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# Polychromy in Roman Portraits from *Asido* (Medina Sidonia, Cádiz, Spain). *Livia*, *Germanicus* and *Drusus Minor*

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**Abstract**

This paper presents a recent study on a Roman period marble sculpture depicting Empress *Livia* and the portraits of *Germanicus* and *Drusus Minor*, found at the *praesidium* of *Asido* (Medina Sidonia, Cádiz, Spain). The sculptures retain extensive evidence of their original polychromy. The properties and spatial distribution of these pigment remains were investigated by portable non-invasive and micro-destructive techniques, applying digital microscopy, and UV/VIS/NIR/SWIR spectroscopy, portable XRF and SEM–EDS analysis. The study revealed the presence of Egyptian blue and ochre on Livia's mantle and charcoal black on Livia's eyes and hair, remains that were not clearly visible to the naked eye. This is a significant approach, used to identify colours on ancient marble sculpture, which transforms our understanding of these unique pieces. Elemental composition analysis by pXRF has confirmed the evidence of pigments, furthermore supported by the Raman results, making it possible to develop and reconstruct the colour palette that originally brought these sculptures to life in vibrant polychrome. The research offers a new methodology for identifying pigments on marble sculpture and opens new ways for investigating other types of material culture aided by the development of the analytical equipment mentioned.

**Keywords:** Roman Sculpture, Roman Portrait, Polychromy, Archeometry, Archaelogical Museum of Cádiz

## Introduction

An important Roman Republican period bastion was located at the foot of the medieval fortress "Cerro del Castillo" of Medina Sidonia (province Cádiz, Spain), the ancient Roman city *Asido*. The Roman *praesidium* of *Asido* played an important part in the confrontation between Caesar and the Pompeians, although recent excavations have dated its construction earlier to this conflict, describing it as an important military enclave that controlled the territory from the second century BC onwards [1, 2]. After Caeser's victory this settlement was granted the rank of *municipium*, and later established as *colonia Asido, quae Caesarina*, by Augustus according to Pliny the Elder [3].

In 1960 several sculptural pieces from the upper part of "Cerro del Castillo" entered the Museum of Cádiz collection. Among these are three portraits, representing *Livia, Germanicus* and *Drusus Minor* (Fig. 1), which possibly were part of the imperial sculptural program of an *Augusteum* [2]. Initially, only the portraits were published [4, 5], but recently, a portrait statue of Livia has also been presented. This piece had been stored away in the museum warehouse but is now on display in the Museum of Cádiz with its corresponding portrait [2, 6, 7] (Fig. 2). Thus, the statue of *Livia*, together with the portraits of *Germanicus* and *Drusus Minor*, and surely those of, or at leastof, *Divus Augustus* and *Tiberius*, would have stood in an *Augusteum* located on the acropolis of *Asido,* dated between 4 -14 AD or even possibly to the beginning of the reign of *Tiberius* [2].

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**Fig. 1** Portraits from *Asido* (Medina Sidonia). 1 *Livia*; 2 *Germanicus*; 3 *Drusus Minor*. Museum of Cádiz

**Fig. 2** Statue of *Livia* from *Asido* (Medina Sidonia). Museum of Cádiz

The stable conditions in the museum warehouse have helped to preserve some of the polychromy on certain areas of the statue of *Livia*. Her portrait also shows some remains of polychromy, as well as the two male portraits. Thus, remains of blue polychrome, particularly on the mantle covering *Livia*'s right shoulder and arm,, can be seen, while on the edges of the upper part of the mantle there are remains of golden colour. Some traces of black are still preserved on the right side of Livia's head, on some of the lower locks and covering the *nodus,* as well as some reddish marks that can be seen with the naked eye on the first strand of the left side. *Drusus Minor* and *Germanicus* show some reddish marks on the eyebrows, eyes and cheeks, which can also be seen with the naked eye.

## Research aim

The Roman sculptures of *Asido* offer an excellent opportunity to determine the polychromy technique, and to characterize the pigments. Although the study of in Roman sculpture polychromy is no longer a novelty, the analysis of the iconographic programme of the Julio-Claudian imperial family marble statues, with its colour combinations and manufacturing technique, has never been investigated in *Hispania*, to our knowledge, from a physicochemical analytical point of view. Considering the lack of appropriate documentation on colours and the small number of findings with traces of pigment remains, the results achieved in this study represent the first analytical data on this type of sculptures. This view is a starting point for achieving greater knowledge on the manufacturing technology and colour schemes in Roman polychrome sculptures.

The purpose of this work is to identify the polichromy of *Livia's* sculpture and the portraits of *Germanicus* and *Drusus Minor*, by applying a multidisciplinary approach involving portable X-ray fluorescence (pXRF), and portable NIR spectroscopy and micro-destructive techniques (field emission scanning electron microscope, FE-SEM).

## Materials

So far, only the iconographic and stylistic description of the sculpture of *Livia* has been carried out, due to the novelty of joining the statue with its known portrait, whereas the three imperial portraits have already been correctly analyzed in the bibliography on the subject [7].

The statue of *Livia* (Museo de Cádiz, nº inv. CE07208 and CE07209) is composed of two separate pieces, the portrait and the statue (Fig. 2) made with two different varieties of marble from Almadén de la Plata (prov.

Sevilla, Spain) quarries [8]. Both pieces are attached through the high hollow worked in the body. The hands are also separate pieces, butcurrently missing. The body has lost part of the legs from the knees down and the base on which it once stood. The right shoulder is also broken, but it is still attached. The head has a long neck, reaching almost the beginning of the bust, which has been worked to be assembled with the body using a well-known early Imperial era technique, as seen in other Roman sculptures of *Livia*, as the *Livia* of the *Augusteum* of *Narona* [9].

The portrait copies with few variations a well-documented model of *Livia*'s portrait from El Fayum, preserved in the Ny Carlsberg Glyptotek [4, 10–13] andcharacterized by a high *nodus* that rises above the forehead, with wide lateral waves as the Albani-Bonn type, but less angular. There are 16 portraits known of *Livia* following the *typus El Fayum* [14]. Most of them are dated to Tiberian era [14], although some examples can be dated back to the Augustan time [9]. *Livia's* portrait from *Asido* has been dated to *Tiberius´* reign [11], however, other authors have placed it in late Augustan period [15]. Both, the portrait, and the statue have been made in order to be seen from the front and within a niche, as the marble of the reverse side has not been fully worked on, but only roughly sketched out in the way of provincial workshops [11].

In the decade of the 30's of the last century, a marble sculpture with a portrait of *Livia* was found, in an imperial cult shrine that stood in the peristyle of the *Villa dei Misterii* of *Pompeii*. The sculpture retained some of the original colours. The first study of this piece pointed out that the original colours were still preserved on the face and the head: the pupils were painted in brown with the iris lined in black; the hair and eyebrows were blond and the lips red, delineated by a carmine red line. There are no details about the treatment of the face skin [16–18]. Also, the fringe of her *palla* preserved some reddish-purple strokes, as seen on other statues of *Livia*, as the example from the *macellum* of *Pompeii* or from the Holkham-Hall collection [16]. In the Ny Carlsberg Museum of Copenhagen, there is a bust of a Roman woman on exhibit, perhaps a representation of *Livia*, which also shows traces of colour on the irises and pupils (http://www.trackingcolour.com/objects/55).

In the case of this statue from *Asido,* both the pigments and the chromatic scheme of *Livia*'s mantle are consistent with the trends of the period, for example, as in the *Diva Augusta* discovered in Torreparedones (Baena, Spain) [19], which presents a very similar colour pattern, the mantle having a blue and gold edging that ran along the entire rim [20].

The same combination of colours on the mantle of the statue of *Livia* from *Asido* can be seen on a well-known Hellenistic period group of Tanagras, which present mantles in light blue with a golden border on the edge, such as a Louvre Museum example, holding a fan in her left hand and related to a group of terracottas from the so-called "Woman in Blue" workshop [21].

The modeling of Livia's potrait, like the other two portraits of the group,, is very schematicand without details, to the point that some areas of the hair are not worked but are only outlined, a characteristic treatment of provincial workshops [11, 15, 22]. However, the areas that are visible to the viewer have been worked with great correctness and clarity, the surfaces highly polished and contributing to the luminosity of the statue before covering it with a final layer of paint. Also, in *Germanicus'* portrait there was still paint preserved in the iris of both eyes.

The workshop that created this sculptural group was in activity between 4 BC, the year *Germanicus* and *Drusus Minor* were adopted by *Tiberius,* until the death of *Augustus* in 14 BC and *Tiberius* achieved the throne; however, it is still a controversial issue and a wide range of possible dates for these sculptures have been suggested, as Garriguet has resumed [15].

The use of local marble could suggest that it was manufactured in the "Medina Sidonia workshop" [22], which started to operate in late Augustan times or under *Tiberius*. The *Asido* pieces were integrated into one of the many sculptural ensembles, erected by the local elites to honor the members of the imperial family of the *Domus Augusta,* a cult well known in other cities of the empire, following a policy that intended to unite the territories and clearly establish the succession line of the empire [15].

## Methods

The *Livia* sculpture and the portraits of *Germanicus* and *Drusus Minor* were examined to locate and document traces of the original paint. The undertaken tasks were divided into two main steps: the first included a visual examination and on-site digital microscopy, full range spectroscopy (UV/VIS/NIR/SWIR), and portable Energy Dispersive X-ray Fluorescence (p-XRF) without pretreatments; the second step involved micro sampling and non-destructive FE-SEM–EDS analysis.

Portable Digital Microscopy was performed with a ShuttlePix P-4000Rv Portable Digital Microscope from Nikon Metrology (20 × optical zoom lens, up to 400 × digital zoom). A LED illuminator is integrated with this microscope.

All measured points were mapped by means of p-XRF and the obtained concentrations were treated as semi-quantitative data. At least five measurements were collected per analysed spot to get reliable and representative results of each paint trace. In-situ elemental analyses were carried out by means of a handheld analyser X-MET 7500 (Oxford Instruments, UK). The instrument uses a Rhodium tube, a silicon drift detector (SDD), and an automatic 5-position filter changer, providing a beam spot size of approximately 100 $mm^2$. The spectra were taken in a very short time (60 s integration time). Semi-quantitative data was obtained directly by the hand-held XRF which uses fundamental parameters approach to provide the concentration of the measured elements.

An ASD Terraspec Halo full range spectrometer measuring the visible and short-wave infrared regions (360–2500 nm) was used to record the reflectance spectra. The instrument uses a CCD and two Peltier cooled InGaAs sensors mounted over a Goertz post dispersive monochromator and three gratings.

7 micro-samples were taken from different parts of Livia's mantle by pressing a scalpel on the blue and golden colours. Samples were placed on the sample-holder and then flattened with the pulsed laser beam of the ZEISS AURIGA field emission scanning electron microscope (FE-SEM).

The micro-morphology and distribution of elemental components in the samples were analysed by means of a ZEISS AURIGA (FE-SEM) equipped with Sigma Element integrated energy dispersive X-ray microanalysis system (ESM-EDS).

## Results and discussion

After a visual examination, traces of polychromy were found on Livia's hair (black stains) and mantle (blue, redish yellow), on *Drusus*' cheek (red), and on *Germanicus* eyes and eyebrows (Fig. 3). All the coloured spots were analysed on-site, and micro samples from *Livia*'s mantle were taken for further laboratory analysis.

### Black traces on Livia's hair

To ensure that the black stains located after visual examination on Livia's hair (Fig. 4) were part of the statue's polychromy, we performed in situ p-XRF and full range spectroscopy.

Handheld EDX analysis (Table 1) shows ~ 4 at. % of phosphorus what could be related to the use of bone black. This is further confirmed by the SWIR spectrum that shows a broad absorption band ~ 1920 nm, which according to card hydroxylapatite_ws425.3404 from the USGS is the only spectral feature of hydroxylapatite (mineral component of bone). This suggests the use of bone black to pigment Livia's hair.

### Blue traces on Livia's mantle

XRF analysis of Livia's blue coloured shoulder area is shown in Table 2 (Fig. 5). The blue-coloured area main components are Si, Ca and Cu. We must highlight, however, a high P content ~ 15 at. %. Roman paintings generally use for blue tones one of the most accessible synthetic pigments, Egyptian Blue (EB), [$CaCuSi_4O_{10}$], a high-fired vitreous compound which is often referred to as cuprorivaite [23–29].

According to Mirti et al. [23] the production of EB could be made by using copper ores, scraps or filings of metallic copper or copper alloys, what lead to the formation of cassiterite ($SnO_2$) or malayaite ($CaSnSiO_5$) if, for example, tin-copper alloys (bronze) were used. Arsenic, tin and lead containing compounds have been recognized in samples of EB [23].

EDX compositional data (Table 2) shows that *Livia*'s blue coloured areas accounts for Pb. Following Mirti et al. [23], the recorded lead may point to the use of lead-bronze in the EB manufacturing process. Analogously, the blue colored area of *Livia*'s mantle could have been made of EB using lead-bronze during the manufacturing process. However, as the p-XRF device used does not account for a collimator, nor for focusing capabilities, it is not possible to determine whether the Pb content measured comes from the use of lead-bronze or a combination of EB with lead pigments readily available in Roman times as white lead ($PbCO_3$), or red lead ($Pb_3O_4$) [29].

Sample 4 of blue pigment from *Livia*'s shoulder was taken for further analyses using SEM–EDS. The SEM–EDS (Fig. 6) revealed a structure composed of a Ca/P matrix with embedded grains of Si-Ca-Cu.

In the area of interest (ROI), where Si-Cu-Ca was recorded, an elemental analysis was realized obtaining an almost stoichiometric chemical composition for EB (Egyptian blue) [CaCuSi4O10]. In our opinion, the compositional difference appreciated in the measurement by P-XRF with respect to this measurement by FE-SEM–EDX is due to the larger measurement area of the latter, resulting, therefore, in a contaminated register from the application of various layers of pigments, or mixtures of EB with Pb pigments, which would have produced different visual effects or a light blue background if mixed with Pb white [29].

The use of a Ca/P matrix for the pigments could be pointing to the use of bonse as a ground/priming layer over which the colour was applied to the sculptures. This is evidenced by *Livia*'s shoulder 4 sample spectrum, whereas in samples 1 and 2 the only elements recorded are Ca, P and C. The FE-SEM–EDS of this sample (Fig. 7) show a very compacted matrix mainly composed of phosphorous and calcium (Table 3), that is, a a Ca-to-P ratio compatible with that of dahallite (carbonate


**Fig. 3** Location of different painted zones where non-invasive analyses were performed: 1. *Germanicus*'s portrait; 2. Drusus's portrait; 3. *Livia*'s hairdressing; 4. *Livia*'s mantle

apatite—mineral compound of bone). So far, the use of bone as priming has not been detected in Roman polychromy, although it has been documented in prehistoric times [30].

Also, a layer of carbonate is covering most of the right side of the *himation,* sometimes, even over the blue layer. In some places it seems as if this carbonate layer was applied as a repair and the entire surface was 'repainted'. Paint repairs in ancient times have been well documented [31].

### Redish yellow traces on Livia's mantle

Besides the blue tones on the mantle are redish/yellow (golden) tones (Fig. 8) that seem to have been made in a different way. FE-SEM–EDS analysis (Fig. 3-4) shows a calcium carbonate matrix with small embedded particles.

**Table 1** EDX. Handheld EDX measured elemental composition for Livia's black hair trace expressed as atomic percentage.

| | Mg | Al | Si | P | S | Cl | K | Ca | Ti | Mn | Fe | Cu | Zn | As | Sr | Sn | Ba | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Livia's* Hair (black) | – | 3.54 | 5.07 | 4.10 | 9.84 | 2.24 | – | 74.57 | 0.15 | – | 0.43 | 0.01 | 0.01 | – | 0.03 | – | – | – |

These particles have no Cu traces. Instead, they are composed by silica, aluminum, iron, and calcium (Table 4) suggesting the use of some sort of iron oxide (ochre). In addition to the FE-SEM-EDS recorded components (Table 4) the EDX analysis (Table 2) recorded Cu and P that is likely to be related with the use of EB for shading on this area. Thus, iron oxide and EB might have been used together to enhance the depth of the mantle folds.

## Redish yellow traces on Germanicus' eyes and eyebrows, and Drusus' cheeks

Red and yellow ochre pigments are generally used for flesh tones in Roman times. However, in order to enhance facial features (eyelids, nose, ears, neck, forehead, or chin), shadings with darker tones might have been used, as with the earthy tones of the mantle.

Some of the most commonly used pigments in ancient times for painting flesh tones (reds and yellows) were hematite ($Fe_2O_3$), a rich red ochre, and goethite (FeOOH), a rich yellow ochre. These natural pigments can be easily identified by its UV-to-SWIR spectral features.

The instrument here used, ASD TerraSpec Halo, performs separate mineral identifications in the VNIR and SWIR automatically by identifying the best peak match between the library and the recorded spectrum in an iterative way by subtracting the spectrum of the identified reference mineral to the recorded signal and by adjusting intensities.

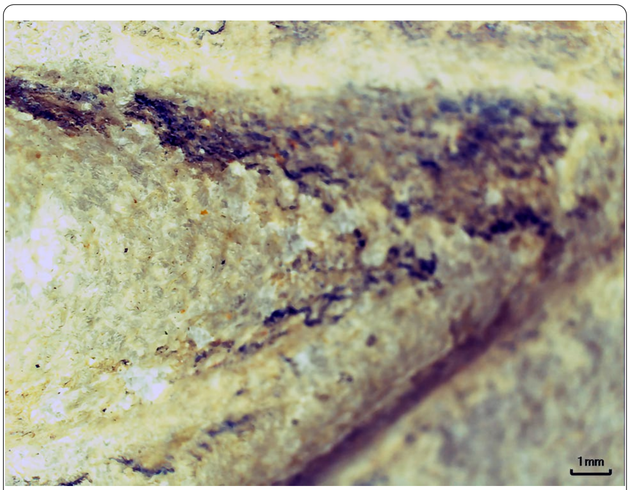


**Fig. 4** ant. 5.1. Microphotograph of the black traces on *Livia*'s hair. >

In *Germanicus*' pupil -452 and *Drusus*' cheek -451 reddish/brown tones, goethite [α-FeO(OH)] and calcite was automatically identified by the spectrometer's software.

Departing from the mineral identification of the Terraspec HALO mineral sorter automatic identification we compared manually by overlaying USGS Digital Spectral Library [27] references to our spectra to identify the mineral components of the measured spots.[1] The spectral features recorded on *Germanicus*'s pupil -452 and *Drusus*'s cheek -451 (Fig. 9) matches that of goethite [α-FeO(OH)] at ~ 475, 910–920 nm [1].

## Conclusions

The larger-than-life size statue of *Livia* is composed of two separate pieces, body statue and portrait, that were manufactured in a local workshop with two varieties of regional marble from the quarries of Almadén de la Plata (prov. Sevilla, Spain) [7]; also the portraits of *Germanicus* and *Drusus Minor* were made in the same local workshop, although the marble has not yet been analyzed. They are dated between the years 4 AD, when the double adoption of *Tiberius* by *Augustus* and of *Germanicus* by *Tiberius* took place, and 19 AD, corresponding with the death of *Germanicus* at the beginning of *Tiberius*' reign. They must have stood in an *Augusteum*, dedicated to the early cult of *Domus Augusta*, located on the acropolis of *Asido*, or the so-called Cerro del Castillo. Along with the statues of *Livia*, *Germanicus* and *Drusus Minor*, there would have been, at least, a representation of the *Divus Augustus* and of *Tiberius*, although these have not been found. Following an ancient sculptural tradition, the pieces were painted, providing a greater degree of realism to the imperial images.

Indeed, polychromy was added to the statue/portrait of *Livia* and to the portraits of *Germanicus* and *Drusus Minor* in order to enhance external appearances. Some remains of paint are still visible, others only recognizable with the use of a digital microscope.

[1] We have pre-processed the measured and reference (USGS Digital Spectral Library [27]) spectra by removing the continuum [28] with the R prospect package [29] to highlight energy absorption features of minerals. Afterwards, the first and second derivatives were calculated using the Gap derivative algorithm [29] to locate spectral features.

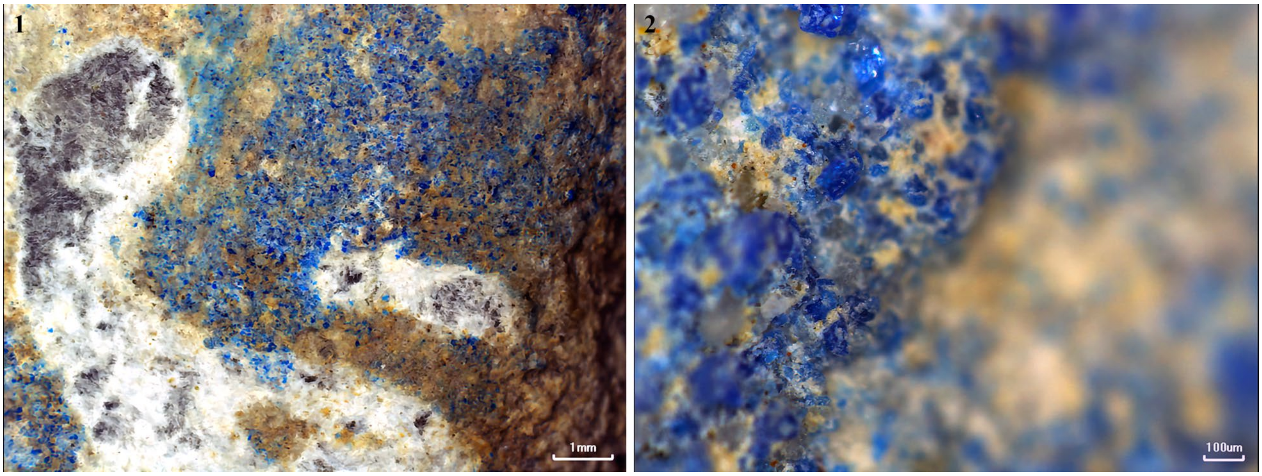


**Fig. 5** Microphotograph of *Livia*'s mantle with blue pigment

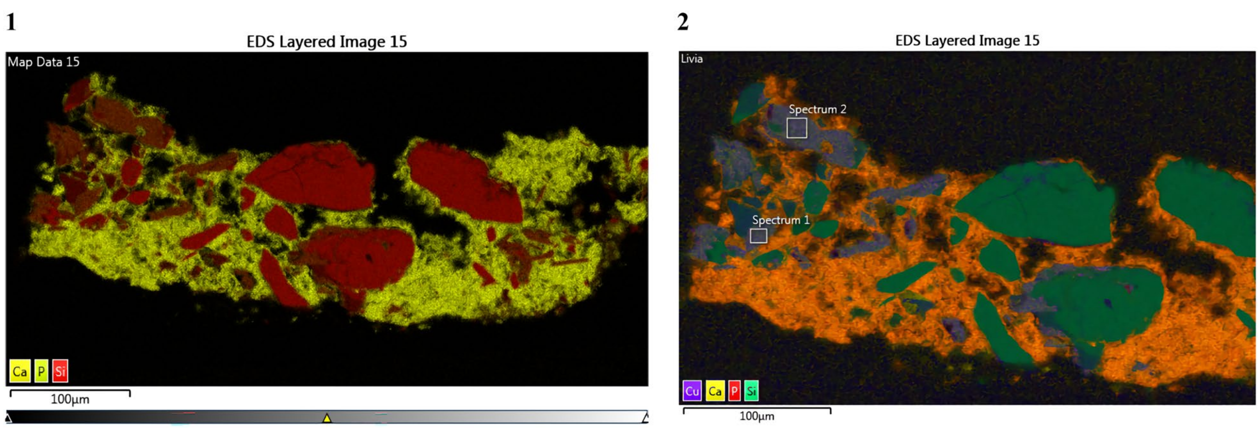


**Fig. 6** 1. Ca/P matrix and Si embedded grains. 2. Ca/P matrix and Si-Ca-Cu embedded grains with indication of EDS area analysis

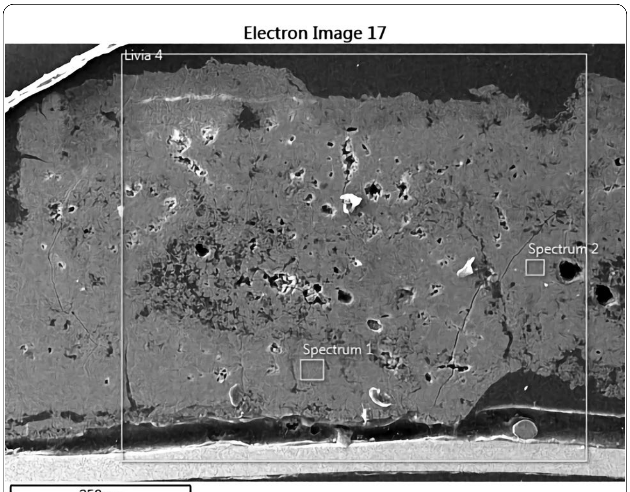


**Fig. 7** SEM-BSE image of *Livia*'s shoulder 4 sample with indication of the EDS area

The blue pigment on the mantle is made of EB. It was applied over a bone (Ca/P) ground /priming layer for the polychromy.

The redish yellow or golden pigment on *Livia*'s mantle consists of ochre (some sort of iron oxide) over a calcium carbonate layer. This carbonate layer might be either a priming layer or a colour layer (calcium carbonate white). Traces of Cu on the analyzed samples points to the use of EB to shade and therefore enhance the depth of the mantle.

The black stains on *Livia*'s hair were made of bone black with a high phosphorous content. Although, the use of a Ca/P ground layer for the polychromy of the mantle could also evidence the use of carbon black over the priming. This is, however, unlikely due to the absence of a ground layer on the portraits.

The red traces on *Drusu*' and *Germanicus*' cheeks, eyes and eyebrows are made of goethite.

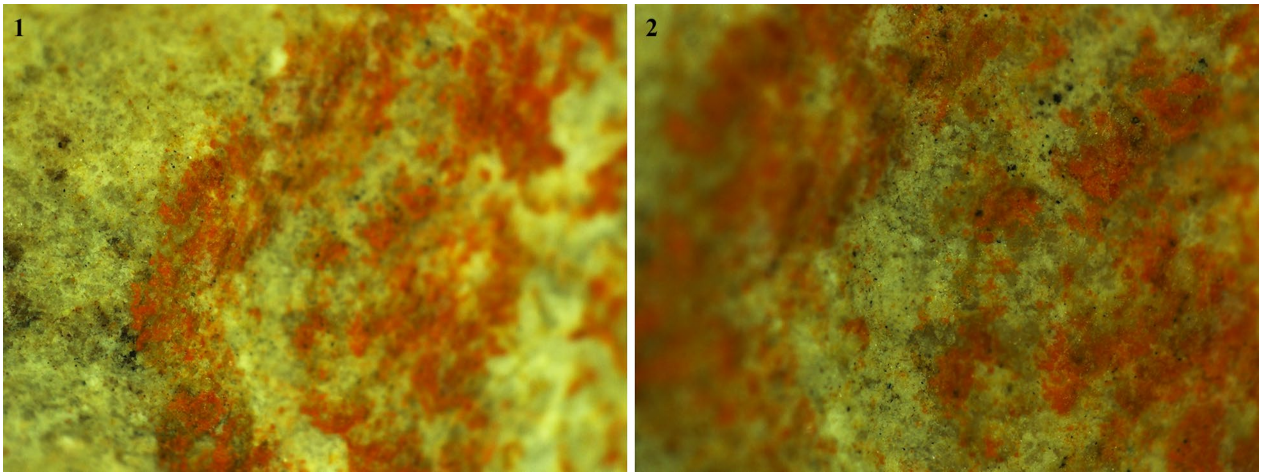

**Fig. 8** 1–2: Microphotograph of *Livia*'s mantle red/golden pigment. 3: *Livia*'s shoulder 1 red/golden pigment with indication of EDS analysis

**Table 2** EDX. Handheld EDX measured elemental composition for blue traces on Livia's mantle expressed as atomic percentage

| | Mg | Al | Si | P | S | Cl | K | Ca | Ti | Mn | Fe | Cu | Zn | As | Sr | Sn | Ba | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Livia's* 1.1 | – | – | 25.54 | 13.65 | 0.94 | 2.12 | 1.41 | 50.30 | 0.00 | – | 1.20 | 4.71 | 0.04 | – | 0.07 | 0.03 | – | – |
| *Livia's* 1.2 | – | 3.40 | 21.99 | 15.72 | 1.08 | 2.14 | 1.17 | 49.54 | 0.18 | 0.05 | 0.95 | 3.66 | 0.03 | – | 0.06 | 0.01 | – | 0.05 |
| *Livia* 1 | 4.27 | 4.15 | 12.40 | 5.96 | 1.32 | 2.44 | 0.00 | 66.79 | 0.12 | 0.06 | 0.67 | 1.74 | 0.01 | – | 0.04 | 0.01 | 0.02 | 0.02 |
| *Livia* 2 | – | 2.00 | 15.94 | 20.05 | 1.40 | 6.00 | 0.73 | 50.21 | 0.09 | 0.05 | 0.56 | 2.88 | 0.02 | – | 0.05 | 0.01 | 0.02 | 0.02 |

**Table 3** Chemical composition obtained by SEM–EDS expressed as atomic percentage (point analysis)

| | O | C | Na | Mg | Al | Si | P | K | Ca | Fe | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Livia's* 2.1—spectrum 1 | 63.0 | – | – | – | – | 25.5 | – | – | 5.8 | – | 4.9 |
| *Livia's* 2.2—spectrum 2 | 63.1 | – | – | – | – | 25.0 | – | – | 6.1 | – | 4.9 |
| *Livia's* 4—spectrum 1 | 59.9 | 13.9 | – | – | – | – | 9.8 | – | 14.3 | – | – |
| *Livia's* 4—spectrum 2 | 60.3 | 14.7 | – | – | – | – | 9.8 | – | 13.8 | – | – |
| *Livia's* 1—spectrum 1 | 53.6 | 13.1 | 5.2 | – | 8.4 | 17.6 | – | – | 1.6 | – | – |
| *Livia's* 1—spectrum 2 | 59.5 | 22.1 | – | – | 10.1 | – | – | – | 1.9 | – | – |
| *Livia's* 1—spectrum 3 | 42.4 | 46.9 | – | 6.1 | – | – | – | – | 3.8 | – | – |
| *Livia's* 1—spectrum 4 | 51.7 | 35.7 | – | 5.2 | – | – | – | – | 7.4 | – | – |
| *Livia's* 1—spectrum 5 | 19.3 | 73.3 | – | – | 1.6 | 4.6 | – | 1.2 | 0.5 | – | – |
| *Livia's* 1—spectrum 6 | 46.1 | 44.1 | – | – | – | 2.9 | – | – | 3.0 | 3.9 | – |
| *Livia's* 1—spectrum 7 | 70.01 | – | – | 6.3 | 7.9 | 7.5 | – | – | 8.3 | | – |
| *Livia's* 1—spectrum 8 | 34.4 | 55.0 | – | 1.2 | 1.5 | 6.0 | – | 0.4 | – | 0.9 | – |

**Table 4** Chemical composition obtained by SEM–EDS expressed as atomic percentage

| | Mg | Al | Si | P | S | Cl | K | Ca | Ti | Mn | Fe | Cu | Zn | As | Sr | Sn | Ba | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Livia's* 2.1 | – | 4.50 | 12.14 | 13.58 | 1.29 | 2.58 | 1.57 | 61.45 | 0.22 | 0.06 | 2.39 | 0.02 | 0.03 | 0.05 | 0.10 | – | – | 0,04 |
| *Livia's* 2.2 | – | 4.41 | 11.84 | 13.99 | 1.20 | 2.25 | 1.31 | 62.48 | 0.28 | 0.07 | 1.95 | 0.04 | 0.03 | 0.05 | 0.09 | 0.01 | – | 0,02 |

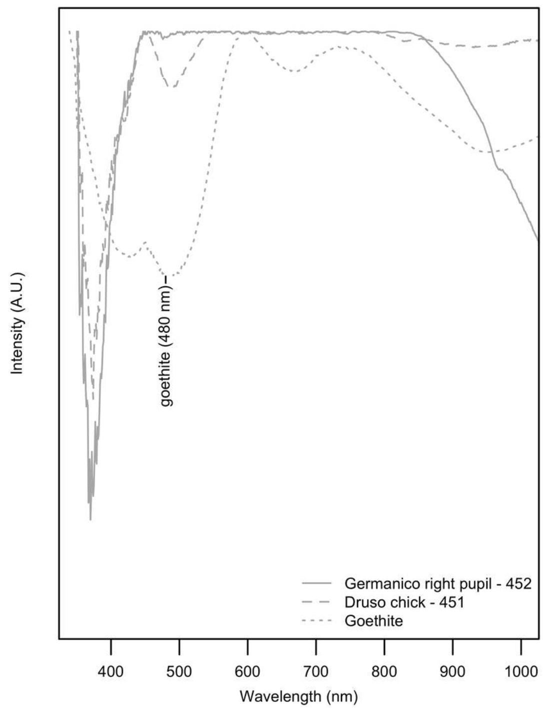


**Fig. 9** Full range spectra of the measured red stains on *Germanicus*'s pupil—452 and *Drusus*'s cheek—451 (350–2500 nm)

A calcium carbonate layer has been recorded on Livia's himation which could possibly correspond to a repainting or repair to this area. This would also explain the differences found between the 'golden' and the blue pigments in the priming layer of the mantle.

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**Author contributions**

CPO: design of the work; the acquisition, analysis, interpretation of data; and have drafted the work and substantively revised it. JBF: design of the work; and have drafted the work and substantively revised it.MLLA: interpretation of data and have drafted the work and substantively revised it. JMMB: the acquisition, analysis, interpretation of data and have substantively revised it. All authors have approved the submitted version that involves the author's contribution to the study; and have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. All authors read and approved the final manuscript

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**Availability of data and materials**

All data generated or analysed during this study are included in this published article.

## Declaration

**Competing interests**

The authors declare that they have no competing interests.

**Author details**

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**References**

1. Montañés S, Montañés M, Ocaña A. Asido Caesarina (Medina Sidonia, Cádiz), in Las cloacas de Caesaraugusta y elementos de urbanismo y topografía de la ciudad antigua. Zaragoza. 2013;409–414.
2. Beltrán J, Loza M L, Montañés S. Esculturas Romanas de Asido (Medina Sidonia, Cádiz). Cádiz-Sevilla. 2018.
3. Pliny the Elder (*NH* III, 11).
4. Blanco A. Retratos de príncipes julio-claudios en la Baetica. Boletín de la Real Academia de la Historia CLVI-2. 1965. 92–95.
5. García y Bellido A. Los retratos de Livia, Drusus Minor y Germanicus en Medina Sidonia. In: Chevallier R, editor. Mélanges d'Archéologie et d'Histoire offerts à André Piganiol. Paris: SEVPEN; 1966. p. 480–94.
6. Beltrán J, Loza ML. La Livia de Asido (Medina Sidonia). Identificación de la estatua en el Museo de Cádiz. Madrider Mitteilungen. 2015;56:260–71.
7. Beltrán J, Loza ML. Corpus Signorum Imperii Romani. España. Provincia de Cádiz. Servicio de Publicaciones de la Universidad de Cádiz, Cádiz-Tarragona. 2020.
8. Ontiveros E, Beltrán J, Loza ML. Estudio arqueométrico del soporte marmóreo de una escultura de Livia hallada en la ciudad romana de Asido (Medina Sidonia, Cádiz). Geoconservación. 2020;18:108.
9. Marin E, et alii. Livia d'Oxford-Opuzen, in E. Marin - I. Rodà, eds., Divo Augusto. El descubrimiento de un templo romano en Croacia. Split. 2004. 76–86; 340–344
10. Fittschen K, Zanker P. Katalog der römischen Porträts der Capitolinischen Museen und anderen kommunalen Sammlungen der Stadt Rom, I, Mainz am Rhein. 1983.
11. León P. El retrato, in P. León, coord., Arte Romano de la Bética. Escultura. Sevilla. 2009. 211–215.
12. Wood S. Imperial Women: a study in public images, 40 B.C.—A.C. 68. Leiden. 1979.
13. Winkes, R. Livia, Octavia, Iulia. Porträts und Darstellungen. Brown University Center for old world archeology and art, Rhode Island-Louvain le Neuve. 1998.
14. Jenssen KE. Portraits of Livia in context: an analysis of distribution through the application of geographic information systems. Master of Arts Thesis, Univ. Iowa. 2013.
15. Garriguet JA. ¿Provincial o foráneo? Consideraciones sobre la producción y recepción de retratos imperiales en Hispania, in D. Vaquerizo; J. F. Murillo, eds., El concepto de lo provincial en el mundo antiguo. Homenaje a la Prof. Pilar León, Córdoba. II. 2006. 143–194.
16. Maiuri, A. Statua marmorea con ritratto di Livia dalla Villa dei Misteri a Pompei. Bollettino d'Arte X. 3–17. http://www.bollettinodarte.beniculturali.it/opencms/multimedia/BollettinoArteIt/documents/1391786842882_06_-_Maiuri_3.pdf. 1930.
17. Bartman E. Portraits of Livia: Imaging the Imperial Woman in Augustan Rome. Cambridge: Cambridge University Press; 1999.
18. Østergaard JS. Emerging Colors: Roman Sculptural Polychromy Revived, in R. Panzanelli (ed.), The Color of Life. Polychromy in Sculpture from Antiquity to the Present. Exhib. Cat. J. Paul Getty Museum, Los Angeles. 2008. 40–61.
19. Márquez, C. El programa iconográfico del foro, in Márquez, C. et al, eds., Torreparedones. Baena-Córdoba. Investigaciones arqueológicas (2006–2012). Córdoba. 2014. 87–97.

20. Ventura A, Fernández L. El color de la imagen imperial en Torreparedones: Estudio de la policromía en las estatuas sedentes del foro, in Actas de la VIII Reunión de Escultura Romana en Hispania. Córdoba. 2017. 854–870.
21. Blume C. When Colour Tells a Story: The Polychromy of Hellenistic Sculpture and Terracottas. In: Brinkmann V, Primavesi O, Hollein M, editors. Circumlitio. München: The Polychromy of antique and mediaeval sculpture; 2010. p. 240–57.
22. León P. Retratos Romanos de la Bética. Fundación El Monte, Sevilla. 2001.
23. Mirti P, et al. Spectrochemical and structural studies on a Roman sample of Egyptian Blue. Spectrochim Acta Part A Mol Biomol Spectrosc. 1995;51:437–46. https://doi.org/10.1016/0584-8539(94)E0108-M.
24. Mazzocchin G, et al. A short note on Egyptian Blue. J Cult Herit. 2004;5:129–33. https://doi.org/10.1016/j.culher.2003.06.004.
25. Kendrick E, Kirk CJ, Dann SE. Structure and colour properties in the Egyptian Blue Family, M1−xM′xCuSi4O10, as a function of M, M′ where M, M′=Ca, Sr and Ba. Dyes Pigm. 2007;73:13–8. https://doi.org/10.1016/j.dyepig.2005.10.006.
26. Verri G. The spatially resolved characterisation of Egyptian blue, Han blue and Han purple by photo-induced luminescence digital imaging. Anal Bioanal Chem. 2009;394:1011–21. https://doi.org/10.1007/s00216-009-2693-0.
27. Dyer J, O'Connell ER, Simpson A. Polychromy in Roman Egypt: a study of a limestone sculpture of the Egyptian god Horus. British Museum Technical Res Bull. 2014;8:93–103.
28. Johnson-McDaniel D, Salguero TT. Exfoliation of Egyptian blue and han blue, two alkali earth copper silicate-based pigments. J Visualized Exp. 2014. https://doi.org/10.3791/51686.
29. Radpour R, Gates GA, Kakoulli I, et al. Identification and mapping of ancient pigments in a Roman Egyptian funerary portrait by application of reflectance and luminescence imaging spectroscopy. Herit Sci. 2022;10:8. https://doi.org/10.1186/s40494-021-00639-5.
30. Odriozola CP,García VR, Ramirez PB,Bermejo RB, lores Fernández RF, Pedro Díaz del Rio P. "Late Prehistory Body Ornaments. Exchange and Social Dynamics in the Middle Tagus Basin." In *KEY RESOURCES AND SOCIO- CULTURAL DEVELOPMENTS IN THE IBERIAN CHALCOLITHIC*, edited by Martin Bartelheim, Primitiva Bueno Ramirez, and Michael Kunst, 59–88. RessourcenKulturen 6. Gemany: Universitat Tubingen, 2017. https://doi.org/10.15496/publikation-19737.
31. Bourgeois B. Thérapéia. In: Østergaard JS, Nielsen AM, editors. Transformations. Classical Sculpture in Colour. Copenhagen: Ny Carlsberg Glyptotek; 2014. p. 190–207.

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