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Minerva in Colours: First Results on a Polychrome Roman Sculpture from Carnuntum (Pannonia)

Gabrielle Kremer [1,*], Robert Linke [2], Georg Plattner [3], Eduard Pollhammer [4], Marina Brzakovic [4], Robert Krickl [1], Nirvana Silnovic [1] and Václav Pitthard [3]

1 Austrian Archaeological Institute, Austrian Academy of Sciences, Georg Coch-Platz 2, 1010 Vienna, Austria; robert.krickl@oeaw.ac.at (R.K.); nirvana.silnovic@oeaw.ac.at (N.S.)
2 Federal Monuments Authority Austria, Arsenal, Objekt 15/4, 1030 Vienna, Austria; robert.linke@bda.gv.at
3 Kunsthistorisches Museum Vienna, Burgring 5, 1010 Vienna, Austria; georg.plattner@khm.at (G.P.); vaclav.pitthard@khm.at (V.P.)
4 State Collections of Lower Austria, Archaeological Park Carnuntum, Badgasse 42, 2405 Bad Deutsch-Altenburg, Austria; eduard.pollhammer@noel.gv.at (E.P.); marina.brzakovic@noel.gv.at (M.B.)
* Correspondence: gabrielle.kremer@oeaw.ac.at

Abstract: This paper presents the first results of a current interdisciplinary research project on the polychromy of Roman provincial stone artefacts in selected areas of the Danubian provinces (PolychroMon). The statuary group of *Minerva* and the *Genius immunium* from *Carnuntum* (Archaeological Museum Carnuntinum inv. CAR-S-48) is dated to the second half of the second century AD and still retains traces of the original polychromy. The aim was to focus on non-invasive techniques and to employ micro-invasive methods for necessary cross-checking and gaining information otherwise not accessible. The investigation revealed that paint was applied on a layer of white lime wash. Additionally, the object shows several traces of Egyptian blue, which was mainly detected in *Minerva*'s and the *Genius*' clothes. Other pigments whose traces were found on the sculpture include green earth, yellow and red ochre, as well as red lead and carbon black. Microscopic analysis confirms the presence of modern-age compounds as well (barium sulphate and zinc oxide) used for modern retouches. Gas chromatography–mass spectrometry revealed the use of egg as the major proteinaceous binding medium in the red lead polychromy.

Keywords: ancient polychromy; Roman provincial sculpture; *Carnuntum*; Egyptian blue; red lead; pigment degradation; binding media; MSI; SEM-EDX; GC–MS

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Citation: Kremer, G.; Linke, R.; Plattner, G.; Pollhammer, E.; Brzakovic, M.; Krickl, R.; Silnovic, N.; Pitthard, V. Minerva in Colours: First Results on a Polychrome Roman Sculpture from Carnuntum (Pannonia). *Heritage* **2023**, *6*, 5213–5241. https://doi.org/10.3390/heritage6070277

Academic Editor: Joanne Dyer

Received: 31 March 2023
Revised: 23 June 2023
Accepted: 30 June 2023
Published: 11 July 2023

1. Introduction

The polychromy of ancient sculpture has been increasingly in the consciousness of experts and the interested public for about two decades, but only sporadic studies on this topic are available concerning Roman artefacts from the western and northern European provinces of the Roman Empire. Excavation reports from the 19th c. onwards occasionally mention visible paint residues on newly discovered ancient sculptures and architectural elements. But apart from some rare fortunate exceptions, e.g., [1–3], they have hardly been documented by means of colour drawings or coloured photographs. Moreover, in most cases, little effort was made to preserve them, so that at first glance, hardly any pigment traces remained visible to the naked eye. Exceptionally well-preserved new finds or freshly restored objects with significant remains of the painted coating leave, however, no doubt that polychrome surfaces of stone monuments must also be expected in the peripheral regions of the Roman Empire.

At present, many questions are still unanswered regarding the original appearance of these sculptures as well as the painting techniques and materials applied. Some corpora and collection catalogues, e.g., [4,5] and [6] (p. 192), provide a good overview of the frequency of observed colour residues. Individual investigations deal with polychrome reliefs of different regions, such as eastern Gaul [7–10] or Roman Germania [11], mainly focusing on art-historical and iconographic questions as well as on painting techniques. A more detailed analysis has also been provided of selected architectural elements [12]. But, although polychrome reconstructions of Roman sculptures and buildings are usually on display in museums and exhibitions, special investigations with up-to-date scientific research methods have been carried out only sporadically.

A similar picture emerges regarding the materiality of polychromy on monuments of the Roman provinces. Isolated studies of the pigments used on sculptures, reliefs or architecture are available, e.g., [13–15], but most of the relevant literature concerning the Roman provinces, and particularly the Danubian provinces, is still based on studies of mural paintings, e.g., [16–21]. In addition, occasional findings of dyes are documented, which must be included in further studies, e.g., [22–24].

Taking polychromy into account not only places the assessment of content-related and stylistic aspects, as well as regional characteristics, of provincial Roman sculpture and architecture in a completely new context, but also opens up new fields of research concerning the economic relations within and outside the Roman Empire.

The four-year research project PolychroMon (2021–2025), funded by the Austrian Academy of Sciences (Heritage Science Austria 2020), aims at analysing the polychromy of ancient sculptures and architectural elements in selected areas of the Roman Danubian provinces. Within a cooperation between the Austrian Archaeological Institute/Austrian Academy of Sciences (ÖAI/ÖAW), the Archaeological Museum Carnuntinum (AMC), the Kunsthistorisches Museum Vienna (KHM) and the Federal Monuments Authority Austria (BDA), new data are gathered and evaluated in an interdisciplinary manner. As a representative case study of this project, the statuette of *Minerva* and the *Genius immunium* from *Carnuntum* (AMC inv. CAR-S-48) is presented here and discussed based on new data (Figure 1).

Figure 1. Statuette of *Minerva* and the *Genius immunium* from *Carnuntum*, AMC inv. CAR-S-48.

2. Materials and Methods

2.1. The Area of Investigation

Carnuntum (Petronell, Bad Deutsch-Altenburg) and *Vindobona* (Vienna) are the two main centres on the Austrian part of the Pannonian *limes* along the Danube, the northern border of the Roman Empire in the province of *Pannonia superior* (e.g., [25]) (Figure 2). Situated at a narrow point of the Danube, the so-called Porta Hungarica, *Carnuntum* marks the eastern edge of the Vienna Basin, whereas *Vindobona* lies at the far western edge. The provincial capital and military centre of *Carnuntum* was strategically located at the crossroads of the Danube and the "Amber Road", an ancient trade route that connected the North Sea with the Mediterranean (e.g., [26]). The site also offered favourable conditions for raw material supply of building materials [27,28]. The military base of the early 1st c. AD developed into an extensive settlement area, which from the middle of the 1st c. included a legionary camp with its surrounding settlement (*canabae legionis*) and from Flavian times an equestrian camp, as well as a civilian settlement, which attained autonomous status as a *municipium* under Hadrian and was upgraded to a *colonia* under Septimius Severus. The area of ancient *Carnuntum* is in large parts undeveloped today, and apart from the excavation results from the mid-19th c. onwards, extensive remote sensing data and geophysical surveys are available [29]. Almost 3000 Roman stone artefacts are known from the settlement area of *Carnuntum*, including sculptures and funerary and dedicatory monuments as well as architectural elements and utilitarian objects. The vast majority is made of local and regional stone material, and only about 10% of marble, which had to be imported [5] (pp. 421–430).

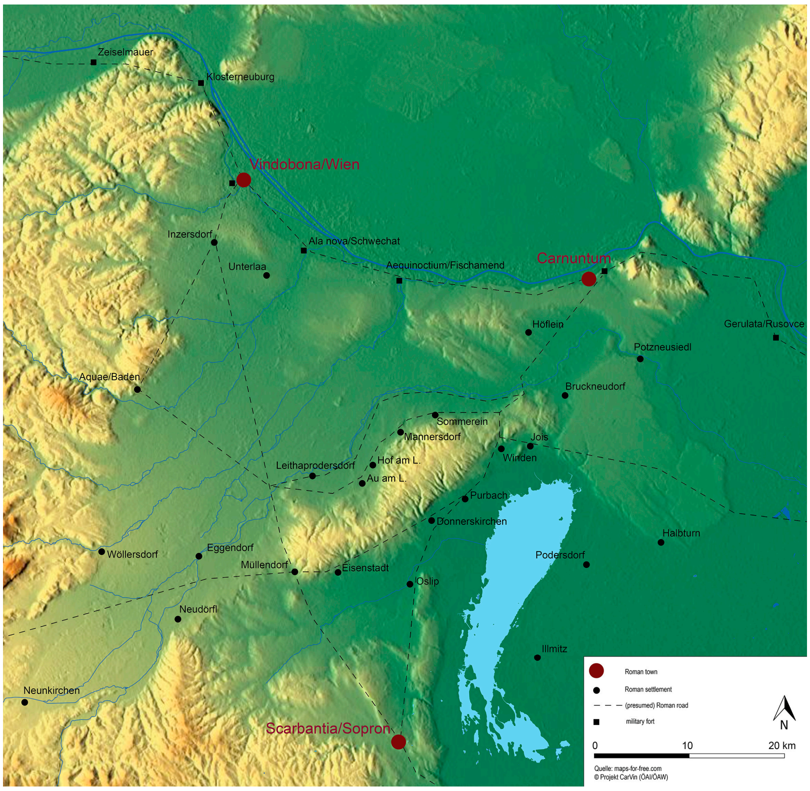


Figure 2. Section of the Pannonian Limes along the Danube, with the military bases and civil settlements of *Vindobona* and *Carnuntum* and their hinterland.

In contrast to *Carnuntum*, the territory of the legionary camp and the civilian city of *Vindobona* is today overbuilt and has only been investigated through limited excavations. Numerous Roman stone monuments with similar characteristics to those in *Carnuntum* were nevertheless recovered, many of them in secondary find contexts [30]. For the procurement of building material for *Vindobona*, the Romans also drew on resources on the western edge of the Vienna Basin [31].

A different situation is given in the hinterland of *Carnuntum* and *Vindobona*, which geographically encompasses the Vienna Basin and the region of the Leitha Mountains [32]. From the beginning of the Roman presence, the quarries on the slopes of the Leitha Mountains provided a large part of the raw material for the emerging stonemasonry workshops. The rich stock of stone monuments from this area reflects both the rural local population and the military Roman element.

2.2. The Collections

In Late Humanism, monuments with Latin inscriptions from *Carnuntum* in particular had aroused the interest of scholars. From the 16th c. onwards, the monuments were mainly transferred to the imperial and private collections in Vienna [33] (pp. 40–42), [34] (p. 40). In the 19th c., however, extensive private collections of local landowners were also established in the area, such as the collections of the Counts Ludwigstorff, the Counts von Abensperg-Traun and the quarry owner Carl Hollitzer. These collections were successively acquired by the private association "Verein Carnuntum", founded in 1884 and dedicated to the investigation of ancient *Carnuntum* and the preservation of its antiquities [35]. Together with the new finds from excavations, which were carried out in cooperation with the "Limeskommission" of the Academy of Sciences, founded in 1897, the purchased collections today form the basis of the Roman Archaeology Collection of the Provincial Collections of Lower Austria.

The collection of Greek and Roman antiquities of the Kunsthistorisches Museum Vienna houses some 200 Roman stone monuments from *Carnuntum*, Vienna and their hinterland, which were discovered in the 19th c. or transferred to the imperial holdings from even older collections. Established in 1798/99 [36] (pp. 38–39), ref. [37] (pp. 82–85), the collection used to be the first and only public authority on classical antiquities in the former Austrian Empire of the Habsburg family in the 18th/19th c. Stone monuments and inscriptions, in particular, were of high interest to an educated audience, and were, therefore, already on display in the earliest public presentations of the imperial collections in the basement of the "Temple of Theseus" in the Vienna Volksgarten [38], and later in the basement of the Kunsthistorisches Museum Vienna, which opened in 1891 [39], ref. [40] (pp. 10–11). For this purpose, the monuments were cleaned and inscriptions partially re-coloured to be more legible. Unfortunately, these measures were mostly not documented and have partially altered the surface of the stone monuments.

2.3. Minerva and the Genius Immunium from Carnuntum

The sub-life-size statuary group of the goddess *Minerva* accompanied by a *Genius* is identified as a votive monument through the inscription on its plinth: *Minervae et Genio imm(unium)/ sacrum* ("Dedication to *Minerva* and the *Genius* of the *immunes*") [5] (pp. 59–60 no. 71) (Figure 1). The two figures are sculpted as a semi-plastic relief against a continuous background with an irregular outline (0.93 m high, 0.67 m wide, 0.28 m deep). The back side is rounded and only roughly worked, without details. The stone has been identified as a corallinaceous calcarenite from the Leitha Mountains [41]. The monument is almost completely preserved, except for the two hands of the goddess, the right hand of the *Genius* and the head of the owl (Figure 3a). Autopsy clearly shows, however, that it has been assembled from several fragments during restoration (Figure 3b). Superficial damage can be observed in many places, especially on the faces of the two figures, as well as on the protruding edges and borders of the drapery. It is visible to the naked eye that large sections of a whitish lime coating and polychrome paint are preserved. Pink and dark grey staining is given in some areas of the stone, attributed to fire exposure.

(**a**) (**b**)

Figure 3. Detail of *Minerva*'s left hand on the shield (partly broken) and the *Genius*' right hand (broken) holding a *patera* (**a**) and restored fractures on *Minerva*'s mantle (**b**).

Minerva wears a sleeveless, belted *chiton* with overfold, which is tied below her breast, held at the shoulders by hemispherical fibulae and which at first glance appears to open over the right leg, although a garment hem is visible on the right foot. The winged *gorgoneion* on her chest makes clear that she wears the *aegis*, the protective shield of *Athena/Minerva*, although no scales are represented in relief. The mantle hangs down from the raised right upper arm, Is passed behind the back to the left lowered forearm and slides from here to the ground where the owl (with a broken head) stands. The left hand was on the oval shield that is placed upright on the ground. The right hand probably held the metal lance, for which a drilled holder is visible on the front left corner of the plinth. *Minerva* wears closed shoes or boots and a helmet with an ornamental forehead guard and short raised cheek guards.

On the left side of the goddess stands the *Genius*, dressed in a *himation* that is wrapped around his hips, with one end thrown over his left shoulder and hanging over his left forearm, leaving his chest bare. On his feet, he wears closed boots with thickened rims. A mural crown is set on his curly, half-length hair. The broken-off right hand was connected to the right hip by a bar and probably originally held a *patera*. The left, oversized hand holds the *cornucopia* wrapped in a leaf and crowned with a huge pine cone.

Both figures are designed according to standard figure types in provincial Roman art, based on models from the Mediterranean region [42]. Execution and proportions—especially of the *Genius*—show typical provincial characteristics, as can be observed in numerous other sculptures dated to the 2nd half of the 2nd c. AD in *Carnuntum* [5].

The sculpture was found during an excavation at the legionary camp in 1903, together with several other fragmentary sculptures and altars [43] (pp. 94, 110). The findspot, in the area of the barracks (K16) [5] (pp. 365–366), and the find circumstances described by Max Groller as "*thrown together in a heap on the roadway*" (translated) clearly indicate that these objects had been secondarily moved to this location, presumably at a time towards the end of the 4th c. AD. However, the original site of installation was probably not too far away. It was most likely a meeting room of the *immunes*, exempted soldiers with special tasks within the military, who worshipped their protective deity (*Genius*) together with *Minerva* within the camp [44].

The excavation report already explicitly refers to the well-preserved paint remains of the *Minerva* statuette: "Traces or clear remnants of painting can be seen all over the surface of the figure. The nude bears traces of red; the upper garment is now dark grey, but may originally have been blue, the lower garment was light, the shield and the phalera on the chest dark brick-red, the helmet green or blue, the hair light brown" (translated) [43] (p. 110), respectively "All parts of the genius figure were painted in different shades of red, except for the light ochre hair. The inscription on the base is painted dark red." [43] (p. 111). Since the colour remains that are visible today give a much more varied impression than those described by Groller, the question of the restoration measures performed on this statuette is particularly important.

After its discovery in 1903, the statuette entered the private collection of the landowner Count Ludwigstorff. Numerous stone monuments found on Ludwigstorff's properties, especially in the area of the legionary camp, were placed in the courtyard of his castle in Deutsch-Altenburg. In 1892, a room in the main building was set up as a cabinet of antiquities. However, the exact location of the statuette at this time remains unknown.

Since the foundation of the Carnuntum Association in 1884, there had been a desire for a museum in order to bring together the archaeological finds from *Carnuntum* and to secure them permanently. Thanks to the efforts of Anton Count Ludwigstorff, who was president of the association for many years, the Museum Carnuntinum in Deutsch-Altenburg was built in 1901–1904 by the architects Friedrich Ohmann and August Kirstein. The Ludwigstorff Collection, as well as large parts of the other collections, were transferred to the new building. The statuette of *Minerva* and the *Genius immunium* was placed on a wallboard in the south wing (Figure 4) [45]. The furnishings and the conception of the exhibition remained largely unchanged from the museum's founding period until after the Second World War.

Figure 4. View into the south wing of the Museum Carnuntinum around 1904[1].

After a renovation of the museum, which had become necessary due to war damage, it was reopened in June 1950 with a systematic new arrangement of the objects. The statuette was now placed at the end of the north wing (Figure 5). In 1952/53, the Ludwigstorff Collection was acquired by the Carnuntum Association [46] (p. 7), ref. [47] (p. 108). In the same year, the museum and its collections were taken over by the state of Lower Austria and attached to the cultural department of the Lower Austrian government. After the original state of the building from 1904 had been restored in 1987, the museum was reopened in 1992 with a new exhibition. In the exhibition catalogue, there is also a reference to the restoration of the statuette, mentioning that the colourful painting could be recovered with the restoration [48] (p. 325). Unfortunately, no restoration report is available today. Archive photos from 1989/1990 show a treatment of the whole object with an aqueous poultice including the use of a solution of ethylenediaminetetraacetate and/or ammonium carbonate to soften the carbonatic layer on the object's surface for removal (cf. Section 3.2).

Figure 5. View into the north wing of the Museum Carnuntinum after 1950.

Since 2004, several exhibitions with changing thematic focuses have followed in the Museum Carnuntinum, in which the statuette has been shown in different contexts [49,50]. Since 29 June 2022, a new permanent exhibition entitled "Carnuntum—World City at the Danube Limes" is installed. The statuette is now on display at almost the same place where it was presented to visitors in 1904 (Figure 6).

Figure 6. The statuette of *Minerva* and *Genius immunium* in the current exhibition in the Archaeological Museum Carnuntinum, Bad Deutsch-Altenburg, 2023.

2.4. Non-Invasive Methods of Investigation

The aim of the study was to focus primarily on non-invasive techniques for the analysis of materials and to employ micro-invasive methods for necessary cross-checking and gaining information otherwise not accessible. In a first step, the object was investigated in detail by visual inspection, with the aid of conventional LED lamps and magnifying glasses (Figure 7a,b). Thereafter, comprehensive multispectral imaging (MSI, cf. [51]) was conducted to identify pigment phases and uncover remnants not visible to the naked eye. Because the immobile stone object was on museal display surrounded by big windows without blinds, acquisitions had to take place at night, with a tent constructed around it. Employed was a specially customized Sony ILCE-7R camera with an 855.6 mm^2 area Bayer filtered 36.4 MP CMOS sensor lacking an ultraviolet- and infrared-cutting filter, that was thus sensitive to the spectral range of ~350–1000 nm wavelength, equipped with a Sony SEL50M28 lens. Recorded image sets for every motif comprised ultraviolet reflected light (UVR), visible reflected light (VIS), near-infrared reflected light (IRR), ultraviolet induced visible luminescence (UVL), visible induced visible luminescence (VIVL) and visible induced infrared luminescence (VIL). The different image acquisition techniques required a changed experimental setup. In every case, two light sources were oriented ~45° on both sides of the optical axis, except for VIVL and IRR, where only one light source was available. For the latter, a commercial Brennenstuhl 400 W tungsten halogen lamp was used, and all other techniques deployed custom-made light sources with 100 W COB LEDs: narrow band emission centred at 450 nm for VIVL (filtered with TECHSPEC® 65201) and 370 nm for UVR and UVL (filtered with Kolari Vision UV58) and broad band emission ~5500 K white light (filtered with Hoya Y1UVIR) for VIS and VIL. Camera filters included broad bandpass Kolari Vision UV52 for UVR and Hoya Y1UVIR for VIS, as well as longpass filters Tiffen 52HZE2A for UVL, Tiffen 52OR21 for VIVL and Schott RG850 for IRR and VIL. As internal standards for white balance and colour calibration, a Zenith Lite™ Diffuse Reflectance Target, Target-UV™ and X-Rite ColorChecker® were included in each image. Post-processing of the acquired pictures and computation of infrared reflected false colour (IRFC) and ultraviolet reflected false colour (UVFC) images were conducted according to the CHARISMA protocol using the nip2 workspace [51].

(**a**) (**b**)

Figure 7. Non-invasive analysis and documentation of colour remains: visual inspection (**a**) and (macro-)photography (**b**).

The differentiated areas of pigment application were then investigated by macro photography, performed with a Sony ILCE-6400 camera with a SEL30M35 lens. Each image was white balanced via a WhiBal® G7 grey card included in every capture. A millimetre scale imprinted on the latter was used for size determination.

In the course of the evaluation of new equipment for fibre optics reflectance spectroscopy (FORS), a test measurement could be performed on the sample using a B&W Tek BTC665N thermoelectric cooled spectrometer with back-thinned CCD detector sensitive to the wavelength range 190–1100 nm. Diffuse UV-VIS-NIR reflectance spectra were recorded using a B&W Tek FRP probe and a BDS130A deuterium/tungsten halogen lamp, with a Zenith Lite™ Diffuse Reflectance Target used as reference.

2.5. Invasive Methods of Investigation

Results obtained by the microanalytical approach provide profound information on the pigments, binders and stratigraphy and of the painting layers on the sculpture. In order to keep the number of invasive sampling low, these analyses were carried out on selected areas, which seemed to be suitable to allow conclusions on the polychromy of the whole object. Analyses were carried out on cross sections of sample material. For this purpose, 18 samples were taken with a scalpel, embedded in epoxide resin, and polished. Stratigraphic analyses on cross sections gave information regarding the pigments, the painting technique or the alteration of pigments due to degradation phenomena. Additionally, the chemical characterisation of the paint reveals contemporary retouching that was applied during former restoration, and enables the distinction from historic intended changes of polychromy. Analyses were carried out using a light microscope (LM) (Zeiss Axio Scope.A1, reflected-light mode, objective: Epiplan 20×/0.4HD; camera: AxioCam Erc 5s) and a scanning electron microscope (SEM) (Zeiss EVO MA 15) with an energy dispersive X-ray detector (Bruker Xflash 630 M).

An additional sample of a red polychrome layer from the cloak on *Minerva*'s right shoulder was taken with a scalpel for investigations of organic components by gas chromatography–mass spectrometry (GC–MS). The chromatographic profile of the studied sample CAR-S-48/1 was compared with chromatographic profiles of fatty acids and amino acids of reference standards already prepared in Kunsthistorisches Museum in 2001. That time, egg was purchased from a local market in Vienna and casein (63200) was acquired from Kremer Pigments, Germany. Whole egg and a water dispersion of casein powder were spread in thin layer on glass slides and were allowed to dry and mature in daylight at room temperature for one month. These mock-ups have then been stored in a box in the dark and used continuously as reference materials.

Two analyses on this sample were performed using a 6890N gas chromatograph connected to a quadrupole mass spectrometer, model 5973N (both Agilent Technologies, USA). The analytical procedure for lipids and resins comprised a transmethylation with trimethylsulfonium hydroxide (TMSH): The sample was placed in a vial with a conical insert and then treated with a 0.2 M methanolic solution of TMSH (30 μL). The sealed vial was heated to 60 °C for one hour, removed from the heat, cooled to room temperature, and centrifuged. Then 2 μL of the clear solution was injected into a GC inlet at a temperature of 300 °C. Separation was accomplished on a DB-5 MS poly(5% phenyl-95% methylsiloxane, J&W, USA) capillary column. The temperature of the oven was programmed from 50 °C (1 min) to 320 °C (12 min) at 10 °C min^{-1}. Helium (purity 99.999%) was used as a carrier gas at an inlet pressure of 100 kPa and flow of 1.5 mL min^{-1}. For analysing proteins, an acidic hydrolysis followed by a derivatisation procedure was performed as follows: The sample was placed in a conical Reacti-vial and treated with 6 M hydrochloric acid (HCl, 100 μL). The sealed vial was heated to 105 °C for 24 h, removed from the heat and cooled to room temperature. The content was evaporated to dryness. High purity water (40 μL) was added, stirred and the content was again evaporated to dryness. Ethanol (40 μL) was added twice, stirred and the content evaporated to dryness. To keep humidity contamination to a minimum, the vial was placed into a sealed exicator for 24 h. The dried sample was then processed with a pyridine–pyridine hydrochloride mixture (10 μL) and a silylation reagent (MTBSTFA, 10 μL), and kept at 60 °C for 1 h. After cooling, 1 μL of the reaction mixture was injected into a GC inlet at a temperature of 300 °C. Separation was accomplished on the same above-mentioned capillary column with the same helium flow of 1.5 mL min^{-1}. The temperature of the oven was programmed from 80 °C (1 min) to 260 °C (12 min) at 6 °C min^{-1} [52,53].

2.6. Visualization of Results as a Working Hypothesis

In the course of the investigation, it turned out that the multitude of selective results obtained with different methods required a graphic visualisation that could serve as a working hypothesis for the further procedure and interpretation. For this purpose, a semi-transparent layer with colour information was placed over a photographic black-and-white image of the object. This colour information was based, on the one hand, on the colour remains visible to the naked eye and on the results of the 18 samples taken from the statuette, in that the colour tones detected at specific points were extended to the corresponding body parts, clothing elements or depicted objects. On the other hand, the MSI-based information on the presence of Egyptian blue was also taken into account. The schematic visualisation thus served as a working tool to summarise the results achieved so far and to address questions of interpretation.

In order to avoid confusion with an intended faithful reconstruction, details of the representation—even if they are proven beyond doubt—are not integrated into the schematic visualisation. Instead, their evidence is pointed out with the help of close-ups of particularly interesting preserved areas. Likewise, since the aim here can by no means be the true reproduction of the original appearance, both hue and shading as well as the transparency and luminosity of the polychrome surface are only approximated.

3. Results

3.1. Results of Non-Invasive Methods

The applied non-invasive methods provided information on the distribution of pigments on the surface and their identification. Results on white, blue, green, yellow, red and black colourants as well as on traces of restoration measures are discussed in order of the applied techniques. One of the main aims of MSI was to differentiate regions of different materiality and to provide first (assisting) evidence for the identification of phases (according to literature data and our own observations of reference material) that could be further investigated and confirmed by microscopic techniques and chemical analysis.

An overview of multispectral images is provided in Figure 8, and macro photos of representative areas are shown in Figure 9 and are, furthermore, included in Section 3.2 for contextualising the samples taken.

As seen by visual inspection and macro photography (e.g., well discernible in Figure 9b,c,i), remnants of a white layer were found on the object. The reflectance and luminescence features revealed by MSI are in the range expected for calcium carbonate (e.g., white in VIS, light tone in UVR, greyish UVL; cf. [54]), which was confirmed by microscopy on cross sections (cf. Section 3.2), showing that lime was used as a base layer to provide a smooth surface for the application of pigments. Furthermore, calcium carbonate may also have served as the only antique white pigment detected on a larger scale on the object so far. A sintered surface layer can be found on large parts of the object. A very prominent example is located at the neck of *Minerva*. These surficial formations typically exhibit stronger UVL and VIVL emissions (in the latter case being the only regions with intensity significantly exceeding the one observed at the 99% reflectance standard), while being dark in UVR images.

In VIL images, distinct areas of very high emission are well recognizable (Figure 10). The spectral behaviour is in good agreement with the known infrared luminescence of Egyptian blue [55]. Due to the very low detection limit and high spatial resolution of the employed MSI system, it was possible to localise even very minute particles not visible to the unaided eye. Macro photos of areas with the mentioned VIL signal revealed tiny blue particles (e.g., Figure 9a–c), thus consolidating the interpretation as Egyptian blue, together with the typical red colour in IRFC images (cf. e.g., [56]). Further evidence is provided by spot analyses in the descried areas on micro-samples taken for LM and SEM/EDX investigations: morphology, optical properties and chemical composition of platy blue particles are in agreement with the expected data for synthetic cuprorivaite, the colouring substance of Egyptian blue [57]—finally providing a strongly supported identification of this pigment and attribution to the found MSI signal via complementary cross-checking with different methods.

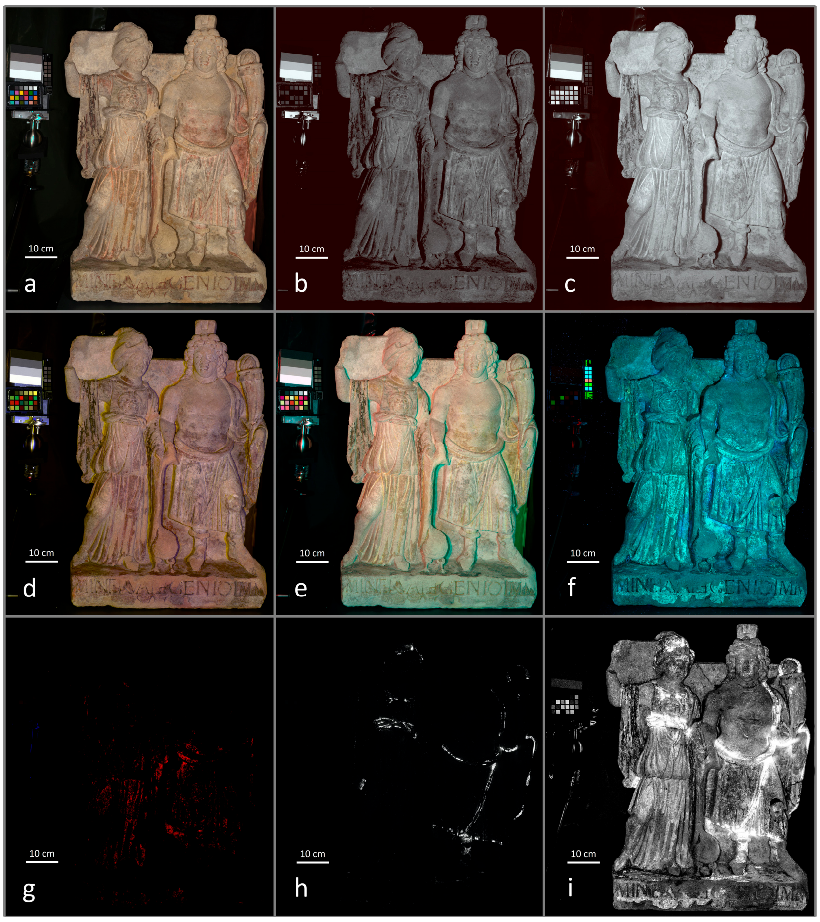


Figure 8. Multispectral image set of the entire object "*Minerva* and the *Genius immunium*" from *Carnuntum*: (**a**) visible reflected light (VIS); (**b**) ultraviolet reflected light (UVR); (**c**) infrared reflected light (IRR); (**d**) ultraviolet reflected false colour image (UVFC; note that blue and yellow colours in the contouring shadows are computational artifacts); (**e**) infrared reflected false colour image (IRFC; note that green and red colours in the contouring shadows are computational artifacts); (**f**) ultraviolet induced visible luminescence (UVL); (**g**) visible induced visible luminescence (VIVL) exceeding the intensity observed at the non-luminescent 99% reflectance target; (**h**) visible induced infrared luminescence (VIL); (**i**) VIL image with a higher degree of contamination by infrared reflected light.

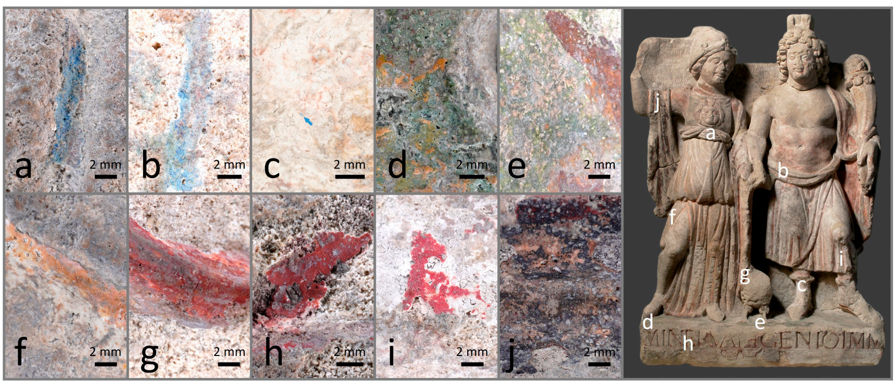


Figure 9. Selected macro photographs showing remnants of former polychromy at different indicated locations: (**a**) roll of drapery around *Minerva*'s waist; (**b**) drapery around the *Genius*' hips; (**c**) the *Genius*' boots; (**d**) upper surface of the plinth; (**e**) the owl's claws; (**f**) *Minerva*'s *chiton*; (**g**) *Minerva*'s shield; (**h**) filling of the inscription letter *E*; (**i**) the *Genius*' mantle; (**j**) *Minerva*'s mantle (for better use of space, all pictures were rotated 90° clockwise to the orientation of capture).

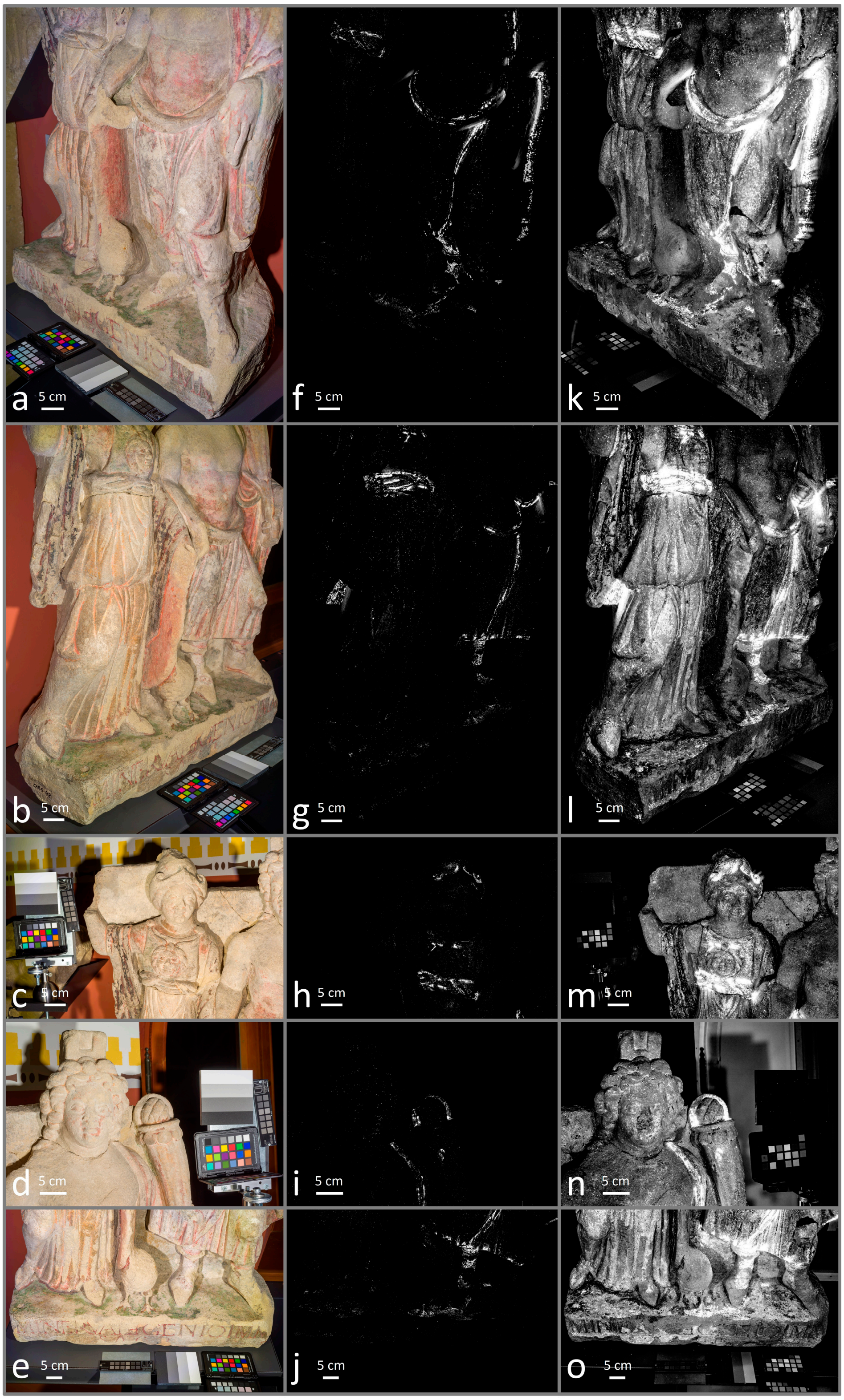


Figure 10. Multispectral image sets of different perspectives, recorded to highlight the distribution of the pigment Egyptian blue: (**a**–**e**) visible reflected light; (**f**–**j**) very pure visible induced infrared luminescence (VIL) images with no contamination by ambient stray light; (**k**–**o**) VIL images showing a higher degree of contamination by infrared reflected light. The white areas in the middle column and the brightest white areas in the right column are attributed to the very intense infrared luminescence of the pigment Egyptian blue.

VIL images suggest the presence of widely scattered minute particles of Egyptian blue on practically all antique surfaces of the object, while they are mostly missing on broken and amended parts and also on the museal pedestal beneath it (close examination in comparison with other MSI images of analogous lighting conditions contraindicate a possibly biased interpretation caused by local specular reflection in the vast majority of cases). This phenomenon has been found on many other Roman-age objects in the region (e.g., [58]) and may be used as an indicator for the temporal delimitation of the dispersal, i.e., being antique and not modern. Due to the perfect cleavage of synthetic cuprorivaite (e.g., [59]), platelets of this sheet silicate are easily disassociated from the crystals in high abundance source areas and may have been redeposited on other parts of the object. This could have contributed to the found occurrences, e.g., on top of the plinth, even though further accumulations, aside from direct deposition, reveal directions and indications for primarily applied paint, suggesting that the latter prevail.

Whereas there was no indication for other blue pigments in this object, Egyptian blue was used extensively—larger areas of preserved accumulations are found on distinct parts of the two figures (cf. Figure 10): In *Minerva*, they are concentrated in the front part of the helmet, in the wings of *Medusa*'s head, the roll of drapery around her waist and the folds of her *chiton* and her mantle. A very distinct part below the folds of the mantle on her right side contrasts strongly with the latter and the background, as it is intensely coloured by Egyptian blue. In the *Genius*, Egyptian blue is mainly constricted to the roll of drapery across his hips, the edge of the *himation* as well as its folds, the background of the pine cone on the *cornucopia* and the boots. For the latter, VIL images reveal a detailed pattern not perceptible to the naked eye (macro photos, however, confirm the presence of scattered blue particles—cf. Figure 9c). This is of particular interest because this feature is only depicted by colour and not by carving. On the better-preserved right foot, the Egyptian blue signal is only present on the front and not at the sides. This part is almost completely lost on the other foot—however, there seems to be a small extant remnant on the outward-facing side.

Comparing the distribution of Egyptian blue with the other pigment phases, some noticeable coincidences can be distinguished: VIL images reveal the presence of Egyptian blue within the green areas on the upper side of the plinth and the reddish colours of the garments. Further confirmation of this mixing of colours was provided by cross-section analyses (cf. Section 3.2). Contrasting to its wide occurrence within the object, there is no discernible areal accumulation of Egyptian blue in the background. However, the latter is characterised by widely distributed remnants exhibiting green colour in VIS while being greenish-black in IRFC and dark in IRR and UVR images. This combination of features is expected for green earth pigments (e.g., [54]), which were also confirmed by cross-section analyses (cf. Section 3.2). Also, on the upper side of the plinth, large areas of preserved green earth applications are detected (cf. below Figure 13). Allocated within these areas, there are distinct areas of high VIL signal of Egyptian blue and, at different locations, also typical features of yellow ochres (orangish yellow in VIS, translucent in IRR, dark in UVR, very absorbing in UVL, greenish yellow in IRFC and purple in UVFC; cf. e.g., [56]). The latter are also found in the *gorgoneion* (cf. below Figure 15), the fillings of the *cornucopia* and the hair of the *Genius*. Remnants of red pigments widely distributed on the draperies of *Minerva* and the *Genius*, as well as in the carved letters in the inscription, exhibit the features expected for red ochres (red in VIS, translucent in IRR, dark in UVR, very absorbing in UVL, golden yellow in IRFC, dark in UVFC; cf. e.g., [56]). This was further confirmed by cross-section analyses (cf. below Figure 19) and a trial measurement with a FORS spectrometer that was available for testing (Figure 11).

In the folds of the mantle hanging down from *Minerva*'s right upper arm, a very complex pattern of signals is found, that does not allow an unequivocal attribution to distinct phases so far. In this area, there is an indication of modern retouching (cf. Section 3.2) and of the use of organic binding media (cf. Section 3.3). Some features of red and black areas are in good agreement with the expectations for red lead (reddish VIS, dark UVR, dark red

UVFC, yellowish IRFC; cf. e.g., [60]) and carbon black (dark in all MSI images; cf. e.g., [56]), which were found by cross-section analyses (cf. below Figure 16).

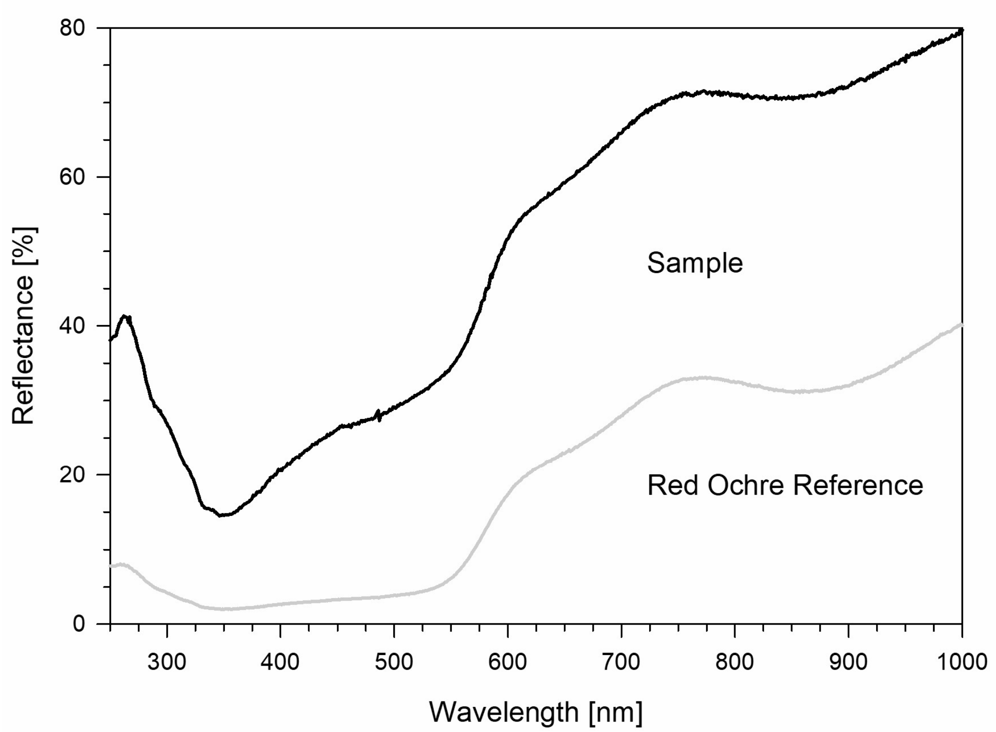


Figure 11. A diffuse UV-VIS-NIR reflectance spectrum recorded by fibre optics reflectance spectroscopy (FORS) on the remnants of red pigments in a pleat of *Minerva*'s *chiton* near sample point B (cf. Figure 12) shows very good agreement with reference spectra of red ochres—here shown is a measurement on a sample of Kremer pigment #116431 ("Red Moroccan Ochre").

No major abnormalities are perceivable via MSI at the locations of known conservation and cleaning actions, and no remnants of the former outlining markings applied within the procedures are discernible anymore.

Very localised patches of bright blueish and yellowish luminescence in UVL images are found on some parts of the object—mainly at the mantle folds of *Minerva*. Here, one sample taken for microscopic analysis revealed the presence of modern-age compounds like barium sulphate and zinc oxide that are not expected to have been used in Roman times (sample A, Section 3.2). Because lithopone and zinc white are known for emitting noticeable luminescence under UV irradiation, the mentioned UVL signals are interpreted as being related to very localised modern retouches performed on the object.

Even though the analysis of extant replenishments and gluing was not within the scope of this study, some prominent results can be recorded, for differences between original and added parts are very pronounced in certain multispectral images: VIL pictures exhibit a striking light grey versus black contrast between the luminescing limestone and the practically non-luminescent material used for replenishments. UVL and VIVL images also visualise this marked difference due to the extremely low emission of modern materials. Although otherwise not very revealing in this respect, UVR images exhibit an anomaly with two different phases within the modern amendments on the left knee of the *Genius*. The differences in materiality as compared, e.g., to the very closely situated fillings of the cracks in his garment, are likely explained by the large time gap of more than a century between them.

The results clearly show that MSI often greatly improves the fast detection and localisation of retouches and refurbishments.

3.2. Chemical Analysis on Cross Sections

All in all, 18 samples were taken on the polychrome surface of the statuette (Figure 12), of which a representative selection is presented below.

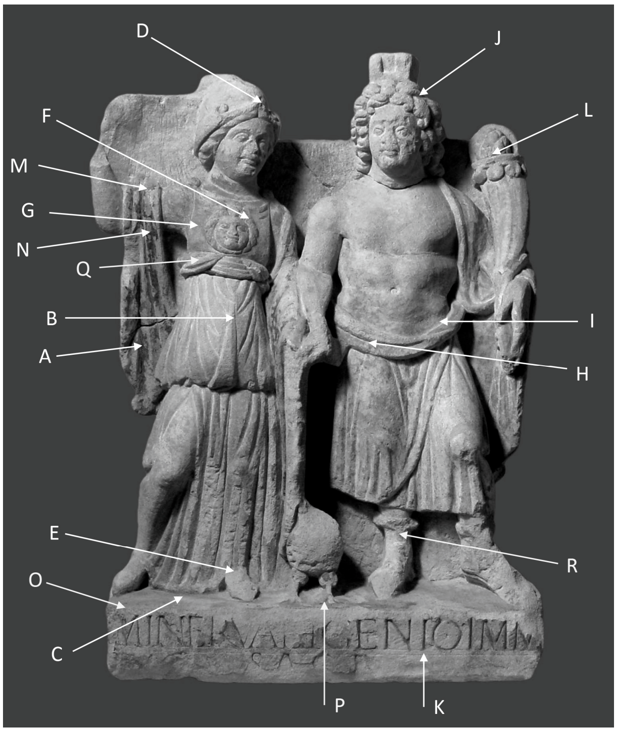


Figure 12. Samples A–R taken for chemical analysis on the statuette of *Minerva* and the *Genius immunium*.

The paint was applied on a layer of white lime wash, which gave the porous stone a homogeneous surface and the sculpture itself a smooth appearance. This lime wash strongly varies in thickness, ranging from approximately 10 µm to approximately 500 µm. Apart from lime, which was used for white areas, variations of red and yellow ochre, green earth, red lead and carbon black could be observed and verified by chemical analysis. Additionally, the object shows several traces of Egyptian blue, which mainly has been detected in *Minerva*'s and the *Genius*' clothes. With the exception of red lead (see Section 3.3), all pigments were applied in lime as a binding medium. Investigations of cross sections partially show a compact surface layer of calcium carbonate, which results from recrystallisation processes during the period of burial (e.g., sample C; Figure 13a–e). Whereas the cross section in the LM shows a combination of green and dark paint layers, which were covered by a layer of recrystallised calcium carbonate (Figure 13b,c), the analysis in the SEM shows a rather compact and homogeneous zone, which has been crystallised throughout (Figure 13d,e). Due to a conservation treatment, which has already been mentioned in Section 2.3, the crystallised surface layer was removed (or at least reduced) by a chemical treatment with ethylenediaminetetraacetate and/or ammonium carbonate.

Flesh tones such as both faces or the *Genius*' body (sample I) were painted with red ochre and, therefore, had a quite dark red appearance. Traces of Egyptian blue were observed on the *Genius*' drapery (sample H) and on *Minerva*'s helmet (sample D; Figure 14a). Comparative analyses, carried out by LM and SEM reveal a characteristic grain size distribution of Egyptian blue up to approximately 100 µm diameter (Figure 14b,c). Besides lime, which was used as a binder, the analyses in the SEM show particles of calcium carbonate that can be interpreted as white pigment to give the painting a light blue appearance. Underneath the blue layer, with a thickness of approximately 200 µm, the cross section shows a white lime wash, which was used as grounding as described previously.

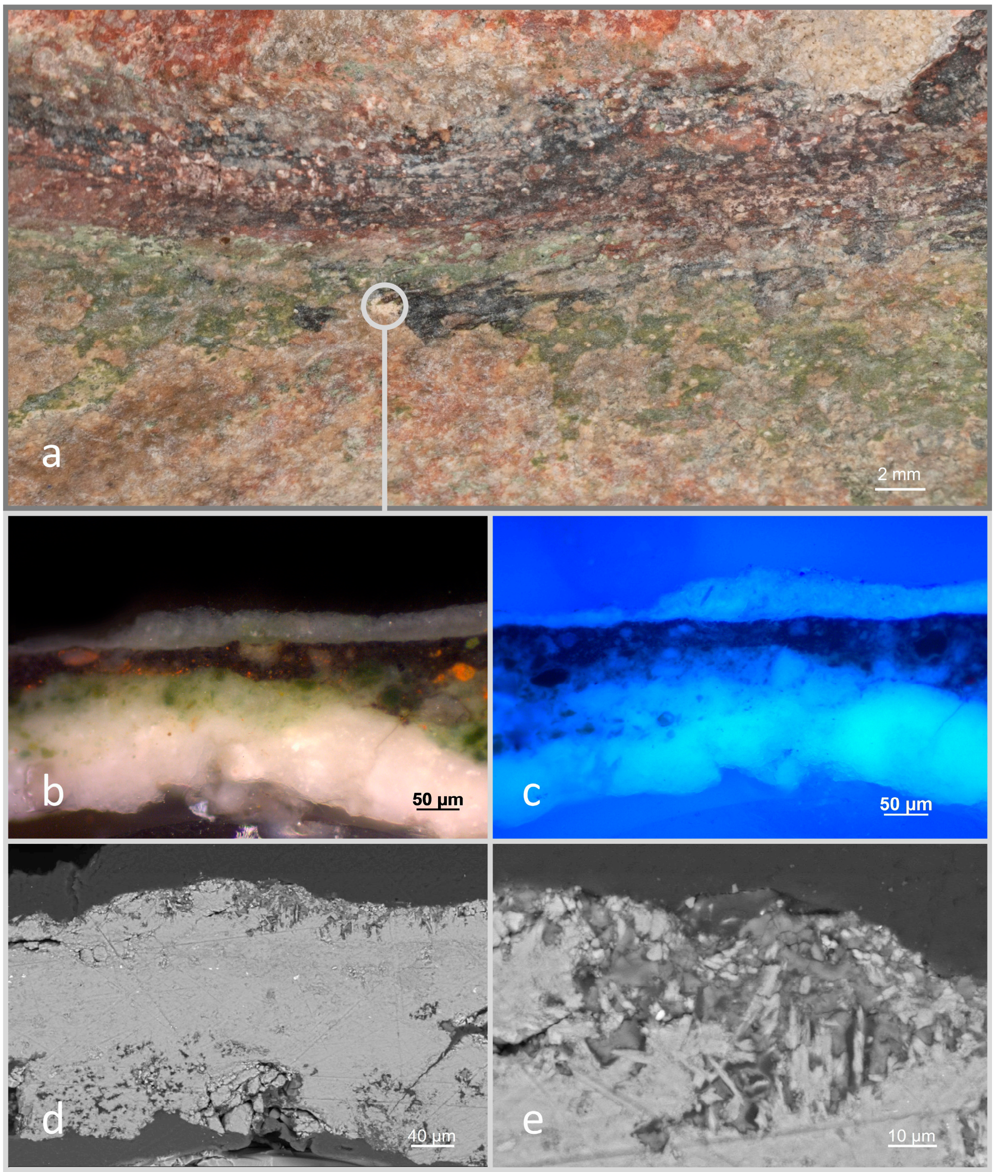


Figure 13. (**a**–**e**) Sample C (219/19): green meadow next to *Minerva*'s feet. (**a**) Macro photography of the area; (**b**) cross section in the light microscope; (**c**) cross section in the light microscope under UV light; (**d**) cross section in the SEM (backscatter electron-mode); (**e**) detail of Figure 13d showing calcite crystals on the object's surface.

A single proof for Egyptian blue was also given at the roll of drapery wrapped below *Minerva*'s breast. Her *chiton* was painted with red ochre in a lime binding (sample B). The background of the sculpture as well as the upper surface of the plinth were painted with green earth (samples C, M). The colour of the *Genius*' hair was yellow ochre (sample J), also giving an intensive appearance. No hints for a former application of gold leaf could be observed.

Some samples show two layers of colour, which can be explained by overlappings during the painting process. For instance, the owl's claw (sample P) was painted with yellow and red ochre, the red colour being on top of the yellow one. Additionally, the absence of green earth that indicates the ground area around the owl gives evidence that the colouring pursued a detailed plan (cf. below Figure 23a).

Three overlapping layers have been detected in sample F near the right wing of the *gorgoneion*. It seems as if the wings were painted with yellow ochre, emphasised by a red ochre outline. On top of this, another application of Egyptian blue was probably applied in order to highlight the background (Figure 15a–c).

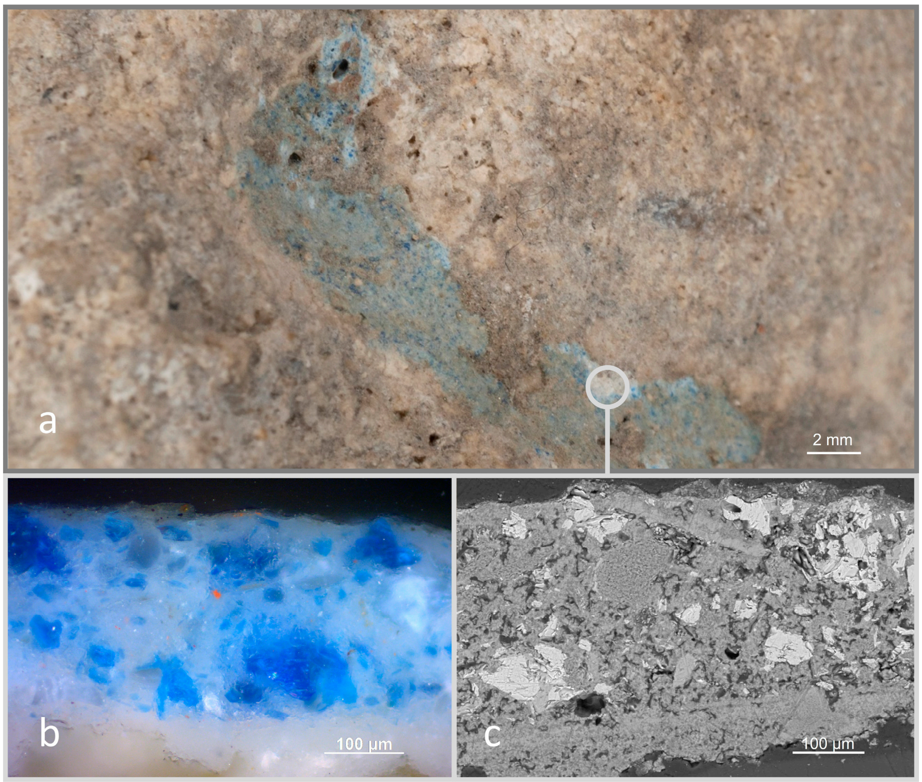


Figure 14. (**a**–**c**) Sample D (220/19): *Minerva*'s helmet. (**a**) Macro photography of the area; (**b**) cross section with Egyptian blue in the LM; (**c**) cross section with Egyptian blue in the SEM.

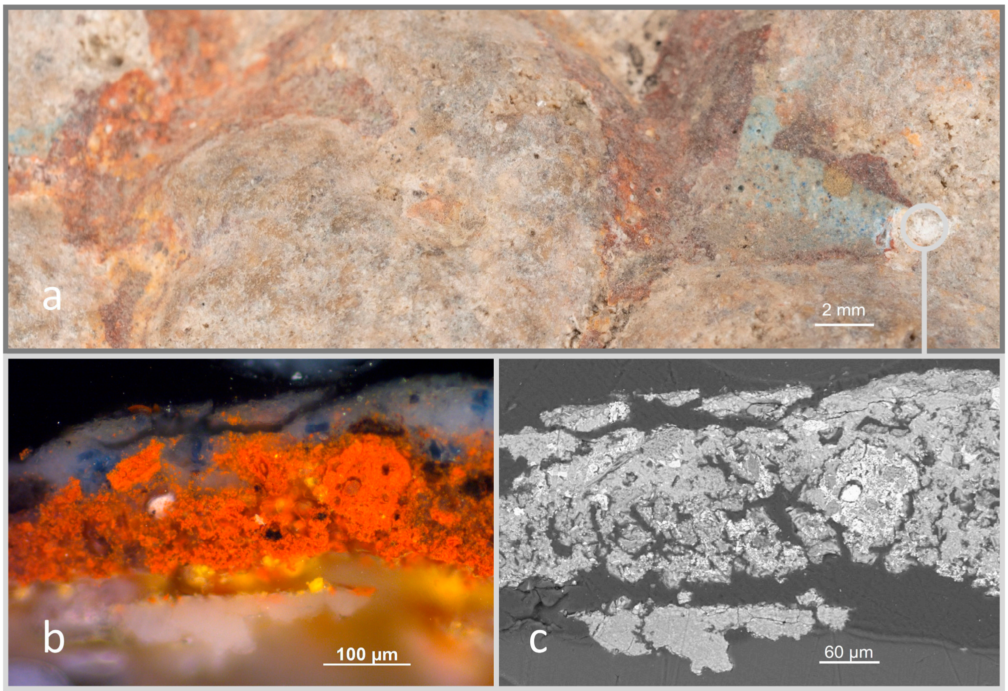


Figure 15. (**a**–**c**) Sample F (222/19): right wing of the *gorgoneion*. (**a**) Macro photography; (**b**) cross section showing three layers of yellow and red ochre and a layer of Egyptian blue in the LM; (**c**) cross section showing three overlapping layers of paint in the SEM.

Contrary to this observation, a sample from *Minerva*'s *chiton* shows two layers of orange-red painting (sample N; Figure 16a,b), which were found by SEM-EDX to be executed using lead-based pigments. The most probable material is red lead, with Pb_3O_4 as the main phase—which has also been verified in similar objects from the same locality in the course of the current project by X-ray diffraction, cf. [61]. The slight difference in colour between the layers may result from the observable difference in grain size distribution and possible variations caused by the production process (e.g., a higher amount of not-converted lead carbonates), indicating the use of two paints of different quality. Between both paintings a thin black film could be observed in the cross section, which looks like a layer of dust or soot. This observation gives evidence that at least some parts of the sculpture were painted twice, with an undefined time interval between both layers of polychromy. A comparison of both paint layers in the cross section in the LM shows a slightly varying grain size distribution and colour of the pigments, which leads to the assumption that two different paints were applied. The chemical analysis by SEM-EDX shows that the thin dark layer mainly consists of dissolved lead ions in an organic matrix, giving an indication for the presence of an organic matrix or the application of an organic binding material, respectively (Figure 16c). It is striking that no other samples of cross sections showed this dark layer in their stratigraphy. If the black film between both paint layers derives from a deposition of soot, caused by fire, an oil lamp or a blaze, there is currently no explanation as to why other parts of the sculpture did not show this kind of soiling. In principle, a discolouration of red lead due to alteration phenomena of red lead pigments cannot be excluded, from the chemical point of view. Although the chemical process of this form of pigment degradation has not been completely clarified so far [62], the chemical composition of the pigments, as well as environmental factors such as light, humidity or microbial activities, seem to play a major role in the chemical stability of red lead pigments, leading to the formation of black plattnerite (PbO_2) [63,64]. This gives rise to the assumption that a colour change might have occurred quite soon after the sculpture was painted the first time, and, therefore, it was overpainted with a second layer. Anyhow, chemical analyses of both layers, as well as other layers that were painted with red lead, show nearly a complete lack of calcium by SEM-EDX, giving evidence that red lead was not painted using a lime technique. Moreover, the chemical analyses of all samples containing red lead showed unusually high concentrations of phosphorus, which frequently indicates the presence of a proteinaceous binding material. Chemical analyses, which were carried out by GC–MS, show the presence of amino acids, which were related to the presence of egg as a binder of the red lead pigments (see Section 3.3). Another explanation could be the chemical reaction from hydrogen sulphide, which is formed in (rotten) eggs, and red lead, leading to black lead sulphide (PbS). As chemical analysis by SEM-EDX does not enable a clear distinction between PbO_2 and PbS, the chemical process could not clearly be identified. However, it seems that at the time of production, it was already known that red lead was unstable in an alkaline matrix (such as lime), and, therefore, egg was used as a binder.

An elemental analysis of the cross section of sample E taken on the hem of *Minerva*'s *chiton*, which was painted with red lead, also shows a clear correlation between the presence of lead and phosphorus in the paint layer (Figure 17a–e). This gives evidence that this element was not just a random detection, but definitely refers to the red lead paint or the binding medium. A closer look to the elemental distributions of Pb and P (Figure 17d,e) gives evidence for a clear correlation between both elements. This observation provides an indication for the lead pigment as a source for P. As this phenomenon has not been observed before or found in the literature, no conclusions could be drawn as to whether these significant amounts of phosphorus could be attributed to the proteinaceous binding medium or to the production procedure of red lead. As the detection of phosphorus solely refers to the areas painted with red lead, a secondary contamination from soil during the time of burial or an (inappropriate) cleaning of the archaeological find with phosphoric acid, at least, seems implausible or can even be excluded.

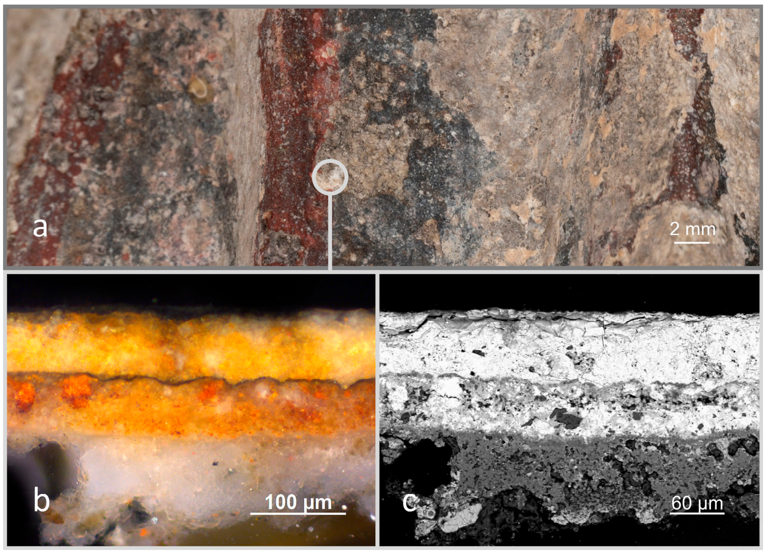


Figure 16. (**a**–**c**) Sample N (230/19): *Minerva*'s mantle. (**a**) Macro photography of the area; (**b**) cross section showing two layers of red lead paint in the LM; (**c**) cross section showing two layers of red lead paint in the SEM.

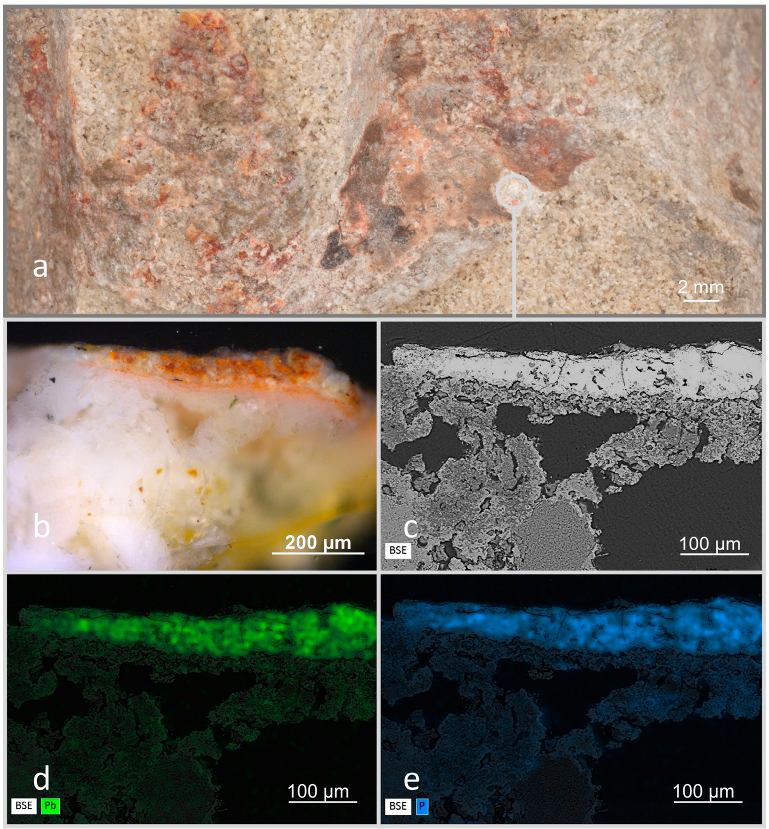


Figure 17. (**a**–**e**) Sample E (221/19): hem of *Minerva*'s chiton. (**a**) Macro photography of the area; (**b**) cross section in the LM; (**c**) cross section in the SEM (BE-mode); (**d**) cross section in the SEM (elemental mapping of Pb); (**e**) cross section in the SEM (elemental mapping of P).

Shadows of grey in a pleat of *Minerva*'s belt (sample Q) show a thin layer of carbon black over a layer of Egyptian blue, which can be interpreted as an indication that shaded areas on the sculpture's surface were painted darker in order to enhance its three-dimensional appearance or plasticity (Figure 18a,b).

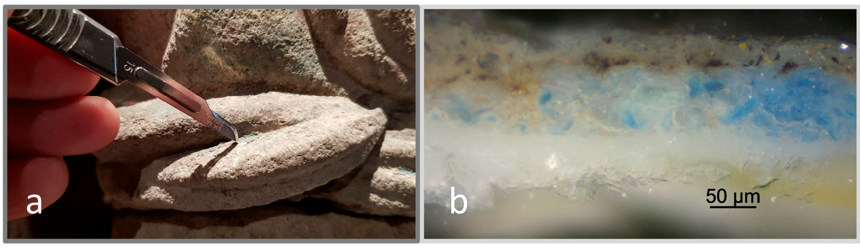


Figure 18. (**a**,**b**) Sample Q (4/23): roll of drapery under *Minerva*'s breast. (**a**) Shaded areas in *Minerva*'s drapery were painted with a thin layer of carbon black; (**b**) in the light microscope, a cross section of sample Q shows a layer of Egyptian blue, covered with a thin layer of carbon black and ochre.

Contrary to a number of archaeological objects with inscriptions discovered in the 19th and early 20th c., the inscription of this sculpture shows no post-antique tracing or improvement of the letters. The original inscription is characterised by an intensive red colour, painted with red ochre that, in contrast to the white background, ensured a good legibility (Figure 19a–c). The cross section in the LM and the SEM shows a thick and recrystallised layer of lime wash, which was used as a ground for the red paint and as background.

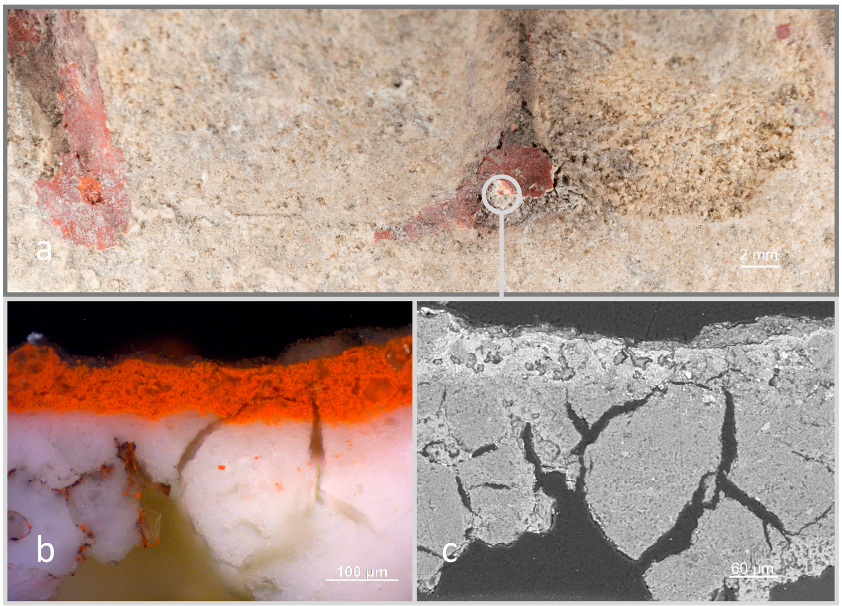


Figure 19. (**a**–**c**) Sample K (227/19): letter *I* in the inscription *GENIO*. (**a**) Macro photography; (**b**) cross section in the LM; (**c**) cross section in the SEM.

Retouchings, which could be observed on some spliced fragments (sample A), contain zinc white and barite but no titanium white, which gives rise to the assumption that these interventions of restoration were done close to the time when the sculpture was found in 1903.

3.3. Gas Chromatography–Mass Spectrometry

Gas chromatography–mass spectrometry allows the identification of organic binding media and can provide important information about ancient painting techniques. This method separates and detects heterogenous mixtures of organic binders in minute samples. The organic binding media are complex organic materials with a polymer structure. Pigment grains dispersed in the binders form a coherent paint film on the surface of the support.

The above-mentioned comprehensive and detailed microscopic investigation on a complex set of cross sections prepared from selected samples, carefully taken from the remaining polychromy of the statuette, revealed that in major areas, lime was mostly applied as a binder, whereas in red pigmented areas an organic binding medium could possibly be suspected. Therefore, an extra sample was taken from this red polychromy layer for subsequent GC–MS analysis to validate this assumption. However, due to the extremely fragile and limited remnants of the polychromy, only one sample could be taken for these investigations.

The red polychrome layer sample taken by scalpel from *Minerva*'s cloak on her right shoulder (same area as sample N) was divided into two parts for the chromatographic investigation. The first part was analysed for the presence of lipids and resins, while the second part was undergoing investigation on proteins. Distributions of fatty acids and amino acids were then crucial criteria to detect and specify particular lipidic and proteinaceous binding media, respectively [65–70].

Despite the ageing and deterioration processes that have caused an alteration of the organic matrix, it was possible to detect remnants of organic binding media in the studied polychrome layer (Tables 1 and 2; Figure 20). From the presence and ratios of both fatty acids originating from the lipidic part and amino acids coming from the proteinaceous part, it could be concluded that the major binding medium is possibly egg. However, the presence of casein should not be excluded either; elevated amounts of lauric and myristic acid with respect to palmitic acid and stearic acid, as is distinctive for casein, were observed. Moreover, for the proteinaceous profile of egg, there is a typical high concentration of serine and aspartic acid, whereas for casein, a high abundance of proline and glutamic acid is indicative.

Table 1. The ratios of the fatty acids (FA) of reference standards and studied sample.

FA Ratios	Whole Egg *	Casein **	CAR-S-48/1
Pa/St	3.2	2.2	2.7
Az/Pa	0.3	-	0.1
Ol/St	0.7	1.1	0.4
Pa + St/My + La	22	4.0	7.5

Note: fatty acids: Pa = palmitic acid, St = stearic acid, Az = azelaic acid, Ol = oleic acid, My = myristic acid, La = lauric acid. * purchased from local market, ** Kremer Pigments, Germany.

Table 2. The ratios of the amino acids (AA) of reference standards and studied sample.

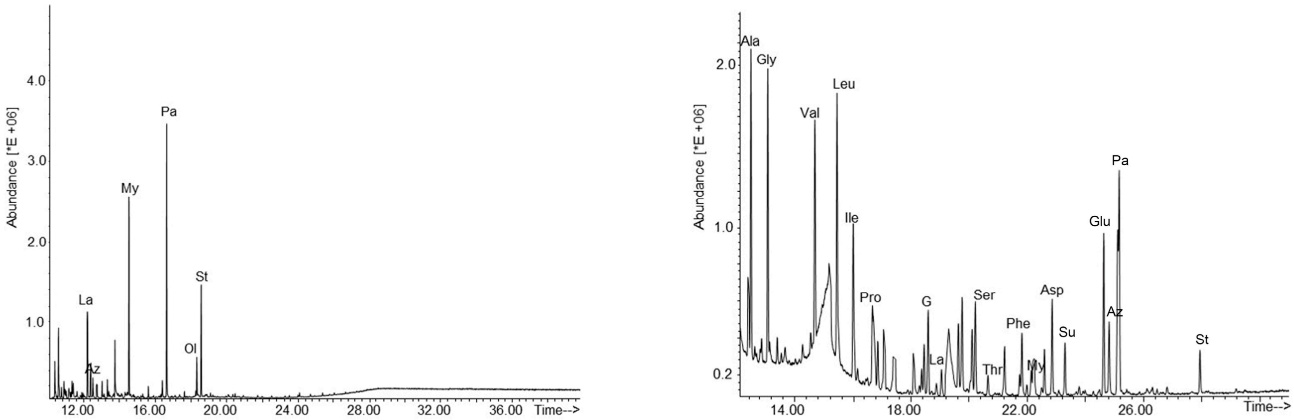
AA Ratios	Whole Egg *	Casein **	CAR-S-48/1
Glu/Asp	0.9	1.6	1.6
Leu/Ala	1.3	2.1	1.3
Val/Ala	0.9	1.3	1.2
Gly/Ile	1.0	0.7	1.3
Ala/Gly	1.3	1.4	1.0
Pro/Leu	0.3	1.2	0.3

Note: amino acids: Ala = alanine, Gly = glycine, Val = valine, Leu = leucine, Ile = isoleucine, Pro = proline, Asp = aspartic acid, Glu = glutamic acid. * purchased from local market, ** Kremer Pigments, Germany.

From the six amino acid (AA) ratios (Table 2) which are considered characteristic markers of how to differentiate a particular protein, it is clear that four ratios out of six match egg, whereas three ratios out of six could correspond more to casein. Additionally, besides a series of fatty and amino acids, the presence of phosphoric acid formed during sample hydrolysis was confirmed. Phosphorus, possibly originating also from the egg, was similarly observed in the polychrome layer by SEM-EDX investigations, as mentioned in Section 3.2.

The choice of binders, in this case the application of egg or the plausible use of a mixture with casein, could be affected by different factors, like the selection of pigments and their stability in the paint layer, the intensity of the anticipated colour hue, and the light exposure of the artifact in its surroundings.

Therefore, knowledge of the binding media composition is crucial for the comprehension of the techniques of the ancient artists, and the obtained results are also important for the adoption of suitable conservation and restoration interventions.



(**a**) (**b**)

Figure 20. The chromatograms of the organic material from sample CAR-S-48/1 after methylation (**a**) and after HCl hydrolysis (**b**). ©KHM Wien. (**a**) Cholesterol (Ch) and fatty acids: La = lauric acid, Az = azelaic acid, My = myristic acid, Pa = palmitic acid, Ol = oleic acid, St = stearic acid. (**b**) Amino acids: Ala = alanine, Gly = glycine, Val = valine, Leu = leucine, Ile = isoleucine, Pro = proline, Ser = serine, Thr = threonine, Phe = phenylalanine, Asp = aspartic acid, Glu = glutamic acid, PhA = phosphoric acid; glycerol (G) and fatty acids: My = myristic acid, Su = suberic acid, Az = azelaic acid, Pa = palmitic acid, St = stearic acid.

4. Discussion

The investigations have shown that the entire front side of the statuette had a polychrome and very differentiated surface. The back side, which was only roughly worked, could not be examined in the current museum setting, but does not show any paint residues visible to the naked eye. The detected pigments carbon black, calcium carbonate white, Egyptian blue, green earth, red lead, and red and yellow ochres were widely available at the time of construction, whereas there is no proof for the use of the more expensive vermilion. Thus, the findings on the statuette of *Minerva* and *Genius immunium* essentially correspond to the preliminary results on similar objects from the area of investigation [58,71–73].

In essence, the existing paint remains are likely to be a more or less uniform paint finish. Only sample N (Figure 16) from the mantle of *Minerva* clearly shows two successively applied layers of paint, which may have been due to the need for a partial touch-up because of soiling or other colour change. The maintenance of the cult images was one of the duties of the worshippers and may be interpreted as a sign of vitality of the cult over a certain period (cf. [74]) (p. 639 note 2716). However, no statement can be made about the time range between the two colour applications. The several layers of paint found in samples C (Figure 13) and F (Figure 15) seem to be more related to the painting technique and are discussed below.

In the schematic visualisation of the results obtained so far (Figure 21), the different elements of the sculpture have been coloured according to the paint residues detected by the methods described above. Differentiation through shading or contouring, as well as subtle nuances of the shades and details of the ornamentation, are not taken into account here. However, the highly simplified and, in many parts hypothetical, overview of the individual colour areas serves as a working tool for investigation and enables a better understanding of the representation and its elements.

Figure 21. Schematic visualisation of the colour distribution in comparison to selected sections of the preserved original surface.

Individual areas, such as the roll of drapery around *Minerva*'s waist and the hem of her *chiton*, as well as the edges of both *Minerva*'s and the *Genius*' mantles, seem to be highlighted through the application of Egyptian blue and red lead (Figure 10). In the case of *Minerva*, the differentiation of the individual parts of the garment does not appear to be entirely logical. The impression created by colour mixing could be aimed at a resemblance to purple and could be reminiscent of the garment hems also known from the Roman *toga praetexta* [75] (pp. 20–26). The choice of binder is likely to have played an additional role in the colour intensity of the different paint applications, especially in certain parts of the garments.

The macro photographs show that chiselled forms are differentiated and modelled by the application of paint. In the draperies, different shades of bright and dark red are based on red ochre and red lead. Darker colouring of the shallow furrows of the drapery create an impression of plasticity (Figures 16–18).

Similarly, an enhancement of the plastic effect is also given in the hair areas, where yellow ochre has been detected (sample J) and an accentuation of the furrows with light brown colour is still clearly visible (Figure 22).

Highlighting by emphasising the outlines was achieved in several other sectors, for example on the claws of the owl (Figure 23a) or on the upper edge of the *cornucopia*, where areas covered by yellow ochre were outlined by red ochre (Figure 23b).

This painting technique likely explains the presence of several layers of paint, also evidenced in samples C (Figure 13) and F (Figure 15). While the recess of the green background in the area of the sculpturally chiselled claws of the owl suggests a planned approach by the painter, the brown paint layer in sample C appears to be a touch-up, as it penetrated under the green layer at a defective spot (Figure 13). Also, the triple overlapping application of paint with Egyptian blue on top in the area of *Medusa*'s wings (Figure 15) is probably due to a correction applied in order to clearly separate the wings from the hair, as both areas are depicted in yellow with red outlines.

The frequent use of the stroke technique, both in emphasising outlines and in differentiating surfaces, can be considered a striking feature of this statuette. Within the framework of the project, further examples will be used to investigate whether this should be regarded as a stylistic device or as a general characteristic of provincial sculptures and/or reliefs.

Figure 22. Head of the *Genius* with yellow ochre hair, the strands being delimited by darker lines.

(**a**) (**b**)

Figure 23. Overlapping colour layers due to red contouring of yellow areas on the owl's claws (**a**), respectively, on the upper edge of the *cornucopia* (**b**).

VIL images reveal the presence of Egyptian blue within the reddish colours of the garments. Especially localised in the pleats, it could have been used for rendering a darker tone to create the impression of shadows and, therefore, improving perceived plasticity. Also, wide occurrences of Egyptian blue within the green areas on the plinth can be interpreted as an adjustment of the colour tone, perhaps meant to achieve the impression of a more complex scenery or to be more contrasting to the background (where there is no indication for extensive amounts of Egyptian blue).

In several areas, details and ornaments were depicted exclusively in colour, without being plastically shaped. Thus, on the faces of the *Genius* and *Medusa*, the indication of the iris and pupil and the outline of the eyelids can be recognised by the naked eye. MSI suggests that a small-scale representation of lacing and ornamentation appears on the red boots (*calcei*) of the *Genius*, thus possibly indicating footwear of a specific rank [76] (pp. 49–50).

In *Minerva*'s helmet, the blue colouring is likely to indicate an imitation of the metallic material (sample D, Figure 14), a procedure that finds parallels in numerous other examples in the study area.

Special attention was paid to the polychromy of the divine attributes, such as the *cornucopia* held by the *Genius* or the *aegis* of *Minerva*, to whose colour has been attributed a symbolic meaning since the Greek Archaic Period [77]. The drawing in the area of *Medusa*'s face and wings, as well as the surrounding areas of the *aegis*, painted in green, but without any discernible scales, can no longer be traced in detail. On the *cornucopia*, Egyptian blue seems to be used to highlight individual parts, such as the "halo" of the pine cone on its top. The shaft and the upper rim with leaves of the *cornucopia* appear to have had a multi-coloured decoration in yellow and different shades of red.

Some MSI images elicit the impression of a rounded feature at the *Genius*' chest (Figures 8b,c and 24). Investigations with raking light confirm the coincidence with a small protrusion at this location, that does not correlate with human anatomy. Examples of related sculptures (e.g., [78]) suggest that a *bulla* attached to a necklace was depicted here, an attribute frequently found in depictions of youthful *Genii*. Although very intriguing, the interpretation of two horizontal features emerging from fine contrasts in the MSI pictures just below the pectoralis major muscle and the umbilicus, respectively (Figure 24a), as leather straps (support of *phalerae*?) is not substantiated enough to elevate it above speculation and could also derive from post-ancient circumstances.

Figure 24. Detail of an infrared reflected light image (**a**) and visible reflected raking light (**b**) of the *Genius*' chest, showing a round and slightly protruding feature, possibly to be interpreted as the depiction of a *bulla* (marked with arrow).

Both deities are represented with blonde hair, and in this way correspond to the divine ideal of beauty (cf. [74]) (pp. 579–580).

While sculptural parallels with preserved painted surfaces are lacking, several fresco depictions of *Minerva* show that the goddess was frequently depicted wearing a red *chiton* (e.g., *Hercules* in *Olympus* with *Iuno* and *Minerva*, 1st c. AD, Hall of the Augustals, *Herculaneum* [79]; *Hercules* and *Minerva*, mid 4th c. AD, *cubiculum* N, Catacombe della Via Latina, Rome [80]). As for the *aegis*, the protective breastplate of *Minerva*, which is often rendered scaled [81] (pp. 1074–1110), a blue-green colour is sometimes attested, possibly reflecting Roman scale armour (e.g., mosaic tondo, 3rd c. AD (?), Museo Pio Clementino, from *Tusculum;* the *aegis* is, however, probably in large parts a restoration of the 18th c.) [81] (p. 1076 no. 3; available online in colour: https://commons.wikimedia.org/wiki/File:Athena_mosaic_Pio-Clementino.jpg. Museo Pio-Clementino (photo by Jastrow 2006 [accessed on 23 March 2023]).

As the *Genius immunium* is the protective deity of a group of soldiers (the *immunes*), a military reference in his clothing could be expected. While the appearance of his *calcei* can no longer be reconstructed in detail, the red waistcoat could refer to the general's coat, the *paludamentum* [82].

The red colouring of the skin parts is visible to the naked eye in numerous places in both figures (Figures 1 and 22). While the choice of red colour for the dresses of the deities is less unusual, the choice for the overall red effect of the two figures, and especially of their skin tone, was certainly charged with meaning. The red colour associated with deities was in the first instance purple, the most exclusive and most expensive colour of classical antiquity [83] (p. 209). Purple was a symbol of power and prestige; it was the colour of triumph and of divine authority [84] (pp. 208–209). However, due to the expensiveness of the purple dye (Tyrian purple), it was not unusual to use other pigment mixtures to emulate the costly purple, like red ochre and red lead mixed with Egyptian blue in our case [84] (pp. 488–489). The chromatic effect of the red figures was additionally emphasised by placing them against the green background (instead of the usual blue). This way, the mighty pair emanated their divine power with special strength, assuring the soldiers of their divine protection and favour.

Author Contributions: Conceptualization, G.K.; collection history and archival work, E.P., G.P. and M.B.; MSI, R.K. (Sections 2.4 and 3.1); chemical analysis, R.L. (Sections 2.5 and 3.2); GC–MS investigation, V.P. (Sections 2.5 and 3.3); archaeological context and interpretation, G.K., N.S., G.P. and E.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Austrian Academy of Sciences, Heritage Science Austria 2020 (Heritage_2020-028_PolychroMon).

Data Availability Statement: The data presented in this study are available on request from the corresponding authors. The data will be partly available in a publicly accessible repository after the end of the project.

Acknowledgments: We owe thanks to the AMC staff, N. Braunecker, J. Cencic, M. Hof, K. Kojan-Goluza, B. Malkiel, E. Pimpel, F. Sapaj, A. Stieberitz and H. Wraunek, for practical support, to the KHM laboratory under M. Griesser for valuable technical support and to the participants of the 11th PRT 2022 in Rome for fruitful discussions.

Conflicts of Interest: The authors declare no conflict of interest.

Notes

[1] Figures 4–6: State collections of Lower Austria, Archaeological Park Carnuntum (AMC photo archive); all other figures: authors.

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