capillary column housed in a temperature-controlled oven and, in combination with the mass spectrometer, can facilitate identification and quantitation of the various components.

Gilding. A term that describes the various decorative techniques for applying a very thin layer of gold leaf or gold powder to a solid surface such as wood, stone, or metal to give the appearance of being made of solid gold. Gold leaf, typically between 18 and 22 karats, is hammered into extremely thin sheets (leaves), or ground into a powder, and then applied with an adhesive.

Green earth (terre verte). A naturally occurring Fe, Mg, Al, K hydrosilicate mineral pigment colored by glauconite or celadonite, with other associated minerals.

Ground (preparation layer). A primary layer applied to a substrate to form a smooth surface on which to paint. Typically, ground layers were composed of a white material such as gypsum, although they can range in color and composition.

Gum. A water-soluble, polysaccharide exudate obtained from various woody plants or other natural sources and used as a binder for pigments. Gum arabic was the most commonly used plant binder in antiquity.

Gypsum (calcium sulfate dihydrate). A soft sulfate-based mineral found in nature. Often mixed with water to form plaster, it is used in the preparation of substrates, such as wood panels for painting. Also used as a white pigment, gypsum was identified in Tutankhamen's paint box. Chemical formula: $CaSO_4 \cdot 2H_2O$

Hadrianic period (AD 117–138). The era that encompasses the reign of Hadrian, who was known for his interest in Greek culture. The visual legacy in the portraiture of this period is exemplified in the Hellenization of male features (a short Greek beard reminiscent of that of the Athenian general and politician Pericles, and a full head of curly hair) and the classicization of female features (modest clothing and coiffures made of braids wrapped around the head).

Hawara. A Roman site in Egypt located in the Fayum basin. The necropolis at this site is well known for the systematic and well-documented excavations by British Egyptologist Sir Flinders Petrie.

Himation (*pallium* in Latin). A mantle worn by both men and women in the Greek world. It consisted of a square piece of cloth worn over the shoulder (typically the left), with the excess cloth draped over to the opposite shoulder. (See *pallium*.)

Horus lock. A distinctive Egyptian hairstyle depicted on the gods Horus/Harpocrates and also worn by children (typically male) and sometimes by adult males. It appears as a single lock of hair (a sign of youth) on the right side of the head, above the ear.

Hyperspectral imaging. A scanning technique that records and processes hundreds of images of the same spatial area at a series of different wavelengths across the electromagnetic spectrum. Spectral data obtained for each pixel in the area can help detect or characterize materials present.

Indigo. A natural blue dye derived from the plant *Indigofera tinctoria* and related species growing in the Mediterranean, India, and Asia, among other locations. It is believed that originally the dye woad (*Isatis tinctoria*), rather than indigo, was used in antiquity. Chemical formula: $C_{16}H_{10}N_2O_2$

Infrared reflectography (IRR). An imaging technique in which an object is irradiated with short-wave infrared radiation (SWIR; 1000–3000 nm). A specialized infrared-sensitive digital camera detects and captures the contrast between materials that reflect the infrared, such as lead white, and those that absorb it, such as carbon-containing pigments. Because infrared is of longer wavelength than visible light, some low-absorbing materials may also allow the infrared to be transmitted through them, revealing hidden underdrawings, artist's modifications and methodology, or modern interventions.

Iron oxide pigments (hematite, ochres, sienna, umber). Also referred to as earth pigments and made from minerals containing oxides and hydroxides of iron, iron oxide pigments can occur in many different colors, such as yellow, orange, red, brown, and black. Approximately sixteen known iron oxides and oxyhydroxides were widely sourced and processed (calcined) for use as pigments.

Julio-Claudian period (27 BC–AD 68). The era that saw the establishment of imperial rule at Rome by five successive members of a single family: Augustus (27 BC–AD 14); Tiberius (AD 14–38); Gaius, often known as Caligula (AD 38–41); Claudius (AD 41–54); and Nero (AD 54–68). Augustus developed a clean-shaven look of somewhat short, neatly cut hair with a fringe of locks above the brow. Later Julio-Claudian court hairstyles were longer and more elaborate, with coiled corkscrew ringlets in front of the ears and tightly wound curls around the face. Wealthy provincial men and women imitated Roman imperial court style, which was rigorously disseminated across the empire, notably on coins and in portraits in many media.

Kermes. An insect-derived ancient red dye/colorant and source of the word *crimson*. Early Egyptians made this red dye from the dried bodies of a female wingless scale insect—either *Kermes ilices* or *Kermes vermilio,* both of which live on certain species of Mediterranean oaks and produce a powerful, permanent scarlet dye and organic colorant. Chemical formula: kermesic and flavokermesic acid, $C_{16}H_{10}O_8$

Lake. A pigment manufactured by precipitating a dye onto an inorganic substrate/mordant (such as the metallic ions aluminum or calcium).

Lead soaps. Products created by the saponification of an oil (such as a drying oil, which hardens due to oxidation) promoted by a lead-based pigment, such as lead oxide. The soaps formed by interaction between fatty acids in the oil and lead ions from the pigment can manifest as insoluble white aggregates within the paint layer or as a white haze (efflorescence) on the surface.

Lead white. A white pigment, both found as a naturally occurring mineral known as hydrocerussite and produced synthetically by exposing metallic lead to an acid (e.g., vinegar). Lead white has been widely used in antiquity and in Egypt since around 400 BC. Chemical formula: Basic lead (II) carbonate, $2PbCO_3{\cdot}Pb(OH)_2$

Linen (flax). A textile derived from the flax fiber, commonly used in but not originally native to Egypt, dating back to the Neolithic period (about 4000 BC). Two types of flax were cultivated in predynastic Egypt: *Linum bienne* (synonym *Linum angustifolium*) and *Linum usitatissimum*. To produce linen thread, flax was dried, retted (soaked), beaten to separate the bast fibers from the stems, spliced, and spun. Although rarely done, linen thread could then be dyed (using ochre or organic colorants) before being woven into cloth. Women, men, and children were involved in linen production, but weaving is most closely associated with women. Linen cloth was very valuable and sometimes used as currency. Egyptian mummies were wrapped in linen because it symbolized wealth, light, and purity.

Liquid chromatography with diode array detection and mass spectrometry (LC/DAD/MS). Many natural dyes consist of more than one chemical compound, and LC is a technique by which the compounds can be separated and then individually identified by DAD and MS detectors.

Madder. A dyestuff derived from the root of the madder plant (*Rubia tinctorum*), which is native to the eastern Mediterranean and Persia. Likely introduced to Egypt by the Greeks or Romans, madder was used throughout antiquity for coloring textiles and as a pigment. Chemical name: Alizarin (1,2-dihydroxyanthraquinone), Purpurin (1,2,4-trihydroxyanthraquinone)

Malachite. A mineral used as a pigment of varying green hues. It has moderate permanency and is sensitive to acids and heat. Found on Egyptian tomb paintings, malachite is perhaps one of the oldest known green pigments. Chemical formula: Basic copper (II) carbonate, $Cu_2CO_3 \cdot Cu(OH)_2$

Modified wax. Beeswax that has been modified by the addition of other materials, such a resin, glue, or oil, or that has been treated with an alkali to make it water soluble, thus paintable cold. Some scholars have proposed that wax was modified in some way for use as a paint medium in ancient Egypt.

Multiband reflectance subtraction imaging (MBR). A digital post-processing technique that subtracts a near-infrared image from a visible light image, thus enabling the characterization of certain materials, specifically indigo.

Multispectral imaging (MSI) / multiband imaging (MBI). The creation of a series of images, each recording reflectance and luminescence within a different limited range of wavelengths. This process involves using a series of band-pass camera filters or a set of narrow-band illumination sources; thus, it records variations in the absorption of materials at different wavelengths. Comparing or combining these images can help to characterize materials or to distinguish between materials that may appear similar.

Orpiment. An orange-yellow pigment with large particles and a glittering quality used to imitate gold. Sourced from the Red Sea and Asia Minor, orpiment, mentioned by Pliny and Vitruvius and also noted in Egyptian works of the Pharaonic period, was widely traded by the Romans. Chemical formula: Arsenic trisulfide, As_2S_3

Pallium. A large, draped rectangular cloth, worn as a cloak or mantle with no undergarment, often associated with Greek intellectual activities. To the Romans, the pallium was a distinctly Greek form of dress, and so it was worn only in specific contexts. (See *himation*.)

Panel. Painting support made from various woods, including lime, sycomore fig, and cedar of Lebanon, among others. The shape of the upper portion of mummy portrait panels may indicate the cemetery in which the mummy was buried: stepped panels are associated with Antinoöpolis, round-topped panels with Hawara, and angled panels with er-Rubayat.

Pastiche. An artwork that incorporates several different styles or is composed of parts drawn from a variety of sources (e.g., a complete panel that is made of two or more panels).

Penicillum. A paintbrush with bristles made from plant fibers or animal hair.

Photometric stereo imaging. A computational imaging technique that separates color from shape data to generate a high-resolution composite image that estimates surface topography.

Pigment. A colorant either derived from natural sources—mineral, plant, or insect—or produced synthetically. Typically, pigments are crushed into a fine powder and mixed with a binder, resulting in a suspension that becomes insoluble when dry; a dye produces a lake pigment when attached to an inorganic substrate or mordant.

Plant resin. A water-insoluble exudate obtained from one of several plants, particularly coniferous trees such as pine, cedar, or fir. Composed of chemical compounds known as terpenes, plant resins are used for the production of varnishes and adhesives and for mummification processes. Many resins have an aromatic quality that also acts as a preservative (biocide).

Polarized light microscopy (PLM). Optical microscopy that utilizes polarized light to study the structure and composition of materials. Particles (of pigments, for example) may be characterized by their appearance and by observing their isotropic and anisotropic characteristics based on their crystallographic structure.

Polychrome. The application of multiple colors to an object to produce a decorative effect.

Provenance. The ownership history of an artifact.

Provenience. The geographic origin of an artifact.

Punic wax. Beeswax prepared in a certain way, as described by both Pliny and Dioscorides. The precise nature and composition of Punic wax have been much debated, with the source texts variously interpreted as describing the preparation of a purified or clarified beeswax, or one that has been partially or completely saponified by the addition of an alkali. In the latter case the product is presumed by some to be water miscible and amenable to application in a cold state.

Radiocarbon dating. A scientific method for dating organic materials or objects containing organic materials.

Raking light. Illumination by a light source positioned at an oblique angle or almost parallel to an object's surface. It is used to provide information about the surface topography.

Raman spectroscopy. An analytical technique used to observe the vibrational, rotational, and other low-frequency molecular modes of a material. When excited by monochromatic light (visible, near infrared, or near ultraviolet) from a laser beam, the collected inelastic scattered light collected with a spectrometer produces spectra that are specific to the chemical bonds and symmetry of specific molecules. Comparing reference spectral databases allows for the identification of materials.

Realgar. Closely related to orpiment, a red-orange pigment that was widely traded in the Roman Empire and used throughout ancient Egypt and Mesopotamia. Pararealgar is formed when realgar is exposed to light (degradation); it has the same elemental composition but different crystalline structure. Chemical formula: Arsenic sulfide, As_4S_4

Red lead (minium). A bright red-orange pigment that was one of the first to be synthetically produced. It is also referred to as *minium*, the naturally occurring pigment named after the river Minius, located in northwest Spain. Chemical formula: Lead (II,IV) oxide, Pb_3O_4

Red ochre. A brownish red earth pigment that contains anhydrous iron oxide, or hematite (from the Greek *hema,* meaning "blood"). Used since prehistory as pigments, ochres may vary widely in shades and transparency. Composition: Anhydrous iron (III) oxide, Fe_2O_3

Reflectance transformation imaging (RTI). A computational imaging technique that reveals surface topography, details, and textures, thus enabling the study of tool and brush marks, etc. RTI produces a polynomial texture map, or pseudo-three-dimensional image, of an object or surface. The light source is positioned at a constant radius from the subject at different angles (i.e., raking light) to create a hemisphere of positions and the image captures acquired from a fixed camera position during each light movement. The final processed file determines all possible light positions within the virtual hemisphere.

Reflected near-infrared (NIR) photography. An imaging technique that records radiation responses in the near-infrared region (700–1100 nm), thus capturing the contrast between materials that reflect the infrared and those that absorb it, such as carbon-containing pigments. Because infrared is of longer wavelength than visible light, some low-absorbing materials may also allow the infrared to be transmitted through them, revealing hidden underdrawings, artist's modifications and methodology, or modern interventions.

Sagum. A long, dark-colored (red, blue, or purple) outer cloak worn by Roman soldiers. The sagum was fastened on the shoulder with a fibula (brooch).

Scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM-EDS / SEM-EDX). An electron microscope that images the surface of a sample by scanning it with a high-energy beam of electrons. The interaction between the electrons and the constituent atoms at the sample's surface reveals topography and elemental composition.

Severan period (AD 193–235). An era characterized by, among other things, a fashion for short military beards and hair cropped close to the head for men and center-parted and pulled-back hair for women. These distinctive styles help scholars to propose a rough chronology of Roman portraiture and art, as images with these coiffures appear on dated materials such as coins and busts.

Shroud. A cloth used to cover or protect another object. The term is most often used to refer to a cloth that covers or envelops a corpse. Many mummy shrouds were painted before being placed over the mummy's head or enveloping the entire body.

Specular light. Light that behaves as in a mirror—that is, a ray of incoming light (incident ray) that strikes a surface and is reflected back in a single outgoing direction.

Stucco. A fine plaster made of either gypsum or calcite that is used for coating surfaces or that is molded into decorative shapes. The mixture is applied wet and shaped/molded; it is typically painted after drying. Funerary masks made of stucco are found in Egypt from the First Dynasty to the first century AD.

Tempera. In the context of ancient art, this term generally refers to a fast-drying, water-miscible painting medium such as animal glue or plant gum. The term *tempera* originates from the Latin *temperare* ("combining, blending").

Trajanic period (AD 98–117). The era that corresponds to the reign of Trajan. This period is exemplified by a distinctive women's hairstyle consisting of a "nest" of braids placed at the back of the head and rolls of curls arranged into a tall diadem (crown or headpiece) towering over the forehead. These distinguishing styles help scholars to propose a rough chronology of Roman portraiture and art, as images with these coiffures appear on dated materials such as coins and busts.

Tunic (chiton). A simple garment that covered the upper body, starting at the shoulders and ending at a length somewhere between the hips and the ankles. The English word *chiton* originates from the Latin *chiton*, which means "mollusk"; that, in turn, is derived from the Greek word *khitōn*, meaning "tunic." The tunic was a basic garment worn by both men and women in ancient Rome. Citizens and noncitizens alike wore chitons (usually white for men and red for women). Citizens might wear a chiton under the toga, especially on formal occasions. The length of the garment and the presence or lack of stripes (*clavi*), as well as their width and ornamentation, indicated the wearer's status in Roman society.

Ultraviolet-induced visible fluorescence (UVF) / UV-visible fluorescence / Ultraviolet-induced visible luminescence (UVL) (historically UV/VisFL). An imaging technique and diagnostic examination method, based on characteristic responses of materials to ultraviolet (UV) radiation (185–400 nm) in the form of fluorescence, in which radiant energy in the UV region is absorbed and then reemitted as lower-energy visible light. The fluorescences revealed by the technique are used to assist in the general characterization or differentiation of materials—such as pigments, coatings, binders, and adhesives—and to diagnose the condition of an object (e.g., to detect restorations). The term *luminescence* also encompasses the possibility of a phosphorescent response to UV radiation in which there is a delay in the reemission of the absorbed energy by some materials, so that emission might even continue for a period after the UV excitation source is turned off. Because fluorescence is by far the dominant phenomenon being observed and documented, the term *fluorescence* has historically been used in describing this technique in conservation (as well as in medicine, nondestructive testing, and forensics); however, *luminescence* is an equally appropriate descriptor.

Ultraviolet reflectance or ultraviolet reflected (UVR) imaging / reflected ultraviolet (RUV) imaging. An imaging technique that records variations in reflection and absorption of ultraviolet (UV) radiation by the surface of a subject. This imaging technique primarily aids in the characterization or differentiation of materials. Also because UV radiation exhibits very limited surface penetration, the technique can also help in characterizing surface sheen.

Umbers (raw and burnt umber). Natural earth pigments containing iron and manganese oxides and hydroxides. Used throughout history as earth tone pigments, umbers range in color from cream to brown, depending on the amount of iron and manganese present. Chemical formula: Iron (III) oxide, partly hydrated + manganese oxide, $Fe_2O_3(\cdot H_2O) + MnO_2\cdot(nH_2O)$

Visible-induced infrared luminescence / visible-induced luminescence (VIL). An imaging technique in which visible light is used to induce the emission of infrared radiation (primarily in the near-infrared [NIR] region [700–1100 nm]) by certain materials. It has been used to identify historical blue pigments (principally Egyptian blue, Han blue, and Han purple) as well as many cadmium pigments and some natural dyes. These materials may show a very strong IR emission when excited by visible light. The setup for this type of imaging requires an excitation source emitting only visible light with no IR component, an imager with sensitivity to NIR (such as an IR-modified digital camera), and a lens filter that absorbs all visible light and transmits NIR.

Visible-induced visible luminescence (VIVL). A method of recording a photo-induced emission of light in the visible region (500–700 nm) when the object is illuminated within a narrow band of visible light of higher energy (400–500 nm). The technique involves careful control of the spectra of the illuminating excitation source and imager lens filtration to limit the spectrum recorded only to the lower energy band of visible light.

Wreath. An assortment of flowers, leaves, fruits, twigs, or other materials constructed to resemble a loop. Typically worn on the head in ceremonial events, wreaths have much history and symbolism associated with them. In the Greco-Roman world, wreaths were used as adornments that could represent a person's occupation, rank, achievements, or status.

X-radiography. An imaging technique used to reveal the internal structure of an object by using X-rays to record variations in the densities of its constituent materials. X-rays are transmitted, absorbed, or scattered in varying degrees by the materials present; the radiation that passes through the object is then captured on photographic film or a digital receptor placed behind the subject, thereby creating the radiograph. Dense materials and/or those containing elements of high atomic number, such as metal and lead white paint, strongly absorb X-rays and will appear white or light in tone; less dense materials, such as wood or other organic matter, readily transmit radiation and appear dark in the resulting image.

X-ray diffraction (XRD). An analytical method used to examine the crystallographic structure, composition, and physical properties of materials, such as mineral pigments.

X-ray fluorescence (XRF) spectroscopy. A technique used for nondestructive elemental analyses of inorganic materials, utilizing a focused beam of X-rays to excite the atoms on the surface of an artwork and measuring the emitted energy. These emissions provide characteristic fingerprints of the elements in the sampled area, allowing researchers to formulate hypotheses about the compounds contained therein.

Yellow ochre. A naturally occurring mineral consisting of silica and clay. Its yellow color is attributed to the mineral goethite. Found throughout the world, yellow ochre has many shades and hues. Chemical formula: Iron oxyhydroxide, $FeO(OH)$

Bibliography

Accorsi et al. 2009
Accorsi, Gianluca, Giovanni Verri, Margherita Bolognesi, Nicola Armaroli, Catia Clementi, Costanza Miliani, and Aldo Romani. 2009. "The Exceptional Near-Infrared Luminescence Properties of Cuprorivaite (Egyptian Blue)." *Chemical Communications* 23: 3392–94. https://doi.org/10.1039/B902563D

Aceto et al. 2014
Aceto, Maurizio, Angelo Agostino, Gaia Fenoglio, Ambra Idone, Monica Gulmini, Marcello Picollo, Paola Ricciardi, and John K. Delaney. 2014. "Characterisation of Colourants on Illuminated Manuscripts by Portable Fibre Optic UV-Visible-NIR Reflectance Spectrophotometry." *Analytical Methods* 6 (5): 1488–500. https://doi.org/10.1039/C3AY41904E

Aldrovandi et al. 2005
Aldrovandi, Alfredo, Ezio Buzzegoli, Annette Keller, and Diane Kunzelman. 2005. "Investigation of Painted Surfaces with a Reflected UV False Colour Technique." In *Art '05: 8th International Conference on "Non-Destructive Investigations and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage," Lecce (Italy), May 15–19, 2005,* edited by Maurizio Marabelli, Claudio Parisi Presicce, et al. Brescia: Associazione italiana prove non distruttive monitoraggio diagnostica.

Allen 2012
Allen, Ruth. 2012. "Three Portions of Mummy Portraits from the Fayoum Egypt: Add. 9455vol2_p573/3." *Rethinking Pitt-Rivers: Analyzing the Activities of a Nineteenth-Century Collector*. Accessed May 2, 2018. http://web.prm.ox.ac.uk/rpr/index.php/object-biography-index/7-farnhamcollection/784-three-portions-of-mummy-portraits-from-the-fayoum-egypt-add-9455vol2p5733/index.html

Antiquités de Maurice Nahman 1953
Antiquités de Maurice Nahman. 1953. *Antiquités égyptiennes, grecques et romaines: Succession de M. Maurice Nahman du Caire, Egypte, 2e vente, Hôtel Drouot, 4–5 juin 1953*. Paris. Auction catalogue.

Arslanoglu 2014
Arslanoglu, Julie. 2014. *FTIR Summary for Shrouds X.390, 25.184.20, X.491a, b, and 66.99.141*. New York: Department of Scientific Research, Metropolitan Museum of Art. Unpublished internal report.

Assmann 1996
Assmann, Jan. 1996. "Preservation and Presentation of Self in Ancient Egyptian Portraiture." In Vol. 1 of *Studies in Honor of William Kelly Simpson*, edited by Peter Der Manuelian, 55–81. Boston: Museum of Fine Arts.

Assmann 2001
Assmann, Jan. 2001. *Tod und Jenseits im Alten Ägypten.* Munich: C. H. Beck.

Baedeker 1890
Baedeker, Karl. 1890. *Great Britain: Handbook for Travellers*. 2nd ed. London: Dulau & Co.

Bagnall 1997
Bagnall, Roger S. 1997. "The People of the Roman Fayum." In *Portraits and Masks: Burial Customs in Roman Egypt,* edited by Morris Bierbrier, 7–15. London: British Museum.

Beckmann 1846
Beckmann, Johann. 1846. *A History of Inventions, Discoveries, and Origins*. Vol. 2. London: H. G. Bohn.

Bellelli 2016
Bellelli, Vincenzo. 2016. "János György Szilágyi, un Profilo." *Studi Etruschi* 78: 17–32.

Beltinger and Nadolny 2016
Beltinger, Karoline, and Jilleen Nadolny, eds. 2016. *Painting in Tempera, c. 1900.* London: Archetype.

E. Berger 1904
Berger, Ernst. 1904. *Die Maltechnik des Altertums.* Munich: Georg D. W. Callwey.

J. Berger 2002
Berger, John. 2002. "The Fayum Portraits." In *The Shape of a Pocket*, 51–60. London: Bloomsbury.

Bergmann 2010
Bergmann, Marianne. 2010. "Stile und Ikonographien im kaiserzeitlichen Ägypten." In *Tradition and Transformation: Egypt under Roman Rule; Proceedings of the International Conference, Hildesheim, Roemer- and Pelizaeus-Museum, July 3–6, 2008*, edited by Katja Lembke, Martina Minas-Nerpel, and Stefan Pfeiffer, 1–36. Culture and History of the Ancient Near East 41. Leiden: Brill.

Bernhard-Walcher 1998
Bernhard-Walcher, Alfred. 1998. "Theodor Graf und die Wiederentdeckung der Mumienportraits." In *Bilder aus dem Wüstensand: Mumienportraits aus dem Ägptischen Museum Kairo*, edited by Wilfried Seipel, 27–36. Milan: Skira.

Bierbrier 2000
Bierbrier, Morris. 2000. "The Discovery of the Mummy Portraits." In *Ancient Faces: Mummy Portraits from Roman Egypt*, edited by Susan Walker and Morris Bierbrier, 32–33. London: British Museum.

Bierbrier et al. 1997
Bierbrier, Morris, Caroline R. Cartwright, Joyce Filer, Sylvia Humphrey, Andrew Middleton, and Susan Walker. 1997. "New Light on Ancient Faces." *British Museum Magazine* 27: 36–39.

Bioletti et al. 2009
Bioletti, Susan, Rory Leahy, John Fields, Bernard Meehan, and Werner Blau. 2009. "The Examination of the Book of Kells Using Micro-Raman Spectroscopy." *Journal of Raman Spectroscopy* 40: 1043–49.

Bisulca et al. 2008
Bisulca, Christina, Marcello Picollo, Mauro Bacci, and Diane Kunzelman. 2008. "UV-Vis-NIR Reflectance Spectroscopy of Red Lakes in Paintings." Paper presented at the Ninth International Conference on NDT of Art, Jerusalem, Israel, May 25–30, 2008. https://www.ndt.net/article/art2008/papers/199Bisulca.pdf

Blom-Böer 1994
Blom-Böer, Ingrid. 1994. "Zusammensetzung altägyptischer Farbpigmente." *Oudhedkundige Mededelingen* 74: 55–107.

Borg 1996
Borg, Barbara. 1996. *Mumienporträts.* Mainz: Philipp von Zabern.

Braumüller 1873
Braumüller, Wilhelm. 1873. "Heraclius, von den farben uned künsten der römer." In *Quellenschriften für kunstgeschichte und kunsttechnik des mittelalters und der renaissance*. Vienna: K. K. Hof- und Universitätsbuchhändler.

Brecoulaki 2006
Brecoulaki, Hariclia. 2006. "Considérations sur les peintres tétrachromatistes et les *colores austeri* et *floridi*: L'Économie des moyens picturaux contre l'emploi de matériaux onéreux dans la peinture ancienne." In *Couleurs et Matières dans l'Antiquité: Textes, Techniques, et Pratiques*, edited by Sandrine Dubel, Valérie Naas, and Agnès Rouveret, 29–42. Paris: Éditions Ens.

Bredal-Jørgensen et al. 2011
Bredal-Jørgensen, Jørn, Jana Sanyova, Vibeke Rask, Maria Louise Sargent, and Rikke Hoberg Therkildsen. 2011. "Striking Presence of Egyptian Blue Identified in a Painting by Giovanni Battista Benvenuto from 1524." *Analytical and Bioanalytical Chemistry* 401: 1433–39.

Brøns and Sargent 2018
Brøns, Cecilie, and Maria Louise Sargent. 2018. "Pigments and Dyes: The Use of Colourants for the Depiction of Garments on Egyptian Mummy Portraits in the Ny Carlsberg Glyptotek." In *Purpureae Vestes VI: Textiles and Dyes in the Mediterranean Economy and Society*, edited by Maria Stella Busana, Margarita Gleba, Francesco Meo, and Anna Rosa Tricomi, 481–90. Muñoz Seca, Spain: Libros Pórtico.

Buzanich et al. 2010
Buzanich, Günter, P. Wobrauschek, Christina Streli, A. Markowicz, D. Wegrzynek, E. Chinea-Cano, Martina Griesser, and Katharina Uhlir. 2010. "PART II (Portable ART Analyzer)—Development of a XRF Spectrometer Adapted for the Study of Artworks in the Kunsthistorisches Museum, Vienna." *X-Ray Spectrometry* 39 (2): 98–102.

Caputo and Cavassa 2009
Caputo, Paolo, and Laëtitia Cavassa. 2009. "La fabrication du bleu égyptien à Cumes." *Archéologie de l'artisanat Antique* 2: 169–79.

Cardon 2007
Cardon, Dominique. 2007. *Natural Dyes: Sources, Tradition, Technology and Science.* London: Archetype.

Cartwright 1997a
Cartwright, Caroline R. 1997. "Egyptian Mummy Portraits: Examining the Woodworkers' Craft." In *Portraits and Masks: Burial Customs in Roman Egypt*, edited by Morris Bierbrier, 106–11. London: British Museum.

Cartwright 1997b
Cartwright, Caroline R. 1997. Wood identifications for *Ancient Faces: Mummy Portraits from Roman Egypt*, edited by Susan Walker and Morris Bierbrier, multiple pages. London: British Museum.

Cartwright 2015
Cartwright, Caroline R. 2015. "The Principles, Procedures and Pitfalls in Identifying Archaeological and Historical Wood Samples." *Annals of Botany* 116 (1): 1–13. https://doi.org/10.1093/aob/mcv056

Cartwright and Middleton 2008
Cartwright, Caroline R., and Andrew P. Middleton. 2008. "Scientific Aspects of Ancient Faces: Mummy Portraits from Egypt." *The British Museum Technical Research Bulletin* 2: 59–66. https://research.britishmuseum.org/pdf/BMTRB%202%20Cartwright.pdf

Cartwright, Spaabæk, and Svoboda 2011
Cartwright, Caroline R., Lin Rosa Spaabæk, and Marie Svoboda. 2011. "Portrait Mummies from Roman Egypt: Ongoing Collaborative Research on Wood Identification." *The British Museum Technical Research Bulletin* 5: 49–58. https://research.britishmuseum.org/pdf/BMTRB_5_Cartwright_Spaab%C3%A6k_and_Svoboda.pdf

Casadio et al. 2018
Casadio, Francesca, et al., eds. 2018. *Metal Soaps in Art: Conservation and Research.* Cham, Switzerland: Springer.

Caylus, Majault, and Pissot 1755
Caylus, Anne Claude Phillipe, comte de, Michel-Joseph Majault, and Noël-Jacques Pissot. 1755. *Mémoire sur la peinture à l'encaustique et sur la peinture à la cire*. Paris: Chez Pissot.

Chiari 2015
Chiari, Giacomo. 2015. *75.AP.87, Results of Duetto Analyses*. Los Angeles: Getty Conservation Institute. Unpublished internal report.

Cianchetta 2013
Cianchetta, Ilaria. 2013. *75.AP.87, Scientific Report*. Los Angeles: Getty Conservation Institute. Unpublished internal report.

Clementi et al. 2008
Clementi, Catia, Brenda Doherty, Pier Luigi Gentili, Costanza Miliani, Aldo Romani, Bruno G. Brunetti, and Antonio Sgamellotti. 2008. "Vibrational and Electronic Properties of Painting Lakes." *Applied Physics A* 92 (1): 25–33. https://doi.org/10.1007/s00339-008-4474-6

Colinart and Grappin-Wsevolojsky 1999
Colinart, Sylvie, and Sibille Grappin-Wsevolojsky. 1999. "La Cire punique: Étude critique des recettes antiques et de leur interpretation; Application aux portraits du Fayoum." In *ICOM-CC 12th Triennial Meeting, Lyon*, vol. 1, edited by Janet Bridgland and Jessica Brown, 213–20. London: James & James.

Colombini et al. 2005
Colombini, Maria Perla, et al. 2005. "Characterisation of Organic Residues in Pottery Vessels of the Roman Age from Antinoe (Egypt)." *Microchemical Journal* 79 (1–2): 83–90.

Corcoran 1995
Corcoran, Lorelei H. 1995. *Portrait Mummies from Roman Egypt (I–IV Centuries AD): With a Catalog of Portrait Mummies in Egyptian Museums*. Chicago: Oriental Institute of the University of Chicago.

Corcoran 2016
Corcoran, Lorelei H. 2016. "The Color Blue as an Animator in Ancient Egypt." In *Essays in Global Color History: Interpreting the Ancient Spectrum,* edited by Rachael B. Goldman, 41–63. Piscataway, NJ: Gorgias.

Corcoran and Svoboda 2010
Corcoran, Lorelei H., and Marie Svoboda. 2010. *Herakleides: A Portrait Mummy from Roman Egypt*. Los Angeles: J. Paul Getty Museum.

Cosentino 2014
Cosentino, Antonino. 2014. “Identification of Pigments by Multispectral Imaging: A Flowchart Method.” *Conservation Heritage Science* 2 (8): 1–12.

Cumont 1939
Cumont, Franz. 1939. “Un Dieu supposé syrien, associé a Hérón en Égypte.” In *Mélanges Syriens, offerts á Monsieur René Dussaud, secretaire perpétuel de l'Académie des inscriptions et belles-lettres, par ses amis et ses élèves*, 1–9. Paris: Librairie Orientaliste Paul Geuthner.

Cuní et al. 2012
Cuní, Jorge, et al. 2012. “Characterization of the Binding Medium Used in Roman Encaustic Paintings on Wall and Wood.” *Analytical Chemistry* 4: 659–69.

Cuno 2008
Cuno, James B. 2008. *Who Owns Antiquity? Museums and the Battle over Our Ancient Heritage*. Princeton, NJ: Princeton University Press.

Daniels et al. 2014
Daniels, Vincent, Thibaut Devièse, Marei Hacke, and Catherine Higgitt. 2014. “Technological Insights into Madder Pigment Production in Antiquity.” *The British Museum Technical Research Bulletin* 8: 13–28.

David 2001
David, A. R. 2001. “Raman Spectroscopic Analysis of Ancient Egyptian Pigments.” *Archaeometry* 43 (4): 461–73.

Delamare 2008
Delamare, François. 2008. *Bleus en poudres: De l'art à l'industrie, 5000 ans d'innovations*. Paris: Presse de l'École des mines de Paris.

Delamare, Monge, and Repoux 2004
Delamare, François, Gabriel Monge, and Monique Repoux. 2004. “À la recherche de différentes qualités marchandes dans les bleus égyptiens trouvés à Pompéi.” *Rivista di Studi Pompeiani* 15: 89–107.

Delaney et al. 2017
Delaney, John K., Kathryn A. Dooley, Roxanne Radpour, and Ioanna Kakoulli. 2017. “Macroscale Multimodal Imaging Reveals Ancient Painting Production Technology and the Vogue in Greco-Roman Egypt.” *Scientific Reports* 7 (1): 1–12. https://doi.org/10.1038/s41598-017-15743-5

Derksen and Van Beek 2002
Derksen, Goverdina C. H., and Teris A. van Beek. 2002. “*Rubia tinctorum* L.” *Studies in Natural Products Chemistry* 26: 629–84. https://doi.org/10.1016/S1572-5995(02)80016-3

Derrick, Newman, and Wright 2017
Derrick, Michele, Richard Newman, and Joan Wright. 2017. “Characterization of Yellow and Red Natural Organic Colorants on Japanese Woodblock Prints by EEM Fluorescence Spectroscopy.” *Journal of the American Institute for Conservation* 56: 1–23. https://doi.org/10.1080/01971360.2016.1275438

Dietemann et al. 2017
Dietemann, Patrick, et al. 2017. “Pigmente und Bindemittel antiker Mumienporträts.” In *Inkarnat und Signifikanz: Das menschliche Abbild in der Tafelmalerei von 200 bis 1250 im Mittelmeerraum*, edited by Yvonne Schmuhl and Esther Pia Wipfler, 200–218. Munich: Zentralinstituts für Kunstgeschichte.

Dobrovits and Oroszlán 1947
Dobrovits, Aladár, and Zoltán Oroszlán. 1947. *Antik kiállítás: Vezető* [Guide to the Exhibition of Classical Antiquities]. Budapest: Museum of Fine Arts.

Doerner 1934
Doerner, Max. 1934. *The Materials of the Artist and Their Use in Painting*. Translated by Eugen Neuhaus. New York: Harcourt, Brace and Company.

Doxiadis 1995
Doxiadis, Euphrosyne. 1995. *The Mysterious Fayum Portraits: Faces from Ancient Egypt.* London: Thames & Hudson; New York: Harry N. Abrams.

Doxiadis 1997
Doxiadis, Euphrosyne. 1997. “Technique.” In *Ancient Faces: Mummy Portraits from Roman Egypt*, edited by Susan Walker and Morris Bierbrier, 21–22. London: British Museum.

Doxiadis 2007
Doxiadis, Euphrosyne. 2007. “The Fayum Portraits: They Are Not Art, They Are Truth.” In *Living Images: Egyptian Funerary Portraits in the Petrie Museum*, edited by Janet Picton, Stephen Quirke, and Paul C. Roberts, 143–48. Walnut Creek, CA: Left Coast Press.

Dyer, O'Connell, and Simpson 2014
Dyer, Joanne, Elisabeth R. O'Connell, and Antony Simpson. 2014. "Polychromy in Roman Egypt: A Study of a Limestone Sculpture of the Egyptian God Horus." *The British Museum Technical Research Bulletin* 8: 93–103.

Dyer and Sotiropoulou 2017
Dyer, Joanne, and Sophia Sotiropoulou. 2017. "A Technical Step Forward in the Integration of Visible-Induced Luminescence Imaging Methods for the Study of Ancient Polychromy." *Heritage Science* 5 (24): 1–21. https://doi.org/10.1186/s40494-017-0137-2

Dyer et al. 2018
Dyer, Joanne, Diego Tamburini, Elisabeth R. O'Connell, and Anna Harrison. 2018. "A Multispectral Imaging Approach Integrated into the Study of Late Antique Textiles from Egypt." *PLOS ONE* 13 (10): e0204699. https://doi.org/10.1371/journal.pone.0204699

Dyer, Tamburini, and Sotiropoulou 2018
Dyer, Joanne, Diego Tamburini, and Sophia Sotiropoulou. 2018. "The Identification of Lac as a Pigment in Ancient Greek Polychrome: The Case of a Hellenistic Oinochoe from Canosa di Puglia." *Dyes and Pigments* 149: 122–32. https://doi.org/10.1016/j.dyepig.2017.09.062

Dyer, Verri, and Cupitt 2013
Dyer, Joanne, Giovanni Verri, and John Cupitt. 2013. *Multispectral Imaging in Reflectance and Photo-Induced Luminescence Modes: A User Manual.* London: British Museum. https://research.britishmuseum.org/pdf/charisma-multispectral-imaging-manual-2013.pdf

Ebers 1893
Ebers, Georg. 1893. *The Hellenic Portraits from the Fayum at Present in the Collection of Herr Graf*. New York: D. Appleton and Company.

Edwards, Jorge Villar, and Eremin 2004
Edwards, Howell G. M., Susana E. Jorge Villar, and Katherine A. Eremin. 2004. "Raman Spectroscopic Analysis of Pigments from Dynastic Egyptian Funerary Artefacts." *Journal of Raman Spectroscopy* 35: 786–95. https://doi.org/10.1002/jrs.1193

El Goresy et al. 1986
El Goresy, Ahmed, H. Jaksch, M. Abdel Razek, and Karl Ludwig Weiner. 1986. *Ancient Pigments in Wall Paintings of Egyptian Tombs and Temples: An Archaeometric Project.* Heidelberg, Germany: Max-Planck-Institut für Kernphysik.

Eng and Maccarelli 2016
Eng, Charlotte, and Laura Maccarelli. 2016. "Technical Examination of M.71.73.62," *Conservation Analytical Report*. Los Angeles County Museum of Art. Unpublished internal report.

Fischer and Kakoulli 2006
Fischer, Christian, and Ioanna Kakoulli. 2006. "Multispectral and Hyperspectral Imaging Technologies in Conservation: Current Research and Potential Applications." *Studies in Conservation* 7: 3–16.

Fournet 2004
Fournet, Jean-Luc. 2004. "Deux textes relatifs à des couleurs: 1. Liste mentionnant des teintures (P.Société Fouad inv. 99); 2. Un portrait avec des indications destinées au peintre (Phoebe Hearst Museum [Berkeley] inv. 6/21378b)." In *Gedenkschrift Ulrike Horak (P. Horak)*, edited by Hermann Harrauer and Rosario Pintaudi, 91–99. Papyrologica Florentina 34. Florence: Gonnelli.

Freccero 2000
Freccero, Agneta. 2000. *Fayum Portraits: Documentation and Scientific Analysis of Mummy Portraits Belonging to Nationalmuseum in Stockholm.* Gothenburg: Acta Universitatis Gothoborgensis.

Frenz 1999
Frenz, Hans G. 1999. "Porträt einer Frau." In *Augenblicke*: *Mumienporträts und ägyptischer Grabkunst aus römischer Zeit*, edited by Klaus Parlasca and Hellmut Seemann. Frankfurt: Schirn Kunsthalle.

Friedman 1989
Friedman, Florence D. 1989. *Beyond the Pharaohs: Egypt and the Copts in the 2nd to 7th Centuries AD.* Providence: Museum of Art, Rhode Island School of Design.

Gaetani, Santamaria, and Seccaroni 2004
Gaetani, Maria C., Ulderico Santamaria, and Claudio Seccaroni. 2004. "The Use of Egyptian Blue and Lapis Lazuli in the Middle Ages: The Wall Paintings of the San Saba Church in Rome." *Studies in Conservation* 49 (1): 13–22. https://doi.org/10.1179/sic.2004.49.1.13

Ganio 2016
Ganio, Monica. 2016. *Getty Conservation Institute Scientific Report, 79.AP.219*. Los Angeles: Getty Conservation Institute. Unpublished internal report.

Ganio et al. 2015
Ganio, Monica, Johanna Salvant, Jane Williams, Lynn Lee, Oliver Cossairt, and Marc Walton. 2015. "Investigating the Use of Egyptian Blue in Roman Egyptian Portraits and Panels from Tebtunis, Egypt." *Applied Physics A* 121 (3): 813–21. https://doi.org/10.1007/s00339-015-9424-5

Gates et al. 2018
Gates, Glenn, Darryl Butt, Jatuporn Burns, Yaqiao Wu, Gordon Alanko, and Jennifer K. Watkins. 2018. "The Internal Morphology and Composition of a Purple Pigment Particle Extracted from an Ancient Faiyum Mummy Portrait." *Microscopy and Microanalysis* 24 (1): 2128–29.

Geary and Klaniczay 2013
Geary, Patrick J., and Gábor Klaniczay, eds. 2013. *Manufacturing Middle Ages: Entangled History of Medievalism in Nineteenth-Century Europe.* Leiden: Brill.

Geoffroy-Schneiter 1998
Geoffroy-Schneiter, Bérénice. 1998. *Fayum Portraits.* London: Thames & Hudson.

Goldman 1999
Goldman, Bernard. 1999. "The Kerch Easel Painter." *Zeitschrift für Kunstgeschichte* 62: 28–44.

Graf 1893
Graf, Theodor. 1893. *Catalogue of the Theodor Graf Collection of Unique Ancient Greek Portraits, 2000 Years Old, Recently Discovered and Now on View in Old Vienna, Midway Plaisance*. Chicago: n.p.

Grifa et al. 2016
Grifa, Celestino, Laëtitia Cavassa, Alberto De Bonis, Chiara Germinario, Vincenza Guarino, Francesco Izzo, Ioanna Kakoulli, Alessio Langella, Mariano Mercurio, and Vincenzo Morra. 2016. "Beyond Vitruvius: New Insight in the Technology of Egyptian Blue and Green Frits." *Journal of the American Ceramic Society* 99 (10): 3467–75. https://doi.org/10.1111/jace.14370

Grimm-Stadelmann 2016
Grimm-Stadelmann, Isabel. 2016. "Crossing Borders: Egyptian Mummy Portraits and Christian Icons." In *Artists and Colour in Ancient Egypt, Proceedings of the Colloquium Held in Montepulciano, August 22nd–24th, 2008*, edited by Valérie Angenot and Francesco Tiradritti, 3–20. Montepulciano: Missione Archaeologica Italiana a Luxor.

Guichard and Guineau 1990
Guichard, Vincent, and Bernard Guineau. 1990. "Identification de colorants organiques naturels dans des fragments de peintures murales dans l'antiquité." In *Pigments et Colorants de l'Antiquité et du Moyen Âge*, edited by Bernard Guineau, 103–16. Paris: CNRS Éditions.

Guichard and Guineau 2002
Guichard, Vincent, and Bernard Guineau. 2002. "Identification de colorants organiques naturels dans des fragments de peintures murales de l'Antiquité: Exemples de l'emploi d'une laque rose de garance à Stabies et à Vaison-la-Romaine." In *Pigments et colorants de l'Antiquité et du Moyen Âge: Teinture, peinture, enluminure, études historiques et physico-chimiques*, edited by Institut de recherche et d'histoire des textes, Centre de recherche sur les collections, and Équipe Étude des pigments, histoire et archéologie, 245–54. Paris: CNRS Éditions. https://doi.org/10.4000/books.editionscnrs.8116

Győry 2002
Győry, Hedvig. 2002. In *Magyar Múzeumi arcképcsarnok,* edited by Sándor Bodó and Gyula Viga, 706–7. Budapest: Pulszky Társaság—Tarsoly kiadó.

Hagen and Ryholt 2016
Hagen, Fredrik, and Kim Ryholt. 2016. *The Antiquities Trade in Egypt 1880–1930: The H.O. Lange Papers*. Copenhagen: Royal Danish Academy of Sciences and Letters.

Han et al. 2016
Han, Jing, Jantien Wanrooij, Maarten R. van Bommel, and Anita Quye. 2016. "Characterisation of Chemical Components for Identifying Historical Chinese Textile Dyes by Ultra High Performance Liquid Chromatography—Photodiode Array—Electrospray Ionization Mass Spectrometer." *Journal of Chromatography A* 1479: 87–96.

Hart 2016
Hart, Mary Louise. 2016. "A Portrait of a Bearded Man Flanked by Isis and Serapis." In *Icon, Cult, and Context: Sacred Spaces and Objects in the Classical World*, edited by Maura K. Heyn and Ann Irvine Steinsapir, 79–89. Los Angeles: Cotsen Institute of Archaeology Press.

Hatton, Shortland, and Tite 2008
Hatton, Gareth D., Andrew J. Shortland, and Michael S. Tite. 2008. "The Production Technology of Egyptian Blue and Green Frits from Second Millennium BC Egypt and Mesopotamia." *Journal of Archaeological Science* 35 (6): 1591–604.

Hetherington 1978
Hetherington, Paul, trans. 1978. *The Painter's Manual of Dionysius of Fourna.* London: Sagittarius Press.

Hofenk de Graaff 2004a
Hofenk de Graaff, Judith H. 2004. *The Colourful Past: Origins, Chemistry and Identification of Natural Dyestuffs.* London: Archetype.

Hofenk de Graaff 2004b
Hofenk de Graaff, Judith H. 2004. “Indigoid Dyestuffs.” In *The Colourful Past: Origins, Chemistry and Identification of Natural Dyestuffs,* 240–61. London: Archetype.

Horváth 2017
Horváth, Hilda. 2017. “Hillinger Oszkár (1887, Eger−1962?, London?) és gyűjteménye” [Oszkár Hillinger and his collection]. *Kisgrafika* 4: 11−12.

Huang et al. 2007
Huang, Gary B., Manu Ramesh, Tamara Berg, and Erik Learned-Miller. 2007. “Labeled Faces in the Wild: A Database for Studying Face Recognition in Unconstrained Environments.” *University of Massachusetts, Amherst, Technical Report* 7 (49): 1–11. http://vis-www.cs.umass.edu/lfw/lfw.pdf

Iannaccone 2015
Iannaccone, Roberta. 2015. “Tecniche di Imaging Innovative per la Messa a Punto di un Protocollo Integrato per la Caratterizzazione dei Pigmenti Utilizzati nell'Antichità (FIS/07).” PhD diss., University of Florence. https://flore.unifi.it/retrieve/handle/2158/988034/31187/Roberta%20Iannaccone%20tesi%20dottorato%20part1%20frontespizio.pdf

Jimenez 2014
Jimenez, Lissette Marie. 2014. “Transfiguring the Dead: The Iconography, Commemorative Use, and Materiality of Mummy Shrouds from Roman Egypt.” PhD diss., University of California, Berkeley.

Joncheray and Joncheray 2002
Joncheray, Anne, and Jean-Pierre Joncheray. 2002. “Chrétienne M, trois épaves distinctes, entre le cinquième siècle avant et le premier siècle après Jésus-Christ.” *Cahiers d'Archéologie Subaquatique* 14: 57–130.

Joyce 2012
Joyce, Rosemary A. 2012. “From Place to Place: Provenience, Provenance, and Archaeology.” In *Provenance: An Alternate History of Art,* edited by Gail Feigenbaum and Inge Reist, 48–60. Los Angeles: Getty Research Institute.

Kakoulli 1997
Kakoulli, Ioanna. 1997. “Roman Wall Paintings in Cyprus: A Scientific Investigation of Their Technology.” In *Roman Wall Painting: Materials, Techniques, Analysis and Conservation*; *Proceedings of the International Workshop, Fribourg, March 7–9, 1996*, edited by Hamdallah Béarat, Michael Fuchs, Marino Maggetti, and Daniel Paunier, 131–41. Fribourg: Institute of Mineralogy and Petrography.

Kakoulli 2002
Kakoulli, Ioanna. 2002. “Late Classical and Hellenistic Wall Painting Techniques and Materials: An Overview.” *Studies in Conservation* 47 (1): 56–67.

Kakoulli 2009
Kakoulli, Ioanna. 2009. *Greek Painting Techniques and Materials from the Fourth to the First Century BC*. London: Archetype.

Kakoulli et al. 2017
Kakoulli, Ioanna, Roxanne Radpour, Yuan Lin, Marie Svoboda, and Christian Fischer. 2017. “Application of Forensic Photography for the Detection and Mapping of Egyptian Blue and Madder Lake in Hellenistic Polychrome Terracottas Based on Their Photophysical Properties.” *Dyes and Pigments* 136: 104–15.

Kantzia and Kouzeli 1987
Kantzia, K., and K. Kouzeli. 1987. “Εργαστήριο Παρασκευής Χρωμάτων Στην Κω.” Αρχαιολογικά Ανάλεκτα Εξ Αθηνών 20: 211–55.

Killen 1994
Killen, Geoffrey. 1994. *Egyptian Woodworking and Furniture*. Buckinghamshire, UK: Shire.

King 2009
King, Davis E. 2009. “Dlib-ml: A Machine Learning Toolkit.” *Journal of Machine Learning Research* 10: 1755–58.

Kirby, Spring, and Higgitt 2005
Kirby, Jo, Marika Spring, and Catherine Higgitt. 2005. “The Technology of Red Lake Pigment Manufacture: Study of the Dyestuff Substrate.” *National Gallery Technical Bulletin* 26: 71–87.

Kirby and White 1996
Kirby, Jo, and Raymond White. 1996. “The Identification of Red Lake Pigment Dyestuffs and a Discussion of Their Use.” *National Gallery Technical Bulletin* 17: 56–80.

Kiss 1996
Kiss, Zsolt. 1996. “Harpocrate-Héron: A propos d'une figurine en terre cuite du Musée National de Varsovie.” In *Archaeological Research in Roman Egypt: The Proceedings of the Seventeenth Classical Colloquium of the Department of Greek and Roman Antiquities, British Museum, Held on 1–4 December, 1993,* edited by Donald M. Bailey, 214–22. Journal of Roman Archaeology Supplementary Series, 19. London: British Museum.

Kiss 2006
Kiss, Zsolt. 2006. “Deux peintures murales de Marina el-Alamein.” *Bulletin de l'Institut Français d'Archéologie Orientale* 106: 163–70.

Knudsen 2017
Knudsen, Sandra. 2017. “Cats. 155–156: Two Mummy Portraits.” In *Roman Art at the Art Institute of Chicago*, edited by Katharine A. Raff. Chicago: Art Institute of Chicago. https://publications.artic.edu/roman/reader/romanart/section/1965/1965_anchor

Kühn 1960
Kühn, Hermann. 1960. “Detection and Identification of Waxes, Including Punic Wax, by Infra-red Spectrography.” *Studies in Conservation* 5: 71–81.

Kushel 2011
Kushel, Dan. 2011. “Photographic Techniques for Conservation.” In *The AIC Guide to Digital Photography and Conservation Documentation*, 2nd ed., edited by Jeffrey Warda, section 6.0. Washington, DC: American Institute for Conservation of Historic and Artistic Works.

La Rie 1982
La Rie, E. René de. 1982. “Fluorescence of Paint and Varnish Layers (Part I).” *Studies in Conservation* 27 (1): 1–7.

Launey 1950
Launey, Marcel. 1950. *Recherches sur les armées hellénistiques*. Paris: E. de Boccard.

Laurie 1910
Laurie, A. P. 1910. *Greek and Roman Methods of Painting.* Cambridge: Cambridge University Press.

Lee and Quirke 2000
Lee, Lorna, and Stephen Quirke. 2000. “Painting Materials.” In *Ancient Egyptian Materials and Technology*, edited by Paul T. Nicholson and Ian Shaw, 104–13. Cambridge: Cambridge University Press.

Leona 2009
Leona, Marco. 2009. “Microanalysis of Organic Pigments and Glazes in Polychrome Works of Art by Surface-Enhanced Resonance Raman Scattering.” *Proceedings of the National Academy of Sciences of the United States of America* 106: 14757–62.

Liang and Scott 2014
Liang, Jiafang, and David Scott. 2014. “Green-Copper Containing Waxy Paint on Two Egyptian Polychrome Artifacts: A Technical Study.” *Studies in Conservation* 59 (6): 391–403.

Lichocka 2004
Lichocka, Barbara. 2004. *Némésis en Egypte romaine*. In Vol. 5 of *Aegyptiaca Treverensia*, edited by Günter Grimm and Erich Winter. Mainz: Philipp von Zabern.

Lluveras et al. 2010
Lluveras, Anna, A. Torrents, Pilar Giráldez, and Marius Vendrell-Saz. 2010. “Evidence for the Use of Egyptian Blue in an 11th-Century Mural Altarpiece by SEM-EDS, FTIR and SR XRD (Church of Sant Pere, Terrassa, Spain).” *Archaeometry* 52: 308–19.

Los Angeles County Art Institute Galleries 1959
Los Angeles County Art Institute Galleries. 1959. *The Phil Berg Collection: The Los Angeles County Art Institute Galleries, January 8 to February 27, 1959*. Los Angeles: Los Angeles County Institute.

Lucas 1926
Lucas, Alfred. 1926. *Ancient Egyptian Materials and Industries*. London: Histories & Mysteries of Man.

Lydakis 2004
Lydakis, Stelios. 2004. *Ancient Greek Painting and Its Echoes in Later Art.* Los Angeles: J. Paul Getty Museum.

Marlowe 2013
Marlowe, Elizabeth. 2013. *Shaky Ground: Context, Connoisseurship and the History of Roman Art.* London: Bloomsbury Academic.

Marshall 1931
Marshall, John, ed. 1931. *Mohenjo-daro and the Indus Civilization*. Vol. 1. London: Arthur Probsthain.

Mathews 1993
Mathews, Thomas F. 1993. *The Clash of Gods: A Reinterpretation of Early Christian Art*. Princeton, NJ: Princeton University Press.

Mathews 2000
Mathews, Thomas F. 2000. “Heron with Attendant Donor, Panephrimmis.” In *Ancient Faces*, edited by Susan Walker, 125–26, cat. 80. New York: Metropolitan Museum of Art.

Mathews 2001
Mathews, Thomas F. 2001. “The Emperor and the Icon.” In *Imperial Art as Christian Art—Christian Art as Imperial Art: Expression and Meaning in Art and Architecture from Constantine to Justinian*, 163–78. Acta ad archaeologiam et artium historiam pertinentia, vol. 15, no. 1. Oslo: Research Council of Norway.

Mathews 2016
Mathews, Thomas F., with Norman E. Muller. 2016. *The Dawn of Christian Art in Panel Painting and Icons*. Los Angeles: J. Paul Getty Museum.

Mazurek et al. 2014
Mazurek, Joy, Marie Svoboda, Jeffrey Maish, Kazuki Kawahara, Shunsuke Fukakusa, Takashi Nakazawa, and Yoko Taniguchi. 2014. “Characterization of Binding Media in Egyptian Romano Portraits Using Enzyme-Linked Immunosorbant Assay and Mass Spectrometry.” *e-Preservation Science* 11: 76–83.

Mazurek, Svoboda, and Schilling 2019
Mazurek, Joy, Marie Svoboda, and Michael Schilling. 2019. “GC/MS Characterization of Beeswax, Protein, Gum, Resin, and Oil in Romano-Egyptian Paintings.” *Heritage* 2: 1960–85. https://doi.org/10.3390/heritage2030119

Melo and Claro 2010
Melo, Maria, and Ana Claro. 2010. “Bright Light: Microspectrofluorimetry for the Characterization of Lake Pigments and Dyes in Works of Art.” *Accounts of Chemical Research* 43: 857–66. https://doi.org/10.1021/ar9001894

Merz 2000
Merz, Susanne. 2000. “Die Textilien von Theodor Graf, vormals im Besitz der Frühchristliche-Byzantinischen Sammlung Berlin-Dahlem.” In *Textilien aus Ägypten. Teil 1: Textilien aus dem Vorbesitz von Theodor Graf, Carl Schmidt und dem Ägyptischen Museum Berlin*, edited by Cäcilia Fluck, Petra Linscheid, and Susanne Merz, 125–74. Wiesbaden: Reichert.

Michaelis 2015
Michaelis, Lucas. 2015. “Le collier en forme de Méduse dans la mode romaine.” *Göttinger Forum für Altertumswissenschaft* 18: 83–90.

Miliani, Romani, and Favaro 2000
Miliani, Costanza, Aldo Romani, and Gianna Favaro. 2000. “Acidichromic Effects in 1,2-Di- and 1,2,4-Tri-hydroxyanthraquinones: A Spectrophotometric and Fluorimetric Study.” *Journal of Physical Organic Chemistry* 13: 141–50.

Miller 2000
Miller, Stella G. 2000. “Roman Painting and Mosaics.” In *The Oxford History of Western Art*, edited by Martin Kemp, 52–59. Oxford: Oxford University Press.

Mills and White 1972
Mills, John S., and Raymond White. 1972. “The Gas-Chromatographic Examination of Paint Media, Part II: Some Examples of Medium Identification in Paintings by Fatty Acid Analysis.” *Studies in Conservation* 17 (S1): 721–28.

Montabert 1829
Montabert, Jacques-Nicolas Paillot de. 1829. *Traité complet de la peinture.* Paris: J.-F. Delion.

Montserrat 1996
Montserrat, Dominic. 1996. “‘Your Name Will Reach the Hall of the Western Mountains’: Some Aspects of Mummy Portrait Inscriptions.” *Journal of Roman Archaeology Supplementary Series* 19: 177–85.

Moritz 1918
Moritz, Bernhard. 1918. “Beiträge zur Geschichte des Sinaiklosters im Mittelalter nach arabischen Quellen.” In *Abhandlungen der Königlich Preussischen Akademie der Wissenschaften, Jg. 1918. Philosophisch-historische Klasse*, no. 4, 3–62. Berlin: Verlag der Königl, Akademie der Wissenschaften. https://archive.org/details/beitrgezurgesc00moriuoft

Mouri and Laursen 2012
Mouri, Chika, and Richard Laursen. 2012. “Identification of Anthraquinone Markers for Distinguishing *Rubia* Species in Madder-Dyed Textiles by HPLC.” *Microchimica Acta* 179: 105–13.

Müller 2017
Müller, Asja. 2017. “New Research on Roman Period Mummy Masks: The Case Example of the Budapest Museum of Fine Arts Collection.” In *Burial and Mortuary Practices in Late Period and Graeco-Roman Egypt: Proceedings of the International Conference Held at Museum of Fine Arts, Budapest, 17–19 July 2014*, edited by K. A. Kóthay, 291–304. Budapest: Museum of Fine Arts.

Nachtergael 1996
Nachtergael, Georges. 1996. “Trois dedicaces au dieu Heron.” *Chronique d'Égypte* 71: 129–42.

Nagy 2013
Nagy, Árpád M. 2013. *Classica Hungarica: A Szépművészeti Múzeum Antik Gyűjteményének első évszázada (1908–2008)* [Classica Hungarica: The first century of the Collection of Classical Antiquities in the Museum of Fine Arts (1908–2008)]. MúzeumCafé könyvek [MuseumCafé Books] 2. Budapest: Museum of Fine Arts.

Nevin et al. 2014
Nevin, Austin, Anna Cesaratto, Sara Bellei, Cosimo D'Andrea, Lucia Toniolo, Gianluca Valentini, and Daniela Comelli. 2014. “Time-Resolved Photoluminescence Spectroscopy and Imaging: New Approaches to the Analysis of Cultural Heritage and Its Degradation.” *Sensors* 14: 6338–55.

N. Newman et al. 2013
Newman, Nicola, Lynne Harrison, David Thomas, Joanne Dyer, and John Taylor. 2013. “A Study and Conservation of Four Ancient Egyptian Funerary Portraits: Provenance, Conservation History and Structural Treatment.” *The British Museum Technical Research Bulletin* 7: 1–13.

R. Newman, Kaplan, and Derrick 2015
Newman, Richard, Emily Kaplan, and Michele Derrick. 2015. “Mopa Mopa: Scientific Analysis and History of an Unusual South American Resin Used by the Inka and Artisans in Pasto, Colombia.” *Journal of the American Institute for Conservation* 54: 123–48.

Nicholson and Shaw 2000
Nicholson, Paul, and Ian Shaw, eds. 2000. *Ancient Egyptian Materials and Technology.* Cambridge: Cambridge University Press.

O'Connell 2007
O'Connell, Elisabeth R. 2007. “Recontextualizing Berkeley's Tebtunis Papyri.” In *Proceedings of the 24th International Congress of Papyrologists, Helsinki, 1–7 August 2004*, edited by Jaakko Frösén, Tina Purola, and Erja Salmenkivi, 807–26. Commentationes Humanarum Litterarum, vol. 122, no. 2. Helsinki: Scientiarum Fennica.

Pagès-Camagna and Guichard 2010
Pagès-Camagna, Sandrine, and Hélène Guichard. 2010. “Egyptian Colours and Pigments in French Collections: 30 Years of Physiochemical Analyses on 300 Objects.” In *Decorated Surfaces on Ancient Egyptian Objects: Technology, Deterioration and Conservation; Proceedings of a Conference Held in Cambridge, UK, on 7–8 September 2007*, edited by Julie Dawson, Christina Rozeik, and Margot M. Wright, 25–31. London: Archetype.

Pagès-Camagna, Guichard, et al. 2010
Pagès-Camagna, Sandrine, Hélène Guichard, Roberta Cortopassi, Claire Bergeaud, Elsa Vigouroux-Gaillard, and Marie-France Aubert. 2010. “The New Life of Crispina: Scientific Analysis and Conservation of an Egyptian Painted Shroud of the Roman Period.” In *Decorated Surfaces on Ancient Egyptian Objects: Technology, Deterioration and Conservation: Proceedings of a Conference Held in Cambridge, UK, on 7–8 September 2007*, edited by Julie Dawson, Christina Rozeik, and Margot M. Wright, 142–47. London: Archetype.

Pagès-Camagna, Laval, et al. 2010
Pagès-Camagna, Sandrine, E. Laval, D. Vigears, and A. Duran. 2010. “Non-Destructive and In Situ Analysis of Egyptian Wall Paintings by X-Ray Diffraction and X-Ray Fluorescence Portable Systems.” *Applied Physics A* 100 (3): 671–81.

Pagès-Camagna and Le Hô 2008
Pagès-Camagna, Sandrine, and Anne-Solenn Le Hô. 2008. “Analyses de laboratoire des matériaux colorés et de la technique des portraits du Fayoum.” In *Portraits funéraires de l'Égypte romaine: Cartonnages, linceuls et bois*, edited by Marie-France Aubert et al., 41–54. Paris: Musée du Louvre.

Panofsky 1955
Panofsky, Erwin. 1955. “The History of the Theory of Human Proportions as a Reflection of the History of Styles.” In *Meaning in the Visual Arts: Papers in and on Art History,* 55–107. New York: Anchor Books.

Parlasca 1966
Parlasca, Klaus. 1966. *Mumienporträts und verwandte Denkmäler*. Wiesbaden: Steiner.

Parlasca 1969–2003
Parlasca, Klaus. 1969–2003. *Repertorio d'Arte dell'Egitto: Greco-Romano Serie B; Ritratti di Mummie*. 4 vols. Palermo: Officine Tipo-Litografiche I.R.E.S.

Parlasca 1977
Parlasca, Klaus. 1977. Vol. 2 of *Repertorio d'Arte dell'Egitto Greco-Romano Serie B: Ritratti di Mummie.* Rome: L'Erma di Bretschneider.

Parlasca 1980
Parlasca, Klaus. 1980. Vol. 3 of *Repertorio d'Arte dell'Egitto: Greco-Romano Serie B; Ritratti di Mummie.* Rome: L'Erma di Bretschneider.

Parlasca and Frenz 2003
Parlasca, Karl, and Hans G. Frenz. 2003. Vol. 4 of *Repertorio d'Arte dell'Egitto: Greco-Romano Serie B; Ritratti di Mummie.* Rome: L'Erma di Bretschneider.

Passeri, Gunnison, and Mysak 2017
Passeri, Ima, Anne Gunnison, and Erin Mysak. 2017. "The Examination of Flesh Tones on an Ancient Painted Shield from Dura Europos." In *Inkarnat und Signifikanz: Das menschliche Abbild in der Tafelmalerei von 200 bis 1250 im Mittelmeerraum*, edited by Yvonne Schmuhl and Esther P. Wipfler, 250–62. Munich: Lehrstuhl für Restaurierung, Kunsttechnologie und Konservierungswissenschaft, Technische Universität München.

Peacock 2000
Peacock, David. 2000. "The Roman Period." In *The Oxford History of Ancient Egypt*, edited by Ian Shaw, 433–34. Oxford: Oxford University Press.

Petrie 1889
Petrie, William Matthew Flinders. 1889. *Hawara, Biahmu, and Arsinoe*. London: Field & Tuer.

Petrie 1910
Petrie, William Matthew Flinders. 1910. *The Arts and Crafts of Ancient Egypt.* London: T. N. Foulis.

Petrie 1911a
Petrie, William Matthew Flinders. 1911. *Roman Portraits and Memphis (IV).* London: School of Archaeology in Egypt, University College.

Petrie 1911b
Petrie, William Matthew Flinders. 1911. "Roman Portraits in Egypt." *Man* 11: 145–47.

Petrie 1931
Petrie, William Matthew Flinders. 1931. *Seventy Years in Archaeology.* London: Sampson Low, Marston & Co.

Picton, Quirke, and Roberts 2007
Picton, Janet, Stephen Quirke, and Paul C. Roberts, eds. 2007. *Living Images: Egyptian Funerary Portraits in the Petrie Museum*. Walnut Creek, CA: Left Coast Press.

Pitthard et al. 2007
Pitthard, Václav, Bettina Vak, Martina Griesser, Sabine Stanek, and Manuela Laubenberger. 2007. "Fayum Portraits from the Collection of Greek and Roman Antiquities, Kunsthistorisches Museum, Vienna: Conservation Treatment and Research into Composition." *Technologische Studien Kunsthistorisches Museum* 4: 11–29.

Pitt-Rivers 1894
Pitt-Rivers, Augustus. 1894. *A Short Guide to the Larmer Grounds, Rushmore; King John's House; The Museum at Farnham; and Neighborhood.* London: Harrison and Sons.

Platz 1887
Platz, Bonifatius. 1887. *Der Mensch, sein Ursprung, seine Rassen und sein Alter.* Würzburg and Vienna: Verlag von Leo Woerl.

Platz 1891
Platz, Bonifatius. 1891. *Die Völker der Erde: Afrika.* Würtenburg and Vienna: Verlag von Leo Woerl.

Prag 2002
Prag, A. J. N. W. 2002. "Proportion and Personality in the Fayum Portraits." *British Museum Studies in Ancient Egypt and Sudan* 3: 55–63.

Raff 2016
Raff, Katharine A., ed. 2016. *Roman Art at the Art Institute of Chicago*. Chicago: Art Institute of Chicago. https://publications.artic.edu/roman/reader/romanart/section/481

Rambaldi et al. 2015
Rambaldi, Diane C., Federica Pozzi, Nobuko Shibayama, Marco Leona, and Frank D. Preusser. 2015. "Surface-Enhanced Raman Spectroscopy of Various Madder Species on Wool Fibers: The Role of Pseudopurpurin in the Interpretation of the Spectra." *Journal of Raman Spectroscopy* 46: 1073–81. https://doi.org/10.1002/jrs.4726

Ramer 1979
Ramer, Brian. 1979. "The Technology, Examination and Conservation of the Fayum Portraits in the Petrie Museum." *Studies in Conservation* 24 (1): 1–13.

Rassart-Debergh 1991
Rassart-Debergh, Marguerite. 1991. "Trois icônes romaines du Fayoum." *Chronique d'Égypte* 66: 349–55.

Regert et al. 2001
Regert, Martine, Sylvie Colinart, Laure Degrand, and Oreste Decavallas. 2001. "Chemical Alteration and Use of Beeswax

through Time: Accelerated Ageing Tests and Analysis of Archaeological Samples from Various Environmental Contexts." *Archaeometry* 43: 549–69.

Requeno 1784
Requeno, Vincenzo. 1784. *Saggi sul ristabilimento dell'antica arte de greci e romani pittori.* Venice: Appresso Giovanni Gatti.

Rice 1999
Rice, Danielle. 1999. "Encaustic Painting Revivals: A History of Discord and Discovery." In *Waxing Poetic: Encaustic Art in America*, edited by Gail Stavitsky, 5–14. Montclair, NJ: Montclair Art Museum.

Riggs 2005
Riggs, Christina. 2005. *The Beautiful Burial in Roman Egypt: Art, Identity and Funerary Religion.* Oxford: Oxford University Press.

Riggs 2014
Riggs, Christina. 2014. *Unwrapping Ancient Egypt.* London: Bloomsbury.

C. Roberts 2013
Roberts, C. 2013. *Green Pigments in Graeco-Roman Egypt.* Los Angeles: Antiquities Conservation Department, J. Paul Getty Museum. Unpublished internal report.

P. Roberts 2008
Roberts, Paul. 2008. *Mummy Portraits from Roman Egypt.* London: British Museum.

Robins 1994
Robins, Gay. 1994. *Proportion and Style in Ancient Egyptian Art.* Austin: University of Texas Press.

Rondot 2001
Rondot, Vincent. 2001. "Le dieu à la bipenne, c'est Lycurgue." *Revue d' Égyptologie* 52: 219–36.

Rondot 2013
Rondot, Vincent. 2013. *Derniers visages des dieux d'Égypte: Iconographies, panthéons et cultes dans le Fayoum héllenisé des II–III siècles de notre ère*. Paris: Éditions du Louvre.

Rondot 2015
Rondot, Vincent. 2015. "Graeco-Roman Fayum Pantheons as Documented by 2nd-Century Painted Wooden Panels." In *Von der Pharaonenzeit bis zur Spätantike: Kulturelle Vielfalt im Fayum, Akten des 5. Internationalen Fayum-Konferenz, 29. Mai bis 1. Juni 2013, Leipzig*, edited by Nadine Quenouille, 145–62. Wiesbaden: Harrassowitz Verlag.

Rowe, Siddall, and Stacey 2010
Rowe, Sophie, Ruth Siddall, and Rebecca Stacey. 2010. "Egyptian Gilded Cartonnage: Technical Study and Conservation of a Mummy Mask from Hawara." In *Decorated Surfaces on Ancient Egyptian Objects: Technology, Deterioration and Conservation; Proceedings of a Conference Held in Cambridge, UK, on 7–8 September 2007,* edited by Julie Dawson, Christina Rozeik, and Margot M. Wright, 106–21. London: Archetype.

Roy 1993
Roy, Ashok, ed. 1993. *Artists' Pigments: A Handbook of Their History and Characteristics*. Vol. 2. Oxford: Oxford University Press.

Sabino 2016
Sabino, Rachel C. 2016. "Cat. 156 Mummy Portrait of a Man Wearing a Laurel Wreath: Technical Report." In *Roman Art at the Art Institute of Chicago*, edited by Katharine A. Raff, cat. 156. Chicago: Art Institute of Chicago. https://publications.artic.edu/roman/reader/romanart/section/1967

Sabino et al., 2019
Sabino, Rachel C., Ken Sutherland, Emeline Pouyet, Federica Pozzi, and Marc Walton. 2019. "Surprise Encounters with Mummy Portraits at the Art Institute of Chicago." *AIC Paintings Specialty Group Postprints* 31.

Sagonas et al. 2016
Sagonas, Christos, Epameinondas Antonakos, Georgios Tzimiropoulos, Stefanos Zafeiriou, and Maja Pantic. 2016. "300 Faces In-The-Wild Challenge: Database and Results." *Image and Vision Computing* 47: 3–18.

Salvant et al. 2018
Salvant, Johanna, Jane Williams, Monica Ganio, Francesca Casidio, Céline Daher, Ken Sutherland, Letizia Monico, Frederik Vanmeert, Steven de Meyer, Koen Janssens, Caroline R. Cartwright, and Marc Walton. 2018. "A Roman Egyptian Painting Workshop: Technical Investigation of the Portraits from Tebtunis, Egypt." *Archaeometry* 60 (4): 815–33. https://doi.org/10.1111/arcm.12351

Sande 2005
Sande, Siri. 2005. "Pagan Pinakes and Christian Icons: Continuity or Parallelism?" *Acta ad archaeologiam et artium historiam pertinentia* 18: 81–100.

Schiegl, Weiner, and El Goresy 1989
Schiegl, Solveig, Kenneth L. Weiner, and Ahmed El Goresy. 1989. "Discovery of Copper Chloride Cancer in Ancient

Egyptian Polychromic Wall Paintings and Faience: A Developing Archaeological Disaster." *Die Naturwissenschaften* 76: 393–400.

Schilling et al. 2016
Schilling, Michael R., Arlen Heginbotham, Henk van Keulen, and Mike Szelewski. 2016. "Beyond the Basics: A Systematic Approach for Comprehensive Analysis of Organic Materials in Asian lacquers." *Studies in Conservation* 61 (S3): 3–27. https://doi.org/10.1080/00393630.2016.1230978

Schweppe 1993
Schweppe, Helmut. 1993. *Handbuch der Naturfarbstoffe.* Hamburg: Nikol.

Schweppe 1997
Schweppe, Helmut. 1997. "Indigo and Woad." In Vol. 3 of *Artists' Pigments: A Handbook of Their History and Characteristics,* edited by Elisabeth West Fitzhugh, 81–107. New York: Oxford University Press.

Scott 2007
Scott, David A. 2007. "Greener Shades of Pale: A Review of Advances in the Characterisation of Ancient Egyptian Green Pigments." In *Decorated Surfaces on Ancient Egyptian Objects: Technology, Deterioration and Conservation; Proceedings of a Conference Held in Cambridge, UK, on 7–8 September 2007*, edited by Julie Dawson, Christina Rozeik, and Margot M. Wright, 32–45. London: Archetype.

Scott 2016
Scott, David A. 2016. "A Review of Ancient Egyptian Pigments and Cosmetics." *Studies in Conservation* 61: 185–202.

Scott, Dodd, et al. 2004
Scott, David A., Lynn Swartz Dodd, Junko Furihata, Satoko Tanimoto, Joy Keeney, Michelle R. Schilling, and Elizabeth Cowan. 2004. "An Ancient Egyptian Cartonnage Broad Collar: Technical Examination of Pigments and Binding Media." *Studies in Conservation* 49: 177–92.

Scott, Warmlander, et al. 2009
Scott, David A., Sebastian Warmlander, Joy Mazurek, and Stephan Quirke. 2009. "Examination of Some Pigments, Grounds and Media from Egyptian Cartonnage Fragments in the Petrie Museum, University College London." *Journal of Archaeological Science* 36 (3): 923–32.

Selvius DeRoo and Armitage 2011
Selvius DeRoo, Cathy, and Ruth Ann Armitage. 2011. "Direct Identification of Dyes in Textiles by Direct Analysis in Real Time-Time of Flight Mass Spectrometry." *Analytical Chemistry* 83 (18): 6924–28.

Seyrig 1970
Seyrig, Henri. 1970. "Antiquités syriennes. 89. Les dieux armés et les Arabes de Syrie." *Syria* 47: 77–112.

Sörries 2003
Sörries, Reiner. 2003. *Das Malibu-Triptychon: Ein Totengedenkbild aus dem römischen Ägypten und verwandte Werke der spätantiken Tafelmalerei.* Christliche Archäologie 4. Dettelbach: Verlag J.H. Röll.

Spaabæk 2007
Spaabæk, Lin Rosa. 2007. "Conservation of Mummy Portraits at the Ny Carlsberg Glyptotek." In *Living Images: Egyptian Funerary Portraits in the Petrie Museum*, edited by Janet Picton, Stephen Quirke, and Paul C. Roberts, 113–41. Walnut Creek, CA: Left Coast Press.

Spaabæk 2012
Spaabæk, Lin Rosa. 2012. "Mummy Portrait Supports." In *Conservation of Easel Paintings*, edited by Joyce Hill Stoner and Rebecca Rushfield, 65–68. London: Routledge.

Spier, Potts, and Cole 2018
Spier, Jeffrey, Timothy Potts, and Sara E. Cole, eds. 2018. *Beyond the Nile: Egypt and the Classical World*. Los Angeles: J. Paul Getty Museum.

Spurrell 1895
Spurrell, F. C. J. 1895. *Notes on Egyptian Colours.* London: Harrison and Sons.

Squire 2015
Squire, Michael. 2015. "Roman Art and the Artist." In *A Companion to Roman Art*, edited by Barbara Borg, 172–94. Chichester, West Sussex, UK: John Wiley & Sons.

Stacey 2011
Stacey, Rebecca J. 2011. "The Composition of Some Roman Medicines: Evidence for Pliny's Punic Wax?" *Analytical and Bioanalytical Chemistry* 401 (6): 1749–59.

Stacey et al. 2018
Stacey, Rebecca J., Joanne Dyer, Chris Mussell, Anna Lluveras-Tenorio, Maria Perla Colombini, Celia Duce, Jacopo La Nasa, et al. 2018. "Ancient Encaustic: An Experimental Exploration of Technology, Ageing Behaviour

and Approaches to Analytical Investigation." *Microchemical Journal* 138: 472–87.

Stavitsky 1999
Stavitsky, Gail, ed. 1999. *Waxing Poetic: Encaustic Art in America*. Montclair, NJ: Montclair Art Museum.

Stock et al., forthcoming
Stock, Stuart R., et al. Forthcoming. "Sex, Age, and Mummification Practices: Evidence From 3-D X-Ray Imaging and X-Ray Diffraction." In *Petrie's Portrait Mummy No. 4: A Girl from Hawara*, edited by Essi Ronkko, Taco Terpstra, and Marc Walton. Evanston, IL: Block Museum of Art.

Strivay 2013
Strivay, David. 2013. *XRF Mapping Reports, 75.AP.87 and 79.AP.219*. Los Angeles: Getty Conservation Institute; Belgium: Centre Européen d'Archéométrie, U.R. Art, Archéologie et Patrimoine, Université de Liège. Unpublished internal report.

Sukenik et al. 2017
Sukenik, Naama, David Iluz, Zohar Amar, Alexander Varvak, Vanessa Workman, Orit Shamir, and Erez Ben-Yosef. 2017. "Early Evidence (Late 2nd Millennium BCE) of Plant-Based Dyeing of Textiles from Timna, Israel." *PLOS One* 12: e0179014. https://doi.org/10.1371/journal.pone.0179014

Sutherland 2017
Sutherland, Ken. 2017. Review of *Painting in Tempera, c. 1900*, edited by Karoline Beltinger and Jilleen Nadolny. *Journal of the American Institute for Conservation* 56: 267–69.

Sutherland and del Río 2014
Sutherland, Ken, and del Río, José C. 2014. "Characterisation and Discrimination of Various Types of Lac Resin Using Gas Chromatography Mass Spectrometry Techniques with Quaternary Ammonium Reagents." *Journal of Chromatography A* 1338: 149–63.

Svoboda and Walton 2007
Svoboda, Marie, and Marc Walton. 2007. "Material Investigations of the J. Paul Getty Museum's Red-Shroud Mummy." In *Decorated Surfaces on Ancient Egyptian Objects: Technology, Deterioration and Conservation; Proceedings of a Conference Held in Cambridge, UK, on 7–8 September 2007*, edited by Julie Dawson, Christina Rozeik, and Margot Wright, 148–55. London: Archetype.

Tanevska et al. 2014
Tanevska, Vinka, Irena Nastova, Bilijana Minčeva-Šukarova, Orhideja Grupče, Melih Ozcatal, Marijana Kavčić, and Zorica Jakovlevska-Spirovska. 2014. "Spectroscopic Analysis of Pigments and Inks in Manuscripts: II. Islamic Illuminated Manuscripts (16th–18th Century)." *Vibrational Spectroscopy* 73: 127–37.

Tchernia 1968–70
Tchernia, André. 1968–70. "Premiers résultats des fouilles de juin 1968 sur l'epave 3 de Planier." *Études Classiques* 3: 51–82.

Thistlewood 2018
Thistlewood, Jevon. 2018. "Ancient Panel Paintings Known as Mummy Portraits." *The Picture Restorer* 52: 6–11.

Thompson 1954
Thompson, Daniel V., Jr., trans. 1954. *The Craftsman's Handbook: Il Libro dell'Arte, Cennino d'Andrea Cennini.* 2nd ed. New York: Dover.

Thompson 1975
Thompson, David L. 1975. "The Hartford Horseman." *Chronique d'Égypte* 50: 321–25.

Thompson 1976
Thompson, David L. 1976. *The Artists of the Mummy Portraits.* Los Angeles: J. Paul Getty Museum.

Thompson 1978–1979
Thompson, David L. 1978–1979. "A Painted Triptych from Roman Egypt." *The J. Paul Getty Museum Journal* 6/7: 185–92.

Thompson 1982
Thompson, David. 1982. *Mummy Portraits in the J. Paul Getty Museum*. Los Angeles: J. Paul Getty Museum.

Tite, Bimson, and Cowell 1984
Tite, M. S., M. Bimson, and M. R. Cowell. 1984. "Technological Examination of Egyptian Blue." *Archaeological Chemistry* 3: 215–42.

Tobin 1975
Tobin, Richard. 1975. "The Canon of Polykleitos." *American Journal of Archaeology* 79 (4): 307–21.

Török 2005
Török, Laszlo. 2005. *Transfigurations of Hellenism: Aspects of Late Antique Art in Egypt AD 250–700*. Boston: Brill.

Trope, Quirke, and Lacovara 2005
Trope, Betsy Teasley, Stephen Quirke, and Peter Lacovara, eds. 2005. *Excavating Egypt: Great Discoveries from the Petrie Museum of Egyptian Archaeology, University College London.* Atlanta: Michael C. Carlos Museum.

Uhlir et al. 2012
Uhlir, Katharina, B. Frühmann, G. Buzanich, M. Griesser, C. Streli, P. Wobrauschek, B. Grossmayer, and S. Smolek. 2012. "A Newly Developed, Portable, Vacuum-Chamber Equipped XRF-Instrument, Designed for the Sophisticated Needs of the Kunsthistorisches Museum, Vienna." *IOP Conference Series: Materials Science and Engineering* 37: 1–7. http://iopscience.iop.org/1757-899X/37/1/012008/pdf/1757-899X_37_1_012008.pdf

Vak 2013
Vak, B. 2013. "Auf der Suche nach dem Original: Anwendungen und Illustrationen naturwissenschaftlicher Diagnostik an attisch figürlich bemalter Keramik aus der Antikensammlung des Kunsthistorischen Museums." *Corpus Vasorum Antiquorum Österreich* 1: 41–72.

Valentyik 2017
Valentyik, Ferenc. 2017. "Back Bernát életútjának gyóni időszakáról" [Bernát Back's years in Gyón]. *Dabasi Újság* 17 (4): 22.

Van den Berg et al. 2000
Van den Berg, Klaas Jan, Jaap J. Boon, Ivana Pastorova, and Leo Spetter. 2000. "Mass Spectrometric Methodology for the Analysis of Highly Oxidized Diterpenoid Acids in Old Master Paintings." *Journal of Mass Spectrometry* 35: 512–33.

Verő 2017
Verő, Mária. 2017. "Back Bernát, gyűjtő és mecénás" [Bernát Back: Collector and art patron]. *Ars Hungarica* 43: 87–113. http://www.epa.oszk.hu/01600/01615/00007/pdf/EPA01615_ars_hungarica_2017_1_087-114.pdf

Verri 2009a
Verri, Giovanni. 2009. "The Application of Visible-Induced Luminescence Imaging to the Examination of Museum Objects." *Proceedings SPIE 7391, O3A: Optics for Arts, Architecture, and Archaeology 2*: 739105–12. https://doi.org/10.1117/12.827331

Verri 2009b
Verri, Giovanni. 2009. "The Spatially Resolved Characterisation of Egyptian Blue, Han Blue and Han Purple by Photo-Induced Luminescence Digital Imaging." *Analytical and Bioanalytical Chemistry* 394 (4): 1011–21.

Verri and Saunders 2014
Verri, Giovanni, and David Saunders. 2014. "Xenon Flash for Reflectance and Luminescence (Multispectral) Imaging in Cultural Heritage Applications." *The British Museum Technical Research Bulletin* 8: 83–92.

Verri et al. 2010
Verri, Giovanni, David Saunders, Janet Ambers, and Tracey Sweek. 2010. "Digital Mapping of Egyptian Blue: Conservation Implications." In *Conservation and the Eastern Mediterranean: Contributions to the 2010 IIC Congress, Istanbul*, edited by Christina Rozeik, Ashok Roy, and David Saunders, 220–24. London: Archetype.

Vogelsang-Eastwood 2000
Vogelsang-Eastwood, Gillian. 2000. "Textiles." In *Ancient Egyptian Materials and Technology,* edited by Paul T. Nicholson and Ian Shaw, 269–98. Cambridge: Cambridge University Press.

Von Richter 1893
von Richter, Otto Donner. 1893. "The Encaustic Painting of the Ancients." In *Catalogue of the Theodor Graf collection of unique ancient Greek portraits, 2000 years old, recently discovered and now on view in Old Vienna, Midway Plaisance at the World's Columbian Exposition, Chicago*, edited by Theodor Graf et al., 45–49. Chicago: n.p.

Walker 1997
Walker, Susan. 1997. "Mummy Portraits in Their Roman Context." In *Portraits and Masks: Burial Customs in Roman Egypt*, edited by Morris L. Bierbrier, 1–6. London: British Museum.

Walker 2000
Walker, Susan, ed. 2000. *Ancient Faces: Mummy Portraits from Roman Egypt*. London: British Museum; New York: Metropolitan Museum of Art.

Walker and Bierbrier 1997
Walker, Susan, and Morris Bierbrier, with Paul Roberts and John Taylor. 1997. *Ancient Faces: Mummy Portraits from Roman Egypt.* A Catalogue of Roman Portraits in the British Museum 4. London: British Museum.

Walton and Trentelman 2009
Walton, Marc S., and Karen Trentelman. 2009. "Romano-Egyptian Red Lead Pigment: A Subsidiary Commodity of Spanish Silver Mining and Refinement." *Archaeometry* 51 (5): 845–60.

Warda 2011
Warda, Jeffrey. 2011. “Equipment.” In *The AIC Guide to Digital Photography and Conservation Documentation*, 2nd ed., edited by Jeffrey Warda, section 2.0. Washington, DC: American Institute for Conservation of Historic and Artistic Works.

Webb, Summerour, and Giaccai 2014
Webb, E. Keats, Rebecca Summerour, and Jennifer Giaccai. 2014. “A Case Study Using Multiband and Hyperspectral Imaging for the Identification and Characterization of Materials on Archaeological Andean Painted Textiles.” *Postprints of the Textile Specialty Group of the American Institute for Conservation of Historic & Artistic Works* 24: 23–35.

White 1978
White, Raymond. 1978. “The Application of Gas-Chromatography to the Identification of Waxes.” *Studies in Conservation* 23: 57–68.

Whitehouse 1999
Whitehouse, Helen. 1999. “A Painted Panel of Isis.” In *Dakhleh Oasis Project, Monograph 8: Preliminary Reports on the 1992–1993 and 1993–1994 Field Seasons*, edited by Colin A. Hope and Anthony J. Mills, 95–100. Oxford: Oxbow Books.

Will 1990
Will, Ernest. 1990. “Heron.” In Vol. 5 of *Lexicon Iconographicum Mythologiae Classicae*, 392. Zurich: Artemis.

Williams 2010
Williams, Jane. 2010. “The Conservation Treatment of the Roman Egyptian Paintings in the Hearst Museum of Anthropology, University of California, Berkeley.” In *Decorated Surfaces on Ancient Egyptian Objects: Technology, Deterioration and Conservation; Proceedings of a Conference Held in Cambridge, UK, on 7–8 September 2007*, edited by Julie Dawson, Christina Rozeik, and Margot M. Wright, 130. London: Archetype.

Winckelmann 2006
Winckelmann, Johann Joachim. 2006. *History of the Art of Antiquity.* Translated by Harry Francis Mallgrave. Los Angeles: Getty Research Institute.

Winkes 1973
Winkes, Rolf. 1973. “The God Heron.” *Bulletin of the Rhode Island School of Design, Museum Notes* 59 (January): 14–15.

Winkes 1982
Winkes, Rolf. 1982. *Roman Paintings and Mosaics: Catalogue of the Classical Collection*. Providence: Museum of Art, Rhode Island School of Design.

Woudhuysen-Keller and Woudhuysen-Keller 1994
Woudhuysen-Keller, Renate, and Paul Woudhuysen-Keller. 1994. “The History of Egg White Varnishes.” *Hamilton Kerr Institute Bulletin* 2: 90–141.

Wouters et al. 2008
Wouters, Jan, Ina Vanden Berghe, Ghislaine Richard, René Breniaux, and Dominique Cardon. 2008. “Dye Analysis of Selected Textiles from Three Roman Sites in the Eastern Desert of Egypt: A Hypothesis on the Dyeing Technology in Roman and Coptic Egypt.” *Dyes in History and Archaeology* 21: 1–16.

Wyplosz 2003
Wyplosz, Nicolas. 2003. “Laser Desorption Mass Spectrometric Studies of Artists’ Organic Pigments.” PhD diss., University of Amsterdam.

Zaloscer 1961
Zaloscer, Hilde. 1961. *Porträts aus dem Wüstensand.* Vienna: Anton Schroll.

Zetina 2018
Zetina, Sandra. 2018. “Diego Rivera's Revival of Encaustic Painting: The Use of Wax in Mexican Avant-Garde Painting.” In *Expression and Sensibility: Art Technological Sources and the Rise of Modernism*, edited by Christoph Krekel et al., 58–66. London: Archetype.

Zhang, Good, and Laursen 2008
Zhang, Xian, Irene Good, and Richard Laursen. 2008. “Characterization of Dyestuffs in Ancient Textiles from Xinjiang.” *Journal of Archaeological Science* 35: 1095–103.

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Evelyn (Eve) Mayberger is Andrew W. Mellon Fellow for Advanced Training at the Museum of Fine Arts, Boston. She holds MA and MS degrees in art history and conservation from the Institute of Fine Arts, New York University, where she specialized in objects conservation. She completed her fourth-year internship at the Penn Museum.

Joy Mazurek

Joy Mazurek is an assistant scientist at the Getty Conservation Institute, where she specializes in the identification of organic materials via gas chromatography/mass spectrometry. She obtained an MS in biology, with emphasis in microbiology, from California State University, Northridge, and a BS degree in biology from University of California, Davis.

Derek Merck

Derek Merck is a computer scientist in the Department of Diagnostic Imaging at Rhode Island Hospital. He holds a PhD from University of North Carolina at Chapel Hill and is a graduate of the University of Chicago and Reed College in Portland, Oregon. His research programs are primarily concerned with image-guided procedure planning, image informatics, and medical visualization.

David Murray

David Murray is director of the Environmental Chemistry Facility at Brown University, where he oversees an analytical facility that handles a wide range of sample types for elemental and compound analysis. He received from Oregon State University a PhD in geological oceanography with a focus on the chemical signatures in deep-sea sediments, which provide insights on past environmental changes.

Erin Mysak

Erin Mysak was an associate conservation scientist at the Institute for the Preservation of Cultural Heritage at Yale University and is now an independent conservation scientist. She earned her PhD in analytical chemistry from the University of North Carolina at Chapel Hill and was the 2009–2012 Andrew W. Mellon Postdoctoral Fellow in Conservation Science at the Straus Center for Conservation and Technical Studies, Harvard University.

Árpád M. Nagy

Árpád M. Nagy is head of the Collection of Classical Antiquities at the Museum of Fine Arts, Budapest; he also teaches in the Department of Classical Philology at the University of Pécs. He studied archaeology and classical philology at Eötvös Loránd University, Budapest. His main research interest is ancient magic, and he is editor in chief of the Campbell Bonner Magical Gems Database. He has published on various topics in ancient iconography and sculpture.

Ingrid A. Neuman

Ingrid A. Neuman is the museum conservator in the Painting and Sculpture Department of the RISD Museum. She holds a BA in Mediterranean archaeology from the University of Massachusetts and an MA and a CAS from the Cooperstown Graduate Program in Art Conservation. Neuman has worked at the National Museum of Natural History and the National Museum of American History at the Smithsonian Institution, the Williamstown Art Conservation Center, and the Museum of Fine Arts, Boston. She currently serves as a member of the Ethics and Standards Committee of the AIC and is a fellow of both the AIC and the International Institute of Conservation (IIC).

Nicola Newman

Nicola (Nicky) Newman trained in conservation at University College London and at the London College of Furniture. She worked at the Historic Royal Palaces before moving to the British Museum in 1999. There she worked with organic materials, specializing in the treatment of decorative surfaces, primarily from ancient Egypt and the Far East. In 2017 she left to freelance and now enjoys working with a wide variety of clients and materials.

Richard Newman

Richard Newman is the head of scientific research at the Museum of Fine Arts, Boston, where he has worked as a research scientist since 1986. He holds a BA in art history from Western Washington University and an MA in geology from Boston University, and he completed a three-year apprenticeship in conservation and conservation science at the Straus Center for Conservation and Technical Studies. He has carried out research on a wide range of cultural artifacts, from stone sculpture of the Indian subcontinent to the paintings of Diego Velázquez. A coauthor of the chapter on adhesives and binders in *Ancient Egyptian Materials and Technology* (Cambridge University Press, 2000), Newman has collaborated with conservators and curators on numerous projects involving ancient Egyptian and Nubian art.

Irma Passeri

Irma Passeri is the senior conservator of paintings at Yale University Art Gallery. She trained at the conservation school of the Opificio delle Pietre Dure, in Florence, Italy, where she received her degree in the conservation of easel paintings. She has published articles on materials and techniques of Italian paintings and on Italian approaches to the restoration treatment of loss compensation.

Federica Pozzi

Federica Pozzi is an associate research scientist at the Metropolitan Museum of Art. She leads the Network Initiative for Conservation Science (NICS), a pilot program designed to offer access to the Met's state-of-the-art scientific research facilities to partner institutions in New York City. Pozzi earned her PhD in chemical sciences from the University of Milan, Italy, and has held positions at the City College of the City University of New York, Art Institute of Chicago, and Solomon R. Guggenheim Museum.

Caroline Roberts

Caroline Roberts is a conservator at the Kelsey Museum of Archaeology and specializes in the conservation of archaeological materials. She has worked as a field conservator at many archaeological excavations, including El-Kurru, Sudan, and Abydos, Egypt. She takes special interest in the conservation of stone objects and architecture and the technical study of ancient paint surfaces. Two forthcoming articles are “Investigating Approaches to the Treatment and Preservation of a Collection of Egyptian Limestone Funerary Stelae” and “A Comprehensive Approach to Conservation of Ancient Graffiti at El Kurru, Sudan,” both in the *Journal of the American Institute for Conservation*.

Rachel C. Sabino

Rachel C. Sabino is an objects conservator at the Art Institute of Chicago. She holds a postgraduate diploma in conservation and restoration from West Dean College and a certificate in conservation of marine archaeology from the Institute of Nautical Archaeology. Sabino held previous positions at the National Gallery, London; Museum of Fine Arts, Houston; and the Chicago Conservation Center. She held internships at the Metropolitan Museum of Art and the J. Paul Getty Museum and a sabbatical at the Corning Museum of Glass. She is a trustee of the International Institute for Conservation and a Fellow of the American Institute for Conservation.

Victoria Schussler

Victoria Schussler is a project objects conservator at the Brooklyn Museum. She received a BA in biology from Yale University and an MS from the Winterthur / University of Delaware Program in Art Conservation. Schussler has held positions at the Yale University Art Gallery, the Central Park Conservancy, the Museum of Modern Art, and the Corning Museum of Glass.

Andrew Shortland

Andrew Shortland is a professor of archaeological science, and the director of the Cranfield Forensic Institute, at Cranfield University. He holds an undergraduate degree in geology, a master's degree in prehistoric archaeology, and a DPhil in Egyptology from the University of Oxford; his doctoral work concerned vitreous materials from the site of Amarna in Middle Egypt. After years as a research fellow and university research lecturer at the Research Laboratory for Archaeology in Oxford, Shortland moved to Cranfield University and established the Centre for Archaeological and Forensic Analysis. Shortland's work concentrates on the identification and interpretation of material culture from the ancient and historical worlds, and he is interested in the fate of archaeological and historical sites, objects, and museums in conflict zones.

Lin Rosa Spaabæk

Lin Rosa Spaabæk is a private conservator in Denmark, where she has restored and studied the collection of mummy portraits at the Ny Carlsberg Glyptotek. Spaabæk obtained her bachelor's degree in paintings conservation from the Royal Academy of Fine Arts, School of Conservation, Copenhagen; there she also completed her master's thesis on the study of mummy portraits. Spaabæk has been a consultant on funerary portraits at the Egyptian Museum in Cairo.

Renée Stein

Renée Stein is the chief conservator at the Michael C. Carlos Museum at Emory University, where she oversees the treatment, preventive care, and technical analysis of the museum's diverse collections. She is also a lecturer in the art history department and teaches courses on conservation and technical study. Stein received a MS in objects conservation from the Winterthur / University of Delaware Program in Art Conservation. She is a professional associate of the American Institute for Conservation of Historic and Artistic Works and has been recognized with that organization's Sheldon and Caroline Keck Award for outstanding mentoring.

Ken Sutherland

Ken Sutherland is a conservation scientist at the Art Institute of Chicago; his research interests concern the characterization of organic materials in works of art to inform an understanding of their technique, condition, and appearance. He received a PhD in chemistry from the University of Amsterdam and a diploma in the conservation of easel paintings from the Courtauld Institute of Art, London. He has held previous positions as scientist in the Conservation Department of the Philadelphia Museum of Art and research fellow in the Scientific Research Department of the National Gallery of Art, Washington.

Marie Svoboda

Marie Svoboda is a conservator in the antiquities conservation department at the J. Paul Getty Museum. She received an MA from the Art Conservation Department at the State University of New York, Buffalo, where she majored in artifacts and minored in paintings conservation. Svoboda worked as an assistant conservator of ancient materials at the Museum of Fine Arts, Boston, before joining the Getty. She is actively involved in the planning and installation of special exhibitions and loans, international collaborations, and various in-depth studies on conservation and technical research. A special interest in Romano-Egyptian material culminated in the publication of the book *Herakleides: A Portrait Mummy from Roman Egypt* (Getty Publications, 2011) and sparked the APPEAR project, the international collaboration on the study of ancient panel paintings that resulted in the research presented in this volume.

Gabrielle Thiboutot

Gabrielle Thiboutot is a PhD candidate at Stanford University, where she is working on the dissertation “Panels and Pigments: The Role of Trade and Innovation in the Production of Romano-Egyptian Mummy Portraits.” She is also a Samuel H. Kress Institutional Fellow at the Institut national d'histoire de l'art in Paris. As a field archaeologist, Thiboutot has excavated and supervised trenches in Turkey, Tunisia, Greece, Italy, and Spain. Her current work is supported by a fellowship from the Social Sciences and Humanities Research Council of Canada as well as grants from the American Research Center in Egypt's Northern California chapter and the Stanford Archaeology Center.

Jevon Thistlewood

Jevon Thistlewood is a conservator of paintings at the Ashmolean Museum of Art and Archaeology, University of Oxford, and an accredited member of the Institute of Conservation (ICON). He graduated from the University of Leeds with a degree in chemistry and a master's degree in sculpture studies; he also has a master's degree in the conservation of fine art from the University of Northumbria. His research projects are mainly concerned with painted surfaces from antiquity to the present.

Katharina Uhlir

Katharina Uhlir teaches chemistry at the University of Vienna. She holds a PhD—with a focus on scientific investigations of ancient glasses of Ephesos using μ-XRF and SEM/EDS—from the Academy of Fine Arts Vienna, where she also was an assistant professor. She has been the scientific assistant in the Conservation Science Department of the Kunsthistorisches Museum, Vienna (KHM), responsible for the XRF investigations at the KHM since 2011.

Bettina Vak

Bettina Vak is a senior conservator for the Kunsthistorisches Museum, Vienna, collection of antiquities. She received her master's degree in objects conservation from the University of Applied Arts Vienna. She was lead conservator of the research project CVA (Corpus Vasorum Antiquorum), Wien 5, 6. She is currently conducting the technical study and conservation of fifteen Romano-Egyptian mummy portraits in collaboration with the Museum of Fine Arts, Budapest.

Susan Walker

Susan Walker was a museum curator in the British Museum from 1977 to 2004 and the Sackler Keeper of Antiquities in the Ashmolean Museum, Oxford, from 2004 until her retirement in 2014. In 1997 she cocurated with Morris Bierbrier *Ancient Faces: Mummy Portraits from Roman Egypt*, a British Museum exhibition that traveled to Rome and New York; she was sole guest curator for the Metropolitan Museum of Art's presentation and associated publication. Walker is now an emerita fellow of Wolfson College, University of Oxford, and an honorary curator at the Ashmolean, where she is studying mummy portraits with Jevon Thistlewood. She recently published *Saints and Salvation: The Wilshere Collection of Late Roman Gold-Glass, Sarcophagi and Inscriptions from Rome and Southern Italy* (Ashmolean Museum, 2017).

Marc S. Walton

Marc S. Walton codirects the Northwestern University / Art Institute of Chicago Center for Scientific Studies in the Arts (NU-ACCESS), and he is a research professor of materials science at Northwestern's McCormick School of Engineering and (by courtesy) of art history at Northwestern University. At NU-ACCESS, he is leading several scientific research projects in collaboration with museums. His research interests are primarily focused on the trade and manufacture of objects and on the development of the use of imaging technologies in the field of conservation science. Before joining NU-ACCESS, he was an associate scientist conducting scientific research on antiquities at the J. Paul Getty Museum.

Jane L. Williams

Jane L. Williams is the director of conservation at the Fine Arts Museums of San Francisco. She received an MA in art history and diploma in conservation from the Institute of Fine Arts at New York University. Williams has held positions and fellowships as an objects conservator at the Phoebe A. Hearst Museum of Anthropology, the Asian Art Museum of San Francisco, the Brooklyn Museum, the Virginia Museum of Fine Arts, and the Walters Art Museum.