NY CARLSBERG GLYPTOTEK — THE COPENHAGEN POLYCHROMY NETWORK

Tracking Colour

The polychromy of Greek and Roman sculpture in the Ny Carlsberg Glyptotek

Preliminary Report 5, 2013

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The Copenhagen Polychromy Network is an interdisciplinary body formed in 2004 on the initiative of the Ny Carlsberg Glyptotek to conduct research on ancient sculptural polychromy, primarily but not only, in the collections of the Glyptotek.

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- Lund University, Department of Archaeology and Ancient History and Humanities Lab
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ACKNOWLEDGMENTS

The project is supported by the Carlsberg Foundation

SUPPORT HAS GENEROUSLY BEEN PROVIDED BY

Dronning Margrethe og Prins Henriks Fond
Kirsten & Freddy Johansen's Foundation

Editor: Jan Stubbe Østergaard,
Copenhagen Polychromy Network

Graphic design: Jakob Helmer, MAA

Published by: Ny Carlsberg Glyptotek, 2013
ISSN: 1904–1888

Contents

Preface

The vital two year research grant provided by the *Carlsberg Foundation* in 2011 ended on May 31st, 2013. Investigation activity within the Tracking Colour project has therefore been limited in the past year. Time has principally been devoted to developing research proposals which might secure renewed funding, and to tying up a number of loose ends to do with report writing and data management.

Investigations were however carried out by the NCG team and the CPN, focusing on further study of *Ny Carlsberg Glyptotek's* collection of Roman portraits. PhD Fellow Amalie Skovmøller's study of the polychromy of Roman portraits includes the museum's group of portraits from the 'Fundilia Room' at the Sanctuary of Diana at Nemi; she and project conservator Maria Louise Sargent have contributed an article on the subject.

The Museum of Geology/Natural History Museum of Denmark has been a member of the Copenhagen Polychromy Network from the start. In our first report (2009), Professor Minik T. Rosing demonstrated the potential of isotopic analysis for locating the source of lead based pigments. A student of his, Peter Fink-Jensen, has continued this line of polychromy oriented archaeometric enquiry in an MSc thesis study of the red lead pigments originally dealt with by Rosing. Fink-Jensen has kindly agreed to contribute an article to this report; in return, 'his' sculpture was chosen as 'Cover God' for this report.

Colour in ancient sculpture is a wonderfully varied phenomenon. In her contribution, Verena Hoft, an MA student of Classical Archaeology at the *University of Hamburg,* reports on her cataloguing of Greek and Roman marble sculptures in *Ny Carlsberg Glyptotek* which featured inlaid eyes, a largely unexplored aspect of polychromy. Her contribution – the result of her 'Praktikum' at the museum – is the first article in our reports in a language other than English. It will not be the last.

As the *Carlsberg Foundation* grant expired, a first evaluation of the work done in Tracking Colour till then seemed relevant. Of the external CPN partners, the *Museum of Geology* gives an, albeit indirect, feed-back in the form of Fink-Jensen's article. Mikkel Scharff, now Head of the *School of Conservation* in Copenhagen, has sent some retrospective, positive comments.

The articles are followed by the usual sections on various activities, the most important being the summaries from the 5th International Round Table meeting in Athens, in November 2013. It was jointly hosted in a most generous and efficient manner by the *Acropolis Museum* and the *National Hellenic Research Foundation*, the papers were of a uniformly high standard and attendance was enthusiastic, with lots of 'new' faces. Of the Round Tables so far held, this was arguably the most successful. A most encouraging experience!

Together with Amalie Skovmøller, project conservator Rikke Therkildsen has had as her particular task in 2013 the so-called 'Reconstruction Project', designed to produce an experimental archaeological reconstruction on marble of the polychromy of the 3rd century CE Roman portrait of a youth investigated in 2012. The project is progressing well and will be reported on more fully at a later stage. We are very grateful indeed for the financial support provided for this (ad)venture by *Dronning Margrethes og Prins Henriks Fond*, and, especially, by *Kirsten og Freddy Johansens Fond*.

Once again, we thank our partners in the CPN and our colleagues at home and abroad for their support. As project director and editor it is my particular and pleasant duty to thank those who have contributed to this report as well as to express my gratitude to the core members of the team, project conservators Maria Louise Sargent and Rikke Therkildsen and PhD fellow Amalie Skovmøller. My colleague Anne Marie Nielsen, Deputy Director of the *Ny Carlsberg Glyptotek* until December 2013 and now Head of the Collection of Ancient Art, has provided very essential support and encouragement. Finally, Tracking Colour must thank the staff of the museum as a whole and the technical staff in particular for all their help.

For support of the project we remain indebted to the *Carlsberg Foundation*. The more so since the year ended on a very happy Carlsberg note indeed. An application to the Foundation for funding of a new, three year research project in collaboration with the British Museum met with success. As the slogan has it: That calls for a Carlsberg!

Jan Stubbe Østergaard
Editor and project director

On behalf of the Ny Carlsberg Glyptotek and the Copenhagen Polychromy Network

'Tracking Colour' in 2013

Jan Stubbe Østergaard

PROJECT FUNDING

The word 'ominous' was used in our report for 2012 to describe the reality facing the project after the end of the Carlsberg Foundation grant on May 31st, 2013.[1] By that time, we would of necessity have had say goodbye to our highly experienced project conservators, Maria Louise Sargent and Rikke H. Therkildsen. At the time of writing, in December 2012, a bid to secure further funding together with The British Museum and the National Museum of Denmark had just failed.

Together with the BM, we moved ahead undaunted, to explore ways forward. A series of meetings in the spring of 2013 led to the idea of collaborating over a period of three years on polychromy research under the heading 'Transmission and Transformation. Ancient polychromy in an architectural context'.This was agreed on, each museum to contribute resources in equal measure, according to its means.

In the case of Ny Carlsberg Glyptotek, it was decided to apply once again to the Carlsberg Foundation. In December 2013, our application to the Foundation met with success. A very brief outline of the research collaboration now to move ahead is given below.

Work on the 2014 exhibition 'The 4th Dimension: Colour in Ancient Sculpture', and on the project for a reconstruction on marble of the Glyptotek's Roman portrait of a youth, IN 821, moved ahead throughout the year. This was possible due to grants from *Dronning Margrethe og Prins Henriks Fond* and the *Kirsten og Freddy Johansen Fond* for the reconstruction, and from *A.P. Møller og hustru Chastine McKinney Møllers Fond til Almene Formål* for the exhibition. The reconstruction will be displayed at the exhibition, planned to open in September 2014. We are most grateful for the support received from the said Foundations.

THE NCG TEAM AND CPN PARTNERS

As will have become apparent from the above and from the preface, the year 2013 has been different from the ones dealt with in previous reports. As of May 31st, Maria Louise Sargent and Rikke Therkildsen had to leave the team, to our great regret. The latter had in fact left her ½ time position earlier in the year, allowing Maria Louise Sargent to work full-time on closing down the project.

Therkildsen remained on the reconstruction project together with Skovmøller; they continue to constitute the professional core of that project.

Amalie Skovmøller went on maternity leave in the spring of 2013, returning in November, a daughter richer, to pursue her PhD research. She continues as (part time) administrator of the Tracking Colour website.

In the early spring of 2013, Verena Hoft, MA student of classical archaeology at the Institute of Archaeology at the University of Hamburg, took her 'Praktikum' as an assistant to 'Tracking Colour'. We asked her to produce a basic catalogue of the twenty or so Greek and (predominantly) Roman sculptures in the Glyptotek with inlaid eyes. A brief report on the

1 J.S. Østergaard (ed.), Tracking Colour. The polychromy of Greek and Roman sculpture in the Ny Carlsberg Glyptotek. Preliminary report 4, 2012, 23-24.

first results is given by her in this publication. It is a very promising work for which we are grateful.

Within the CPN partnership, the School of Conservation has been an invaluable ally over the limited period available for investigations in 2013. The advice and constructive criticism offered by Mikkel Scharff, now Head of the School, has played an important part in shaping ideas for research collaboration with The British Museum.

The presence, support and active interest of the Museum of Geology was made manifest during the year by the investigations made by the then MSc student Peter Fink-Jensen on a sculpture in the Glyptotek. It is the subject of an important article in this report, and we hope to continue our collaboration with Fink-Jensen, now MSc.

INVESTIGATIONS IN 2013

The five months remaining of the Carlsberg Foundation grant in 2013 were allotted to three objectives. Maria Louise Sargent conducted an investigation of the portraits from the 'Fundilia Room' at the Sanctuary of Diana at Nemi, in collaboration with PhD Fellow Amalie Skovmøller. This included a visit by Sargent to examine the Fundilia Herm from Nemi in the Castle Museum at Nottingham. The results are described elsewhere in this report.

Following on this, Maria Louise Sargent made sure that all project reports were completed, uploaded to the project website and stored in back-up on DVD and in the 'cloud'. After this management effort, the project data were ship-shape when the project ended.

The third objective was to explore and develop ways of making further research possible. An outline of the results of these endeavours form the concluding section of 'Tracking Colour in 2013'.

LOOKING FORWARD, 2014–2016

The meetings held between the Ny Carlsberg Glyptotek and The British Museum in 2013 led to an agreement on research collaboration over the coming three years; it formed the basis of the Ny Carlsberg Glyptotek's successful application to the Carlsberg Foundation.

In short, the intention is that by combining the potential of our collections and the competences of our staffs, we will seek to throw light on ancient polychromy in an architectural context.

Under the title 'Transmission and Transformation', the overarching research question concerns the possible transmission of traditions of polychromy in architecture, sculpture included, from East to West in the formative, Archaic phase of Greek architecture, and the subsequent transmission and transformation of such traditions in an architectural context, in Greece and in Magna Graecia, to the close of the Classical Period.

In a letter of support of our application, the Antikensammlung in Berlin has expressed its interest in being involved in the proposed collaboration as an external research partner.

One of the tasks immediately ahead of us is to establish a website for this collaborative effort, to provide more detailed information and to manage and make accessible the data accruing from the new chapter of polychromy research now about to open.

Painted portrait sculpture from the Sanctuary of Diana at Nemi

Amalie Skovmøller[1] and Maria Louise Sargent[2]

ABSTRACT

This paper presents the preliminary results of a study of a group of portrait sculptures originating from the Diana Nemorensis sanctuary in Italy. The portraits have been examined for any remains of their original polychromy, and the results are debated according to the sculpting and surface texturing of the individual portraits and their original contexts and overall purpose.

KEYWORDS

Portrait statue, portrait herm, marble material properties, colour, polychromy.

INTRODUCTION: THE SANCTUARY

The nine examined portrait sculptures were found in the late 1880's at a sanctuary dedicated to the goddess Diana Nemorensis just 25–30 kilometres southeast of Rome located in a grove (Nemorensis means "In the Grove") by the side of Lake Nemi, a crater lake in the Alban Hills (Fig. 1). In Roman times it was believed that Diana inhabited these areas. Dense woods and mountain streams made access to the area difficult.[3] The site attracted many wealthy Romans during the Late Republican and Early Imperial periods and the ruins of at least four great villas have been excavated.[4] Written sources tell us that prominent Romans, such as Julius Caesar, had their private villas erected there, and the Emperor Caligula had two enormous ships, which were more or less floating villas, placed on the lake.[5]

It is difficult to date the beginning of the cult of Diana. The areas surrounding the Alban Hills were sacred to the Romans as well as to the rest of Latium from at least the 5th century BCE.[6] The sanctuary dedicated to Diana Nemorensis was most likely a part of this cult centre, but due to the fragmentary archaeological remains, it is difficult to date the first temple.[7] A large amount of terracotta sculpture both architectural and votive, dating to the last three centuries BCE has been found within the sanctuary, indicating the existence of a temple from at least the beginning of the 3rd century BCE.[8] During the 2nd century BCE the sanctuary was remodelled and given a large terrace (approximately 50.000 m^2) on the slope facing the lake, which supported several smaller buildings and constructions. At the end of the 2nd cen-

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2 Project conservator, the Tracking Colour Project: mls@glyptoteket.dk

3 Guldager Bilde 1997A, 166-167.

4 Guldager Bilde 1997B, 168.

5 Zahle 1997, 169-171.

6 Ghini and Diosono 2012, 119-121.

7 Känel 1997, 185.

8 Känel 1997, 184-187.

Fig. 1: Map of Latium (c. 5th century bce).

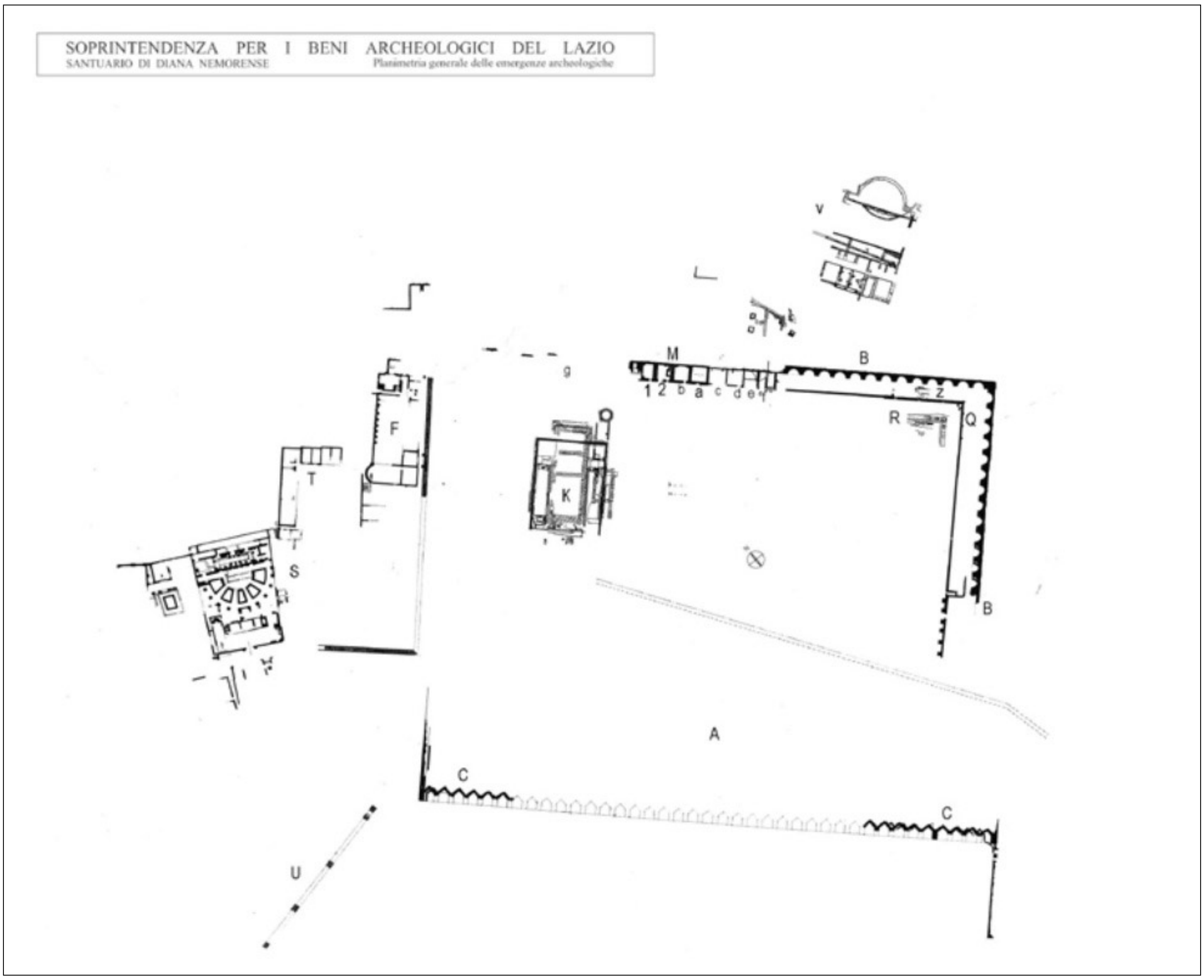

Fig. 2: The sanctuary of Diana Nemorensis.

Plan:
A: Lower terrace.
B: Foundation of the wall supporting the row of semicircular rooms.
C: Lower foundation of the wall supporting the row of triangular rooms.
F: "Dwellings of the priests".
K: Temple of Diana.
M: Rooms for dedications (1, 2, a, b, c, d, e, f and g: see fig. 2).
Q: Wall of opus incertum.
R: Colonnade of opus incertum and opus mixtum.
U: Access road to the sanctuary.
V: Nymphaeum and exedra of the upper terrace.
Z: Doric colonnade in peperino.

Ghini and Diosono 2011, 120.

tury BCE the sanctuary was given yet another remodelling, which included a row of niches and rooms along the supporting wall (Fig. 2).[9]

By the end of the Republic the sanctuary was largely finished, and any constructions during the Empire were either additions or renovations. Such remodelling was in particular common for the small rooms along the supporting wall. During the Antonine period the use of the sanctuary suddenly ceased, most likely due to a natural disaster.[10]

THE PORTRAIT SCULPTURES: EXCAVATION AND ORIGINAL CONTEXT

The north-eastern wall of the sanctuary was occupied by several rooms supporting the central portico of the sanctuary and facing the paved terrace (Fig. 3). The portrait statues dealt with in this article, were found in room a popularly referred to as the "Room of Fundilia".[11]

The portrait sculptures are all dated to the middle of the 1st century CE.[12] The room in which they were found, measured approximately 5,6-8 × 6.1 m.[13] The floor was paved with a black and white mosaic bordered by a mosaic band in coloured stones. In the middle of the floor was a dedicatory inscription, also in mosaics, by Servilius Quartus: M. SERVILIVS QVARTVS ALAM EXPOLIT ET ET QVAE INTVS POSITA SVNT DIA ("M. Servilius Quartus decorated this room and to Diana dedicated that which is exhibited herein").[14] The walls were painted red. The façade was flanked by two columns covered with stucco and painted red (ca. 1 m. in diameter) (Fig. 4). The construction of the room is dated to the second half of the 1st century BCE based on the mosaic and its inscription. This means that the portraits excavated within the room were dedicated at a later stage – perhaps at the same time as the front of the room, including the red stuccoed columns, was renovated.[15]

The room was first excavated in 1885 by British ambassador Lord Savile. Savile focussed on the outer half of the room, which was excavated in two days. During this campaign he uncovered the Fundilia herm portrait (Nottingham, Castle Museum, inv. No. N 827), the herm shaft of Hostius Capito (IN 1436), and a shoulder piece[16], which belongs to the portrait of a young woman (IN 759), and two fragmented marble plinths: one in Nottingham which supported an under life-size female statue dedicated by Tontius to Diana[17]; the other, now lost, was a votive inscription for Fundilia Rufa.

The second half of the room was excavated by the Roman art dealer Luigi Boccanera in 1887. This excavation uncovered more statuary: the statue of Fundilius (IN 707), the statue of Fundilia (IN 708), the portrait of Lucius Aninius Rufus with herm shaft (IN 1437), the herm portrait of Staia Quinta with herm shaft (IN 1435), the portrait of Hostius Capito (IN 1436), the portrait of an unknown woman (IN 759), portrait of an unknown, mature woman (IN 761) – belonging to the herm inscribed Licinia Chrysarion, found in "rooms 2–3" (listed in

9 Känel 1997, 186; Guldager Bilde 1997A, 167; Ghini and Diosono 2012, 123-131.

10 Guldager Bilde 1997A, 167.

11 Poulsen 1941, 20-52; Moltesen 1997, 172-176; Guldager Bilde 1997B, 209-210; Salskov Roberts 1997, 210-213; Guldager Bilde 2000, 93-109; Fejfer 2008, 285-304; Moltesen 2012, 134-142.

12 On the dating of the portraits see Fejfer 2008, 285-286.

13 Fejfer 2008, 286; Ghini and Diosono 2012, 125-128.

14 Poulsen 1941, 21; Guldager Bilde 2000, 209.

15 Guldager Bilde 2000, 100-101.

16 Nottingham, Castle Museum N 810.

17 Nottingham, Castle Museum N 731.

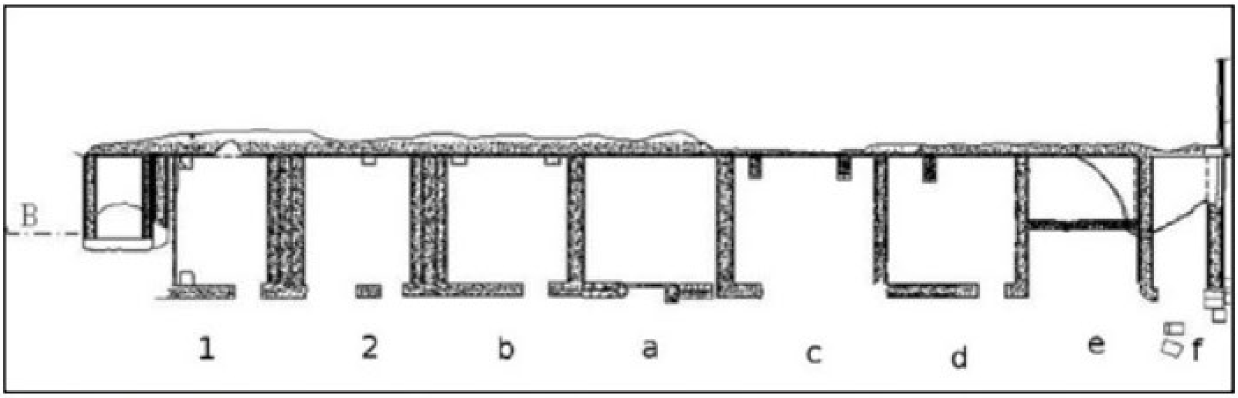

Fig. 3: Rooms for dedication.

Plan:
1,2: Excavated in 1999 and 2000.
b: Excavated in 1885, 1999 and 2000: Asklepius-Virbius acrolith (N 832*) and "a large amount of fragmentary marble sculptures" (Rossbach 1890) were found.
a: Excavated in 1885, 1887, 1999 and 2000: "Room of Fundilia" (6,1 x 5,6-8 m.).
c: Excavated in 1885, 1888, 1895, 1999 and 2000 (6,1 x 6,63 m.).
d: Excavated in 1885, 1888, 1895, 1999 and 2000 (6,1 x 5 m.): A large amount of terracotta sculpture were recovered.
e: Excavated 1887, 1888, 1895, 1999 and 2000: Inscriptions and fragments of a gilt bronze frieze were found.
f: Excavated in 1885, 1895, 1999 and 2000: Head from an acrolith sculpture of Diana (IN 1517), for inscribed marble amphorae (MS 3446-3447; IN 1518-1519) and four marble cauldrons with inscriptions were found (MS 3448-3451).

Guldager Bilde 2000, 93-109; Ghini and Diosono 2011, 127.

* N = Nottingham, Castle Museum.
IN = Copenhagen, Ny Carlsberg Glyptotek.
MS = Philadelphia, University Museum.

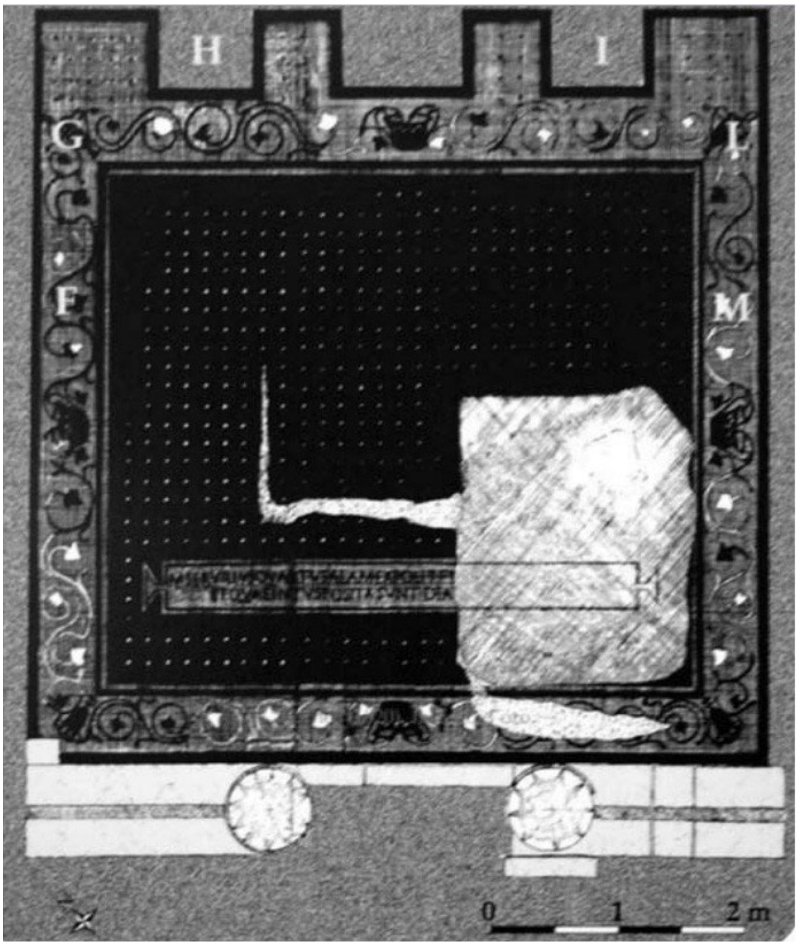

Fig. 4: The Room of Fundilia.

Plan with mosaic:
H: Statue of Fundilia (IN 708).
I: Statue of Fundilius (IN 707).
G: Herm of Aninius Rufus (IN 1437).
F: Herm of Fundilia (N 827).
L: Herm of Staia Quinta (IN 1435).
M: Herm of Hostius Capito (IN 1436).

Ghini and Diosono 2011, 127.

the excavation accounts, but never supported archeologically) and now in Nottingham- and the portrait of a man wearing a wreath (IN 1438).[18]

As no other finds were documented during the excavations, the portraits must have been the main decoration of the room. But due to the fragmentary excavation reports reconstructing the original, total portrait ensemble within the "Room of Fundilia" is difficult. The portraits which we can place within the room with certainty are the two statues of Fundilia (IN 708) and Fundilius (IN 707), and the portraits on herm shafts of Fundilia (N 827), Staia Quinta (IN 1435), Hostius Capito (IN 1436) and Lucius Aninius Rufus (IN 1437).[19] Less certainly connected with the room, due to the lack of herm shafts, are the portrait heads of the unknown woman (IN 759) and the man wearing a wreath (IN 1438). In a publication from 1890, O. Rossbach mentions that two further herm shafts were on display in the room: one inscribed Faenius Faustus[20]; the other inscribed Licinia Chrysarion.[21] Excavations of the room indicate yet another, unknown sculptural dedication between Fundilius and Fundilia.[22] The original position of the portrait of Licinia Chrysarion is also a bit controversial. As the portrait head was found in the "Room of Fundilia", we must assume that it was originally on display among the others. During the exhibition "In the sacred grove of Diana" in the Ny Carlsberg Glyptotek in 1997, the portrait head was successfully paired with a herm shaft in Nottingham (inv. no. N 830), which was found in 1885 in "rooms 2–3" referred to by Savile.[23] But no such rooms have been located since.[24] Either the herm shaft is the missing shaft from the "Room of Fundilia", which Rossbach mentions in 1890; or there were originally two very similar herm portraits on display of Licinia Chrysarion, of which one was on display in the "Room of Fundilia". Or perhaps the portrait sculptures were moved around within the sanctuary already in antiquity.[25]

THE PORTRAIT SCULPTURES: DESCRIPTIONS AND IDENTIFICATION

The statue of Fundilius (IN 707) portrays a mature man wearing a *toga* with a *tunica* underneath (Fig. 5). His hair is short and shaped by flat chisel, the chin is clean shaven with a mat-gloss polish of the facial skin. The *tunica* is shaped by chisel imitating a thin fabric, revealing the contours of a male chest beneath. The *toga*, on the other hand shows a more extensive use of running drill creating the illusion of a heavy fabric. The surface of the *toga* has been treated with the utmost attention to detail: small folds in the surface gives the impression of a wrinkled fabric and testifies to a high level of craftsmanship, which exploits the material properties of the white marble to full perfection (Fig. 6). On his feet he wears soft, leather boots with an overfold and by his left foot is placed a cylindrical leather case for book rolls, a *capsa*. On the *capsa* is chiselled an inscription: C. FVNDILIVS DOCTVS APOLLINIS PARASITVS,

18 Moltesen 2000, 113-114; Guldager Bilde 2000, 93-100

19 Borsari 1887, 196.

20 Nottingham, Castle Museum, N 828.

21 This note is however not in agreement with other excavation accounts, which places the herm shafts of Licinia Chrysarion and Faenius Faustus in Rooms 2-3 along with another inscribed herm shaft for Staia Quinta. Guldager Bilde 2000, 98.

22 Ghini 1997, 43-51; Moltesen 2012, 137.

23 Moltesen 2000, 114-116.

24 Guldager Bilde 2000, 96-98.

25 Moltesen 2000, 113-115.

Fig. 5: Portrait statue of Fundilius (IN 707).

Fig. 7: Portrait statue of Fundilia (IN 708).

Fig. 8: Portrait herm of Fundilia (N 827).

Fig. 6: Portrait statue of Fundilius (IN 707): Detail of *toga*.

which is repeated on the plinth. The plinth is roughly shaped by point chisel contrasting the velvet-like polish of the soft shoes.

The inscription identifies the man as Fundilius Doctus, and due to the lack of paternal ancestry in the inscription, we know that he was a freedman (former slave), who was an actor (APOLLINIS PARASITVS). Furthermore the nomenclature identifies him as the dedicator of the statue.[26] The identification of Fundilius as a former slave is further supported by the inscription on the Fundilia portrait statue and herm (see below).

The statue of Fundilia (IN 708) portrays a mature woman wearing a *chiton* beneath a *stola* underneath a tightly wrapped *palla* (Fig. 7). Her facial features are distinctive and closely resemble those of a herm portrait, which was also found in the room and is now on display in the Castle Museum in Nottingham (See below: inv. no. N 827): The nose is long, narrow and distinct, the mouth is full, and the skin has received a mat polish. Her hair is gathered in a so-called *nodus* at the back of the head, which were in fashion during the Late Republic (although the *nodus* has gone missing, the same coiffure with inserted *nodus* can be seen on the herm portrait; inv. no. N 827 below).[27] The individual hair strains are shaped by flat chisel without plasticity. She is dressed as a *matrona*: The *chiton* and the *stola* are both formed by chisel and running drill, creating the illusion of a light fabric for the *chiton*, which appears by the neck but otherwise concealed by the heavy and compact fabric of the *stola*.[28] Clasped by her right hand and draped over her left arm, the folds of the *palla* appear large and coarse with deeply drilled furrows. Along the edges of the *palla* light use of a sharp flat chisel has decorated the surface, and an extensive use of rasp in a triangular pattern support an illusion of a coarse – perhaps woollen – fabric. The soft leather shoes, which are visible from underneath the narrow folds of the *stola*, have been given a mat polish contrasting the roughly textured travertine plinth.

The inscription on the plinth of the statue identifies the portrayed as FVNDILIAE C. F. PATRONAE, indicating that she was the daughter of Gaius (C[aii] F[ilia]) and once the owner (PATRONAE) of the dedicator of the statue (i.e. Fundilius Doctus. See N 827 below).[29]

The herm portrait of Fundilia (N 827) resembles that of the statue (Fig. 8). Due to the distinctive physiognomy the identification would have been possible even without the inscription on the herm shaft.[30] The head (and neck?) and feet are carved from a white, fine-grained marble; the shaft from a bluish-grey (perhaps Bardiglio marble)[31]; and the base of a coarse, white marble. The shaft is clad in a *tunica* wrapped in a *palla*, carved with use of flat chisel and without any volume or plasticity, following the square shape of the herm shaft.

The inscription on the base reads FVNDILIA C. F. RVFA PATRONA DOCTI. It is the same woman as the statue, who was the owner of Fundilius Doctus (PATRONA DOCTI).[32]

The portrait herm of Staia Quinta (IN 1435) portrays a young woman (Fig. 9). She wears an elaborate coiffure, which is parted in the middle, flatly shaped by chisel, curled at both sides

26 Salskov Roberts 1997, 210; Fejfer 2008, 286.

27 Fejfer 2008, 286.

28 Fejfer 2008, 286.

29 Salskov Roberts 1997, 211.

30 Both portrait heads have been scanned in order to reveal how alike they are. The results show some variations between the two, which raises some interesting question as to the practice of portrait carving in the Roman Empire. Schofield, Lorenz, Davy-Jow and Anderson 2012, 169.

31 Fejfer 2008, 300.

32 Salskov Roberts 1997, 211.

of the head and gathered in a thick braid at the back of the head. The curls are delicately and individually shaped by point- and flat chisel and running drill creating a refined volume. The face is full with a long narrow nose and small mouth. She wears what appears to be a buttoned *chiton*; the fabric is shaped by chisel without plasticity creating the illusion of a thin, almost transparent textile, which has slipped down over her left shoulder to reveal her skin.

She can be identified by the inscription on the herm: STAIA L. L. QUINTA, which furthermore reveals that she was a freedwoman of a Lucius (L[ucii] L[iberta]: Freed by Lucius).[33]

The portrait herm of Hostius Capito (IN 1436) portrays a mature man (Fig. 10). His hair is cut very short, merely suggested by flat chisel punctuating the marble surface. The face is full, clean-shaven and given a mat polish. The portrait is identified by the inscription on the herm shaft: Q HOSTIVS Q. F. CAPITO RHETOR. He was the son of Quintus (Q[uinti] F[ilius]), and a teacher in elocution (RHETOR). He might have taught the actor Fundilius, and the display of his portrait herm close to that of Fundilius perhaps lends some dignity to the latters profession as an actor.[34]

The fourth portrait herm which we can place within the “Room of Fundilia” with certainty is of a young man (IN 1437) (Fig. 11). The hair is short cut and the individual hair locks are shaped by use of flat chisel. The skin is mat polished and the face without any particularly distinctive features. He can be identified due to the inscription on the herm shaft: L ANINIO L. F. RVFO Q. ARICIA PRIMA VXOR. His name was Aninius Rufus, he was the son of Lucius (L[ucii] F[ilius]) and held public office as Quaestor (Q.) in the city of Aricia. His wife Prima set up the herm (PRIMA VXOR). The name Rufus suggests some kinship with Fundilia Rufa.[35] The name Lucius suggests, that he (or his father) could have been the former owner of Staia Quinta (IN 1435).[36]

The remaining portraits, which were found in the “Room of Fundilia” and perhaps also originally on display there, are the portrait (with herm shaft) of Licinia Chrysarion (IN 761), the portrait of an unidentified, young woman (IN 759) and the portrait of a man wearing a wreath (IN 1438), which might belong to the shaft inscribed L. FAENIVS FAVSTVS QVARTAR. PAR. APOL. (L. Faenius Faustus, Parasite of Apollo, actor in the fourth role).[37]

The portrait of Licinia Chrysarion is that of an elderly woman (IN 761) (Fig. 12). Her hair is parted in the middle and gathered at the back of the head in a thick braid, and kept in place by a smaller, thinner braid which runs from the crown of the head and terminating in the thick braid. Her skin is mat-gloss polished; the cheek bones and jaw are accentuated giving her a mature and somewhat elderly look. This is strengthened by accentuated bags under the eyes and accentuated nasolabial folds around the mouth. As seen on the portrait statue of Fundilius, faint contours of once clearly visible, chiselled eyebrows can be seen over both eyes.

33 Salskov Roberts, 1997, 213.

34 Salkov Roberts 1997, 213; Fejfer 2008, 301; Moltesen 2012, 137.

35 Poulsen 1941, 31.32; Fejfer 2008, 301; Moltesen 2012, 137.

36 Salskov Roberts 1997, 211.

37 Fejfer 2008, 300-301; Moltesen 2012, 138. Whether the portrait head and herm originally belonged together remains speculative. Salskov Roberts 1997, 212.

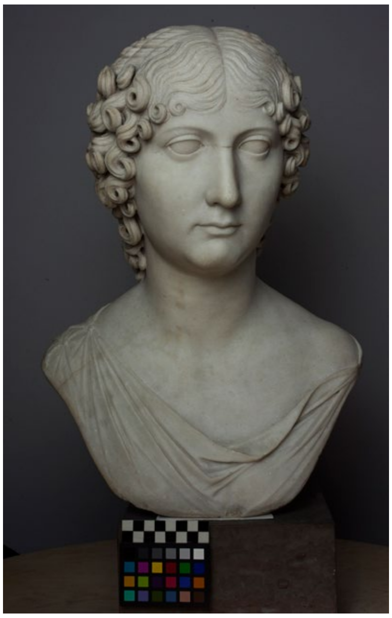

Fig. 9: Portrait head of Staia Quinta (IN 1435).

Fig. 10: Portrait head of Hostius Capito (IN 1436).

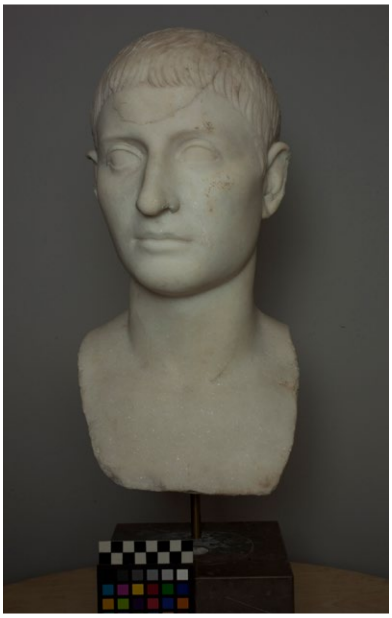

Fig. 11: Portrait head of Lucius Aninius Rufus (IN 1437).

Fig. 12: Portrait head of Licinia Chrysarion (IN 761).

Fig. 13: Portrait head of an unknown Roman woman (IN 759).

Fig. 14: Portrait of unknown Roman wearing a wreath (IN 1438).

The matching herm shaft (now in Nottingham, inv. no. 830) identifies the woman: LICINIAE CHRYSARIONI M. BOLANUS CANUSAEUS H. C. D. N. S.[38] Her name was Licinia Chrysarion, and the herm portrait was dedicated by a Marcus (M.) Bolanus from Canosa (CANOSAEUS). She belonged to the famous Licinian family, but as the inscription does not mention anything of her father, she was most likely a slave. This would also explain the Greek-sounding name Chrysarion.[39]

The portrait head of the unidentified woman (IN 759) portrays a young, beautiful woman (Fig. 13). Her eyes are large and almond shaped; her nose is long and narrow and the mouth small. Her skin is mat polished. The hair is parted in the middle, curled at both sides, held in place by a thin braid and gathered in a thick braid at the back of the head. The styling of the coiffure looks a bit like that of Licinia Chrysarion (IN 761), although executed in a more elaborate fashion like that of Staia Quinta (IN 1435). She wears what appears to be a buttoned *chiton*. Use of flat chisel creates the appearance of a thin and translucent textile, much like that worn by Staia Quinta (IN 1435).

The man wearing a wreath (IN 1438) is portrayed as a mature man (Fig. 14). His forehead has deep furrows above slightly frowning eyebrows. Bags are indicated beneath both eyes, the nose is long and distinct, the mouth a tightly closed with prominent nasolabial folds. The hair is short cut beneath the wreath, and hair locks are plastically shaped over the forehead and in the sideburns. The wreath consists of a band of leaves with inserted flowers, and could have been a prize in some sort of competition – perhaps in acting.[40]

INVESTIGATING THE POLYCHROMY

METHODOLOGY

The portrait sculptures were examined to locate and document traces of original paint. The investigation undertaken was divided into two main steps using non-invasive techniques: First step includes visual examination and *in situ* microscopy with a video microscope; the second step involves technical imaging with different types of radiation using ultraviolet fluorescence (UV-FL) and visible-induced luminescence (VIL).
The visual examination of preserved original paint was accompanied by elemental analysis performed by x-ray fluorescence spectrometry *in situ* (XRF) to identify the pigments.

Invasive, non-destructive technique was also employed. Minute samples were taken from the garments on the statue of Fundilia (IN 708) and Fundilius (IN 707) and prepared for microscopic cross-sectional analysis. This was done to get information on the preparation of the pigments, the grain size and possible layers.

RESULTS

All of the portrait sculptures have received extensive cleaning after they were excavated in the late 1880's. This has off course affected the remains of their original painted surface.

38 Moltesen 2000, 115.

39 Salskov Roberts 1997, 213; Moltesen 2000, 114-116.

40 Salskov Roberts 1997, 211; Moltesen 2000, 113.

The portraits are otherwise in an overall complete state of preservation, which suggests that they have not been too affected by their post-antique deposition.

IN 707: The statue of Fundilius is carved from one single block of Afyon marble (white, compact and fine-grained).[41] The statue is well preserved, and only small pieces of the folds on the *toga* are post-antique repairs.

The examination of the statue showed that it was originally almost fully polychrome. The remains are sparse and dominated by red ochre pigments found mainly on the garments and on the hair (Fig. 15) (Fig. 16–17). The face has been vigorously cleaned and only minute traces of red are found on the skin (Fig. 18). A cross-section of a sample taken from the *toga* shows only a one layer-structure of a red pigment painted directly onto the marble surface.

Egyptian blue has been identified by means of VIL-imaging and is most conspicuous in the folds of the *toga* and *tunica* and next to the *capsa* suggesting that the pigment was primarily used for shadows (Fig. 19).

The remaining pigments embedded in the marble surface of the statue does not allow for a full reconstruction. The scattered traces of ochre on the *toga* does, however, allow for some speculation on the original look of the garment. As the remains of Egyptian blue do not appear in the same areas – or mixed in with – the red ochre, it seems to have been reserved for accentuating the shadows between the deeply drilled folds. The location of the red pigments on the back of the statue seems to create one or maybe two lines following the draping, suggesting original painted borders of the *toga*, making a reconstruction of a *toga praetexta* possible. The *toga praetexta* was a white *toga* with a purple border worn by high officials such as magistrates and priest, and was sometimes allowed other Roman citizens or foreign personages to wear as a sign of special honour.[42] The colour purple used for the *toga praetexta* could change in nuance ranging from a vague, reddish nuance to a dark purple.[43]

IN 708: The statue of Fundilia is carved from two pieces of marble: Carrara marble for the body and Dokimeion marble for the head.[44] The remains of the original painting are affected by modern cleaning and restoration of the statue, leaving very little for a reconstruction of its original apperance. Microscopy revealed only few red grains on the skin of the face. Also the original colouring of the eyes is poorly preserved, but a detailed VIL-image of the eyes shows a white luminescence due to Egyptian blue along the upper rim of the left eye (Fig. 20). The blue pigment was probably mixed into a white pigment to achieve a brighter white.[45] A pale pink, preserved as a transparent layer is observed between the lips. Furthermore the VIL-image revealed a "shadow" of a once painted pupil in her left eye. Technical imaging with UV-FL did not detect fluorescence from the use of organic dyes.

The remains of paint found on the surface of the *stola* testify to a once purple colouring, almost violet. Traces of red and violet are observed together with the extensive use of Egyptian blue found on both the upper and lower parts of the garment documenting the use of the pigments in the base colouration of the surface (Fig. 21) and for shadows in the deeply drilled folds (Fig. 22). The covering *palla* was painted with an intense, dark red colour and correspond to the element analysis of hematite (Fig. 23–24). The *palla* appears in a warmer

41 Moltesen, Romano and Herz 2002, 106.

42 Reinhold 1970, 40-42; Goette 1989, 4-6; Edmondson 2008, 28-29;George 2008, 94-95;

43 Reinhold 1970, 41-45; Bradley 2009, 197-201.

44 Moltesen, Romano and Herz 2002, 106.

45 The same technique of mixing Egyptian Blue and lead white pigments for painting the white in the eyeballs has been documented on the Sciarra amazon in the Ny Carlsberg Glyptotek and the Treu Head in the British Museum. Sargent and Therkildsen 2010, 33; Verri, Opper and Deviese 2010, 49;50-51.

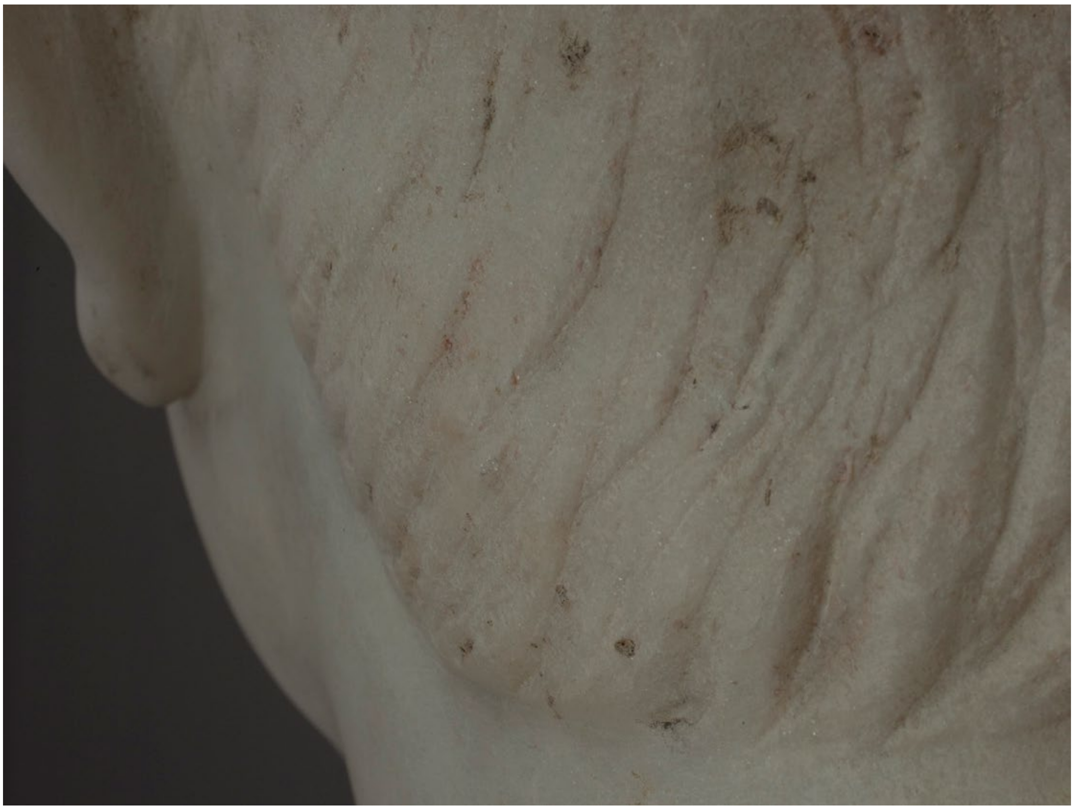

Fig. 15: Portrait statue of Fundilius (IN 707): Detail of hair: Red remaining pigment.

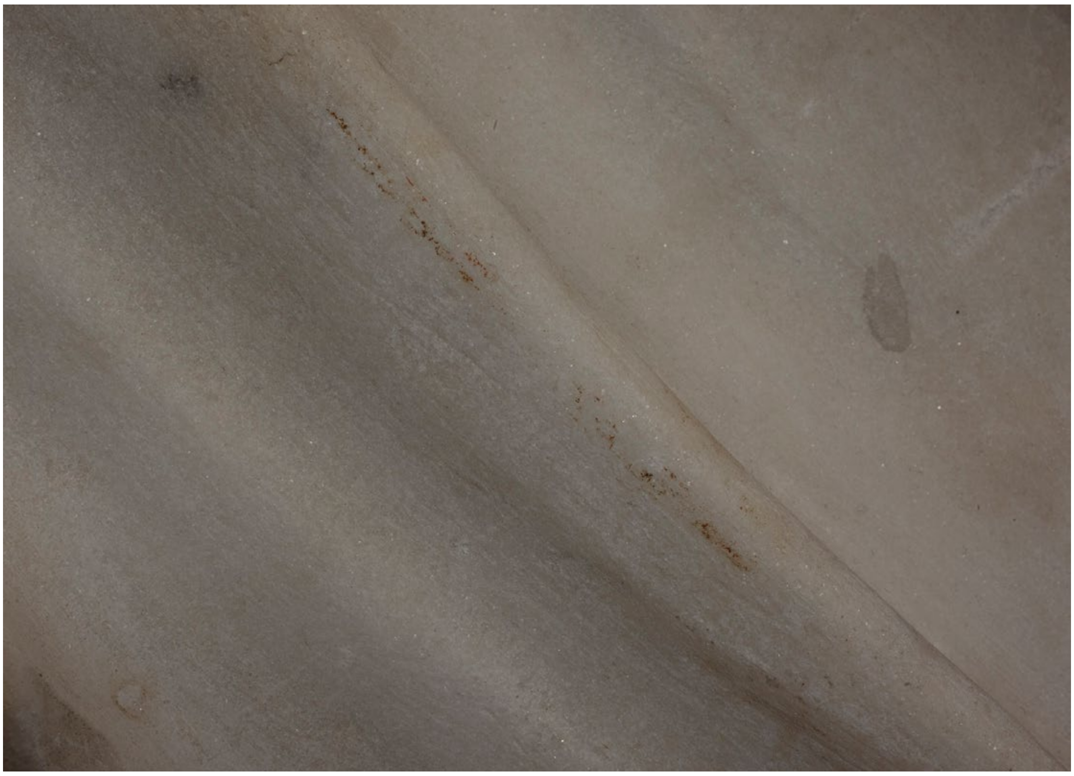

Fig. 16: rtrait statue of Fundilius (IN 707): Detail of *toga*: Red painted border.

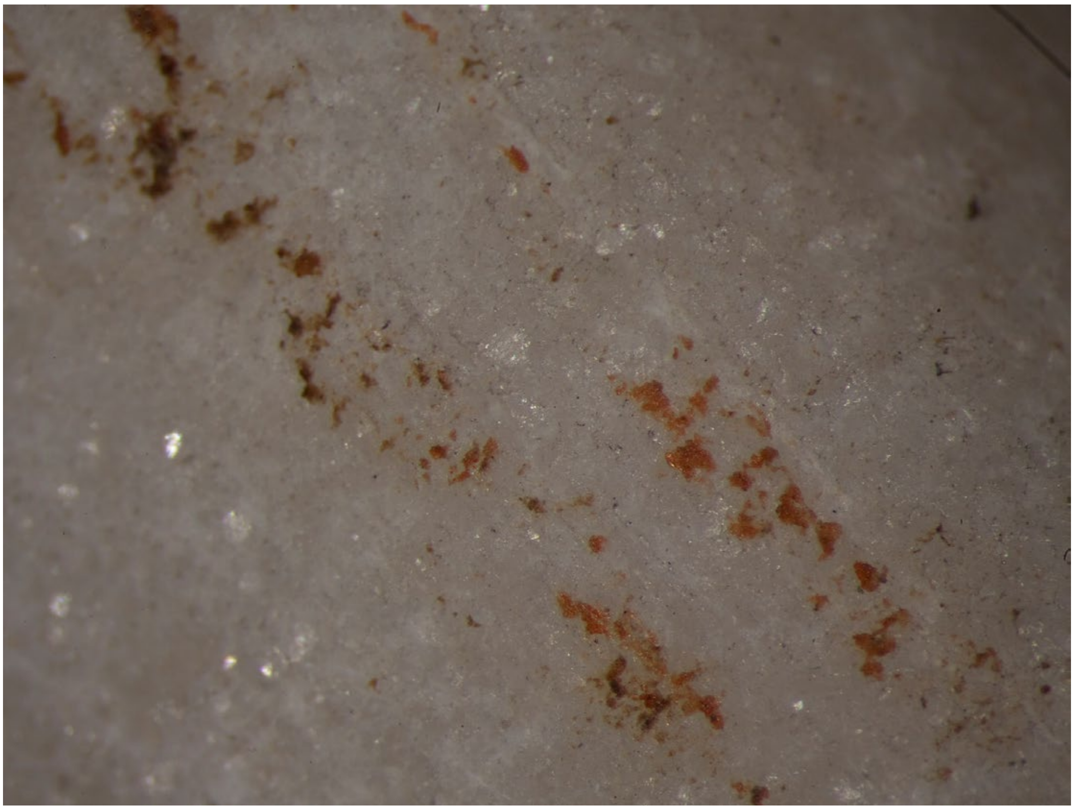

Fig. 17: Portrait statue of Fundilius (IN 707): Microscope image of red painted border on the *toga* (fig. 707).

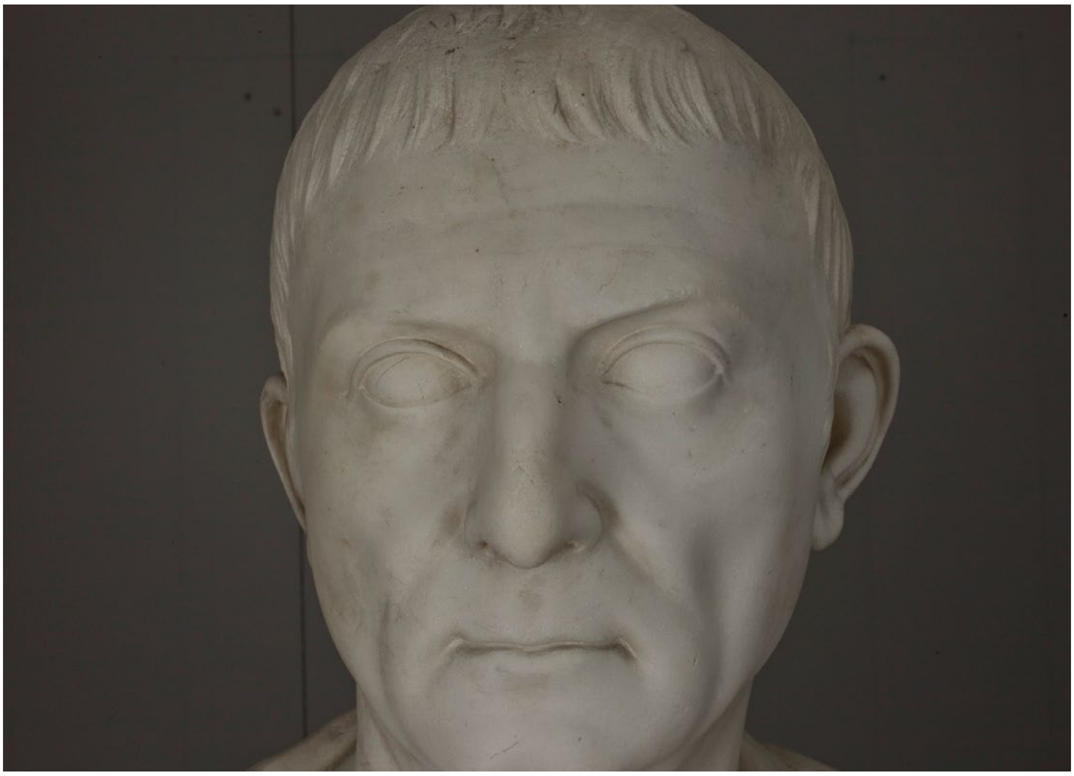

Fig. 18: Portrait statue of Fundilius (IN 707): Detail of face. The extensive cleaning of the face is visible to the naked eye.

Fig. 19: Portrait statue of Fundilius (IN 707): VIL image of *capsa* and background. The luminescent particles indicate Egyptian blue pigment.

Fig. 20: Portrait statue of Fundilia (IN 708): VIL image of the eyes. The luminescent particles indicate Egyptian blue pigment.

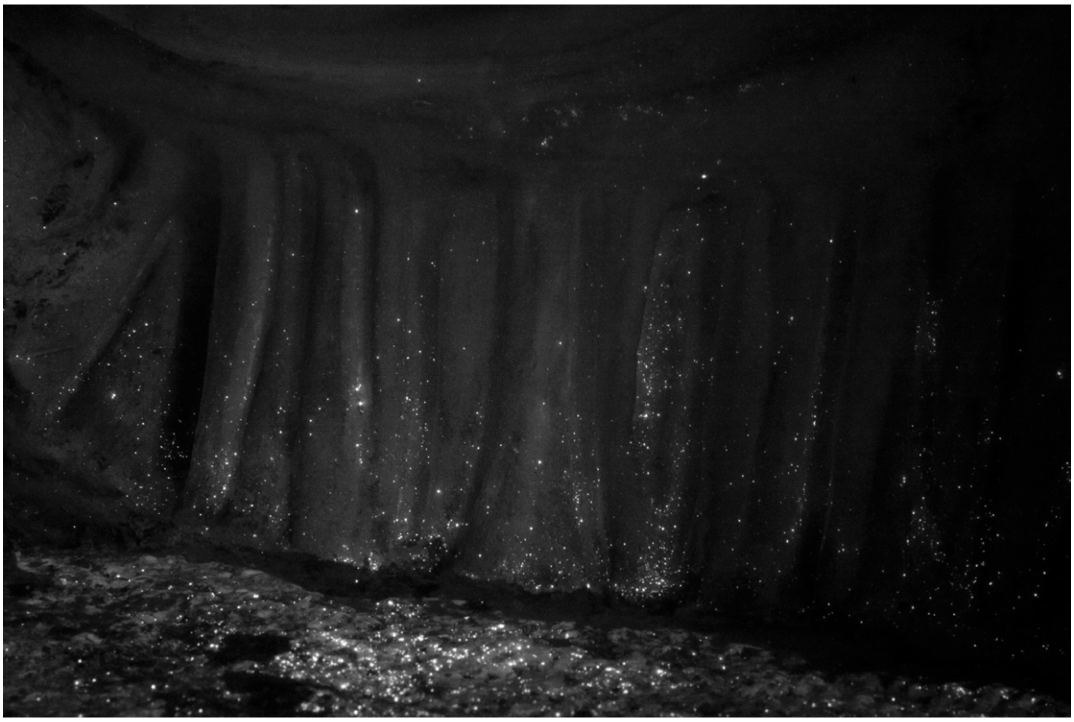

Fig. 21: Portrait statue of Fundilia (IN 708): VIL image of folds of the stola above the feet. The luminescent particles indicate Egyptian blue pigment.

Fig. 22: Portrait statue of Fundilia (IN 708): VIL image of *tunica* and *palla*. The luminescent particles indicate Egyptian blue pigment.

Fig. 23: Portrait statue of Fundilia (IN 708): Detail of *palla*: Remains of purple paint.

nuance and less blue in tone than the *stola* underneath it. Microscopy of a cross-section taken from the *palla* shows a single-layer structure of an almost golden colour with a variety of yellow and red grains (Fig. 25).

The analysed remains of the original polychromy on the garments of Fundilia testifies to an artistic use of paint including the effects of shadow and highlights.

N 827: This portrait herm of Fundilia, now in Nottingham, bears traces of original paint, especially on the garments where a red orange colour is observed (Fig. 26). The pigment exists mostly as scattered particles. On the left side of the herm shaft the traces are preserved as a compact layer of red. A few traces of red are also found on the hair, mainly on the back of the head. Egyptian blue has been identified by means of VIL-imaging and is most conspicuous on the clothing especially on the lower areas, where a larger concentration is observed across the folds suggesting that ornamentation was intended (Fig. 27). The only evidence that the skin has been painted, are the few shining particles of Egyptian blue observed on the skin of the neck, used as part of the carnation colour.
In the inscription, traces of red are found in several of the letters.

IN 1435: The portrait head of Staia Quinta is carved from Parian Lychnites for the head. The base shaft is carved from a yet unidentified bluish-grey marble with yellowish veins. The portrait has been thoroughly cleaned, but a large amount of remaining colour has been preserved in the hair – primarily embedded in the encrustations between the drilled hair locks and in the deep furrows of chisel marks.

The well-preserved remaining colour in the hair allows for a reconstruction of her original hair colour. The documented colour palette ranges from yellow to a dark toned red ochre, dominated by a very bright and uniform yellow nuance (Fig. 28–29). Only a few grains of Egyptian blue are observed in between the curls for shadow effects.

The use of pigments for this restricted colour palette is different from what has been documented on Roman portraits so far: traces of a variety of pigments (carbon black, Egyptian blue, red, yellow and brown ochres, cinnabar, lead white) testify to an artistic use of different tonal values for imitating life-like human hair.[46] But on Staia Quinta the restricted colour palette suggests a less "natural" – almost synthetic – hair colour. Combined with the elaborately styled coiffure this suggests that the hair of Staia Quinta was originally meant to imitate a cosmetically enhanced hair colour either by dye or by wig. Both was commonly used by Roman women; and in particular bright hair colours such as blond and red were coveted when the women wanted to change the look of their hair.[47]

IN 1436: The portrait herm of Hostius Capito is carved from Parian Lychnites, while the herm shaft is carved from the same marble as IN 1435.[48] Like the other portrait sculptures this one has received extensive cleaning. And the broken off front piece of the chest has been restored in plaster to fit in the herm shaft, as clearly seen on the UV-FL image (Fig. 30). Therefore, the remains of its original polychromy are restricted to a few red ochre pigments in the hair and on the skin and few traces of Egyptian blue between the lips. In the inscription, however, remains of a compact, blue paint layer was documented (Fig. 31). VIL-imaging did not prove any luminescence of Egyptian blue and the identification of the pigment is not yet confirmed. But since incrustations cover areas of the blue colour in some of the letters of the inscription, the colour was most likely applied in Antiquity (Fig. 32).

46 Skovmøller and Therkildsen 2011, 35-46; Therkildsen 2012, 45.

47 Mannsperger 1998, 25-28; Bartman 2001, 7-12; Bradley, 2009, 174-178.

48 Moltesen, Romano and Herz 2002, 106.

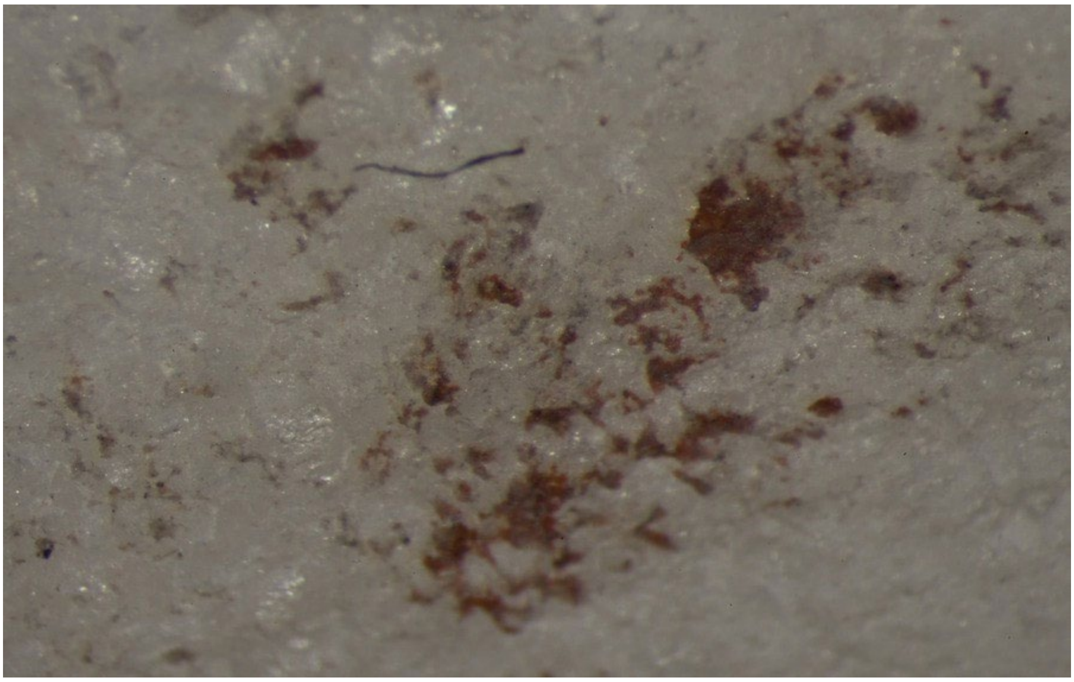

Fig. 24: Portrait statue of Fundilia (IN 708): Microscope image of the remaining purple paint on the *palla*.

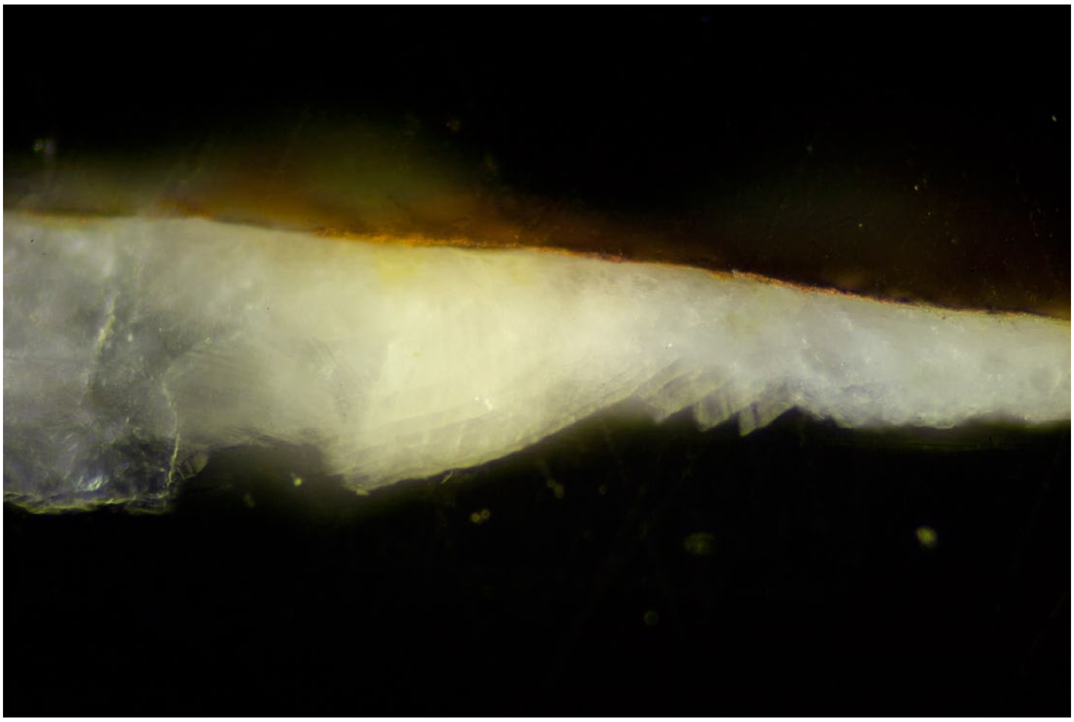

Fig. 25: Portrait statue of Fundilia (IN 708): Thin section of the remaining purple paint on the *palla*.

Fig. 26: Portrait herm of Fundilia (N 827): Detail of *palla*: Remaining red pigment.

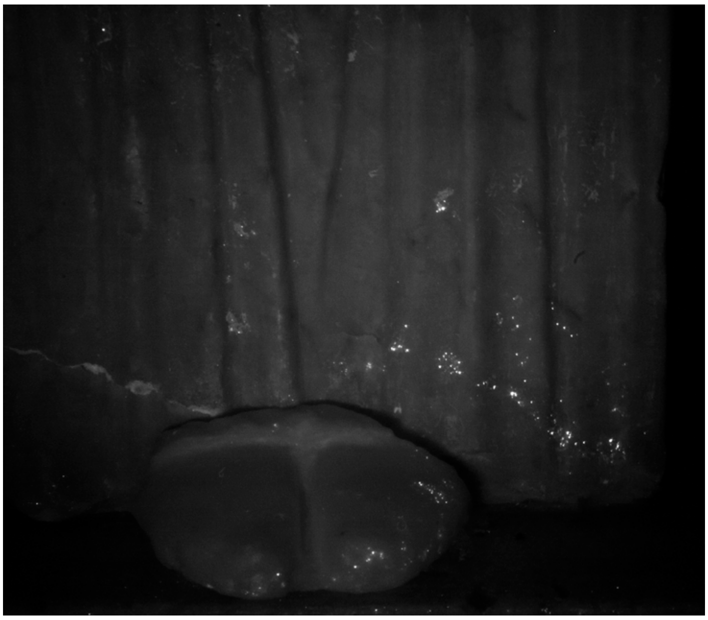

Fig. 27: Portrait herm of Fundilia (N 827): VIL image of painted horizontal and ornamental border above the feet. The luminescent particles indicate Egyptian blue pigment.

Fig. 28: Portrait head of Staia Quinta (IN 1435): Detail of hair.

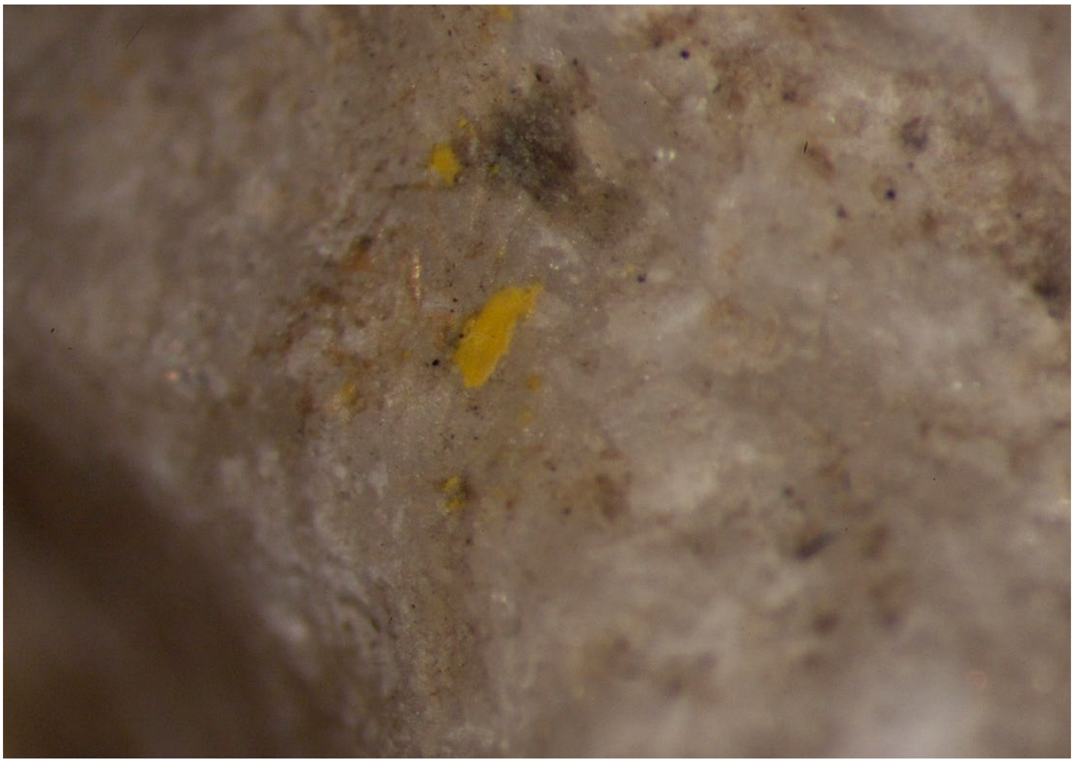

Fig. 29: Portrait head of Staia Quinta (IN 1435): Detail of hair: Microscope image of remaining yellow paint.

Fig. 30: Portrait head of Hostius Capito (IN 1436): UV-FL. image. The plaster restoration of the chest is visible.

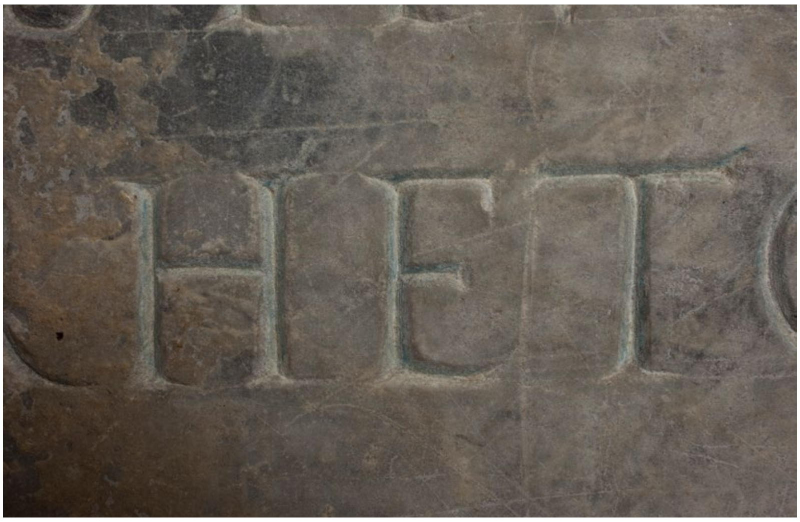

Fig. 31: Portrait head of Hostius Capito (IN 1436): Detail of herm shaft: Letters with visible remaining blue paint.

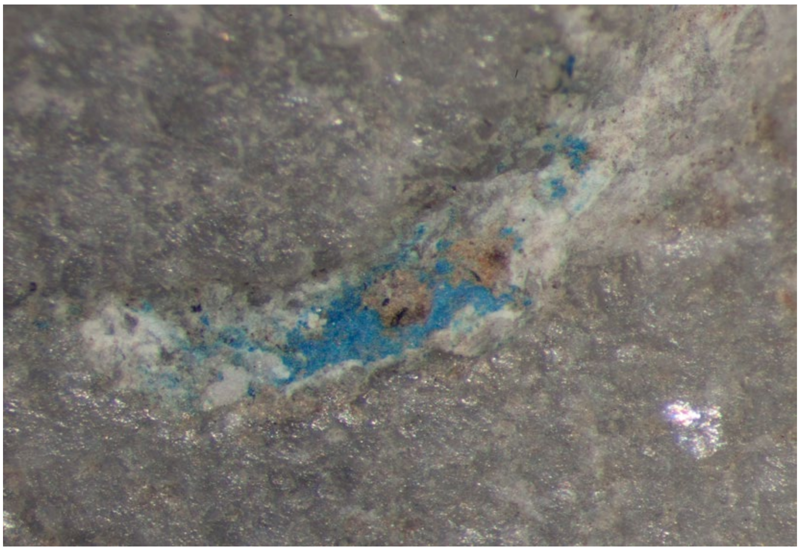

Fig. 32: Portrait head of Hostius Capito (IN 1436): Detail of herm shaft: Microscope image of letters with remaining blue paint

Fig. 33: Portrait head of Licinia Chrysarion (IN 761): Detail of hair: Microscope image of remains of red/brown pigment.

IN 1437: The portrait of Aninius Rufus is carved in marble from Ephesos, while the shaft is carved from the same marble as those of Staia Quinta and Hostius Capito.[49] Apart from the front of the forehead, which had broken off and was reattached, the portrait appears in a complete state of preservation. Nuances of red ochre and brown found in the hair together with grains of Egyptian blue, especially at the fringes of the forehead, testifies to the character of the original colour indicating a once reddish hair colour. UV-FL imaging indicated vague contours of a once painted iris and pupil in the left eye.

IN 761: The portrait of Licinia Chrysarion is carved from fine-grained Carrara marble.[50] The tip of the nose is missing and the back of the head is broken off and was most likely separately carved originally. Extensive remains of Egyptian blue were documented by VIL in the hair and were found together with traces of red/brown (Fig. 33). The pigments are embedded in the chiselled contours of the hair strands, which are particularly evident on the braid at the back of the neck (Fig. 34). The extensive use of Egyptian blue combined with the brown/red ochre suggests the approximate original hair colour. The blue pigment was used not only in the paint mixture for the hair colour, but also for shadows and details such as hair strands, which are not plastically rendered in the braid. Furthermore Egyptian blue and nuances of red ochre was documented in the areas around both eyes – in particular beneath the eyebrows – testifying to the presence of a skin colour (Fig. 35).

IN 759: The portrait of the unidentified, young woman is carved from Parian Lychnites.[51] It is in a state of preservation similar to the other portrait sculptures: The nose is chipped and the front of the breast has been joined with a piece from the collection in Nottingham.[52]

In the hair extensive remains of yellow, orange and red ochre were found. Furthermore VIL-imaging revealed the use of Egyptian blue in between the deeply drilled hair locks (Fig. 36) as well as in a high concentration on the *chiton* (Fig. 37).

IN 1438: The portrait of the man wearing a wreath is carved from Parian Lychnites and has been heavily cleaned, which explains the few remaining paint traces preserved on the marble surface.[53] Reddish colour is found in the hair mainly on the bangs, the right side of the head and the top of the head. The colour is preserved as a transparent layer. In both eyes small traces of red are present especially in the area of iris, upper rim and in the right lacrimal caruncle (Fig. 38). A pale red is observed between the lips. On the skin a few traces of red are found. On the left cheek the traces appear darker than elsewhere. Minute traces of red are also found on the petals of the flower above the right ear. The presence of luminescent particles indicates the use of Egyptian blue and is primarily seen as small single particles on the back of the neck, on the hair and on the left cheek.

49 Moltesen, Romano and Herz 2002, 106.

50 Moltesen, Romano and Herz 2002, 106.

51 Moltesen, Romano and Herz 2002, 106.

52 Moltesen 2000, 113.

53 Moltesen, Romano and Herz 2002, 106.

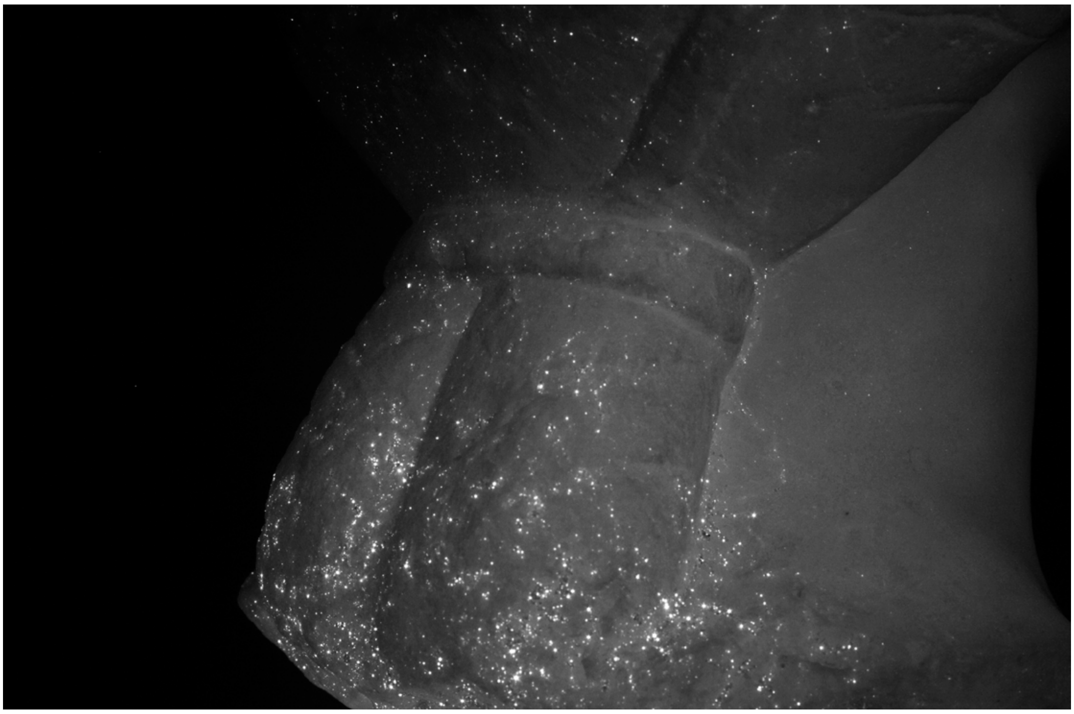

Fig. 34: Portrait head of Licinia Chrysarion (IN 761): Detail of the braid on the back of the head: VIL image. The luminescent particles indicate Egyptian blue pigment.

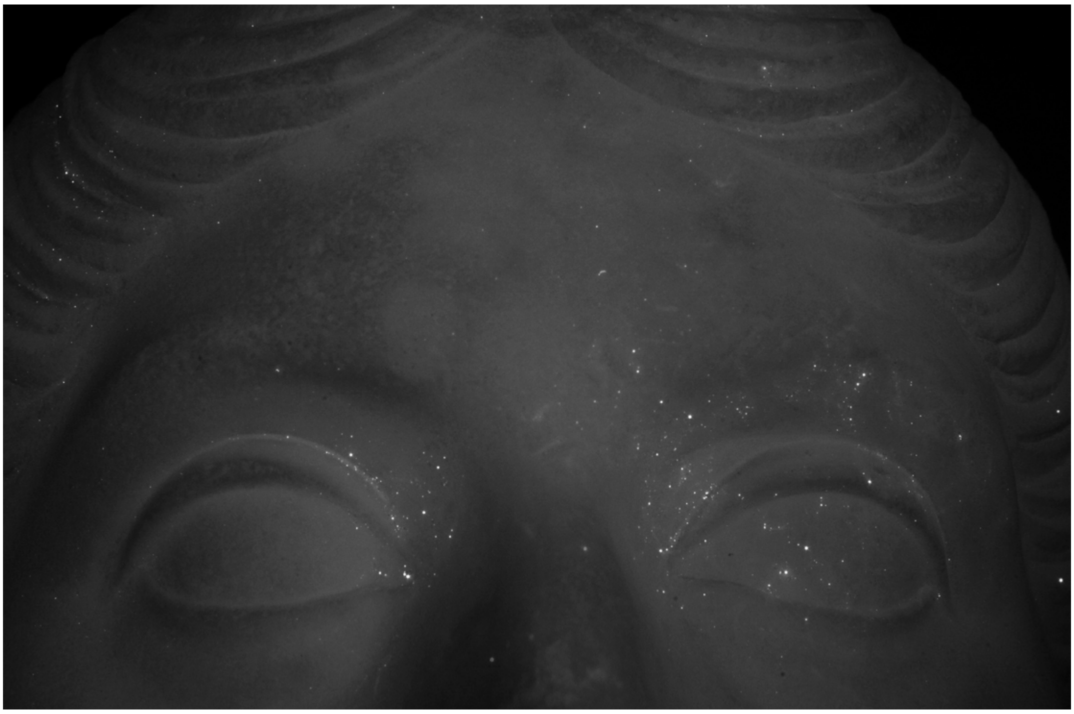

Fig. 35: Portrait head of Licinia Chrysarion (IN 761): Detail of the eyes: VIL image. The luminescent particles indicate Egyptian blue pigment.

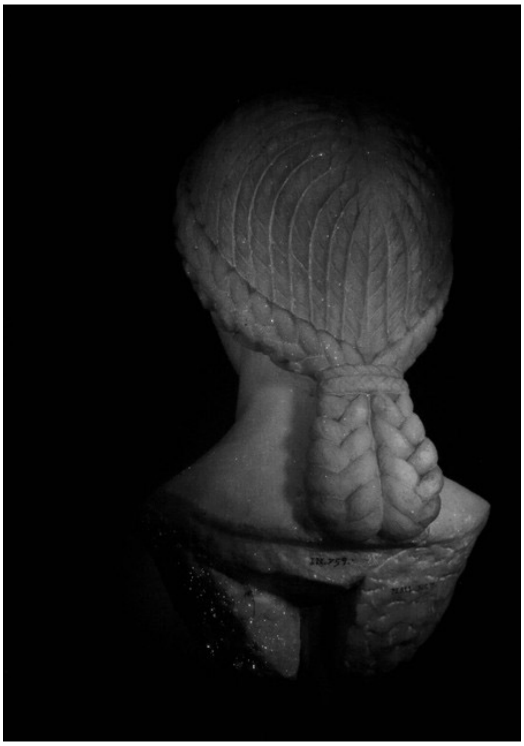

Fig. 36: Portrait head of unknown Roman woman (IN 759): Detail of curled hair locks: VIL image. The luminescent particles indicate Egyptian blue pigment.

Fig. 37: Portrait head of unknown Roman woman (IN 759): Detail of chiton: VIL image. The luminescent particles indicate Egyptian blue pigment.

Fig. 38: Portrait head of unknown Roman wearing a wreath (IN 1438): Detail of the eyes: Remaining red paint.

SUMMING UP

Due to the highly artistic exploitation and de-materialising of the marble materiality to create illusions of life-like human hair, skin, textiles and shoes, the portrait sculpture from the Diana Nemorensis sanctuary can be considered amongst some of the most remarkable examples of white marble sculptural craftsmanship which we have preserved from the Roman Empire. The high quality has led scholars to question their authenticity, but the results of our investigations prove that all the portrait sculptures are Roman originals and not 19th century forgeries.[54]

The results also reveal a high level of craftsmanship in the painterly techniques applied in the polychromy of portrait statuary of the 1st century CE. The paint mixtures applied on the *toga* of Fundilius and the *palla* of Fundilia consist of carefully ground pigments placed directly onto the marble surface in delicately thin layers.

Furthermore the documented remains of the original polychromy of the portraits provide us with new knowledge on how Roman portraits were originally meant to be perceived and experienced.

Without their polychromy, some of the status which they all sought to communicate would have been lost on the viewer. The extraordinary efforts put into the surface detailing, texturing and painting of the *toga* on Fundilius (IN 707) reflect the resources which this freedman and actor was in possession of. Whether the praetexta interpretation of the red/orange painted border is correct or not, the delicately applied paint layer still reveals an extraordinary and highly sophisticated colouration, which completed the artistic illusion of real, life-like textile. Further research into the painting of *toga* statues will help broaden our understanding of how the *toga* was originally used and decorated. The *stola* and *palla* of the statue of Fundilia (IN 708) were painted in two different shades of purple underlining her high social status as *matrona* and former *patrona* of Fundilius. The styling of the garments and her dated *nodus*-hairstyle lends her *gravitas*, which combined with the purple coloured garments makes her recognisable as a member of the higher strata of Roman society. Her importance is further emphasised by the two (and perhaps originally three) sculptural commemorations including both statues and herms. The strong, blond colour of the elaborate coiffures on the portraits of Staia Quinta (IN 1435) and the unidentified young woman (IN 759) underlines their beauty. Placed within the same room as the mature Fundilia (IN 708 and N 827) and (perhaps also) Licinia Chrysarion (IN 761), the strong yellow hair colour helps separating the young women from the older, the latter being given red/brown hair colours.

This paper has presented the preliminary results of the examinations of the portrait sculptures from the "Room of Fundilia". Further research into the original order of display of the portrait sculptures within the sanctuary of Diana Nemorensis is under way in order to improve our understanding of the original function and purpose of three-dimensional, painted marble portraiture in the Roman Empire. Also an in-depth investigation of the use of colour on the individual portraits will be undertaken in order to broaden our knowledge of how colour was used – and perceived – on Roman marble portraits.

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54 Moltesen 2012, 136.

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An archaeometric study of lead pigments from a 1st century BCE Roman marble sculpture

INVESTIGATIONS OF LEAD PROVENANCE, MATERIAL HETEROGENEITY AND ANCIENT ORE PROCESSING TECHNIQUES

Peter Fink-Jensen

ABSTRACT

Remains of a reddish colour on a 1st century BCE Roman marble head sculpture contain lead pigments, that have previously been identified as red lead. In this study, powder samples of the remains were submitted to a thorough archaeometric analysis, using lead isotope analysis (TIMS & SIMS), EDS and XRF to examine mineralogical composition, lead provenance and ancient metallurgical techniques involved in the production of the lead materials. The combination of methods provides viable scenarios for lead provenance but the study suffers from the some of the problems commonly associated with lead isotope analysis. The pigments most likely contains lead from two different sources, one of which could be lead ores located at Nova Carthago and/or Mazzarón in south-eastern Spain, while the other could be lead ores located either on Sardinia or in The Iberian Pyrite Belt in south-western Iberia. Besides lead, the colour traces also contain Ba-S-, Zn-S- and Fe mineral phases that probably originate from one of the involved ore deposits. Variations in lead isotopic compositions are detected in pigments from different parts of the sculpture, which could indicate the presence of a second lead pigment besides red lead, such as lead white. These pigments could have been mixed in order to vary the polychromy. No finite conclusions on the industrial processes involved in producing the pigments can be made on the basis of the data, but the detected accessory minerals could indicate that temperatures no higher than 500°C were used, thus ruling out the involvement of lead smelting techniques.

KEYWORDS

Polychromy, red lead, minium, litharge, lead isotope analysis, lead isotopic compositions, lead pigments, lead source, lead provenance, cupellation, silver refinement, Nova Carthago, SIMS, TIMS, XRF

INTRODUCTION

This article is a shortened version of the author's Master's Thesis ”An archaeometric study of lead pigments from a 1st century BCE Roman marble sculpture”. The study was carried out at The Natural History Museum of Denmark, The University of Copenhagen and the Ny Carlsberg Glyptotek as part of the Copenhagen Polychromy Network from February 2012 to March 2013.

The Master's Thesis is a continuation of the work presented in the article Rosing & Østergaard, 2009, which was presented in The Copenhagen Polychromy Network's preliminary report 1, 2009. Rosing & Østergaard discovered lead pigments in remains of a reddish colour on a 1st century BCE Roman marble sculpture. The mineral minium (Pb_3O_4) was detected in the pigment through X-ray Diffraction analysis, and thus the lead pigments were identified as red lead (M.T. Rosing, personal communication, February 2013). A subsequent lead isotope analysis was interpreted as the pigments containing lead from two different lead sources: Nova Carthago in south-eastern Spain and Rio Tinto in south-western Spain.

The aim of the subsequent Master's Project was to perform a deeper archaeometric analysis of the lead pigments in order to gain a greater understanding of their origin and the materials and processes involved in their production; more specifically:

- To establish lead isotopic compositions in lead grains on a µm-scale using the SIMS method. By comparing the results to previous lead isotopic studies this could perhaps reveal specific lead origins
- To determine the degree of lead isotopic heterogeneousness on a µm-scale. This could hopefully reveal how the lead sources had been mixed during industrial processing
- To examine lead isotopic variations in colour traces from different parts of the sculpture. This could perhaps reveal whether just one or multiple types of paints were used
- To determine the mineralogical and microstructural composition of the colour traces. An identification of all involved phases and their internal relationships could assist in the understanding of ancient Roman industrial processes involved in the manufacture of the lead pigments
- To examine lead concentrations in colour traces and marble surfaces, in order to examine the potential presence of airborne gasoline pollution or other contamination factors

The analytical techniques used to obtain these aims were Secondary Ion Mass Spectrometry (SIMS), Thermal Ionization Mass Spectrometry (TIMS), Electron Microprobe (EMP), Energy Dispersive Spectroscopy (EDS) and X-ray Flourescence (XRF) scanning.

INFORMATION ON THE EXAMINED SCULPTURE

The examined artefact is a Roman marble head, which probably depicts the Greek god Zeus. It is currently located in the collection of antiquities from the ancient Mediterranean at the Ny Carlsberg Glyptotek (IN 1664). The sculpture was acquired by Ny Carlsberg Glyptotek in 1898. It has been dated to approximately the 1st century BCE based on a stylistic analysis (Moltesen et al., 1996).

The sculpture has maximum measurements of 54 cms in height and 45 cms in width. It is believed to have been part of an acrolith: a sculpture where hands, feet and head are made of marble, while the rest of the body is made of wood. Only the mentioned extremities were meant to be visible, while the trunk was concealed by gilding or drapery. The sculpture's marble is believed to originate from Greece (J.S. Østergaard, personal communication, February 2013).

On the sculpture's beard, cheeks, lips, eye brows and irises reddish brown pigment is preserved. Traces of the same pigment are found elsewhere on the sculpture; mostly in the hair (see Fig. 1). The pigment originates from of a presumably red paint, which would have been applied either for the purpose of polychromy or as a preparation/grounding layer for gilding (Moltesen et al., 1996).

The back of the head was attached as a separate piece as made evident by a flat, cut surface with a dowel hole. The cut surface contains no traces of polychromy and was most likely never painted as it was not meant to be visible (J.S. Østergaard, personal communication, December 2013).

BACKGROUND ON LEAD ISOTOPE ANALYSIS

In lead isotope analysis, relationships between the lead isotopes ^{206}Pb, ^{207}Pb and ^{208}Pb are examined. Using lead isotope analysis in provenance studies is based on the principle that all geological regions have characteristic lead isotopic signatures rooted in their time of formation and their internal Th-U-Pb relationship. As lead minerals are common in most metallic ores, this principle is used to distinguish different ore districts and thus allows for identification of the geographic and geological origin of the ores used to produce metals for ancient metallic materials (Cattin, 2009). By identifying lead origins it can often be revealed whether an artefact is comprised of a homogenous or heterogeneous material; that is, whether material from just one or several geological sources where used in the production of said artefact. Such knowledge adds to the understanding of ancient mining operations and trade routes.

There are, however, two major disadvantages to the lead isotopic method. First of all, many different metallic ores may have been involved in the production of the raw materials used to manufacture an antique metal artefact. The raw materials may also have been produced from recycled metal products. As such, lead isotopic compositions in metal artefacts may reflect mixtures of lead from many different sources. If a sample contains a mixture of just two lead sources, then all mixtures of these two sources should plot on a linear binary mixing line between the average lead isotopic compositions of the two lead sources. Thus the specific lead isotopic composition of each lead source is not revealed. If multiple sources are involved it can be very difficult to determine specific lead origins using this method.

The other problem is that different geographical regions may have overlapping lead isotopic signatures, which can make it nearly impossible to determine an exact origin, based on lead isotope analysis alone. In southern Europe two major tectonic events, the Hercynian and the Alpine orogenies, are responsible for the formation of most lead ore deposits in the region. Thus overlap between lead isotopic signatures exists between many region in southern Europe (see e.g. Gale and Stos-Gale, 1982; Yener et al., 1991; Sayre et al., 1992; Budd et al., 1993; Stos-Gale et al., 1995; Degryse et al., 2007; Boni et al., 2000; Klein et al., 2004; Cattin et al., 2009).

ROMAN INDUSTRIAL LEAD PRODUCTION

Lead was used in a variety of different industries in the ancient Roman society. During the height of Roman power and influence a maximum of about 80,000 metric tons were produced each year, which is approximately the same rate as during the Industrial Revolution (Hong et al., 1994). It has been estimated that an average of 80,000 workers per year were engaged in the mining and smelting of lead in the whole of the Roman Empire. Another ~60,000 workers were employed in related industries, such as the crafting of various commercial products (Nriagu, 1983). Lead was used in industries such as manufacturing, arms, ship-building, coinage, fishing, pharmacology, cosmetics, food preservation and the arts (Waldron, H.A., 1973; Nriagu, 1983; Trincherini et al., 2010).

In Roman times, lead materials were produced by two different metallurgical techniques: direct smelting of lead ores and the extraction of gold, copper and, in particular, silver from leady ores. Most lead materials were produced as a by-product of the silver extraction process, during which lead was used to draw the silver out of the ore.

DIRECT SMELTING OF LEAD ORE

Lead is generally relatively easy to separate from its ores. In ancient times direct smelting of lead ores, containing such lead minerals as galena (PbS), cerussite ($PbCO_3$) and anglesite ($PbSO_4$), would take place in a single furnace with bellows that were used to create an oxidising environment. Galena was the most commonly worked lead mineral and shall be used as an example here. First, the galena ore was heated at relatively low temperatures (<500°C) in an oxidising environment. Tylecote, 1987, describes this process as "roasting". The roasting would result in a solid mixture of litharge (PbO) and various accessory minerals from the lead ore. By exposing this litharge mixture to temperatures of ~800°C while adding coal or charcoal to the process liquid metallic lead could be produced. If during this process the temperature was too high, copper- (Cu), iron- (Fe) and zinc (Zn) phases would form and alloy with the lead, which would harden the lead. If, however, the temperature could be kept at ~800°C most metallic impurities would concentrate in slags within the furnace, while other impurities, such as arsenic and sulphur would be oxidised and leave as gas. The end product would be a relatively soft metallic lead containing very few impurities. This was considered "high quality lead" (Tylecote, 1987; Craddock, 1995).

LEAD FROM SILVER EXTRACTION

In the Roman period most lead was produced from the extraction of silver. Silver production would yield large quantities of lead oxides, particularly litharge, which could be reworked to metallic lead (Craddock, 1995; Tylecote, 1987). The rate of lead to silver produced during silver extraction could be up to 300 to 1 (Hong et al, 1994).

Lead was used as a "collector" during early stages of silver extraction. The same principle was also applied to gold- and copper extraction. During smelting the noble metals alloy with the lead and can then be separated from the melt by exposing it to a highly oxidising, high temperature environment through a process called cupellation. During cupellation the lead concentrates in non-metallic oxides, mostly litharge, while silver, gold and copper remain as metals due to their noble character (Craddock, 1995, Tylecote, 1987; Rapp, 2009). Due to the high temperatures involved (~1000°C), litharge alloys with oxides of various elements, such as copper (Cu), antimony (Sb) and tin (Sn) (Craddock, 1995, Tylecote, 1987; Rosing & Østergaard, 2009). Other elements from the original lead ore are concentrated in slags or leave as gas. The litharge was then reworked to metallic lead, which would have a relatively low quality due to the high content of metallic impurities.

Litharge from either production method could also be reworked to other lead oxides, such as minium. Minium was produced by "roasting" litharge or metallic lead at 450–480°C in an oxidising environment (Tylecote, 1987).

SAMPLES

Two sets of samples were collected by scraping them off the sculpture: Set 1 was collected for EMP, EDS and SIMS analysis, while Set 2 was collected for TIMS analysis. Each set contained a few samples from the same areas so that SIMS and TIMS data from these areas could be compared.

The powder was adhered to the sculpture's marble surface and as such most of the scraped off material is actually marble.

SAMPLES FOR EMP-, EDS- AND SIMS ANALYSES

See Fig. 1 for sampling locations. See Fig. 2 for close-up images of the colour traces.

SET 1: 2 SAMPLES (SAMPLES A AND B):

Samples A and B consist of two ~5 mm long, <1 mm wide strands of red-brown colour traces and marble. They were placed on a 25 mm wide and 5 mm thick glass cylinder. Sampling areas are as follows:

- Sample A was collected from the right cheek, a few mm's off the right nose wing
- Sample B was collected the right moustache whisker.

It should be noted that a sample containing remains of a yellow-green colour from a 2nd century CE Roman sculpture, depicting an amazon warrior, was also attached to the same glass cylinder, lying next to Sample B. This sample belongs to a separate study, but is mentioned here as it has some common features with the samples from the Zeus head. This will be discussed in a later section.

SAMPLES FOR TIMS ANALYSIS

SET 2: 8 SAMPLES (SAMPLES ZA-ZF, MARBLE 1, MARBLE 2):

Set 2 contains 6 samples (Za – Zf) of red-brown colour traces and marble, and 2 marble samples (Marble 1 & 2):

- Za: Was collected from the lower lip
- Zb: Was collected from the left eye brow
- Zc: Was collected from the full beard
- Zd: Was collected from the right moustache whisker. Zd was sampled from the same location as sample B
- Ze: Was collected from the hair on the right side of the head
- Zf: Was collected from the right cheek. Zf was sampled from the same location as sample A

There is no apparent colour distinction between samples taken from different sampling locations.

Samples Marble 1 & 2 are each ~ 5mm × 5mm × 5mm pieces of marble collected from the surface of the hair at the back side of the Zeus head. They could potentially contain small amounts of the pigment. A blank sample was used during TIMS analysis to determine the degree of lead contamination introduced during sample preparation and TIMS analysis. The weight of the lead in the blank sample was 0.184 ng. Calculations showed that the lead from the blank sample would not have influenced the other lead isotopic data.

APPLIED ANALYTICAL METHODS AND THEIR USE

Different analytical methods were used to shed light on different archaeometric aspects of the preserved pigment. The applied analytical methods were:

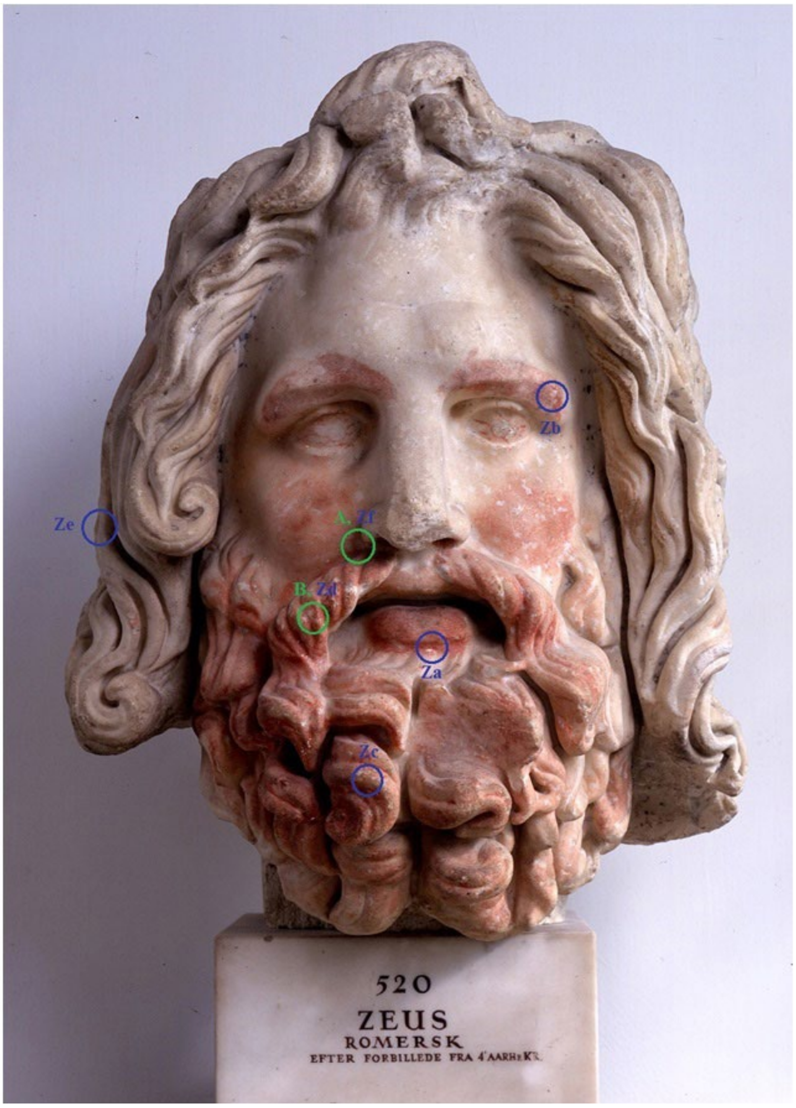


Fig. 1: The Zeus head as seen from the front in natural lightning. Marked locations indicate where pigment samples were taken. Sample locations are marked by circles and sample name: dark blue = TIMS samples, green = EMP/EDS/SIMS samples.

Fig. 2: Two close-up images of the left cheek and left eye of the Zeus head. Taken from Rosing & Østergaard, 2009.

- Secondary Ion Mass Spectrometry (SIMS) and Thermal Ionization Mass Spectrometry (TIMS), used to acquire lead isotopic data, the purpose of which was to examine lead provenance and material heterogeneity
- An Electron Microprobe (EMP), capable of performing Energy Dispersive Spectroscopy (EDS), was used to identify the mineral phases in the colour traces and sample microstructure
- A handheld X-Ray Flourescence (XRF) scanner was used to determine Pb-concentrations in areas of the sculpture that contained visible colour traces on the surface as well as in areas without any visible remains. This was done in order to assess the possible influence of lead from sources other than the pigments, such as lead in the marble or potential airborne gasoline pollution, on the mass spectrometry data

Data and observations from these methods were compared to modern and historical literature on ancient pigments and Roman mining practices for a joint discussion on the composition of the colour traces, lead provenance and ore processing techniques.

The following section elaborates on the use of the applied analytical methods, describing some of their advantages and disadvantages, as relevant to this study:

EMP/EDS

EMP- and EDS analyses of samples A and B were carried out on a JEOL JXA-8200 Superprobe at the Department of Geosciences and Natural Resource Management, Section of Geology, University of Copenhagen.

The electron microprobe is capable of magnifying a sample up 300,000 times at high resolution. It can image samples using back-scattered electron images, where phases are displayed by levels of brightness based on their density; which in turn is a reflection of their average atomic weight. High density minerals are brighter than low density minerals. Given the high density of lead minerals compared to calcite (marble) the two are thus easily distinguishable on back-scattered electron images.

EDS analysis is a qualitative method, used to reveal the presence of elements in very small sampling areas. However, EDS cannot identify the specific chemical compositions of mineral phases. Elements lighter than natrium, such as oxygen, carbon and hydrogen, are not detected via EDS, and as such the method gives a somewhat ambiguous image of involved mineral phases. A quantitative analytical method, such as wavelength dispersive spectrometry (WDS), could not be applied as the mineralogical phases were too small.

MASS SPECTROMETRY ANALYSES

TIMS analysis was performed at the Department of Geosciences and Natural Resource Management, Section of Geology, University of Copenhagen, on samples Za-Zf, Marble 1, Marble 2 in order to obtain the average lead isotopic composition of the bulk lead in each a sample. Compared to SIMS analysis, TIMS analysis has less statistical uncertainty, primarily due to a much larger sample size and the matrix of the sampled material not being a factor.

If a lead product contains lead from just one geographical region, the average lead isotopic composition, obtained from TIMS analysis, will fall within the lead isotopic signature of that region. In a heterogeneous sample, containing lead from two or more source regions, a TIMS analysis will yield an average isotopic composition that plots somewhere in between the individual isotopic compositions of involved sources; i.e. along a binary mixing line if just two sources are involved. Naturally, the higher the participation of a source region, the more it will be represented in this average composition. This makes TIMS analysis very useful for determining the degree of participation of each major lead source in a lead product, if the specific lead sources can be identified through a different method, such as SIMS analysis.

SIMS analysis was carried out at Naturhistoriska Riksmuseet in Stockholm, using two methods: monocollector and multicollector. The advantage of SIMS analysis is that it allows investigation of lead isotopic compositions in samples areas as small as 5 µm in diameter. This is particularly useful when examining small scale compositional variations in an isotopically heterogenous material (Cattin et al., 2009). The disadvantage of SIMS, however, was made apparent during the analysis. Ideally the analysed surface should be flat and “horizontal” during measurements, but during this testing the lead pigments were being slowly corroded and dissolved by the focused ion beam. This meant that during the period of a single analysis, lead isotopic ratios were measured from different, uneven surfaces. As such, isotopic ratios from isotopically heterogeneous lead grain clusters were not comparable. Also, the multicollector analyses suffered from low lead count rates, and the isotopic ratios of the standard sample used internally at the lab at Naturhistoriska Riksmuseet, in order to calibrate for instrumental mass fractionation, are not known precisely. A method, known as peak-hop correction, was attempted to counter some of these problems but as can be seen in the SIMS lead isotopic data presented in Fig. 7, the SIMS data suffers from high statistical uncertainty with great scatter of data points, resulting in high standard deviation values.

As such, the SIMS data cannot be considered reliable. It has been attempted to include it in the overall interpretation of the mass spectrometry data, but this use is highly speculative.

XRF ANALYSIS

In situ XRF analyses were carried out at Ny Carlsberg Glyptotek with an Innov-X Alpha-8000 LZX Handheld X-Ray Fluorescence scanner. The scanner measures the concentration of elements within a 10 × 10 mm area. First, ten scans were carried out in areas at the back of the head without any visible colour traces. Five of these measurements were carried out on the previously mentioned cut surface. These five measurements should only reveal concentrations of lead contained in the marble plus any secondary contamination, such as from airborne gasoline pollution. The other 5 measurements were carried out in areas of the hair that may or may not have contained colour traces.

The second set of scans was performed in facial areas where the majority of the 10 × 10 mm sampling area was filled with colour traces. The scanner is designed to measure surfaces, but it has been suggested that it actually measures a few centimetres down into some materials (T. Dahl, personal communication, October 2012). As such, in situ scans of the thin colour trace layers do not necessarily reveal exact concentrations of lead in the colour traces, as subsurface marble may also have been included in the scanning field. Due to a limited amount of available sampling material it was not possible to measure solely on colour trace material.

RESULTS AND DISCUSSION

EDS ANALYSIS

Detected elements	Ca	Pb	Ba-S	Fe-Cr	P	Fe	Zn-S
Presumed compound	Calcite ($CaCO_3$). Marble	Minium (P_3O_4) and perhaps other lead compounds	Pigment or contaminant. Most likely barite ($BaSO_4$)	Stainless steel	Phosporous inclusions in marble flakes	An iron oxide	Pigment or contaminant. Could be sphalerite ([Zn, Fe]S)

Table 1: Results of the EDS analysis. Listings of the elements detected in samples A and B and the presumed compounds that each listing likely represents.

Table 1 lists the elements detected during EDS analysis on Samples A and B. Each listing represents a unique compound.

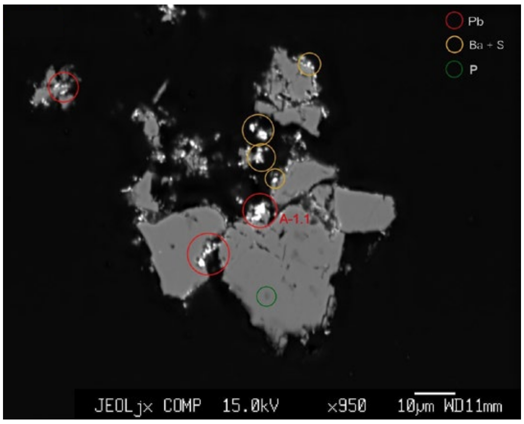
Back-scattered electron images of a few relevant sample sections are presented in Figs. 3, 4, 5 and 6. More than 95% of Samples A and B consisted of large angular calcite ”flakes”. The flakes differ in size and shape, with sizes ranging from <10µm to >500 µm. Some flakes contain cracks and holes, while others are relatively intact. The high calcite content originates from the sculpture’s marble, which was scraped off along with the colour traces. The flakes consist almost entirely of calcite, except for a few tiny, phosphorous inclusions.

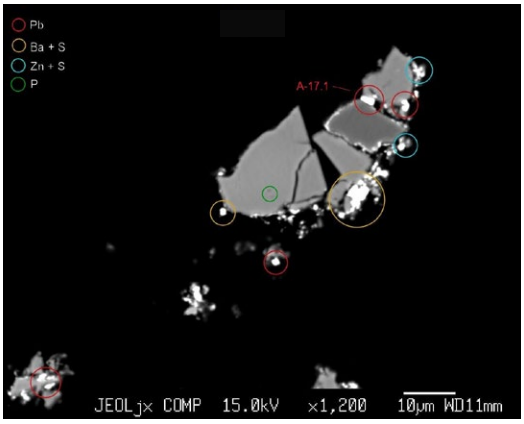
Mineral phases other than calcite each constitute less than 2% of the total sample size. Pb- and Ba-S minerals are the most abundant of these phases, while Zn-S minerals occur less frequently. The remaining mineral phases occur very infrequently. Only a minor percentage of the calcite flakes are found in association with other minerals, which suggests that most marble flakes originate from below the outer, coloured surface. Pb minerals are e.g. found on less than 5% of the calcite flakes.

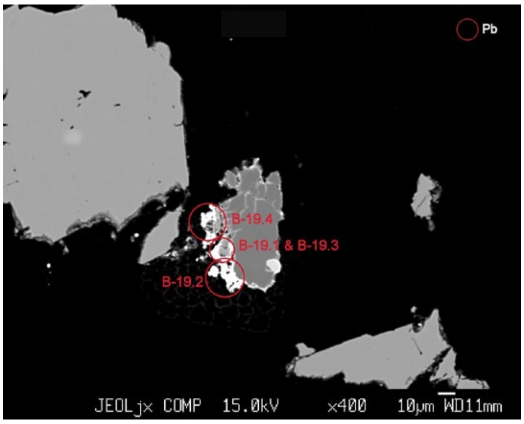
Pb-, Ba-S- and Zn-S minerals occur as ~0.5–2 µm grains that are aggregated in clusters. All grain clusters are adhered to calcite flakes, either at the outer surface or filling up cracks (Figs. 3, 4 & 5). Grain cluster sizes vary from a few grains to more than a hundred grains. EDS analysis indicates that all grain clusters contain only one type of mineral. Pb-, Ba-S- and Zn-S mineral grains are not found cohesively, except in one unique instance discussed below. However, different mineral clusters are often found adhered to the same marble flake.

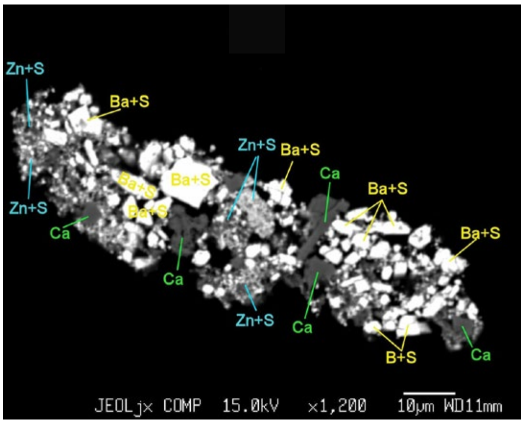
A single occurrence of a large grain cluster consisting of a mush of angular Ba-S-, Zn-S- and Ca-mineral crystals was found in Sample B (Fig. 6). Two similar clusters were found in the Amazon warrior sample, which was adjacent to Sample B on the sampling glass. Despite being from a different time period[1] the Amazon sample has a mineralogical composition very similar to the colour traces from the Zeus sculpture, in that it also consists almost entirely of calcite flakes that have grain clusters of Pb-, Ba-S- and Zn-S minerals adhered to the surface. However, the colour traces from this sample are yellow-green so a different pigment must be involved here. The mushy grain cluster in Sample B could be the result of contamination from the Amazon warrior sample. However, the Pb-, Ba-S- and Zn-S mineral grain clusters adhered to calcite flakes do not appear to be the result of contamination, as

1 The sculpture of the Amazon warrior (IN 1568) has been dated to the 2nd century CE









Figs. 3, 4, 5 & 6: Back-scattered electron images of a few relevant sections of Samples A (Figs. 3 and 4) and B (Figs. 5 and 6). Phase brightnesses depend on mineral densities (the heavier, the brighter), so the grey and white tones should not be mistaken for actual mineral colours. Image brightness can be adjusted during analysis, so the brightness levels of individual minerals might vary from image to image. Some mineral occurrences are highlighted with coloured circles: Red = Pb, Yellow = Ba-S, light blue = Zn-S, green = Ca (see also legends in top corners). See Table 5 for presumed compounds of these mineral phases. Fig. 11, 12 and 13 show relatively large (grey) marble flakes, with (white) Pb-, Ba-S-, and Zn-S mineral grains sitting in clusters close to marble surfaces. Fig. 6 shows a large cluster that differs from the rest of the sample material. It consists of a mush of angular crystals of Ba-S -, Zn-S -, and Ca phases. Also shown are the grain clusters analysed by SIMS: A-1.1, A-17.1, B-19.1+3, B-19.2, and B-19.4. A 10 μm scale is indicated by a white line in the bottom right corner of each image. The number following the "x" slightly to the right of the bottom middle indicates the magnification level.

all occurences of these clusters are adhered directly to calcite flake surfaces. Calcite flakes could have been transferred from one sample to the other, but this is not likely to have happened on a large scale.

There are very few and isolated occurences of a Fe-Cr phase. This is most likely stainless steel from the sampling tool. Rosing & Østergaard, 2009, suggest that it could be the mineral chromite ($FeCr_2O_4$) that originated from mortars used during pigment preparation. In any case, this mineral is not likely to belong to a pigment.

An iron phase also occurs very sporadically and isolated from the other non-calcite mineral phases. This could be an iron oxide, such as magnetite (Fe_3O_4). Its isolated occurrence suggests that it may not belong to the pigment.

Chlorine was detected in the colour traces examined by Rosing & Østergaard, 2009, but was not encountered in this study.

identification of the lead compound(s)

As the colour traces could potentially contain other lead compounds than minium, a discussion on involved lead compounds is presented in the following section.

Based the eds analysis, with its known limitations, involved lead pigments can most likely be narrowed down to any of the following: lead white ($2PbCO_3 \cdot Pb(OH)_2$), red lead (Pb_3O_4), litharge (PbO), massicot (PbO), lead acetate ($Pb(CH_3COO)_2$) or cerussite ($PbCO_3$).

It is unlikely that the red colour of the trace powder could be attributed to any of the non-plumbic components of the colour traces. The samples do not contain enough of the iron mineral phase to explain the red colour as coming solely from an iron oxide, such as hematite (Fe_2O_3), and known Ba-S and Zn-S pigments are white.

The lead pigment that is most likely to have yielded the observed red-brown colour is red lead. Red lead is a scarlet red pigment, which consists of minium. It is known to have been used by the Romans and has often been identified in studies of ancient colouring (see e.g. Pérez-Rodríguz et al., 1998; Walton & Trentelman, 2008; Campos-Suñol et al., 2009; Cardell et al., 2009; Wei et al., 2012). Minium will turn from red to chocolate-brown when exposed to strong light over a longer period (Pérez-Rodríguz et al., 1998). This fits well with the brownish tan of the colour traces. With its current position in the exhibition at the Ny Carlsberg Glyptotek the Zeus sculpture is not exposed to sunlight, but bright spot lamps light it up during museum opening hours. It should be noted here that the sculpture's conservational history is not known.

Litharge and massicot usually exhibit a yellow to orange colour, but litharge is known to produce red crusts when formed as an oxidation product of metallic lead (Eastaugh et al., 2004). However, red lead was much more widely used as a red pigment and as minium has previously been identified in the colour traces, red lead is the most likely source of the red colour. Litharge and massicot are often found as impurities in synthetic minium due to imperfect synthesis, but traces of these would not have changed the colour of the colouring noticeably.

A different lead pigment, such as lead white, cerussite or lead acetate, could potentially be present along with the minium, "clouded" by the red-brown colour. This is discussed in a later section.

identification of ba-s and zn-s compounds

Barium and zinc are not known to have been worked in Europe until the late Middle Ages, while pigments containing barium and zinc were not introduced until the 18^{th} and 19^{th} centuries, respectively (Casadio et al., 2005; Eastaugh et al., 2004). As such, the Ba-S and Zn-S compounds are not likely to have been used intentionally during the 1st century BCE. Their appearance in the pigment is probably due to one of the following reasons:

- The sculpture has been repainted at some point during the past couple of centuries
- They are derived from a type of secondary contamination
- These are accessory minerals from the lead ores involved in the production of the lead pigments

Two different pigments, consisting of mixtures of zinc sulfide (ZnS) and barium sulfate ($BaSO_4$), are known to have been widely used in the paint industry during the second half of the 19th century. These are known as "Lithopone" and "Freeman's White". They were manufactured by crushing the two compounds and mixing them together (Eastaugh et al., 2004). Either of these pigments could be likely candidates to explain the large Ba-S – Zn-S – Ca-cluster found in Sample B, as this cluster could well have been produced by crushing and mixing, as indicated by the angular grains and the mushy mixing. However, the Ba-S and Zn-S mineral grains adhered to marble surfaces have very different sizes and structures, and are also not found in direct association with each other. They are thus not believed to be remnants of the above mentioned pigments.

The fact that Ba-S- and Zn-S mineral phases were also detected in the adjacent Amazon warrior sample speaks for a repainting scenario. However, there is no record of the Zeus head having been repainted for neither maintenance nor preservation purposes while in the possession of the Ny Carlsberg Glyptotek. It is also not a possibility that such repainting could have taken place prior to the museum's acquisition of the sculpture (J.S. Østergaard, personal communication, February 2013).

There are other scenarios for the presence of the Ba-S- and Zn-S minerals. If the Zeus head has at some point been exposed to salt water, the Ba-S phase could be barite ($BaSO_4$), formed as an evaporite from salt water. Another explanation could be that a limestone mortar, bowl or other tool used during lead pigment preparation could have supplied barium- and zinc minerals or secondary products thereof. It is also a possibility that these minerals could be a constituent of the marble substrate (Rosing & Østergaard, 2009). These options are obviously speculative and not based on direct evidence.

It is likely that the Ba-S and Zn-S mineral phases are accessory minerals from the polymetallic ores from which the minium was produced. This will be elaborated thoroughly in a later section.

XRF ANALYSIS

XRF scans on marble	Pb (ppm)
Neck hair, right 1	22
Neck hair, right 2	18
Neck hair, left 1	45
Neck hair, left 2	54
Right side of head	19
Cut surface 1	18 +-4
Cut surface 2	15 +-4
Cut surface 3	28 +-5
Cut surface 4	13 +-4
Cut surface 5	16 +-4

XRF scans on colour traces	Pb (ppm)
Lower right beard	299
End of right moustache	40
Lower left beard	69
Left moustache whisker	2581
Centre of lower lip	64
Right nostril	88
Left cheek	301
Left eye brow	85

Table 2. Lead concentrations detected at various areas of the Zeus head during XRF analysis. XRF measurements were carried out on a number of different marble and paint trace surfaces.

Not surprisingly, the XRF data listed in Table 2 reveals that lead concentrations are highest in areas containing visible colour traces. However, these concentrations are not markedly higher, except for the measurement on the left moustache whisker. This is most likely due to the XRF scanner measuring slightly into the marble below. As seen in the back-scattered images the amount of lead in samples A and B is very small compared to marble. As such, these measurements cannot be considered representative of actual lead concentrations in the colour traces.

The scans on the cut surface largely reveal lead concentrations similar to what is typically found in marble (~10–20 ppm). Two of the scans in hair areas have slightly higher lead concentrations, which can perhaps be attributed to slight traces of pigment. Also, lead concentrations in marble may exceed 200 ppm (Green, 2002). In any case, the XRF data seems to suggest that airborne gasoline pollution is a negligible factor and should thus not have affected the affected mass spectrometry data significantly.

MASS SPECTROMETRY ANALYSIS

Because of the uncertainties associated with determination of lead provenance on the basis of lead isotope analysis, a presentation of all possible lead provenance scenarios are outside the scope of this report. It has been attempted to overcome the issue of compositional overlap between ores from different geographical regions by excluding regions on the basis of literary references. This method is not really scientifically "accurate" because of uncertainties regarding the use of ancient literary texts, the somewhat approximated lead isotopic signature fields and the somewhat approximated age of the sculpture. Thus, discussion of the mass spectrometry data focuses on the most likely provenance scenarios.

In Fig.'s 7, 8 & 10 results of the mass spectrometry analyses are presented in $^{208}Pb/^{206}Pb$ vs $^{207}Pb/^{206}Pb$ diagrams in order to assess lead provenance. The data is compared to typical lead isotopic signature fields of a number of geographical regions that may or may not have supplied lead to the Roman civilisation during the 1st century BCE. These signature fields represent the lead isotopic compositions that are typically found in ore deposits within these regions, but may not encompass all lead isotopic compositions that exist within a geographical region. In other words, it is possible that geographical regions may contain rocks, whose lead isotopic composition fall outside their respective signature field.

DISCUSSION OF TIMS DATA

The scatter of TIMS data points in Fig. 7 is strong evidence that more than one lead source was present in the analysed samples. Also, no single geographical signature can encompass all data points and as such the samples should contain lead from different geographical regions.

In Fig. 8, a binary mixing line E has been drawn between two compositional end-members, here called lead sources A and B. All 8 TIMS data points appear to plot at or near mixing line E, which suggests the involvement of just two lead sources. Included in Fig. 8 are data points taken from Walton & Trentelman, 2009, who did a provenance study on red lead pigments from 7 Egyptian red-shroud mummies, which have been dated to ~31 BCE to 1st century CE (approximately the same age as the Zeus head). The Walton & Trentelman data plots (shown as WT-plots) lie at or near mixing line E, which suggests that the lead in these pigments also originated from lead sources A and B. Egypt became a Roman province in 30 BCE so it is entirely possible that the lead in these pigments could have the same origin as the lead in the Zeus head pigments. It would be a stretch to make a conclusion on the basis of samples from just two artefacts, but it would appear that mixtures of these particular lead sources were not uncommon within the Roman territory at this time.

TIMS data plots can be divided into three different groups based on sampling locations:

- Data plots from samples Zb, Zc and Zd are tightly clustered (see Fig. 8). These samples were all taken from areas of the sculpture that depict facial hair (Zb: eyebrows, Zc and Zd: beard). The Rosing & Østergaard (RØ) sample was taken from the beard and has a lead isotopic composition very similar to the other facial hair samples
- Samples taken from areas of the face that depict tissue – Zf: right cheek/nostril and Za: lower lip – have similar lead isotopic compositions
- Samples collected in hair areas – Samples Ze, Marble 1 and Marble 2 – have somewhat similar lead isotopic compositions

This relationship between lead isotopic compositions and sampling locations suggests that different paint mixtures were applied to different parts of the sculpture. Two scenarios are suggested here as to why that might be:

- Red lead pigments containing two different lead sources: The lead isotopic variations can be attributed to two different lead sources that were mixed during refinement of the lead ores and/or during production of the pigments and/or paint. Minium from different sources would likely have had uniform colours and properties. As such, it is probably coincidental that the participation of each source varies in different areas
- Red lead and a different lead pigment: The fact that lead source participations vary but are similar for the associated areas – facial hair, tissue, hair on the head – could indicate intention on the part of the painter. Particularly the uniform lead isotopic compositions found in beard and eye brow samples suggest that this was no coincidence, as these facial areas are not immediately adjacent. Perhaps the painter wanted to vary the polychromy, so that facial hair, tissue and hair were different shades of red. Such colour variations would have required more than one type of pigment. Perhaps, two different lead pigments, e.g. red lead and lead white, that each represented a different lead source were mixed to create shades of

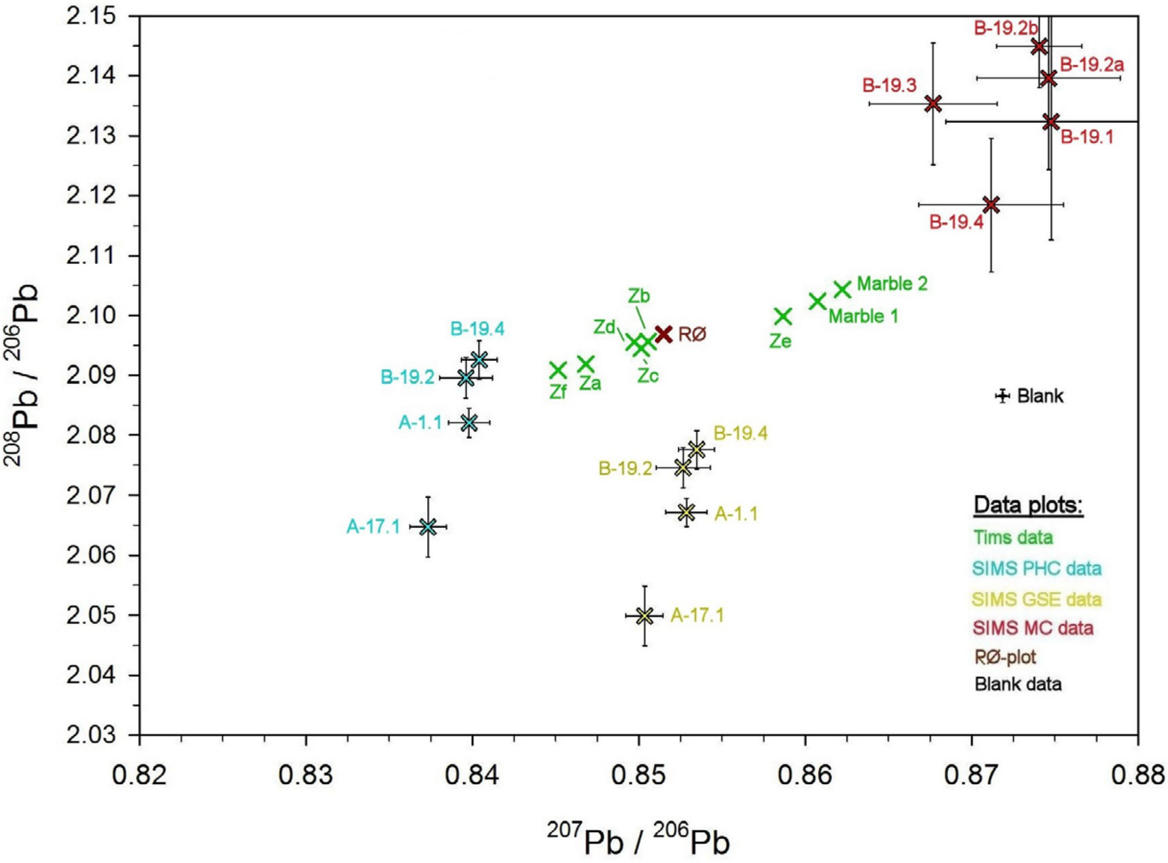


Fig. 7: Data from sims and tims analyses plotted in a ^{208}Pb/^{206}Pb vs ^{207}Pb/^{206}Pb diagram. sims data plots are presented with 2σ error bars. Error bars for tims data are not shown as the standard deviation values are insignificantly small. The RØ data plot is taken from Rosing & Østergaard, 2009. Data plots are shown as X'es and are distinguished by different colours, which are explained in the legend. sims phc data = peak-hop corrected multicollector data, sims gse data = gse-ig corrected multicollector data, sims mc data = monocollector data.

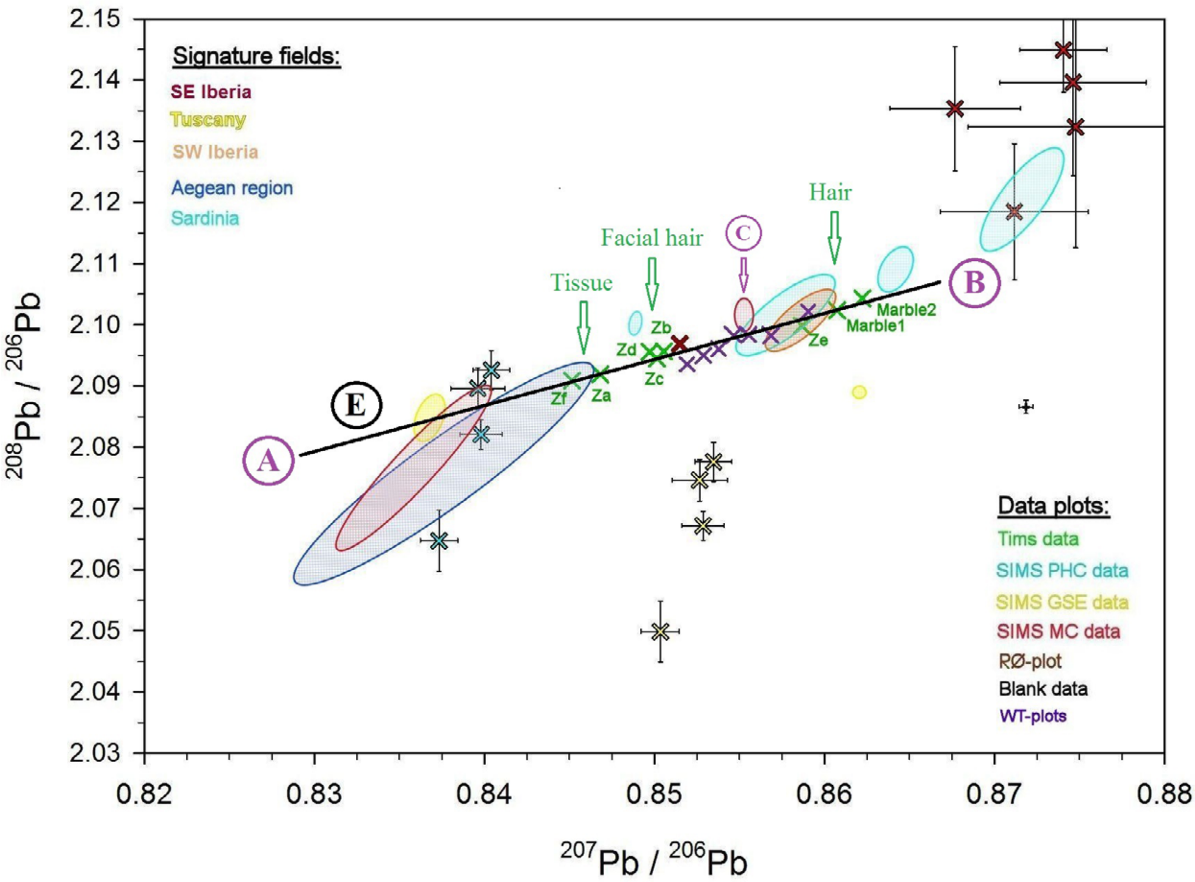


Fig. 8: Data from SIMS and TIMS analyses plotted in a $^{208}Pb/^{206}Pb$ vs $^{207}Pb/^{206}Pb$ diagram. SIMS data plots are presented with 2σ error bars. Error bars for TIMS data are not shown as their standard deviation values are insignificant. The RØ data plot is taken from Rosing & Østergaard, 2009. WT-plots are taken from Walton & Trentelman, 2009. In this diagram the SIMS and TIMS data is compared to lead isotopic signature fields for the five regions suspected to be the most likely candidates for lead source provenance: SE Iberia, Tuscany, SW Iberia, the Aegean region and Sardinia. Data plots are shown as X'es, while signature fields are shown as ellipses. Data plots and signature fields are distinguished by different colours, which are explained in the two legends. A suggested binary mixing line (E) between two lead sources A and B has been drawn. The isotopical signature field for SE Iberian Ore Group 1, which in the text is named lead source C, is indicated by a purple arrow. Groups of data plots that are related by their sampling locations are indicated by green arrows and text. Please note that terminations of the mixing lines and the position of the purple lead source letters/circles do not indicate suspected positions of lead source isotopic compositions.

red. Lead white is known to have been mixed with other pigments as a diluent to diminish the colour intensity (Pérez-Rodríguez et al., 1998). The different pigments could also have been applied in different paint layers in order to create optical effects that could not be obtained by directly mixing different pigments (Pérez-Rodríguez et al., 1998; J.S. Østergaard, Personal communication, 2012). At present day, the colour traces do not exhibit colour variations, but this could be attributed to the minium turning brownish when exposed to light, which could have negated slight colour variations

The above suggestions are of course speculative, as specific lead compounds could not be determined through EDS analysis.

As mentioned previously, the red paint may have been used for the purpose of polychromy, but it could also have served as a grounding layer for gilding (Moltesen & Nielsen, 1996). Minium has previously been detected in colour traces that are believed to originate from such grounding layers (Pérez-Rodríguz et al., 1998). In both cases, polychromic or grounding, the colour of the layer would have mattered, as grounding layers for gilding, by e.g. leaf gold, were intended to influence the appearance of the gilding (J.S. Østergaard, Personal communication, December 2013).

A further analysis of the chemical composition of involved lead phases is needed to clarify which and how many lead pigments were used. If sufficiently large lead clusters can be detected in a new set of samples, then a WDS analysis can be used to identify specific lead minerals.

LEAD PROVENANCE BASED ON TIMS DATA AND PREVIOUS STUDIES

A comparison between mixing line E and the isotopic signature fields puts the geographical placement of lead source A at SE Iberia, Tuscany and/or the Aegean region. Lead source B could be located either on Sardinia or in SW Iberia. Lead isotopic compositions of the marble samples plot just outside the signature field for SW Iberia, but this could very well be due to the signature field being inaccurate. If the marble had a Sardinian origin then this could potentially explain this trend but, as mentioned previously, the marble is believed to originate from Greece.

A look at previous studies on Roman lead mining shows a strong tendency towards southern Iberia being the main lead producing region at the time. Southern Iberia is pointed out as being the largest lead producing region in the world in a time period spanning from the Iron Age and up to the end of the Roman Empire. Estimates suggest that mines in southern Spain constituted ~40–45% of total worldwide lead production during this time (Nriagu, 1983). A total of ~25–30 million tons of ancient slag heaps have been identified at mining sites in SE- and SW Spain, such as Nova Carthago (SE Spain), Mazzarón (SE Spain), Tharsis (SW Spain) and Rio Tinto (SW Spain) (Allan, 1970; Forbes, 1971, as cited in Nriagu, 1983).

Both SE- and SW Iberia contain vast sulphide ore deposits that formed as a response to tectonic events during the Hercynean- and the Alpine orogenies. Roman mining activity in these regions evolved around the mining, extraction, and production of silver. In southeastern Spain silver was extracted mainly from lead ores. The Greek historian Polybius mentioned that the mines at Nova Carthago alone employed 40000 workers in the first half of the 2nd century BCE (Davies, 1935). In south-western Spain mining mostly took place in the region known as The Iberian Pyrite Belt. Here, silver was extracted from non-plumbic jarosite deposits (Patterson, 1972). Leady sulphide ores are however also present in SW Iberia and as the addition of lead was vital to the silver extraction process, both local lead and imported lead materials were utilised in the silver extraction process.

Lead fallout from metal producing furnaces in southern Iberia has been registered in Greenlandic ice cores. It has been estimated that up to 70% of lead fallout detected from the period 366 BCE to 36 CE originated from the mines of Rio Tinto, with most of the remaining 30% originating from mines in SE Spain (Rosman et al., 1997).

The Aegean region had some very important mining districts during the Bronze- and Iron ages, particularly the legendary mining district of Laurion in Greece. During the late Bronze Age and Iron Age, Laurion was considered the world's largest mining area (Tylecote, 1987; Craddock, 1995). However, during the 1st century BCE lead production in the Aegean had greatly diminished (Nriagu, 1983), making it unlikely that lead from the examined pigments originates from there.

It is not quite clear when the Romans started mining in Sardinia, but it has been suggested that large-scale mining did not commence until the time of the Roman Empire (Nriagu, 1983; Hirt, 2010). Davies, 1935, suggests that Sardinian lead mines closed temporarily around 0 AD, probably because they were outrivaled by the Spanish lead mines.

In Tuscany in central Italy the Etruscans produced silver and lead from argentiferous lead ores prior to 2nd century BCE and production was continued after Roman conquest of the region (Davies, 1935).

Different archaeometric lead isotope studies indicate that both Sardinia and Tuscany probably supplied lead to the Roman civilisation in the 1st century BCE (Boni et al., 2000; Klein et al., 2004), albeit on a much smaller scale than the mines in southern Iberia.

All in all, a south Iberian origin of the lead in the examined pigments appears to be the most likely scenario. Fig. 9 shows the lead isotopic composition of different ore groups in the geological region known as The Betic Zone in SE Spain. Mixing line E from Fig. 8 intersects with the lead isotopic compositions of Ore group 2; more specifically the lead ores found at the ancient mining sites of Carthagena (Nova Carthago) and Mazzarón (see Fig. 9). These ores must be considered a likely origin of lead source A.

Rosing & Østergaard, 2009, suggest that minium found in colour traces from the beard of the Zeus head contains a mixture of lead from Rio Tinto ores (SW Spain) and Nova Carthago ores (SE Spain), which could have been mixed during silver refinement at Rio Tinto. At Rio Tinto the exploited ores are non-plumbic jarosite ores, which probably did not provide much lead to the process. If however lead from nearby lead ores was also used in the silver extraction process, then it could explain the observed TIMS data. Litharge produced from different smelting batches could have different lead isotopic compositions, which could explain the spread of lead isotopic compositions found in different areas of the Zeus head. Different provenance scenarios include lead from Nova Carthago/Mazzarón and/or Tuscany having been mixed with Sardinian lead.

LEAD PROVENANCE BASED ON SIMS & TIMS DATA

The SIMS data are not trustworthy and are most likely not valid for the discussion of lead provenance. However, an attempt is made here to include the SIMS data in this discussion.

In Fig. 10 it has been attempted to combine the TIMS data with the peak-hop corrected (PHC) SIMS data in order to setup a possible lead provenance scenario. Please note that this interpretation is dependent on the accuracy of the mixing lines, the isotopic signature fields and, most importantly, the validity of the PHC SIMS data. Both the glass standard (GSE) data and the monocollector (MC) data plot outside any known lead isotopic signature fields, and are thus not valid for this discussion.

Multicollector measurements B-19.2 and B-19.4 were carried out on relatively large grain clusters, so pigment lead probably constituted the majority of the sampling field (see Fig. 5), whereas marble lead would have had an insignificant influence on the data. Multicollector measurements A-17.1 and A-1.1 were carried out on smaller grain clusters that only covered a small area of the 5 μm diameter sampling field (see Figs. 3 & 4). In these measurements

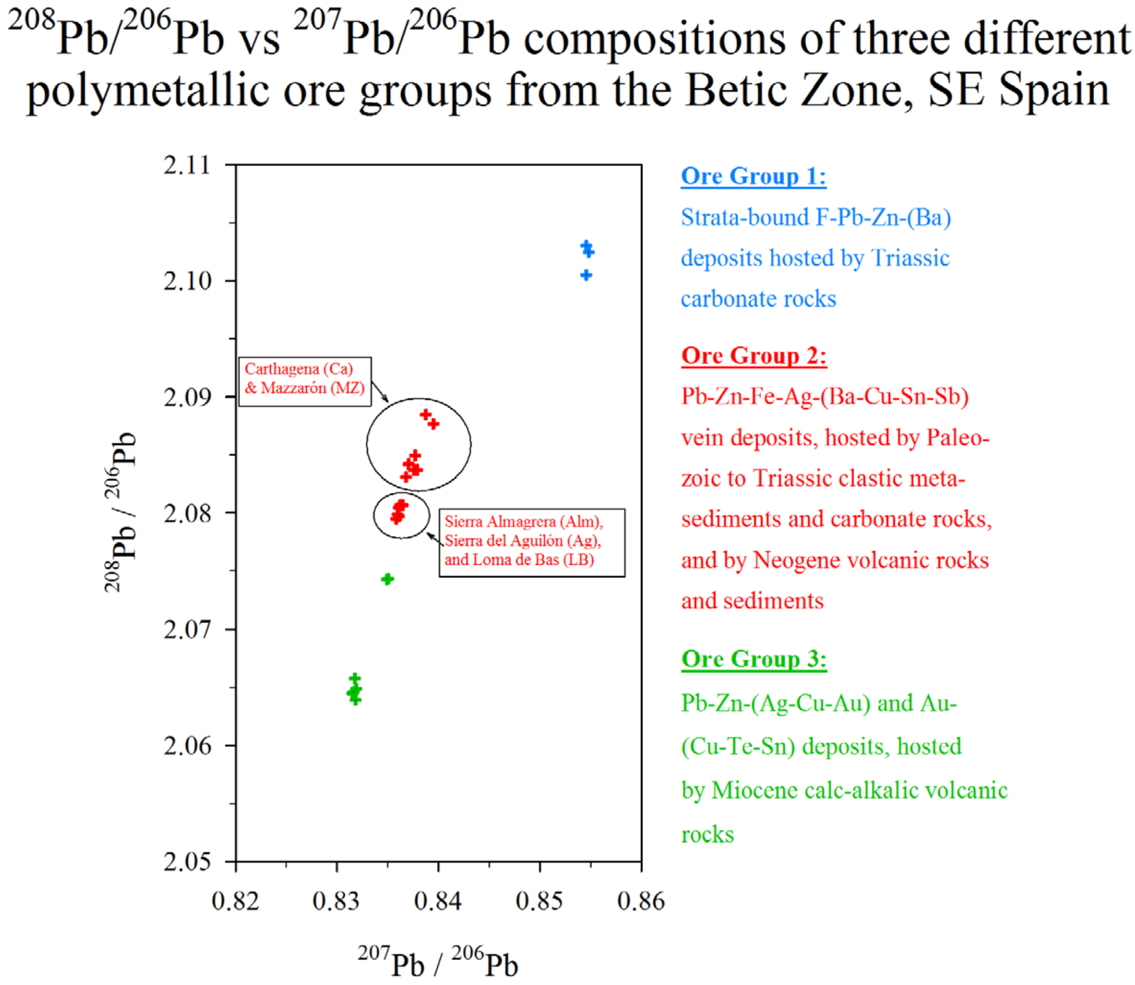


Fig. 9. ^{207}Pb/^{206}Pb vs ^{208}Pb/^{206}Pb diagram, showing the spread of lead isotopic compositions between three ore groups from the Betic Zone. See legend for brief descriptions of the involved ore groups. Notice how Ore Group 2 lead isotopic compositions vary depending on their geographical occurrence. Data sources are: Arribas & Tosdal, 1994; Oxford Archaeological Lead Isotope Database (Oxalid), http://oxalid.arch.ox.ac.uk/

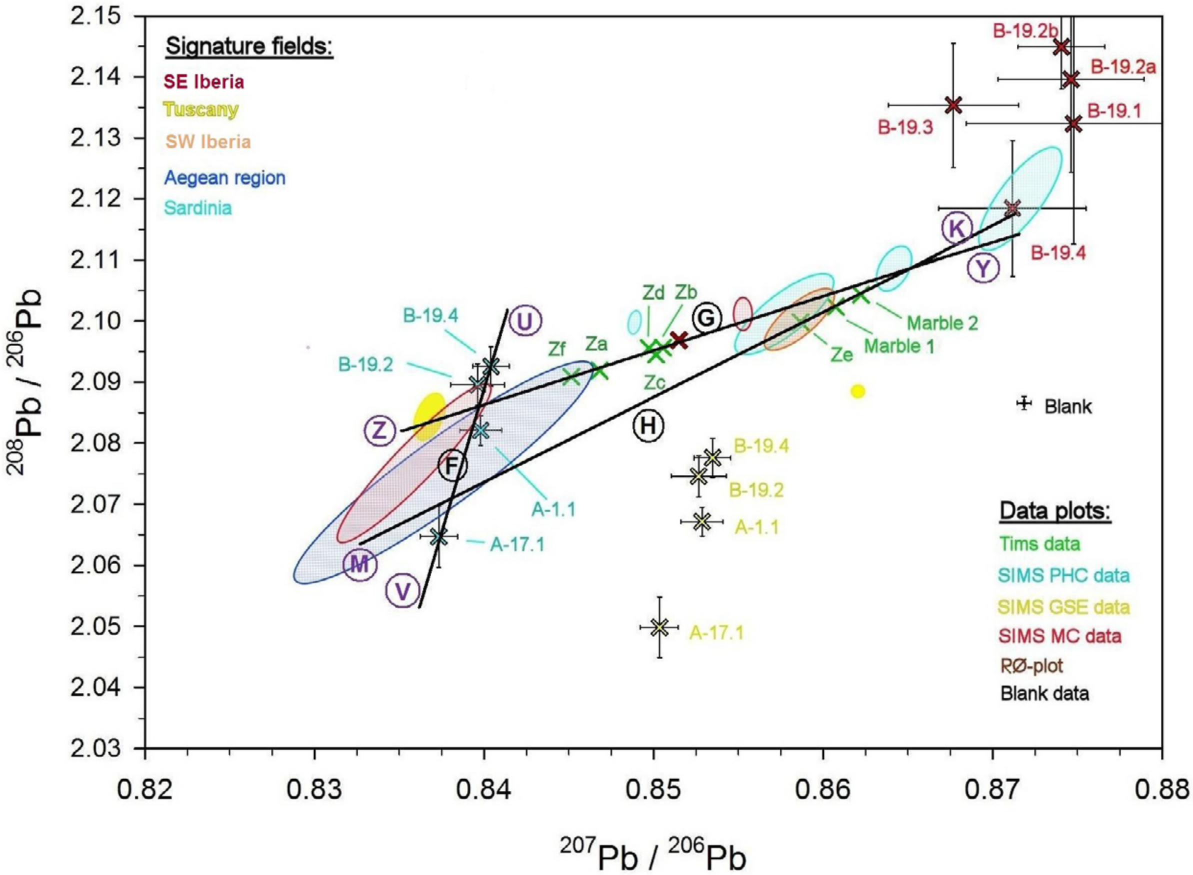


Fig. 10: Data from the sims and tims analyses plotted in a $^{208}Pb/^{206}Pb$ vs $^{207}Pb/^{206}Pb$ diagram. sims data plots are presented with 2σ error bars. Error bars for tims data are not shown as the standard deviation values are insignificantly small. RØ data plot is taken from Rosing & Østergaard, 2009. In this diagram the sims and tims data is compared to lead isotopic signature fields for five regions that are suspected to be the most likely candidates for lead source provenance: SE Iberia, Tuscany, SW Iberia, the Aegean region (including Greece) and Sardinia. These regions have been selected on the basis of literary sources on Roman mining practices and modern archaeometric studies. Data plots are shown as X'es, while signature fields are shown as ellipses. Data plots and signature fields are distinguished by different colours, which are explained in the legends. Suggested binary mixing lines (F, G and H) mentioned in discussion sections are shown. Lead sources (U, Z, V, M, K and Y) mentioned in discussion sections are represented by purple letters. Please note that terminations of the mixing lines and the position of the purple lead source letters/circles do not indicate suspected positions of lead source isotopic compositions.

marble constituted a significant portion of the sampling fields, and as a lot of pigment was burned away during the initial monocollector measurements, marble lead could have influenced the lead isotopic compositions obtained from these measurements. This despite the generally low lead concentrations in marble (~20 ppm).

Lead from Greek marble should plot within the isotopic signature field for the Aegean region. This allows for a linear binary mixing line (F) between two end-members U and V, where U appears to represent a SE Iberian lead ore, whereas V could represent Greek marble. This scenario also allows for a reinterpretation of the TIMS data, which can be divided into two separate groups: Facial samples Zf, Za, Zd, Zc and Zb containing mixtures of lead sources Z and Y, and hair samples Ze, Marble 1 and Marble 2 containing mixtures of lead sources M and K. In this scenario the total number of lead sources can be narrowed down to three, with intersections between mixing lines representing the approximate isotopic composition of each lead source, so that:

- The intersection between mixing lines G and H represents a Sardinian lead ore (K/Y)
- The intersection between mixing lines F and G represents a SE Iberian lead ore (U/Z); probably mined at Nova Carthago/Mazzarón
- The intersection between mixing lines F and H represents lead from Greek marble (M/V)

In this provenance scenario pigments from facial areas contain two different lead sources, K/Y and U/Z, whereas pigments from hair areas contain just lead source K/Y. If the idea of different parts of the sculpture being intentionally painted with different pigments for polychromic variation is applied to this scenario, then lead source K/Y would be represented by red lead pigments, as colour traces from both face and hair are reddish brown. Lead source U/Z could then be represented by a different type of lead pigment.

One problem with this interpretation is the position of hair sample plots Ze, Marble 1 and Marble 2 along mixing line H. The marble samples have higher participations of the Sardinian lead source (K/Y), and lesser participation of the marble lead (M/V) compared to sample Ze. This is not in line with notion that sample Ze should contain much more red lead and less marble than the marble samples. Another problem is the position of the PHC SIMS data, which only indicates the presence of lead source U/Z in the samples, whereas lead source K/Y is absent. This is not in line with the TIMS data, which state that both lead sources are present in the lead pigments. Please note here that TIMS samples Zf and Zd were collected from the same locations as SIMS samples A and B, respectively, and thus should be comparable. The non-presence of lead source K/Y could be due to one of the following reasons:

- The PHC SIMS data is invalid. Each grain cluster contains both lead sources and the true lead isotopic composition of each grain cluster should plot along mixing line E
- The PHC SIMS data is valid, but as only lead source U/Z is detected in the measurements, the two lead sources have not been mixed thoroughly, so that each grain cluster (or at least the examined grain clusters) contains just one lead source. This also implies that the two lead sources were not mixed in a smelting process, as this would have homogenised lead isotopic compositions throughout the pigments. The absence of lead source K/Y is thus a statistical anomaly due to the low number of analysed grain clusters

Unfortunately, as the SIMS data cannot be considered accurate they have been left out of the final provenance interpretations.

LEAD ORIGINS AND INDUSTRIAL PROCESSING

It has been attempted to determine specific pigments and lead source provenance on the basis of the TIMS data, the accessory mineral content and previous literature on ancient metallurgical techniques.

LEAD SOURCE A

Lead source A is believed to be Betic Zone Ore Group 2 (see Fig. 9). These ores consist of Pb-Zn-Fe-Ag-(Ba-Cu-Sn-Sb) vein deposits. At first glance this is in line with the presence of Ba-, Zn- and Fe minerals in the colour traces. However, Cu-, Sn-, Sb- and Ag minerals were not detected during EDS analysis.

Litharge and minium produced through silver extraction would probably contain Cu-, Sn- and Sb phases, while Ba-, Zn- and Fe minerals would be concentrated in slag. Litharge and minium produced through lead ore roasting could come with a number of accessory minerals, depending on the mineralogical composition of the lead ore. As such, if Betic Zone Ore Group 2 is represented by minium produced from lead ore roasting, then the presence of Ba-, Zn-, Fe phases but absence of Cu-, Sn-, Sb- and Ag phases from the colour traces could be explained as either:

- The roasting process or a different type of post-productional refinement process removed Cu-, Sn-, Sb- and Ag phases, while preserving Ba-, Zn- and Fe phases. This seems highly unlikely
- Cu-, Sn-, Sb- and Ag phases were not present in the particular ore used to produce this minium. Pb-, Ba- and Zn- minerals are often found coherently in ore deposits, so this is not entirely unlikely
- The Ba-, Zn- and Fe- phases stem from an altogether different source, such as repainting, environmental contamination, etc., as discussed in an earlier section. However, a repainting scenario has been ruled out, and environmental contamination of the mentioned phases cannot really be determined

Neither of these scenarios seem particularly plausible, so it appears to be more likely that the Ba-, Zn- and Fe phases originate from lead source B. The absence of Cu-, Sn-, Sb- and Ag phases in the colour traces suggests that the pigment originating from this source was produced from high quality metallic lead, produced by direct smelting. The pigment could be red lead or a different type of pigment.

LEAD SOURCE B

According to the TIMS data, lead source B should be located in SW Iberia or Sardinia. A possible origin of lead source B could be typical Pb-Zn-Ba-F ore deposits, which are commonly found in hydrothermal sulphide ore systems (Cook & Kirk, 2007) such as is found in SW Iberia. However, lead production during the 1st century BCE was in both SW Iberia and Sardinia tied to the exploitation of argentiferous ores. Potential Pb-Zn-Ba-F deposits may not have received any interest unless they also contained high concentrations of silver. If lead was mined from such deposits it would most likely be for the purpose of applying the lead to silver extraction. As mentioned, Ba-, Zn- and Fe minerals would not have alloyed with litharge during silver extraction, and so if these minerals originate from lead source B, silver extraction was not involved.

If Pb-Zn-Ba-F ores from these regions were subjected to just roasting, then it is possible that Ba-S- and Zn-S minerals could have been carried over into a produced litharge/minium.

Sphalerite ([Fe, Zn]S), which is a typical zinc mineral in these types of deposits, requires temperatures of ~800°C under oxidising conditions in order to convert to sulfur dioxide (SO_2) and zincite (ZnO), and would thus have been decomposed by roasting temperatures (Kopp & Kerr, 1958). Barium is probably concentrated in barite, which is also known to be thermally stable. Fluorine is probably concentrated in fluorite (CaF_2). Fluorine cannot be detected by EDS analysis and calcium is obviously everywhere in the sample due to the abundance of marble. As such, it would probably not be possible to distinguish fluorite from calcite on the basis of the applied methods. This thus seems like a likely scenario to explain the presence of Ba-S- and Zn-S in the colour traces.

LEAD SOURCE C

A lead provenance scenario that has not been mentioned yet involves SE Iberian Ore Group 1 (see Fig. 9), whose lead isotopic compositions is intersected by both mixing line E in Fig. 8 and mixing line G in Fig. 10. In Fig. 8, this ore group is marked as lead source C. Lead source C could represent the higher radiogenic end-member of mixing line E, effectively replacing lead source B for facial samples. In this scenario, lead pigments from facial areas would thus contain mixtures of lead sources A and C, whereas lead pigments in hair areas contain lead source B.

SE Iberian Ore Group 1 are F-Pb-Zn-(Ba) deposits that consist mainly of fluorite, galena (PbS), sphalerite and pyrite (FeS_2) (Arribas & Tosdal, 1994). A barium compound, most likely barite, can also be found. Roasting of these ores would follow the same rationale as the Pb-Zn-Ba-F ore deposits mentioned in the previous section. Also, pyrite could have been weathered into haematite (Fe_2O_3), which would explain the iron compound detected during EDS analysis.

SE Iberian Ore Group 1 belongs to the Alpujárride tectonostratigraphic complex, which can be found in several locations in SE Iberia; one of which is Nova Carthago. Thus, in this scenario all lead in facial pigments could originate from Nova Carthago (lead sources A & C), whereas the lead in hair pigments most likely would have a Sardinian and/or SW Iberian origin (lead source B)

What speaks against this scenario is that it would be peculiar if facial and hair areas contained pigments from completely different lead sources. Another slight problem is that this interpretation does not fit well with the data from Walton & Trentelman, 2009, as two of the WT-plots have a higher lead isotopic ratio than the field for SE Iberian Ore Group 1 (see Fig. 8). Thus, the lead pigments from the Zeus head and the Egyptian red-shroud mummies would not have identical origins.

CONCLUSIONS

Unfortunately this study cannot present finite conclusions on the provenance of the involved lead sources and the industrial processes involved in manufacturing the pigments. The study was subject to some of the problems typically encountered during lead isotope analysis, as the lead isotopic data is ambiguous in terms of lead provenances. Interpretations are subject to several uncertainties, such as the validity of SIMS data from easily degradable materials, the reliability of historical sources, overlap of lead isotope signatures, the possible influence from marble lead on the lead isotopic data, and limitations to the analytical methods.

However, the TIMS data strongly suggests that only two lead sources, A and B, can account for all the lead in the examined pigments. Based on comparisons to previous studies it is likely that the geological origin of lead source A is lead ores located within the Betic Zone in SE Spain; more specifically the ancient mining sites of Nova Carthago and/or Mazzarón. Lead source B most likely originates from lead ores located on Sardinia or in the Iberian Pyrite Belt in SW Iberia. A third lead source, C, located in the Betic Zone may or may not be involved.

As is often the case with lead isotopic data, the TIMS data can be interpreted differently: In one scenario, all lead pigments on the Zeus sculpture contain mixtures of lead sources A and B. In a different scenario, facial pigments contain mixtures of lead sources A and B, whereas hair pigments contain only lead source B. In a third scenario, facial pigments contain mixtures of lead sources A and C (two different Nova Carthago ore deposits), whereas hair pigments contain only lead source B.

There is no definitive explanation for the presence of Ba-, Zn- and Fe phases in the colour traces. If one is to believe the scenario suggested by Rosing & Østergaard, 2009, where silver refinement is involved, then these phases do not originate from one of the involved ores, as Ba-, Zn- and Fe phases would have been concentrated in slag during silver refinement. At first glance, it appears likely that they could be derived from a form of repainting, which would have taken place at some point during the past 130 years or so. The Ba-S-, Zn-S-, Fe phases, as well as a mushy Ba-S – ZnS – Ca-cluster, are found on both the Zeus head samples and the Amazon warrior sample, which could indicate that such repainting, which could have been done for maintenance purposes in order to protect the original colouring, was performed on several of the sculptures at the New Carlsberg Glyptotek. However, such repainting has been ruled out by museum staff. The Ba-S-, Zn-S-, Fe phases could also be contaminants derived from environmental factors, pigment preparation tools, the marble substrate or the likes.

It seems more likely, however, that silver refinement was not involved in the production of the lead pigments, as the Ba-S-, Zn-S-, and Fe phases could then originate from the ore from which the lead was mined. A possible origin could be Sardinian or SW Iberian Pb-Zn-Ba-F ore deposits (lead source B), which are commonly found in hydrothermal sulphide ore systems, or from the F-Pb-Zn-(Ba) deposits found in SE Iberia (lead source C). By submitting one of these ores to roasting temperatures, lower than 500°C, in an oxidising environment litharge could be produced, which could then be reprocessed to minium. Lead source A would then likely be represented by a lead pigment produced from high quality metallic lead. This pigment can be either red lead or a different pigment.

The TIMS data can probably be divided into three groups based on sampling locations: facial hair, tissue and hair. Within each of these groups samples have similar lead isotopic compositions. Each group can be perceived as coming from a separate paint batch or mixture. The relationship between compositions and sampling areas may be a sign of intent on behalf of the painter. Different lead pigments, such as red lead and lead white, may have been added in different quantities to each batch in order to obtain different colours and thus vary the polychromy. If all lead is represented by lead sources A and B, then the red lead pigments probably contain lead source B, whereas the other lead pigment contains lead source A.

Further analyses of the lead pigments could no doubt narrow down the number of possible provenance scenarios. If more sampling material was acquired from both facial and hair areas, then perhaps larger aggregations of lead-bearing grains could be found. This could allow for WDS analysis, which could identify specific mineralogical compounds, and hopefully more accurate SIMS measurements. Better sampling techniques and precise estimates of lead concentrations in colour traces and marble could also shed light on some unanswered questions. Once such analyses have narrowed down the number of likely lead origins, field investigations at the mining sites of suspected lead sources could provide the last bit of information required to identify specific lead origins.

ACKNOWLEDGEMENTS

I would like to acknowledge the following people for their contributions to the Masters Project:

- Main academic advisor on this project, Professor Minik T. Rosing from Statens Naturhistoriske Museum, Copenhagen and Nordic Center for Earth Evolution (NordCEE), Copenhagen, for presenting this interesting project and for his generous assistance
- Co-advisor Jan Stubbe Østergaard, research curator at the Ny Carlsberg Glyptotek and project coordinator for the Copenhagen Polychromy Network, for making this project possible and for his generous assistance
- Co-advisor Tod E. Waight, Research Associate Professor at the Institute of Geography and Geology, University of Copenhagen, for providing ideas and generous assistance
- Martin Whitehouse, Senior Research Fellow at the Swedish Museum of Natural History, Stockholm, for his generous assistance with the SIMS analysis

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Der Blick in eingelegte Augen: Griechische und römische Skulpturen der Ny Carlsberg Glyptotek

Verena Viktoria Hoft[1]

ABSTRACT

In this article the first results of my investigation of inlaid eyes are given. That this technique is an aspect of polychromy has so far never been discussed thoroughly. To find out more about the antique techniques, I investigated the eye cavities for inlay of 22 sculptures in the collections of the Ny Carlsberg Glyptotek, described them and made detailed photographic documentation. In a datasheet I collected the archaeological evidence, which will be part of a database. These Greek and Roman sculptures demonstrate that there are different shapes of eye cavities. Up to now there are three diverse forms distinguishable: first, the inner surfaces taper to a V-shape, second, the eye cavities are almond-shaped and like a cylinder at the rear and lastly, forms which seem to be random without a clear, identifiable shape. Further research is necessary to better understand the liveliness and vitality of the visual appearance of inlaid eyes, their context and the technical aspects involved.

KEYWORDS

Polychromy, inlaid eyes, Greek and Roman sculpture

In den letzten Jahrzehnten ist die polychrome Gestaltung antiker Skulpturen erneut intensiv erforscht worden[2]. Dass auch die Technik eingelegter Augen als ein Aspekt der Polychromie verstanden werden muss, wurde bis dato jedoch nicht genauer herausgearbeitet. Die Erscheinung der Augen trägt aber zu einem ganz wesentlichen Teil der visuellen Präsenz einer Skulptur bei. Durch nähere Untersuchung der Einlegetechniken können weitere Aufschlüsse über die künstlich geschaffene Lebendigkeit und deren Bedeutung in der Antike erzielt werden.

Um die aufgeworfenen Fragen zu untersuchen, entstand im Frühjahr 2013 im Rahmen eines Praktikums die erste dokumentarische Erfassung aller 22 Steinskulpturen der Ny Carlsberg Glyptotek in Kopenhagen in einem Katalog. Es handelt sich um Skulpturen, bei denen die Augen aus unterschiedlichen Materialien eingelegt wurden. Ziel war es, den gesamten Bestand aufzunehmen, um einen Überblick über das vorhandene Material zu erhalten, zunächst ungeachtet seiner chronologischen Verteilung und Provenienz.

Eine erste kurze allgemeine Zusammenstellung von Steinskulpturen mit eingelegten Augen, vor allem in der Idealplastik, lieferte Brigitte Freyer-Schauenburg 1983[3]. Ferner haben

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1 Verena Viktoria Hoft B.A. Universität Hamburg.

2 U. a. durch Beteiligte des Tracking Colour-Projekts in Kopenhagen siehe http://www.trackingcolour.com, sowie Brinkmann 2003, Bourgeois/Jockey 2005, Brinkmann et al (Hrsg.) 2010, Blume 2010.

3 Ihrer Ansicht nach sei diese Technik vor allem in der römischen Idealplastik verwendet worden, und nur selten bei Porträts, vgl. Freyer-Schauenburg 1983, 130 f.

zuletzt Götz Lahusen und Edilberto Formigli auf die verschiedenen Techniken der Augenkonzeption bei Bronzeskulpturen hingewiesen[4]. Keine Arbeit zeigt jedoch umfassend die Charakteristika der Herstellung, die zeitliche oder regionale Verbreitungen sowie die Bedeutung der Technik für die Skulptur.

Im Folgenden möchte ich meine Vorgehensweise und einen Auszug der ersten Ergebnisse an drei Beispielen vorstellen[5].

DATENBLATT

Da die Autopsie und Dokumentation der Objekte bei dieser Bearbeitung von größter Bedeutung sind, wurde wie folgt gearbeitet. Nach erster Sichtung des Materials wurde ein Datenblatt zur Erfassung der wesentlichen Informationen entworfen. Dabei mussten alle eventuell nützlichen Kriterien zur weiteren Bearbeitung sowie schon vorhandene Informationen für spätere Untersuchungen zusammengetragen werden.

Der Aufbau erfolgte zunächst nach einem naheliegenden Schema eines Datenblattes für Skulpturen[6]. Beginnend mit den Grundinformationen, schließt sich der Teilabschnitt, in dem die gesamte Skulptur erfasst wurde, an. Dieser geht unter anderem auf Aspekte der Polychromie ein[7]. Jene Informationen wurden teils der Literatur entnommen und am Objekt in direkter Autopsie überprüft[8].

In dem darauf folgenden Abschnitt des Datenblattes erfolgen die Daten zur Erfassung der Augen[9]. Da in den bisherigen Veröffentlichungen zu den betreffenden Stücken lediglich auf die Existenz der Technik der Augeneinlage hingewiesen wird, konnten keine älteren und spezifischen Beobachtungen eingefügt werden[10]. Alle eingetragenen Ergebnisse stammen demnach aus eigenen Beobachtungen. Explizit soll hier der Punkt der Beschreibung der Morphologie der Augenhöhle erwähnt werden. Nach den ersten Untersuchungen konnten verschiedene Formen identifiziert werden. Daher ist die Dokumentation dieses Bereiches besonders wichtig und könnte für weitere Forschungen entscheidend sein.

Bisher zeichnen sich drei markante Gruppen ab: spitz nach hinten zulaufende, in V-Form angeordnete Innenwände der Augenhöhle, eine mandelförmige, nach hinten versetzte Rückwand, sowie ohne erkennbares Muster ausgearbeitete Augenhöhlen.

4 Formigli – Lahusen 2001, 462-470.

5 Die vorliegenden Untersuchungen sind Bestandteil meiner Masterarbeit, die 2014 in Hamburg vorgelegt werden soll.

6 Katalognummer, Inventarnummer, Betitelung des Objekts in den verschiedenen Sprachen, Kategorie der Plastik, Datierung, Künstlerzuweisung, Typus, Original/Kopie, Provenienz, Aufbewahrungsort im Museum, Fundort, Erworben von/ Datum und Ort.

7 Neben den Maßen und Restaurierungszustand wurden Material und deren Provenienz, Spuren von Farbe, Erhaltungszustand, Bearbeitungsspuren des Herstellungsprozesses sowie die genaue Beschreibung von eventuellen Metallanfügungen von Schmuck in Datenblatt aufgenommen.

8 Im Rahmen des Tracking Colour Projektes wurden bis dato drei der bearbeiteten Objekte in die online Liste aufgenommen. Siehe: http://www.trackingcolour.com/objects/34, http://www.trackingcolour.com/objects/51 sowie http://www.trackingcolour.com/objects/28

9 Aufgenommen wurden die Maße, Morphologie der Augenhöhle, verwendetes Material der Einsatzstücke und deren Provenienz, Erhaltungszustand und Beschreibung, Spuren von Farbe und Beschreibung der Technik, sofern sie noch vorhanden und erkennbar war.

10 Meistens wurde die Technik nur mit den Worten „eingelegte Augen/ inlaid eyes“ vermerkt und auf keine weiteren Details eingegangen. Eine für diese Fragen sehr hilfreiche fotografische Dokumentation liefert Sande 1992, die detaillierte Fotos der Augenhöhlen vorgelegt hat.

Im letzten Abschnitt des Datenblattes wurden Vergleichsstücke und Literatur zu dem Objekt vermerkt[11].

METHODIK

Um weiterführende Ergebnisse zu den Techniken der Herstellung zu erlangen, wurden folgende Dokumentationen durchgeführt. Es erfolgten Detailaufnahmen mit einer handelsüblichen Kamera sowie Fotos mit einem digitalen Videomikroskop[12]. Mithilfe dieses Mikroskops konnten zahlreiche neue Beobachtungen gewonnen werden, die sich für die Analyse der genauen Technik der Augeneinlagen als sehr aussagekräftig erwiesen. Die hochauflösenden Bilder ermöglichten u.a. Rückschlüsse auf Werkzeugspuren, wie Reste von Bohrlöchern, und Klebematerialien. Zusätzlich war es teilweise möglich, die für die Einlagen verwendeten Materialien zu bestimmen. Ferner wurden Methoden wie Untersuchung mit UV-Licht und Infrarot[13] an einem Beispiel exemplarisch angewandt[14].

DREI FALLBEISPIELE

Im Folgenden sollen die Untersuchungsergebnisse an Beispielen genauer dargestellt werden, um einen Einblick in die Vielfallt der Techniken und Erhaltungsstadien zu veranschaulichen. Dabei stellen diese Exemplare nur einen kleinen Ausschnitt und die potentielle Vielfältigkeit der unterschiedlichen, im Einzelfall nachzuweisenden Techniken dar.

LÖWE IN 2448

Eines der frühesten Stücke innerhalb der bearbeiteten Gruppe ist die Skulptur eines Löwen[15] in geduckter Haltung (Abb. 1)[16]. Es handelt sich dabei um eine Grabskulptur[17], die von der Forschung in die Zeit um ca. 330. v. Chr. datiert wird[18]. Die Skulptur weist einige Beschädigungen auf, so sind die Hinterläufe und die Plinthe abgebrochen. Zusätzlich finden sich auf der Oberfläche Beschädigungen, wie Bestoßungen und Abschürfungen. Antike Farbreste konnten bis dato nicht festgestellt werden. Im Folgenden soll nun genauer auf die Augen eingegangen werden.

Die Skulptur ist insofern sehr interessant, da im linken Auge der eingesetzte Augapfel noch vorhanden ist (Abb. 2). An dieser Seite finden sich jedoch auch etliche Beschädigungen, so sind Fragmente des Augenlids sowie Partien der Fassung für die Iris abgebrochen. Die Einlegearbeit scheint noch in situ vorzuliegen.

11 Dabei sind sowohl Vergleichsobjekte, anhand derer die gesamte Skulptur verglichen werden kann, als auch welche die nur einen Vergleich der Technik zulassen. Ferner wurde die entsprechende Literatur aufgelistet und Angaben zu Bearbeitungsdatum, Bearbeiter und Bemerkungen angeführt.

12 Dino-Lite Pro AM413FI2TA.

13 Brinkmann 2010, 16-19.

14 Bei dem Athletenkopf IN 455. An dieser Stelle meinen herzlichsten Dank für die Unterstützung und Hilfe an Maria Louise Sargent.

15 H.: 57, L.: 125 Weitere Literatur (Auswahl): Poulsen 1951, Kat. 238a; Willemsen 1959, 52, Taf. 61; Brown 1960, 150 Anm. 1 Nr. 9; Vermeule 1968, 100; Frel 1969, 42 Nr. 299; Vermeule 1972, 50, Anm. 2; Vedder 1985, 294 T 51.

16 Vedder nennt die Typen geduckt, hockend sowie stehend. Vedder 1985, Anm. 607; Moltesen 1995, 78-79.

17 Vedder 1985, T51.

18 Vgl. u. a. Vermeule 1968, 100; Moltesen 1995, 78.

Abb. 1: Gesamtansicht Löwe IN 2448.

Abb. 2: Detailaufnahme der Augen.

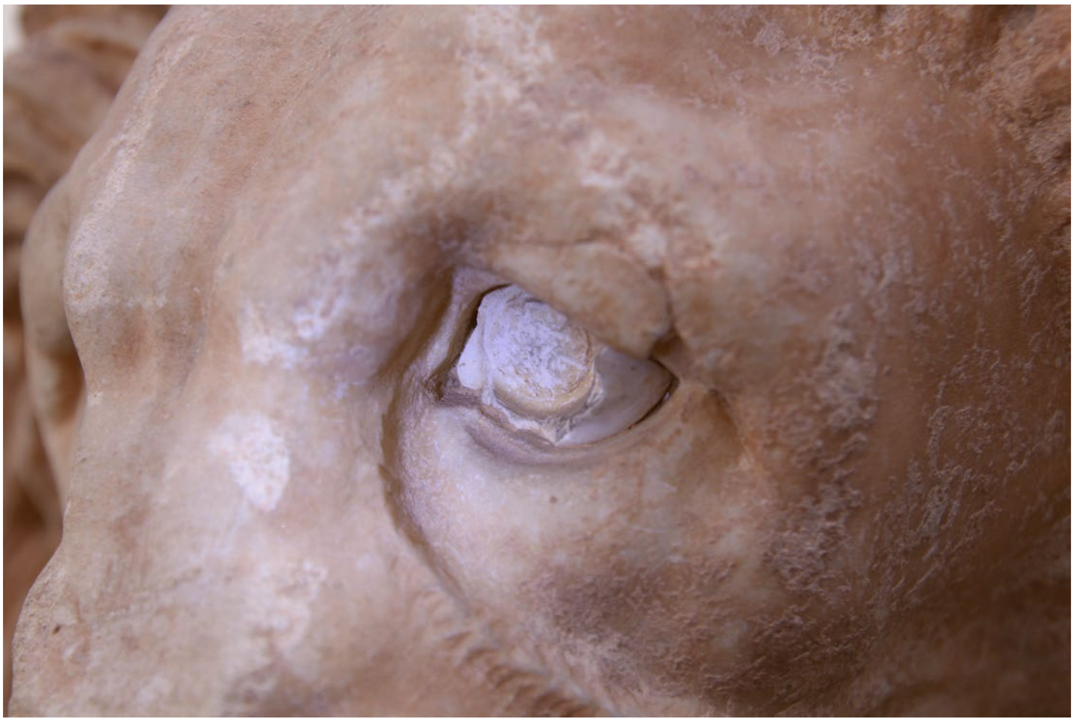

Abb. 3 und 4: Detailaufnahme des rechtes Auges: mit Einlagearbeit und Aussparung für die Iris und Pupille.

Bei dem Material handelt es sich laut Vedder[19] um eine Marmorpaste. Nicht mehr erhalten sind die aus einem gesonderten Material[20] gearbeitete Pupille und die Iris (Abb. 3 und 4). So müssen Details wie Farbgebung und Material der einzelnen Augenelemente ungeklärt bleiben. Zur Fixierung dieser wurde mit einem großen Bohrkopf eine runde Vertiefung eingearbeitet, welche als Fassung diente. Klebematerial hat sich an dieser Stelle nicht erhalten, nur zwischen Augenhöhle und Augapfel lassen sich Klebereste nachweisen. Es handelt sich um eine beige-orange-farbene Substanz, deren Zusammensetzung noch nicht identifiziert werden konnte. Im Innenwinkel des Auges findet sich ein Bohrlochansatz sowie eine Aussparung im Augapfel, welche als Fassung für ein gesondert gearbeitetes Karunkel konzipiert worden sein könnte[21].

Rechts finden sich keine Beschädigungen an den Augenlidern, jedoch ist die Augenhöhle leer wodurch die Morphologie ersichtlich wird (Abb. 5 und 6). Die Vertiefung ist mandelförmig, nach hinten leicht verjüngend gearbeitet. Auffällig ist die Tiefe der Augenhöhle[22] sowie die präzise Ausarbeitung der Form. Werkzeugspuren sind jedoch deutlich zu erkennen, so ist die Rückseite grober bearbeitet als die Seitenwände. Bohrlöcher sind nicht sichtbar, lediglich im Innenwinkel des Auges findet sich eine Vorbohrung[23].

ATHLET IN 455

Bei dem zweiten Beispiel handelt es sich um einen Jünglingskopf mit Binde, der von M. Moltesen als Athletenkopf identifiziert wurde (Abb. 7)[24]. Der Hals ist bis zum Schlüsselbein erhalten. Die untere Hälfte der Nase fehlt fast vollständig, weiterhin weist die Oberfläche des Gesichts einige Beschädigungen auf. Hinterkopf und Nacken sind mit Ablagerungen überzogen (Abb. 8).

Beide Augeneinlagen sind vorhanden, jedoch nur auf der rechten Seite noch in situ (Abb. 9 und 10). Das linke Auge wurde Anfang der 80er Jahre im Zuge einer Untersuchung zum Klebematerial im Getty-Museum in Malibu entnommen. Dabei wurde überprüft, ob es sich bei der Skulptur um eine Fälschung handeln könnte (Abb. 11 und 12).[25] Detaillierte Untersuchungsberichte liegen nicht vor. Z. Barov und J. Frel äußerten sich bislang nur zur Authentizität des Kopfes, die sie nicht anzweifeln[26]. Die Einlage auf der linken Seite weist einige Zerstörungen auf[27], so ist die Oberfläche der Iris teils abgesplittert und die Unterlidkante beschädigt.

Der Augapfel besteht aus weißem, großkristallinen Marmor und die Iris aus Obsidian[28]. Das schwarze Glas weist eine raue Oberfläche auf, die Vertiefung für die Einlage der Pupille wurde mit einem Bohrer gearbeitet. Deutlich sind die Drehrillen am Rand zu erkennen. Das Material der Pupille ist jedoch verloren gegangen.

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19 Vedder 1985, 294. Genaue naturwissenschaftliche Untersuchungsergebnisse liegen nicht vor.

20 Hierbei könnte es sich um ein anderes Material wie Glas oder andersfarbigen Stein handeln.

21 Vergleiche Louvre Ma2664. Die Technik der extern gearbeiteten Karunkel findet sich auch bei Bronzeskulpturen. Siehe Lahusen – Formigli 2005, 462.

22 Tiefe: von 2,2–2,8 cm. Kein anderes Objekt aus dieser Untersuchung weist vergleichbar tiefe Augenhöhlen auf.

23 Als Vorbohrung sollen Bohrlöcher verstanden werden, die zum Beispiel an den Augenwinkeln platziert wurden um die maximale Außenpunkte des Auges zu markieren.

24 H.:23 cm. Weitere Literatur: Poulsen 1951, Kat. 117; Frel 1982, 24, Anm. 24; Lehmann 1980, 115-116, Anm. 31; Barov - Frel 1981, 108-109; Moltesen 2000, 185, Nr. 15 Abb. 8; Moltesen 2005, 310-311.

25 Lehmann 1980, 115-116.

26 Barov – Frel 1981, 108-109.

27 Die Dokumentation der Untersuchungen im Getty Museum lag mir nicht vor.

28 Obsidian: Jan Stubbe Østergaard und Maria Louise Sargent. Diorite: Moltensen 2005, 310.

Abb. 5 und 6: Detailaufnahme des linken Auges: leere Augenhöhle mit erkennbarer Morphologie.

Abb. 7:
Frontalansicht des
Kopfes IN 455.

Abb. 8: Rückansicht mit deutlichen Ablagerungen.

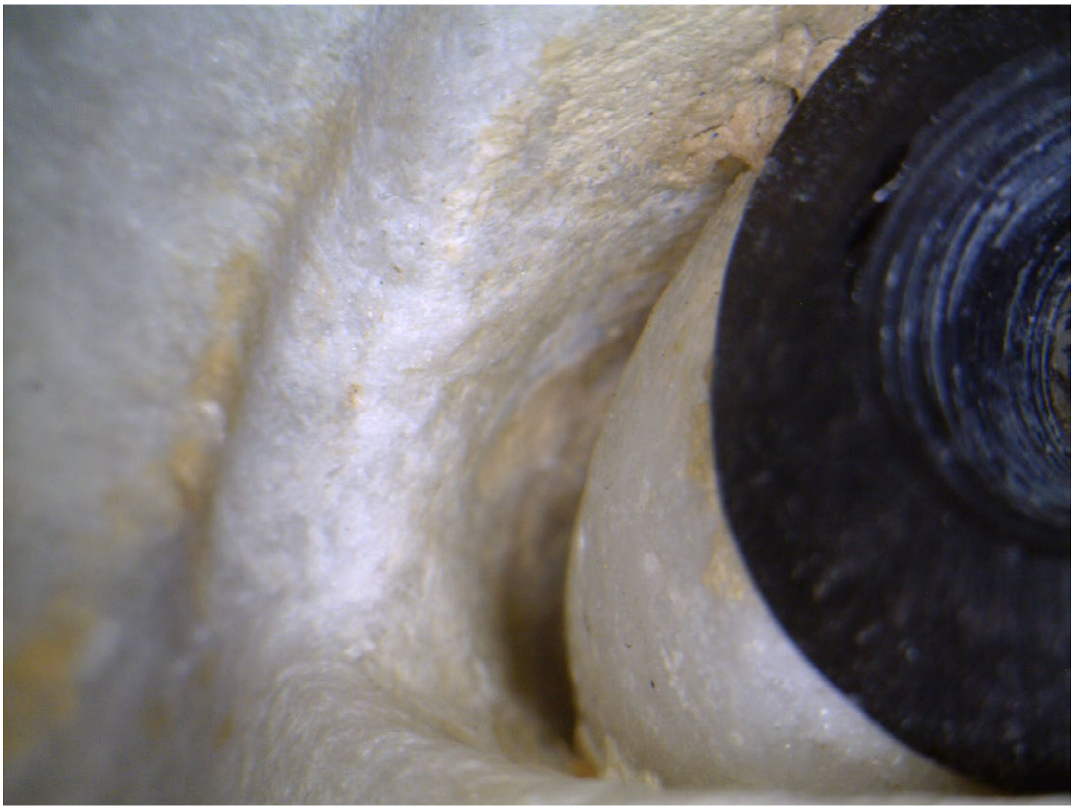

Abb. 9 und 10: Mikroskopaufnahmen der Augen. Rechtes Auge: In situ mit Drehrillenspuren an der Iris und Klebematerial.

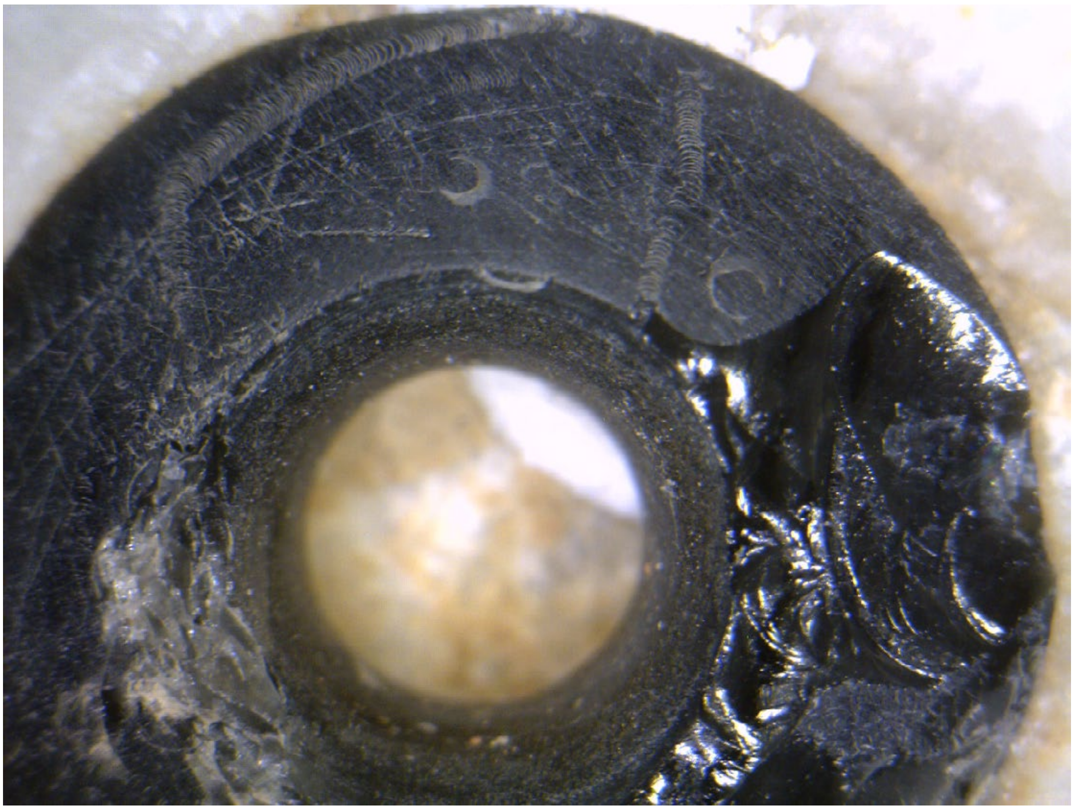

Abb. 11 und 12: Mikroskopaufnahmen der Augen. Linkes Auge: Beschädigte Iris und weiße moderne Gipsreste.

Die Einlegearbeit sitzt relativ tief in der Augenhöhle, wobei der Obsidian der Iris nicht bündig eingearbeitet wurde. Morphologie und Bearbeitungstechniken der Augenhöhlen sind in diesem Zustand nicht zu erkennen.

TISCHBEIN IN 1609

Ein weiteres Beispiel für die Einlegetechnik von Augen stellt ein Tischbein in Form eines stehenden Satyrs dar (Abb. 13)[29]. Der Stützfigur fehlen beide Arme ab der Schulter, der Phallus sowie die Unterschenkel. Letztere wurden für die Aufstellung inklusive der Stützsäule ergänzt. Auch die Oberfläche des Objekts weist einige Beschädigungen auf, vor allem im Gesicht und an den Haaren. An der rechten Hüfte des Satyrs sind deutliche Werkzeugspuren zu erkennen sowie ein Dübelloch mit Metallkorrosionsspuren (Abb. 14).

Die Augen weisen heute keine Einlagen mehr auf, die Augenhöhlen sind leer (Abb. 15 und 16). Auffällig beschädigt ist die rechte Oberlidkante. Die Morphologie der Augenhöhle ist nicht genauer definiert, es ist keine klare Form zu erkennen, jedoch zeigen sich deutliche Werkzeugspuren. Weitere Indizien, welche auf die Technik der Einlage verweisen könnten, wie Reste von Klebematerial, sind nicht erhalten.

An den Rückseiten der Vertiefungen lässt sich je eine tiefe Bohrung auf der linken Seite erkennen. In dem linken Auge befindet sie sich so weit in den Augenwinkeln, dass nur noch wenig Steinmaterial zwischen Bohrloch und äußerer Oberfläche vorhanden ist. Das Objekt muss, nachdem die originalen Einlagen mit einem Werkzeug, das die Schäden an der rechten Oberlidkante verursachte, bearbeitet worden sein.

Aufgrund der ungewöhnlichen Gestaltung und Positionierung der Bohrungen wäre es auch denkbar, dass man in einer späteren Nutzung diese Bohrungen als Pupillenangaben gesehen hat. Position und eine auffällige Blickrichtung scheinen dafür zu sprechen (Abb. 17).

ERGEBNISSE UND AUSBLICK

Folgende vorläufige Ergebnisse zeichnen sich durch die vorgenommenen Untersuchungen ab: Die Morphologie der Augenhöhle kann potentiell in Gruppen eingeteilt werden. Ferner könnte die Form Hinweise auf die verwendete Technik geben. Dazu sind allerdings noch weitere Untersuchungen und Forschungen an möglichst zahlreichen Objekten vorzunehmen, die in diesem Rahmen nicht geleistet werden konnte.

An dem Athletenkopf wird vor allem deutlich, welch ein natürlicher und lebendiger Eindruck durch Verwendung der Intarsientechnik entstehen kann (Abb. 18). Inwiefern eine polychrome Fassung eine Bedingung für Skulpturen mit eingelegten Augen ist, was diese Lebendigkeit für die Aussage einer Statue und ihren Kontext, sowohl räumlich als auch visuell bedeutet, soll in weiteren Forschungen untersucht werden.

Die Untersuchung der 22 Objekte der Ny Carlsberg Glyptotek stellt erst den Anfang dar. Im Folgenden soll in zeitlicher und regionaler Differenzierung die Verbreitung der unterschiedlichen Techniken detaillierter untersucht werden. Dies kann nur durch eine erste Aufnahme des Materials und exakte Dokumentationen erfolgen, um Besonderheiten und Verbreitung zu erfassen. Eine Datenbank für den einen großen Überblick über das gesamte Material ist bereits in Arbeit. Anhand dieser Sammlung können nun neue Strategien zur Bearbeitung des Themas entwickelt werden.

29 H.: 1,0m (restauriert) Weitere Literatur: Poulsen 1951, Kat. 498; Dayan 1981, 8; Moss 1988, 403, A 18; Østergaard 1996, 210-211. Literatur zu Vergleichsbeispielen: Berger 1963, 74, A 22; Kapossy 1969, 69, Anm. 2; Schmidt-Colinet 1977, Anm. 263; Dayan 1981, 8; Koppel 1985, 106, Anm. 1.2.

Abb. 13: Frontalansicht des Tischbeines IN 1609.

Abb. 14: Detailaufnahme der Hüfte.

Abb. 15 und 16: Rechtes und linkes Auge: Morphologie und Bohrloch am seitlichen Rand.

Abb. 17:
Detailansicht des Gesichtes.

Abb. 18:
Jünglingskopf IN 455 mit eingelegtenen Augen noch in situ erhalten und so den lebendigen Ausdruck, der einer Statue durch diese Technik verliehen wird, anschaulich verdeutlicht.

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Ten years of studies in ancient sculptural polychromy revisited

Mikkel Scharff[1]

As part of the preparation for the 2004 exhibition "ClassiColor" at the Ny Carlsberg Glyptotek[2] a pilot project was initiated consisting of examination, analysis and documentation of the assumed original polychromy on one of the Greek sculptures the Glyptotek, a Female Head (IN 2830) (Fig. 1). As described elsewhere[3], there were several reasons for instigating the project. The plan was to use the head as a test case for examination and analyses, as well as for documentation methods, in order to establish a methodology and protocol for further examination, analyses and documentation of a larger number of objects in the collection. At the same time the pilot project and the preliminary result of this was to be presented at the "ClassiColor" exhibition as a showcase. Another reason for planning for a further examination was to establish a more solid ground for the interpretation of results to come from the analytical data: since only in a limited number of cases the exact provenance of the objects were known there was in fact very limited information available on the condition and appearance of the many sculptures at the time of their excavation. As long as the immediate appearance, including possible original or later polychromy, upon excavation, was not known it would be difficult if not impossible to interpret correctly the fragments of polychromy regularly observed on antique sculptures in various collections including in the Glyptotek. However – and as a personal interest and hypothesis – clues may be gained from technical comparison with an area of sculptural polychromy rather well investigated and known to me: medieval, European polychromy.[4] The latter could be compared with an area of common interest between art historians, conservators and conservation scientists, the emerging interdisciplinary research area "technical art history".[5]

At the time of beginning the pilot project only a very limited number of examinations and analysis had been performed and only by a few persons, primarily a group around Vinzenz Brinkmann.[6] Brinkmann and his group consisted among others of archaeologists, conservations scientists performing various analytical and documentation techniques, and experimental archaeologists producing replicas of the assumed original appearance of some of the examined sculptures. Remarkable results have been obtained from multispectral examination and documentation – previously un-seen areas of paint and patterns were revealed, reconstructed on replicas of the original sculptures and the results disseminated in exhibitions and publications. "Classicolor" was in fact a Danish version of the 'Bunte Götter' exhibition which disseminated the results of many years of research and documentation by the Brinkmann group.[7]

1 Head of School, assoc.prof., The School of Conservation, The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation.

2 Nielsen – Østergaard 2004.

3 Scharff et al. 2009, p. 13-16.

4 Cf. Sauerberg et al. 2009 and Heritage 2012.

5 See for example Ainsworth 2005

6 Brinkmann 2010.

7 The latest version is Brinkmann – Scholl 2010.

Fig. 1: Ny Carlsberg Glyptotek in 2830.

When the pilot project began we tried to establish an overview of what – from the technical point of view – was known about the polychromy by then, and what not, and to establish which means of investigation and documentation had been used so far and with what results. Jan Stubbe Østergaard provided the necessary background on what was known about polychromy from the antique authors as well as on the re-appraisal of antique sculptures in the renaissance of southern Europe, the excavations of the 17th and 18th century, Winckelmann and his influence and well as writings on the subject after Winckelmann and not least in the area of archaeology dealing with the European antiquity. Furthermore, interesting information was available as well on documentation of antique polychromy and traces of polychromy by various artists from the last couple of hundred years, typically in form of drawings and watercolours.[8]

On the other hand the number of publications on technical examinations, examination methodology and protocol, results of analyses and documentation was small, to say the least. A few scattered examples of technical analyses and documentation could be found, mostly on related items from Greek and Roman antiquity, but seldom sculptures. Greek and Roman wall paintings have been comparatively better examined and published and so has painted pottery. To what extent these latter results could be compared technically with the polychromy of sculptures remained unknown. And since the provenance of many of the items in collections established hundred years ago was unknown we could not be entirely sure that possible finds would in fact be applied originally to the sculptures or if the polychromy was a later phenomenon.

Finally we would ultimately like to be able to establish and document the polychromy – not least in order to be able to monitor the traces of polychromy over time as there was a suspicion that small traces of paint continuously came loose and fell off. If this could be established and documented, the results of a systematic analytical campaign could form the basis of a strategy of establishing better conditions for the sculptures and if necessary perform actual treatments on the sculptures in order to secure the fragile and loose paint flakes.

In short, we began the pilot project on a fairly vague basis concerning what to find and regarding the best practice of examination and documentation. During the preliminary work we were able – based on the first results – to propose a suitable way of photographic documentation and protocol using UltraViolet (UV) fluorescence, visible light and images of InfraRed (IR) reflected radiation. This was complimented by a minute description of the surface based on examination utilizing microscopes, raking light and studying and analyzing a few minute samples of the polychromy. The photographs did reveal hidden information on the application of colours in the eyes, and the paint samples revealed a hitherto unknown layer of paint in the face that could be interpreted as a ground layer and one or two layers of paint that should give the appearance of a skin color (Figs. 2–3). In order to remain skeptic concerning the results obtained we suggested a number or explanations. The traces of paint might be part of original paint layers, but then again there were no proof that it might not have been applied at a later stage. We continued examining a few more sculptures, began refining the photographic techniques, the written documentation and – in all – the protocol to be used in future examinations and analyses. At the same time, a proper work space for visual examination was established at the Ny Carlsberg Glyptotek, acquiring microscopes, video-microscopes, a camera and special light and radiation equipment, and facilities for

8 As Østergaard 2010.

Fig. 2: IN 2830. Paint samples 1+2, top center: head with location of samples (bottom left and right are details); top and centre left: Sample 1 (flesh colour) in tungsten light and UV-FL; top and centre right: Sample 2 (damaged area at forehead and hairline) in tungsten light and UV-FL.

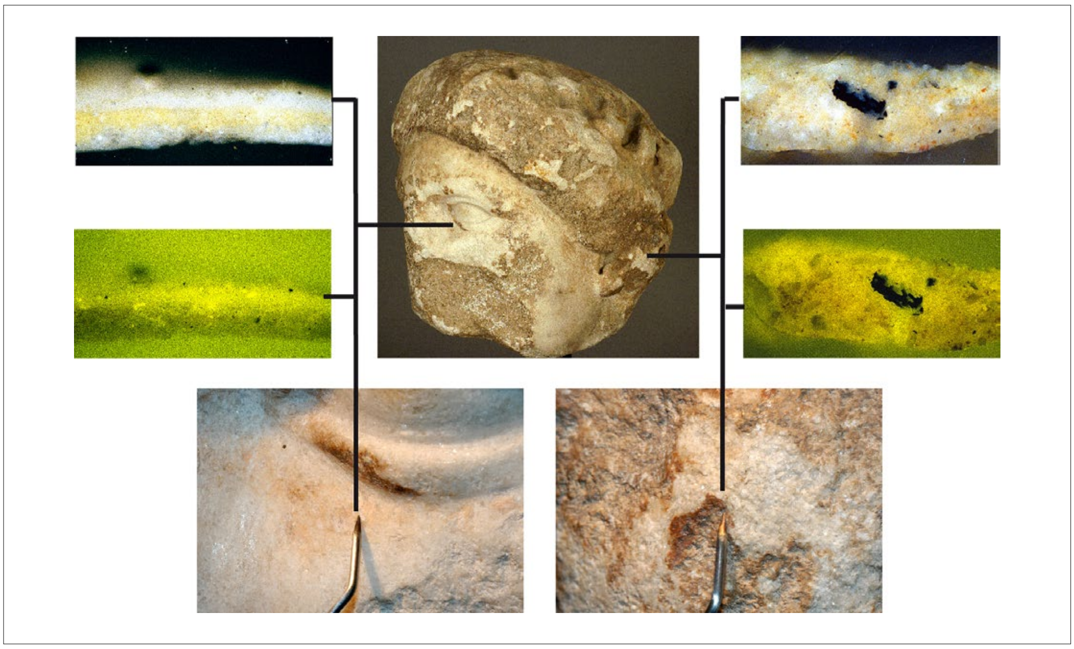

Fig. 3: IN 2830. Paint samples 3+4, top center: head with location of samples (bottom left and right are details); top and centre left: Sample 3 (flesh colour) in tungsten light and UV-FL; top and centre right: Sample 4 (hair colour) in tungsten light and UV-FL.

studying paint cross-sections. Not least the establishment of the Copenhagen Polychromy Network (CPN) during these years was a major step forward in the interdisciplinary research project.[9]

The first results were published in 2006 as a conference poster and soon after more publications including technical information on antique sculptural polychromy became available from our own hands as well as from a growing number of colleagues within and outside the network. In 2009 and 2010 Round Table meetings were organized by the CPN, with Danish as well as international participation. These meetings have since been held annually at other venues.[10] At the same time the Glyptotek's Tracking Colour project staff has been very actively studying and documenting a number of sculptures. The Round Table meetings, the interchange of information between partners in the CPN network and the work done by many other researchers, as well as the development of sometimes groundbreaking new examination techniques that gives us a wealth of new information – the application of the VIL-technique for example[11] – has truly facilitated the research in the area of Greek and Roman sculptural polychromy.[12]

Now – about ten years after the onset – how is the status, having revisited the development of the examination and documentation of sculptural antique polychromy?[13] In terms of technical information about the polychromy of Greek and Roman sculptures from archaic times and four-five centuries onwards a fascinating amount of sculptures have been investigated and in short we have a much better ground to stand on when comparing new results with the now greater amount of existing knowledge. Although there may still be only a few examples from each "school", from each period, geographical area, or century, this is nonetheless much better that just ten years ago. Apparently ground layers were in fact used in some cases (contrary to previous belief), as a lower layer on some sculptures have in fact been found where a reasonable interpretation of such layers would be to identify them as ground layers. Multi-layer structures have been found, and painted details on some sculptures do not appear much different from – if at all different – the quality of the polychromy of the best medieval polychrome sculptures. In such cases it appears that it is actually possible to make direct comparisons between antique and late medieval painting techniques, promoting the possibility that we can extrapolate known medieval painting techniques and apply this knowledge onto – hitherto – unknown paintings techniques on antique sculptures. This may help us understand the original appearance of – sometimes very minute – traces of paint on antique sculptures.

This remains necessary in some areas. While the results from analyses of antique sculptures from the past ten years has brought us much forward in terms of knowledge of pigments used – we find more or less the same twenty or so pigments, coloring matter and metal leaves as in medieval Europe – we are much less informed about the binding media used and thus the overall appearance (matt, shiny, or combinations). This is an area that needs much more attention also in the near future, but the fact is that it remains very difficult to extract and analyze minute amounts of binding media in a paint layer of such age.

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9 On the CPN see Østergaard 2009a.

10 Summaries are published in the Preliminary reports of the Tracking Colour project, available for downloading from www.trackingcolour.com.

11 For the first use of VIL in a CPN context see articles in Østergaard 2010a.

12 The most recent overview of the field remains Brinkmann et al. 2010.

13 Cf. the Tracking Colour annual preliminary reports 2009 -2012 and the present report.

Again, we may benefit from what is known in far greater detail from medieval European paintings techniques. In any case, since much else in Greek and Roman sculptural polychromy and other types of paintings has a remarkably high quality and diversity it could be expected that a variation in use of binding media reflecting the use in medieval European painting technique is to be expected.

Looking back, it has been stimulating for me to witness the development over the past ten year from the first pilot study we did to the present situation where numerous results appear every year and where it probably will not be many years before it will be possible to be able to trace the outline of basic principles of antique sculptural polychromy, to study the development in antiquity, to begin understanding the painting techniques, to be able to trace the development of painting techniques from the antiquity to medieval Europe (and for that matter to and from related cultures and those further away but kept in contact through e.g. the Silk road). It has also been interesting to see that the examination protocol established seems to work as refined after numerous tests and reconfigurations. For the School of Conservation in Copenhagen[14], it has certainly been valuable being part of the CPN. Partly because the results can be used in future treatment work on antique sculpture and its relation to later polychromy within the framework of the educational program, but also because a number of students have become interested in the field and has graduated as MSc in conservation on subjects dealing with antique sculptural polychromy. Thus, for our faculty and students it has been an experience of new insights, but also one which poses new challenges to be met in the coming years.

14 The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, the School of Conservation.

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Lectures and papers given, *et al.*

J.S. Østergaard
"Colour: the fourth dimension of Roman sculpture"
London Roman Art Seminar 2013. Royal Holloway / Institute of Classical Studies / King's College. 25.2.2013

J.S. Østergaard
"The polychromy of a 2nd century CE Palmyrene funerary portrait"
XVIIIth International Congress of Classical Archaeology, Mérida, 13.–17.5.2013

J.S. Østergaard
"Integrating Imaging and Analytical Technologies for Conservation Practice."
Experts Meeting. Getty Conservation Institute 10.–12.9.2013 (invited participant)

J.S. Østergaard
"Skønheden fra Palmyra. Farver på et gravportræt fra Palmyra"
Palmyra Portrait Project lecture series. University of Aarhus. 23.10.2013

J.S. Østergaard
"Preliminary evaluation of the 'Tracking Colour'-project 2009-2013 and some thoughts on future activity"
The 5th International Round Table on Greek and Roman Sculptural and Architectural Polychromy. The Acropolis Museum, Athens, 7.–8.11.2013

J.S. Østergaard
"The polychromy of a 2nd century CE Palmyrene funerary portrait"
The World of Palmyra Conference. Royal Danish Academy of Sciences and Letters, 16.–18.12.2013

Various activities in 2013

CONTACT WITH PROJECTS IN DENMARK

2013 saw continued and increased dialogue with the Danish National Research Foundation's Centre for Textile Research, based at the University of Copenhagen (cf. http://ctr.hum.ku.dk/).

Contact was made in 2013 with the Cultural Heritage and Archaeometric Research Team (CHART, cf. http://www.sdu.dk/en/om_sdu/institutter_centre/c_chart) at the Institute of Chemistry at the University of Southern Denmark, Odense. This experienced and excellently equipped team is headed by Kaare Lund Rasmussen.
CHART has accepted an invitation to join the CPN and we look forward to the collaboration. A consequence of this archaeometrically focused team of chemist is that, for the time being, the Institute of Chemistry at the Technical University of Denmark is leaving the CPN. We are very grateful for the support given by the DTU.

At the University of Aarhus, the international Palmyrene Portrait Project (cf. http://projects.au.dk/palmyraportrait/) is at full steam. Since the Glyptotek has an important collection of such portraits, we can look forward to a useful synergy – polychromy included.

CONTACT WITH PROJECTS ABROAD

The network of contacts established over recent years is as active as ever. Of particular importance is in this respect is the British Museum within the framework of an agreement to collaborate in research on polychromy in an architectural context ('Transmission and Transformation'; see above, p. 8)

PUBLICATIONS

C.A. Graham: 3D digization in an applied context, in: J.S. Østergaard (ed.) 2012 (see below), 64-88.

M.L. Sargent: Investigations into the polychromy of some 5th century BCE Etruscan architectural terracottas, in: J.S. Østergaard (ed.) 2012 (see below), 26-44.

R.H. Therkildsen: A 2nd century CE colossal marble head of a woman: a case study in Roman sculptural polychromy, in: J.S. Østergaard (ed.) 2012, 45-63.

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The 5th International Round Table on Greek and Roman Sculptural and Architectural Polychromy

Athens 7th–8th November, 2013

Hosted by:[1]
The National Hellenic Research Foundation, Institute of Historical Research
The Acropolis Museum

THURSDAY 7 NOVEMBER 2013 (AMPHITHEATRE OF THE ACROPOLIS MUSEUM)

9.00-9.30 Welcome reception at the Acropolis Museum

9.30-10.05
Dimitrios Pandermalis
Archaic Color in the Acropolis Museum

The unique collection of archaic sculptures with rich traces of color on their surfaces urged investigation. At the Acropolis Museum we have progressively communicated our work to the public. As part of the research we created exact copies of sculptural details in Parian marble, and applied mineral pigments mixed with beeswax to replicate the original polychromy. Yet another approach used digital technology, initially creating an exact three dimensional model of the Peploforos onto which the sculpture's original marble texture and color was superimposed. Finally we address the close relationship between the application of paint and the sculpted surface of the archaic sculpture.

10.05-10.40
G.G. Franzti, A.M. Maridaki, E.Ch. Papakonstantinou, G. Verri, S. Sotiropoulou and H. Brecoulaki
The revelation of the decorative pattern of the coffered ceiling on the Porch of the Maidens in the Erechteion

The ceiling of the Porch of the Maidens in the Erechtheion is decorated with coffers which have horizontal bands alternating in steps with cymatia (curved surfaces). In order to reveal the hidden painted pattern, the soot deposits that covered the ceiling, were removed by laser cleaning. An extensive black layer and parts of an off white and also an orange coating are visible on almost all the coffers, while traces of blue colour can be discerned only on the cymatia and around the relief astragals. Various methods of examination and analysis were applied in order to investigate the composition of the black layer, which appeared to be the

1 Sponsors: DACALBO project; Thales; National Strategic Reference Framework 2007-2013

substrate of the ancient written decoration, though it is most likely to be a later intervention. At the same time, there has been an investigation regarding the origin and composition of the two coatings, applied at a later time, which cover the ancient layers: the off white layer and the orange one that survives in several places. This presentation focuses on the methods used to ascertain and identify the blue colour in relation to the ancient decoration pattern. In accordance with all the observations (macroscopic and microscopic), blue colour has been found on a considerable number of coffers and there has been a question of determining if this is Egyptian blue or azurite. On the other hand the pattern of the painted decoration was ultimately confirmed through the special photographic method VIL (Visible Induced Luminescence) (Fig. 1), over which the cyan colour was identified as "Egyptian blue". However it is still possible that there are other colours to be found, in a future plan of investigation.

10.40-11.15

E. Aggelakopoulou, A. Panou, I. Kotsifakos, A. Moutsatsou, A. Bakolas, M. Karoglou and E. Sioumbara

Technical investigation of the polychromy of the Parthenon north-west corner-sima

This paper is a technical investigation of the polychromy of the northwest raking sima of the Parthenon (Fig. 2), where traces of colour and decoration survive. The purpose of the present study is to illustrate the decoration of the surfaces, to collect information on the stratigraphy of paint layers and to identify regions of interest (ROIs) from which micro samples for the instrumental determination of various pigments and/or organic mediums, can be taken. In order to achieve this objective, modern imaging techniques were applied, i.e. optical microscopy by means of a portable microscope, examination with raking light, Visible Induced Luminescence (VIL) imaging, Ultraviolet Fluorescence (UVF) imaging, imaging of ultraviolet fluorescence with USB measuring microscope and infrared thermography (IR-thermography).

The results of the investigation showed that on the west side of the raking sima, a primer layer of a whitish-yellowish hue had been used on the entire extent of the Lesbian cymatium. On this layer the original engraved drawing was incised (outline), reaching the surface of the marble. The colour layers were then applied. VIL revealed the entire painted decoration in the area of the curved elliptical part and the Lesbian cymatium. The observation is generally in agreement with the literature, with the exception of the pattern of the lotus blossom. Egyptian blue was detected in the background of the Lesbian cymatium on the SW raking sima and this observation is in agreement with the literature. By means of the UVF techniques, interesting micro sampling positions were determined. Strong luminescence and fluorescence (VIL, UVF) and different thermal energy (IR-thermography) are recorded at the ends/edges of the lion's mane and in the areas where the marble has undergone fracturing, extensive deterioration and fatigue. This phenomenon requires further investigation.

11.15-11.30 Coffee break

11.30-12.05

H. Piening, V. Brinkmann and U. Koch-Brinkmann

Two Ionic capitals from the Agora

(No abstract)

Fig. 1: VIL image of the North face of the coffer "F1D". Thanks to the photoluminescence of Egyptian blue, the painted decorative patterns are revealed: the egg pattern (ionic cymatium) on the coffers' cymatia, as well as the palmettes on the corners.

Fig. 2: Frontal view of the Parthenon north-west corner sima.

12.05-12.40

Vinzenz Brinkmann, Ursula Buck, Lorenzo Campana, Edilberto Formigli, Paola Donati and Ulrike Koch-Brinkmann

The colors of Riace A. An archaeological experiment

The polychromy of Greek bronze sculpture had been already object to scientific research and archaeological experiment in several cases.

On the occasion of the recent Classic-Exhibition in Frankfurt a further experimental approach has been launched. Due the courtesy of the Soprintendenza Archeologica di Calabria and with the assistance of GOM Braunschweig and the University of Bern an ultrahigh resolution scan of the Bronze hero Riace A could be acquired. A wax infiltrated PMMA print of the head was used for a lost wax bronze cast carried out by the German based company Strassacker.

After precise chasing, asphalt lacquer was applied to the bronze surface in different grades of solution. Written sources inform us that asphalt lacquer was regularly applied to bronze objects. Our experimental processing of this brownish to blackish, but mostly transparent material resulted in a quasi-painterly rendering of hair and skin.

Both eyes were reconstructed by Edilberto Formigli in colored stone and inserted together with the copper eye lashes. Silver teeth were integrated, copper lips applied. Since sulfur remnants often has been detected on the surface level of ancient bronze statuary, sulfur liver was brought in contact to the hair band in order to evoke a blue tone by chemical reaction of the bronze alloys copper component.

Clear traces indicate that Riace A once wore a Corinthian helmet. The ancient bronze helmet from the tomb of Dendra was subsequently scanned and electronically fitted on Riace A. The data model had been printed, cast, chased and finally gilded and serves now as an almost perfect substitute of the lost helmet.

Due to the different metal colors, chemical surface treatments, gilding and painterly application of asphalt lacquer the overall appearance of the experimental reconstruction is full of color and life.

12.40-13.15

B. Bourgeois, V. Jeammet, S. Pagès

Greek gilded wood: an exceptional polychrome peplophoros from Kertch (Musée du Louvre)

Dated to the first half of the fourth century B.C. and said to come from Kertch, a rare painted and gilded wooden statuette of a peplophoros entered the Louvre collection sometime in the mid-19th century (Department of Greek, Etruscan and Roman Antiquities, inv. S 2045). As hypothesized by some scholars, it might have been part originally of the sarcophagus found in the Tumulus of the Snakes (Zmeiny Kurgan), now kept in the Hermitage Museum. The standing figure, whose head and arms are missing, wears a gilded peplos ornamented with a violet-painted border along the edge of the apoptygma and down the legs. It is stylistically close to Attic late-fifth century sculpture.

The talk will summarize the historical and stylistic data (V. Jeammet) and present the new scientific study carried out at the C2RMF with results of video-microscopy examination (B. Bourgeois) and analysis of ancient materials (S. Pagès-Camagna). Results point out to the high-quality of craftsmanship involved, of Greek character, combined with the possible use of local raw materials.

13.15-14.30 Lunch break (Café of the Acropolis Museum)

14.30-15.05
E. Korka, H. Brecoulaki, S. Protopapas, S. Sotiropoulou, M. P. Colombini and A. Andreotti
Evidence for tempera technique on an Archaic painted sarcophagus from Chiliomodi (Corinthia)

In July 1984 a sarcophagus hollowed from a single block of stone, was uncovered in the site «Faneromeni», at Chiliomodi in Corinthia. The interior part of the sarcophagus lid preserved a unique painted composition, consisting of two lions facing each other, separated by a huge anthemion (Fig. 3). This monument represents the only known example of painting on stone during the Archaic period, using a tempera technique. The technological examination of the painting allowed us to reveal interesting information on the nature of pigments and the original painting technique (egg was identified as the binder) and to reconsider issues on the relationship between monumental and vase painting.

15.05-15.40
H. Brecoulaki, A. Kottaridi, G. Verri, A. Karydas, S. Sotiropoulou, L. Lazzarini, M.P. Colombini, A. Andreotti, Z. Papliaka, J. Dyer and G. Georgiou
A new technological investigation on two exceptional painted marble artifacts of the late Classical period: The sarcophagus from tomb 128 at Kition (Cyprus) and the marble throne from the "Tomb of Eurydice" at Aigai

Recent investigation on two outstanding painted marble artifacts of the late Classical period revealed new information on their technology and their iconography. Other colleagues have already subjected both artifacts to analytical investigation in the past and therefore our results are confronted and discussed. Interesting information has come up regarding the original painting technique, which seems to correspond to egg tempera. Imaging techniques applied on the throne of the so called Tomb of Eurydice at Aigai (Fig. 4) revealed both new iconographic elements and documented a much more extensive use of Egyptian blue. Marble analysis confirmed the use of Parian marble for the sarcophagus of Kition (Fig. 5) and Pentelic marble for the throne at Aigai.

15.40-16.15
G. Verri, M. Kalaitzi
The painted stelae from Aigai (Vergina), Macedonia: new findings on the distribution of pigments and aspects of their iconography

Ancient Greek and Roman polychrome objects or architecture are not always easily accessible for investigation. For example, access and analysis of in situ wall paintings, architectural elements or large sculpture can be a task fraught with difficulties even in confined environments, such as tombs or museums.

Multispectral imaging (MSI) systems are capable of capturing visible-, infrared-, ultraviolet-reflected images, as well as photo-induced luminescence in the visible or infrared range. Such systems normally make use of continuous radiation sources, such as tungsten bulbs, LEDs or Black Light Blue Wood's tubes. While these radiation sources are very efficient and provide excellent results, their physical positioning for imaging might provide difficult, as they normally tend to be rather bulky. A highly portable, integrated system, composed of a modified camera, a set of filters and noble-gas flashtubes was tested and used in situ for the

Fig. 3: Archaic painted sarcophagus from Chiliomodi (Corinthia). The use of egg tempera technique was evidenced in the painted composition preserved in the interior part of the sarcophagus lid.

Fig. 4: "Tomb of Eurydice", Aigai. Handheld XRF measurements conducted by A. Karydas.

Fig. 5: Sarcophagus A, T. 128 Kition. Painting of the pediment depicting a mourning scene.

non-invasive mapping and analysis of a select group of painted stelae and a relief naiskos stele from the 'Great Tumulus' at Aigai (Vergina), Macedonia, in the attempt to confirm and expand on the curatorial interpretation of the monuments and to characterize the distribution of pigments whenever possible.

The paper will highlight the main findings of the following MSI techniques and will provide technical details on the equipment: visible-, infrared-, ultraviolet-reflected, photo-induced luminescence and raking light imaging.

The MSI system, which could be used without blacking out the gallery even for ultraviolet-induced luminescence imaging, mainly gave new findings concerning the mode of employment and the distribution of Egyptian blue in the figured scenes and the decoration of the architectural elements of the tombstones, and allowed confirming the new reading of the scene of the previously undeciphered stele of Harpalos (Vergina Museum ΒΛ 9).

16.15-16.30 Coffee break

16.30-18.00
D. Maraziotis, K. Vasileiadis and Th. Katsaros
Workshop/Experimental demonstration of polychromy and painting applications on marble

FRIDAY NOVEMBER 8 (AMPHITHEATRE OF THE ACROPOLIS MUSEUM)

9.30-10.05
C. Blume
The spectrum of skin colours on Hellenistic sculptures. A wide range with different meanings.

In contrast to earlier periods, in Hellenistic times skin colours of depictions of male and female figures often assimilate. Nevertheless, there was a wide spectrum of flesh tones applied to Hellenistic sculptures. The hues are usually based on mixtures of various colourants leading to different light and dark complexions. Furthermore, particular depictions were shown with golden skin as well as, most likely, with marble white skin. With my presentation, I intend to shed light on the spectrum of complexions found on Hellenistic sculptures and to discuss the strength of the chosen skin colour for the message to the observer of the individual sculpture.

The approximation of the skin colours of male and female figures can for instance be seen in two examples depicted here: a portrait of Berenike II (Fig. 6–7) and a terracotta statuette (Fig. 8–9) showing to females sitting on a couch. Berenike is depicted with a pinkish-beige and the two figures on the couch with a light plain beige flesh tone. This stands in contrast to the pre-Hellenistic preference of showing females with very light and males with dark reddish skin. By this new development, flesh tones in depictions, figurines and sculptures became more naturalistic and the clear differentiation of the gender was rarely differentiated by means of their complexion.

In addition, the portrait of Berenike is of significance for our knowledge on ancient polychromy since it shows remains of two different colourations. First a pinkish-beige tone had been painted on the flesh directly. At some later phase, when the colouration of the portrait, or at least parts of it, was refurbished, the skin was covered with a thin white coating which

Fig. 6:
Portrait of Queen Berenike II. The British Museum, inv. No. 1861, 1127.145 / 1927,0214.1

Fig. 7:
Detail of the chin of the portrait of Berenike II, showing two phases of polychromy.

Fig. 8: Terracotta statuette. The British Museum, inv. No. 1885,0316.1

Fig. 9: Detail of the terracotta statuette.

again had been painted with a pinkish-beige tone. Both phases of the colouring of the flesh can be recognised in the detail image showing the chin of the portrait (Fig. 7).

10.05-10.40

J.S. Østergaard / The Copenhagen Polychromy Network:

Preliminary evaluation of the 'Tracking Colour' project 2009–13 and some thoughts on future activity

The present phase of the Tracking Colour project ended May 31st, 2013. The aim of the project was to contribute to an increase of primary data about polychromy on Greek and Roman stone sculpture by examining works in Ny Carlsberg Glyptotek selected as being representative of the strengths of the collections and of the main periods of the history of Greek and Roman sculpture. The staff resources made available to the project was 1 full-time curatorial post in classical archaeology and a ½ time position for a project objects conservator, later increased to two ½ time positions. Funding was initially provided by the Glyptotek and a private donor, and subsequently mainly through a grant from the Carlsberg Foundation.

Partner institutions in natural science and conservation science joined the museum during a pilot phase from 2005 onwards to form The Copenhagen Polychromy Network, providing the project with the analytical resources not found at the Glyptotek. This interdisciplinary collaboration has been a sine qua non for achieving useful results. Equally important has been the international network to which we belong and to which we are indebted for advice and support.

The number of sculptures examined from January 2009 till the end of investigations in January 2013 was considerably lower than stipulated in the original project description. At the outset, we had no prior experience to guide us in estimating the time required – and we were far too optimistic in our planning. At the meeting, this aspect will be dealt with in more detail.

The equipment acquired for visual examination and the protocols established are results on which future activity can build. But how can they be improved? The same goes for the experience and qualifications attained during the project: where do we need to further strengthen our team?

The data gathered come from stone sculpture of all periods, Archaic through Late Roman; selected Etruscan works in alabaster and terracotta and one Late Egyptian limestone relief have also been examined. The work done on Metropolitan Roman ideal sculpture, portraits and sarcophagi extends the range of data available to scholarship. At the meeting and overview and general interpretation of these data will be offered.

By April 2013, a modest project website and database was launched at www.trackingcolour.com, offering an objects and bibliographical resource as well as preliminary on-line reports to all users. Out thoughts on the future of the website and its use as an integrated element of a more complete electronic publication of our results will be presented. The contribution closes with an outline of the ideas we have for a possible continuation of the project in 2014 and of the initiatives being taken in that regard.

I hope the issues raised in this contribution will be critically discussed at the Round Table.

10.40-11.15
P. Adam-Veleni, K. Tzanavari, Cr. Katsifas, D. Karolidis and O. Kourakis
Pigment identification on ancient sculptures from the collections of the Archaeological Museum of Thessaloniki

An important number of sculptures from the collections of the Archaeological Museum of Thessaloniki preserve pigments, which complement the plastic decoration of statues or reliefs. This fact leads us to the realization of a project to document and identify these pigments, through the application of archaeometric methods of analysis and specialized photographic techniques (Fig. 10–11). The final aim of the project is to restore, if possible, the initial synthesis of the artifacts.

11.15-11.30 Coffee break

11.30-12.05
M. Abbe
Painting and gilding on marble sculpture at Roman Corinth

This presentation will briefly summarize current interdisciplinary investigations into the extant polychromy of Roman marble sculpture excavated at Corinth by the American School of Classical Studies in Athens (as Fig. 12). This large, representative body of evidence provides a broad foundation of the materials and techniques used in the painting and gilding of Roman marble sculpture in the capital of Roman Greece and the larger region. Contextualized studies of coloration reveal how the frequently-replicated subjects of Roman statuary were given varying appearances according to their subject matter, function, and display environment. Current ambiguities and avenues for future research will be emphasized.

12.05-12.40
P. Adam-Veleni
Painted invitation from the Roman Forum of Thessaloniki

(No abstract)

12.40-13.15
Paolo Liverani, Susanna Bracci, Roberta Iannaccone, Sara Lenzi.
Monochromes on marble from Herculaneum and Pompei: new researches

This is a new step in the research about "monochromes on marbles", twelve painted marble slabs from Pompeii, Herculaneum and maybe Rome, now in the Museo Archeologico Nazionale in Naples and in the Kunsthistorisches Museum in Vienna.

These marble pinakes were set in walls of roman buildings with iron clamps. The scenes are of different subjects spanning from mythological to athletic ones.

Their name, Monochromes, was chosen during the Bourbonic period due to the red colour visible on the surface, but actually the slabs show also green, yellow, brown and black pigments, still visible to the naked eye.

The paper will present the preliminary results obtained by means of transportable, non-invasive techniques employed for the analysis of the ten slabs in Naples. The employed

Fig. 10: One of the sculptures in the Archaeological Museum of Thessaloniki examined in the project. Natural light.

Fig. 11: VIL image of the relief sculpture in Fig. 11 showing the luminescence of Egyptian blue.

Fig. 12: Head of Sarapis, marble with details of overall gilding. From the South Stoa, Corinth. 2nd half of 2nd century CE. H. 40 cm. Inv. no. S-2387.

techniques can be divided in two groups: i) imaging (Ultraviolet reflected photography, Ultraviolet fluorescence photography, Ultraviolet false colour, Near Infrared photography, Infrared false colour, Visible Induced Luminescence) and ii) single spot (X-ray fluorescence spectroscopy, Fiber Optics Reflectance Spectroscopy in UV-VIS); Portable Optical Microscopy was used for documenting the analysed areas. An example is shown in Fig. 13.

Crossing the visual results obtained with imaging techniques with data analyses some new information about drawings, pigments and conservation history have been provided, in order to deepen the knowledge of this rare kind of archaeological finds.

13.15-14.30 Lunch break (Café of the Acropolis Museum)

14.30-15.05
E. Siotto
Roman sarcophagi, use and reuse: application techniques of the colour and repainting

As it is well known, some Roman sarcophagi were reused for new depositions already in the Roman period. Typically they underwent several changes and adaptations, like the repainting. Characterizing a second painting is not easy, but, from the study of the polychromy of sarcophagi preserved in the National Roman Museum in Roma, we found a clue that could help its identification: the presence on the same sarcophagus of two different application techniques of the pigments. Starting from the results obtained from the scientific analysis on one of these sarcophagi, we present the other case studies that could show the same feature. Finally we present the result obtained by the virtual reconstruction of the different layers of colour on a 3D model of the sarcophagus, analysing the strengths and limitations of the current rendering software.

15.05-15.40
A. Nagel
Reconstructing the process of paint applications, pigment composition, and polychromy in the Ancient Near East: recent investigations from the Smithsonian

This report gives an update on a number of recently finished and ongoing research projects focusing on the polychromies of the Ancient Near East and Western Asia in the Smithsonian Institution, Washington DC. Building on a large tradition of in-house research and scientific applications on material, the report summarizes recent investigations attempting to reconstruct technologies of paint and pigment application by introducing projects on wall painting fragments of Pasargadae and monumental architectural sculpture from Persepolis (Iran), on Assyrian stone reliefs in Nimrud (Iraq) and on Greco-Roman stone sculptures from the South Arabian peninsula.

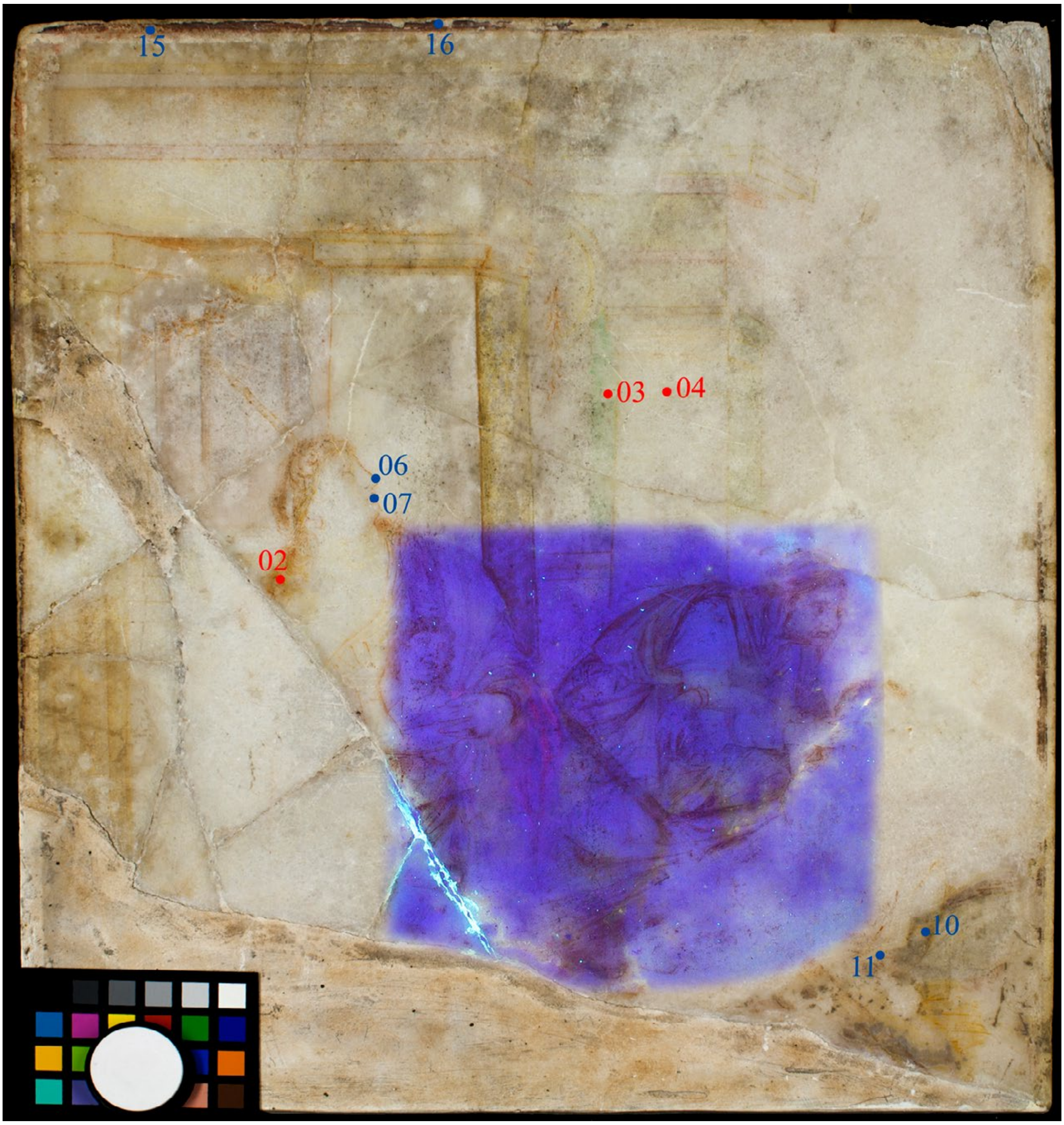

Fig. 13: Niobe and the Niobides. Naples, Museu Archeologico Nazionale inv. no. 109370Example of analyses done on the ten pinakes with the indication of single spot analyses (numbered dots) and a detail of ultraviolet fluorescence photography.

15.40-16.15

Th. Katsaros

In search for the mineral pigments described by Theophrastus of Eressos –Three case studies cyanus from Scythia, miltos from Sinope and ochre from Cyprus

After two decades of research for mineral pigments described in treatise On Stones of Theophrastus from Eressos (4th century B.C.) we put some questions and on the other hand we shall discuss some results from the field (in situ) investigations.

Our proposal is that Theophrastus uses a specific colour terminology not to describe the general species but to identify the specific mineralogical specimens. In the case of miltos (red earth rich in iron oxide, ruddle) the separation in accordance to geographical origin which have been made by him, probably means the distinction of different mineralogical species or the differentiation in chemical analogies between the same mineral. In the special case of miltos from Sinope, Theophrastus said that became from caves of Cappadocia. So under this point of view we have many kinds of miltos from many different places, which have a different geochemistry.

The writer prefers the reference of the provenance of a colour to clarify the identity of his material. We conclude after this concept, that the colours names in his text On Stones have been used as trade named colorant products.

The problem is where these products were coming from? Where Cappadocia and Scythia were in times of Theophrastus, and what kind was the yellow ochre with the bright colour in resemblance to the orpiment, which came from Cyprus. Scythia in accordance to Herodotus and Strabo lies in one part of the world totally different than the times of Theophrastus, and Cappadocia during the time was a name absolutely dark and cloudy and describes a huge territory of Asia Minor. The historical boundaries of Cappadocia have varied many times.

Why Pliny the Elder (1st century A.D.) notes that sinopis comes from Pontus and not from Cappadocia? And the geographical position of Scythia starts from northern Thrace (later Roman Moesia) and continuous across to the eastern Romania and the coasts of Black Sea (modern Ukraine) to the modern Tajikistan and Afghanistan (ancient Bactria and Scythia also) above to the Indian Caucasus (Hindu Kush). So, where was the Scythia of Theophrastus' era?

The hypothesis of existence of another Scythia in the territory of Palestine could be the specific place of our interest on the trade road of lapis lazuli from Afghanistan in the Mediterranean Basin. The separation of Cappadocia in three smaller parts could be an explanation for the locality of the mines of sinopis during Theophrastus' times.

All these are problems in research for the specific sites of provenance of the raw materials for pigment production in antiquity. We approach to resolve some of these, such as the positions of the geographical frontiers of Scythia and Cappadocia, and on the other hand we shall try to uncover the hidden meaning of the nature of ochre from Cyprus.

16.15-16.30
E. Papathoma, G. Moraitou
Paint on some wooden artifacts from Brauron

The discovery of wooden archaeological finds in Greek soil is rare due to the prevailing environmental conditions which are adverse for the preservation of organic materials. Nevertheless in the wetland of the archaeological site of Brauron a considerable number of wooden artifacts dating from the 6^{th} and 5^{th} century BC were discovered in the years 1960 and 2011in a waterlogged condition. Some of the artifacts bare traces of paint (as Fig. 14). Two kinds of paint were observed: a) Traces of red pigment and b) remains of black decorative zones. A non destructive protocol for the imaging and identification of the painted decoration is proposed which will be implemented as soon as the necessary funding is available.

16.30-17.00
Concluding remarks by E. Walter-Karydi
After the concluding remarks, the participants expressed their special appreciation for the efforts made by H. Brecoulaki in organizing this very successful 2013 Round Table.

17.00-18.30
Coffee break and meeting with the group of participants from the Polychromy Network
At this meeting it was agreed to meet on November 5–7 in Copenhagen, for the 2014 Round Table. The Acropolis Museum was invited to join the Polychromy Network, and happily accepted.

20.30 Dinner with the participants at the restaurant of the Acropolis Museum

Fig. 14: Wooden pyxis from Brauron with painted decoration (Courtesy of the 2nd EPCA).

A bibliography of publications on ancient sculptural and architectural polychromy in 2013[1]

N. Ammannati, E. Martellucci - S. Natali - C. Colibri - P. Piccardo: Valutazione del colore dei bronzi tramite misurazione CieL*ab*, in: E. Formigli (ed.) 2013, 41-47.

P. Bertelli - E. Formigli - F. Marinelli - B. Morsani - A. Pacini: Archeologia sperimentale, in: E. Formigli (ed.) 2013, 91-95.

C. Blume, Review of M. Kunze et al.: Die Artemis von Pompeji und die Entdeckung der Farbigkeit griechischer Plastik. Katalog einer Ausstellung im Winckelmann-Museum vom 2. Dezember 2011 bis 18. März 2012 (2011), in: BMCR 2013.03.29. http://www.bmcreview.org/2013/03/20130349.html

V. Brinkmann (ed.): Zurück zur Klassik. Ein neuer Blick auf das alte Griechenland. Ein Ausstellung der Liebieghaus Skulpturensammlung, Frankfurt am Main. 8.2. – 26.5.2013 (2013) passim.

O. Colacicchi Alessandri - M. Ferretti - E. Formigli: L'occhio pesto del pugile. Indagini archeometriche sulla statua in bronzo del Museo Nazionale Romano, in: E. Formigli (ed.) 2013, 25-31.

C. Coluzza - E. Formigli: Interazione luce-materia nei trattamenti superficiali dei bronzi antichi, in: E. Formigli (ed.) 2013, 61-69.

D. Ferro - E. Formigli - S. Bovani: La patina artificiale antica nei grandi bronzi di Ercolano, in: E. Formigli (ed.) 2013, 33-39.

S. Fine: Menorahs in color: polychromy in Jewish visual culture of Roman antiquity, Images 6, 2013, 3-25

P. Fink-Jensen: An archaeometric study of lead pigments from a 1st century BC Roman marble sculpture. Investigations of lead provenance, material heterogeneity and ancient ore processing techniques. Master's thesis, Faculty of Science, University of Copenhagen 2013.

M. Florenzano: Pourquoi une telle aventure?, in: M. Garsson (ed.), Le Trésor des Marseillais. 500 av. J.-C., l'éclat de Marseille à Delphes, 98-101 (2013).

E. Formigli (ed.): Colore e luce nella statutaria antica in bronzo, Rome, L'Erma di Bretschneider, 2013.

1 Some titles before 2013 are included. We would be most grateful for being notified of publications we have missed. Please also consult the bibliography on www.trackingcolour.com. Additions would be most welcome and should be sent to Amalie Skovmøller at amsk@glyptoteket.dk.
Thank you to Paolo Liverani for having contributed to this Bibliography.

E. Formigli: Le tecniche del colore nella statutaria antica in bronzo, in: E. Formigli (ed.) 2013, 1-23.

E. Formigli: Le patine 'naturali' greche e le patine artificiali romane, in: E. Formigli (ed.) 2013, 49-53

E. Formigli: Il ruolo della luce nella statuaria antica in bronzo, in: E. Formigli (ed.) 2013, 71-75.

R.B. Goldman: Color-terms in social and cultural context in ancient Rome. Gorgias studies in classical and late antiquity, 3. Piscataway, NJ: Gorgias Press, 2013

C.A. Graham: 3D digization in an applied context, in: J.S. Østergaard (ed.) 2012 (see below), 64-88.

A. Grand-Clément: Review of M. Bradley, Colour and Meaning in Ancient Rome (2009), BMCR 2010.09.17 http://bmcr.brynmawr.edu/2010/2010-09-17.html

A. Grand-Clément: La fabrique des couleurs: histoire du paysage sensible des Grecs anciens : VIIIe-début du Ve s. av. n. è. (2011).

Ph. Jockey: La mythe de la Grèce blanche. L'histoire d'une rêve occidentale (2013).

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W. Massmann: Verblasste Farbenpracht. Erste Untersuchungsergebnisse an der Berliner Göttin in: U. Peltz – O. Zorn (eds.), KulturGUTerhalten. Restaurierung archäologischer Schätze an den Staatlichen Museen zu Berlin (2009) 242-243.

H. Piening: Examination Report: the Polychromy of the Arch of Titus Menorah Relief, Images 6, 2013, 26-29.

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M.L. Sargent: Investigations into the polychromy of some 5th century BCE Etruscan architectural terracottas, in: J.S. Østergaard (ed.) 2012 (see below), 26-44.

Th. Schäfer: Marmo e bronzo. Sui materiali di luzzo nella plastica greca di età tardo-arcaica, in: E. Formigli (ed.) 2013, 77-89.

A. Schwarzmaier: Die Masken aus der Nekropole von Lipari. Palilia 21, 2011.

A. Schwarzmaier: Review of R. Posamentir, Bemalte attische Grabstelen klassischer Zeit (2006), in: Gnomon 85, 2, 2013, 152-156.

S. Settis: Schicksale der Klassik. Vom Gips zur Farbe, in: V. Brinkmann (ed.), Zurück zur Klassik. Ein neuer Blick auf das alte Griechenland. Ein Ausstellung der Liebieghaus Skulpturensammlung, Frankfurt am Main. 8.2. – 26.5.2013 (2013) 59-83.

R.H. Therkildsen: A 2nd century CE colossal marble head of a woman: a case study in Roman sculptural polychromy, in: J.S. Østergaard (ed.) 2012, 45-63.

G. Zimmer: Sull'importanza della luce per i grandi bronzi antichi, in: E. Formigli (ed.) 2013, 55-59.

J.S. Østergaard: 'Tracking Colour' in 2012, in: J.S. Østergaard (ed.) 2012, 6-25.

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I. Reiche – K. Müller - M. Albéric – O. Scharf – A. Wähning – A. Bjeoumikhov – M. Radtke – R. Simon: Discovering vanished paints and naturally formed gold nanoparticles on 2800 years old Phoenician ivories using SR-FF-microXRF with the Color X-ray Camera, Analytical Chemistry, Publication Date (Web) : May 13, 2013 (Article), DOI : 10.1021/ac4006167

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