NICOLAI ABILDGAARD'S 'THE WOUNDED PHILOCTETES':

THE COLOURS AND GENESIS OF A DANISH ICON

Annette S. Ortiz Miranda[1]*, Troels Flintenborg[2]
(1) Walters Art Museum, Baltimore, MD, USA
(2) Statens Museum for Kunst, Copenhagen, Denmark
(*) aortiz@thewalters.org

Abstract

Nicolai Abildgaard (1743 – 1809) was the leading history painter and the most renowned Danish artist of his time, known for his somewhat erratic technique and interchanging methods of painting. However, little is known about the extent to which this applies to his early production and, more specifically, to *The Wounded Philoctetes* at the National Gallery of Denmark (SMK), probably his most famous painting. Executed in 1775 while Abildgaard was studying in Rome, the painting is an impressive achievement and contributed to the making of his career. A striking composition in dimension, character and technique, the painting nonetheless has a tonality and colours which are unusual in Abildgaard's oeuvre.

This study focuses on using non-invasive analytical techniques to increase the knowledge of Nicolai Abildgaard's painting technique and, specifically, *The Wounded Philoctetes*. The results of macro X-ray fluorescence (MA-XRF) and Fiber Optic Reflectance Spectroscopy (FORS) analyses, together with X-ray radiography (XRR), are presented. Among the results, the palette, compositional changes, and the unusual occurrence of powdered gold are discussed.

Keywords:

Nicolai Abildgaard; MA-XRF; FORS; non-invasive analysis; pigment identification; painting; powdered gold

Introduction

The background aim for the technical examination of *The Wounded Philoctetes* was to gain insight into the painting's genesis, including the palette employed by Abildgaard in its execution. The project was closely linked to a monographic calendar featuring the painting which was made in 2022 by the art historian Peter Kær for Danish national TV. In this context, it was decided to carry out a study using only non-invasive techniques.

Nicolai Abraham Abildgaard (1743 - 1809) is considered one of the greatest Danish artists of the Neoclassical era and perhaps the most significant painter of the generation before C.W. Eckersberg and other artists from the Danish Golden Age of Danish Painting (c. 1800 – 1850). He was admitted to the Royal Danish Academy of Fine Arts in Copenhagen in 1764 at the age of 21, and, three years later, was already assisting his professor, Johan Edvard Mandelberg, in executing paintings for the domed hall at the Fredensborg Palace. Following his studies in Copenhagen, Abildgaard spent the years

1772-77 in Rome and, on returning, travelled via Paris, where he stayed for a few months. However, it is doubtful whether the sojourn in the French capital influenced his practice. Rather than associating with French artists, he preferred the company of painters such as Johann Heinrich Füssli, and his compatriot, the portrait painter Jens Juel (Filtenborg, 2014). Soon after his return to Copenhagen, he was appointed professor at the Academy, and, over the following years, produced a number of paintings with classical, mythological and historical scenes, including large-scale royal commissions as well as decorative assignments.

Techniques and materials employed in the production of Abildgaard's paintings have been the subject of a number of studies (Filtenborg 2014, Filtenborg 2015, Filtenborg et al. 2016). In the case of *The Wounded Philoctetes*, however, little information is known regarding the painting's genesis and materials, including to what extent they conform to those of his later paintings. An early work by Abildgaard, it was executed in Rome and sent back to Copenhagen as documentation of his progress. On the right-hand side of the image, an inscription (upside down) in Greek on the overturned stone translates to: 'Nicolai, Søren's [son], Copenhagener, made [this picture]'. The painting, partly based on classical imagery, depicts the Greek hero and archer Philoctetes who, on his way to besiege Troy with other Greek soldiers, was bitten in the foot by a snake. His festering wound and screams of agony were so unbearable to his fellow soldiers that they abandoned him on the island of Lemnos. According to myth, Philoctetes' bow and quiver of poisoned arrows, given to him by the dying Herakles, were famous for never missing their mark, and were instrumental in the Greeks victory in the Trojan War. The painting, with a theme that was also the subject of a play by Sophokles, created a stir on its arrival in Copenhagen and has remained the best-known work by Abildgaard. It was copied several times, most likely by his students. It has even been argued that one of the copies was an autograph replica, and that the painting in the SMK collection might not even be the first version.

Despite Abildgaard's changeable working methods and techniques, the majority of his paintings have survived in good condition. This is also the case for *The Wounded Philoctetes.* The paint does have some age cracks and an area of large, circular, concentric cracks to the left of the centre, but apart from an old lining with glue paste, no structural treatment has been required. The painting was cleaned and re-varnished in 1992.

In recent years, technical examination of artworks has become increasingly widespread, allowing the materials and techniques used by artists to be identified and characterised. In addition to illuminating artistic practices, the knowledge gained from the research is often a significant factor qualifying preservation and treatment choices (Alfeld et al. 2013; Noble et al. 2012). In some cases, it may also inform conclusions regarding the dating and attribution of artworks, including the identification of forgeries (Saverwyns et al., 2018).

Figure 1. *The Wounded Philoctetes* (1775), Nicolai Abildgaard (1743 – 1809) (oil on canvas, 123 cm x 175.5 cm). National Gallery of Denmark, KMS586. Photo: SMK.

Due to the unique nature of an artwork, it is preferable to carry out analyses using non-destructive techniques whenever possible. The characterisation of materials and painting techniques using non-invasive analysis based on X-ray analytical methods, including macro X-ray fluorescence spectroscopy (MA-XRF), is now widely used in the study of paintings (Alfeld et al. 2011; Saverwyns et al. 2018; Mazzinghi et al. 2022; Vermeulen et al. 2022; Haddad et al. 2022; Klisinska-Kopacz et al. 2023). MA-XRF analysis based on element analysis allows for accurate detection, distribution, and identification of inorganic materials, especially pigments. This technique has become an acknowledged method for the study of painting materials owing to its non-invasiveness (Rampazzi et al. 2017). But in addition to the analysis of paintings, it has also been applied to the analysis of different types of other materials such as wall paintings (Dal Fovo et al. 2020; Koskiasmenou et al. 2020; Vadrucci et al. 2020), drawings (Clarke et al. 2021), and manuscripts (Clarke, 2001; Delaney et al. 2014; Ricciardi et al. 2016).

Against this background, MA-XRF was chosen as the primary method for determining the composition of the palette and tracing the creative process in the making of *The Wounded Philoctetes*. Complementing this, an X-radiograph was made of the painting, and analysis of organic pigments was carried out using Fibre Optic Reflectance Spectroscopy (FORS).

Materials and Methods

MA-XRF Scanner

A Bruker CRONO MA-XRF scanner developed by XGLab S.R.L. was used for characterizing inorganic pigments. The instrument consists of a measuring head with a Rh-target microfocus X-ray tube (30 W, maximum voltage 50 kV, maximum current 0.6 mA) and a 30 mm² Xflash SDD with beryllium window (energy resolution <145 eV at Mn-K_a). The measuring spot can be varied by changing the distance between the paint surface and the measuring head. The instrument was operated at 50 kV and 60 µA. The elemental 2D mapping of the painting surface was achieved through an automatic XY-motorized stage with a 30 ms/pixel acquisition time and a 2-mm step size. The elemental maps were produced using open-source PyMCA software. Due to the dimensions of the painting, 16 maps were collected and stitched together using registration and stitching plugins available in the open-source image-processing Fiji suite.

Fiber Optic Reflectance Spectroscopy (FORS)

FORS measurements were performed with a FieldSpec 4 fiber optic spectrodiometer (PANalytical-ASD Inc., CO). Spectra were collected over the range of 350 – 2500 nm (UV-vis-NIR), with a spectral sampling of 1.4 nm to 2 nm. The spectral resolution was 3 nm at 700 nm, and 10 nm at 1400 nm and 2100 nm. Measurements were carried out using a bifurcated fiber optic probe; each of the bifurcated ends is composed of 78 fibers and all 156 fibers (core 2000 µm in diameter) and 64 spectra were averaged for each sample. The instrument was calibrated using a white reference panel from ASD, which is made of a totally reflective material.

X-ray radiography (XRR)

XRR was obtained with a YXLON SMART EVO 160D directional X-ray system with 1.0 mm focal spot, 20–160 kV, 0.5–7.0 mA tube range, with an additional 3 mm AlMg3 filter, and a Dürr HD-CR 35NDT CR digital scanner, using 30×40 cm HD Image plates from Dürr NDT. The distance between the tube and the painting was 110 cm.

Results and Discussion

Palette

The palette of the painting as determined from the MA-XRF analysis, is broadly consistent with that found in other works by Nicolai Abildgaard, and with pigments available to artists in the late eighteenth century. In the following section, the pigments and other materials employed, based on the detected elements, are discussed. Table 1 summarizes the pigment identifications obtained by the non-invasive techniques used.

Calcium (Ca) is ubiquitously present in the painting (Figure 2a), suggesting the occurrence of a traditional calcium-based (e.g. chalk) ground layer. However, a cross-section made from a sample taken in 2014 shows a stratigraphy with the ground in fact consisting of two layers, a brown first layer containing chalk, lead, and a pale greyish second layer, of lead white and lower amount of chalk (Filtenborg, 2014). In addition to the presence of calcium in the ground the co-presence in the elemental distribution maps of Ca and P throughout the paint layer confirmed the use of bone black ($Ca_5(PO_4)_3$). Based on the current results, we can assume that the dark particles observed in the second ground layer of the cross-section and the greyish aspect relates to the use of this black pigment. However, this must be confirmed with further analysis of the sample, since the presence of other black pigments, such as carbon black, cannot be excluded based solely on the MA-XRF results. Bone black was also used in the paint of the darker areas of the composition (mostly the background), the hair of Philoctetes, and the inscription (Figures 2a and e).

Table 1. List of pigments identified in the specific study using MA-XRF and FORS analysis.

Colour	Pigment*
Black	Bone black
White	Lead white
Red	Vermilion, and iron earths pigments
Yellow	Naples yellow, and iron earths pigments (ex. yellow ochre)
Blue	Prussian blue
Green	Green earth, and a mixture of Naples yellow and Prussian blue
Flesh tones	Lead white mixed with vermilion and iron earth pigments
Metallic aspect	Gold powder

*The presence of organic pigments and carbon-based black cannot be excluded.

The heterogeneous distribution of lead (Pb) is probably due to the use of lead white as a pigment in the paint layer, both in white areas and in a mixture with other pigments, for instance in the foliage, fur, and flesh tones (Figure 2b).

The MA-XRF elemental maps revealed the presence of mercury (Hg), lead (Pb), and iron (Fe), indicating that a mixture of vermilion, lead white, and an iron-rich earth pigment was used to create the different hues in the flesh tones of the figure that dominates the painting (Figures 2d, b, and c). However, as seen in the Hg-L map, the figure was modelled to a great extent by using different proportions of vermilion, with a sharply delineated presence of the pigment in the facial features, including the nose, eye, and ear (Figure 2d). Vermilion was also found in details of the arrow quiver and the foliage.

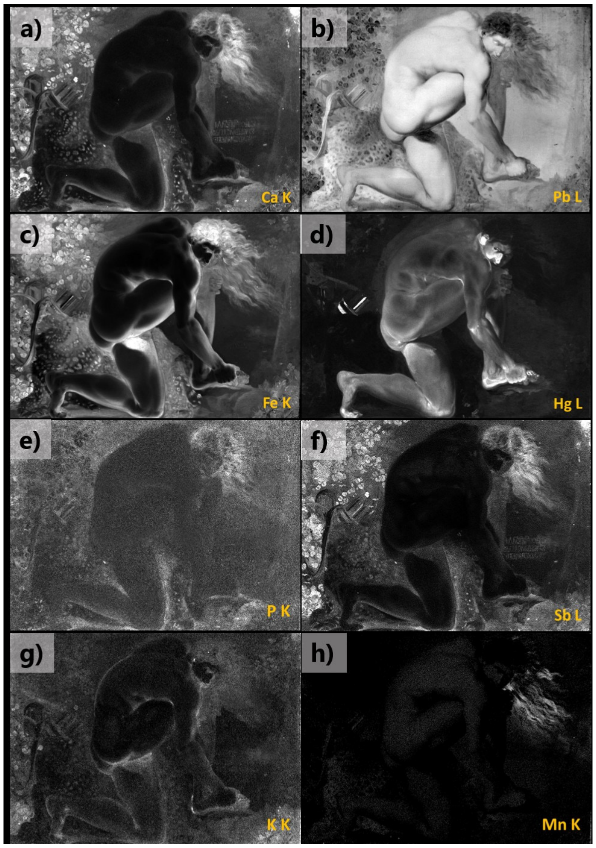

Figure 2. MA-XRF elemental distribution maps obtained for Ca, Pb, Fe, Hg, P, Sb, K, and Mn. Ca associated with the presence of a calcium-based ground layer (likely to be mainly chalk); pigments of the paint layer include lead white, iron earth pigments (Fe, Mn, and K most likely iron red oxide, ochre, umber and green earth); vermilion (Hg), and Naples yellow (Sb/Pb).

As mentioned, an iron earth pigment was mixed with vermilion and lead white and used to create the different hues of the flesh paint. In addition, manganese (Mn) was detected in many brown-coloured areas like the fur, but mostly in Philoctetes' dark hair (Figure 2h). This element is a typical trace element in a number of earth pigments, but particularly indicates the use of umber (Helwig, 2007). Traces of potassium (K) were also found in green areas of the painting, matching the distribution of iron (Fe). In these cases, their co-occurrence can be associated with the presence of green earth (Grissom, 1986) (Figure 2g). Figure 3 shows the distribution of the iron-based earth pigments including pigments rich in Mn (in red) and K (in blue).

Naples yellow ($Pb_2Sb_2O_7$), a pigment used since the early eighteenth century, was identified as the yellow compound found in mixtures with other pigments and materials. Yellow pigments like Naples yellow (lead antimonite) have a specific elemental composition (antimony (Sb) and lead (Pb)) identified by the XRF responses (Hradil et al. 2007). By contrast, no MA-XRF signal other than lead was obtained for the blue-coloured ribbon behind the Philoctetes figure. As Prussian blue has an extremely high tinting strength, a very small amount would be needed in the colour mixture to obtain the shade of blue found in the ribbon, in contrast with the surrounding areas of the composition containing pigments with strong iron (Fe) signal. These features might explain the lacking detection of iron in this area in the Fe map. Nevertheless, the presence of Prussian blue ($Fe^{III}[Fe^{II}(CN)_6]^{3-}$) was confirmed by FORS spectra that exhibited the maximum absorption band of ca. 700 nm (Figure 4) (Aceto et al. 2014). While usually not identified solely by MA-XRF, Prussian blue has a unique reflectance spectrum, which allows for its unambiguous identification (Miliani et al. 2007; Aceto et al. 2014; Grandjean et al. 2016; Biron et al. 2020).

Apart from yellow ochres, which have a particular reflectance spectrum, yellow pigments are in general difficult to identify through FORS. However, MA-XRF is often considered specific enough to allow the association of the elemental co-presence with a specific yellow pigment, such as lead/antimony (Pb/Sb) for Naples yellow. Therefore, coupling both techniques makes it possible to differentiate between various pigments or mixtures of pigments for a given colour based on the combination of the colour analysed, its elemental composition, and the reflectance spectrum. This was the case for some of the bluish-green leaves in the foliage in which a mixture of Prussian blue and Naples yellow was identified (Figures 4b and c). With the concomitance between the FORS results, from the areas where a mixture of a yellow and a blue pigment was found, and the Sb elemental distribution map, we can conclude that the bluish-green highlights used by Nicolai Abildgaard in these areas is a mixture of Prussian blue and Naples yellow.

Prussian blue, in widespread use since its discovery in the early eighteenth century, is probably the only blue pigment employed by Abildgaard throughout his

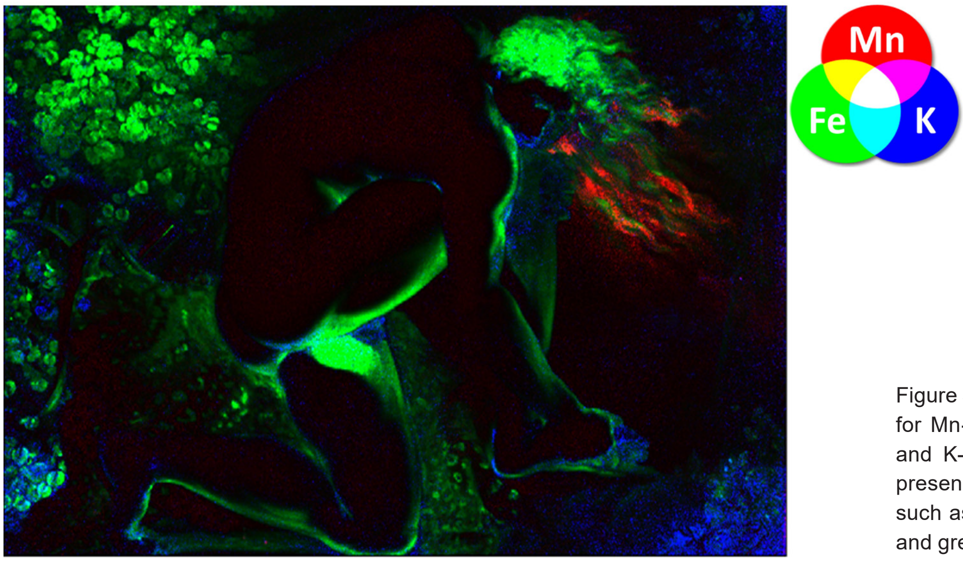

Figure 3. RGB elemental distribution map for Mn-Kα line (red), Fe-Kα line (green) and K-Kα line (blue) associated to the presence of different iron earth pigments such as red iron oxide Fe, umber Fe/Mn and green earth Fe/K.

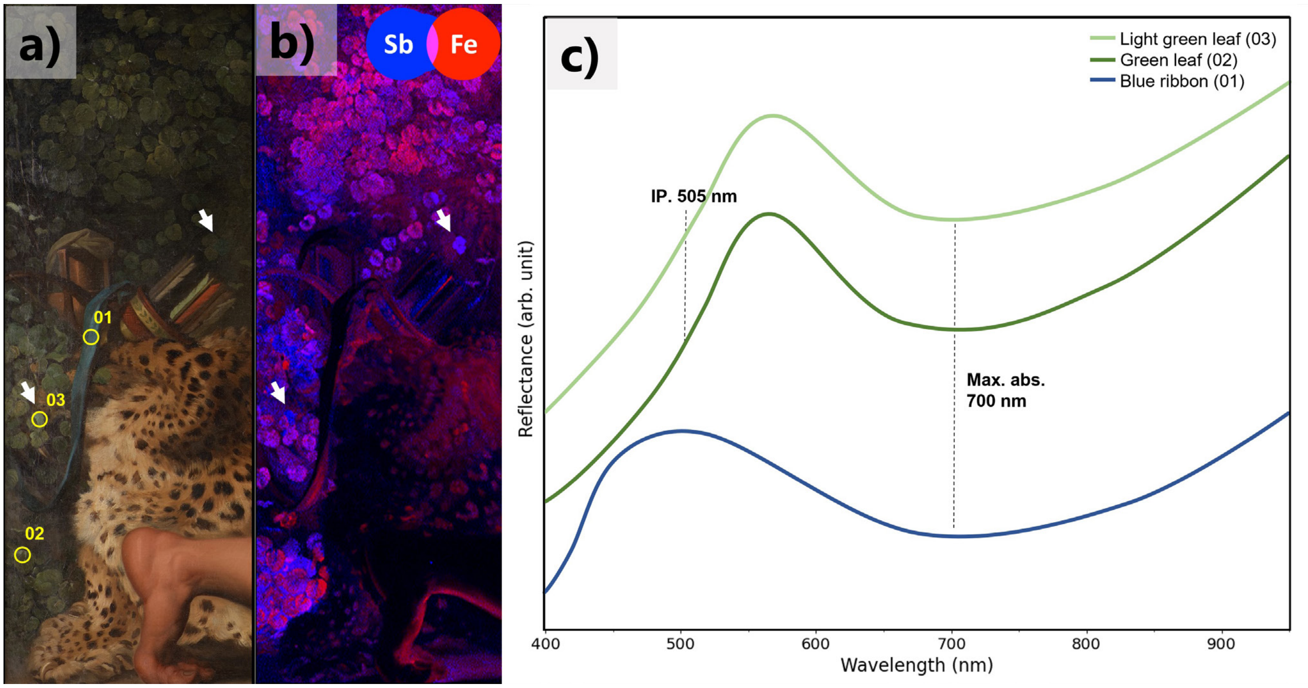

Figure 4. Visible light image of the painting. FORS acquisition points are indicated with a yellow circle (a), the arrows indicate areas with a mixture of blue and yellow. MA-XRF elemental distribution map obtained for antimony (Sb (L_{α} line)) in blue associated with the use of Naples yellow and iron (Fe (K_{α} line)) in red associated with the use earth pigments (b); FORS spectra from the blue ribbon and bluish areas in the foliage from The Wounded Philoctetes (c).

career, judging by analyses of a number of his paintings (Filtenborg 2014, Filtenborg et al. 2016). As the pigment has a high tinting strength, and was inexpensive compared to other blue pigments, Abildgaard's choice in this case is hardly surprising, given his probably limited financial allowance during his years in Rome.

Interestingly, a gold-based material was detected in one of the arrows and in the decorations of the quiver. Based on the scattered aspect of the MA-XRF elemental distribution map, it appears to be powdered gold mixed with the other pigments (Figure 5). There are no findings of gold powder in any other Abildgaard paintings, and the use of this material is highly unusual in eighteenth-century easel painting. Abildgaard would have seen gilding used in early Italian paintings during his Roman sojourn, but the discovery in this painting was unexpected and not fully understood. Potentially, it was an attempt by Abildgaard to emphasize visually the significance and crucial role of the bow and arrows in the story of Philoctetes by accentuating the details with the particular lustre and sheen of gold. However, as its presence in the paint is not detectable to the naked eye today, the admixture probably remained a trial which was abandoned in the completed painting.

Changes in composition associated with the shape of the figure can be seen in the MA-XRF Hg (mercury) elemental distribution map. Along with the X-radiograph, it can be inferred that Philoctetes back was slightly more prominent when Abildgaard first painted it (Figure 6a and c red dotted lines). This initial shape is more closely related to one of the preliminary drawn sketches of the figure made by the artist. Based on the MA-XRF iron elemental distribution map, the genitalia of the figure were also depicted more explicitly in the early stage of the painting (Figure 2c), once again, rather consistent with the depiction of Philoctetes in the sketch (Figure 6b).

Equally interesting is the original position of the bow. The Hg elemental distribution map, revealed that the bow was initially positioned atop the arrow quiver and not next to it. In addition, the shape of what seems to be the lid of the quiver shifted into the position seen in the final version of the painting. *The Wounded Philoctetes* was in many ways Abildgaard's 'debut' work; unsurprisingly, these changes are indicative of his efforts in working on the ambitious composition which was intended to demonstrate his early artistic and technical skills. They may also be seen as incorporated in the typical academic painting technique of the time, based on a methodical build-up of paint layers with a controlled succession of distinctive phases. This as opposed to a contrasting alla prima manner of execution with its wet-in-wet paint application where there was no clear separation between the stages of underpainting and final paint layers. It is difficult to determine with certainty the level of completion of the early features of the composition that were changed during the execution of *The Wounded Philoctetes*. However, an initial underpaint layer, applied to lay out the main elements of the composition with no attention to detail or modelling, was a crucial part of the first stage of the academic method, and the abandoned details may well have been part of this particular layer. In view of the importance of the work as a mark of achievement for Abildgaard, it would not be surprising if he adhered to the controlled approach of this method in his execution of the painting. In that sense, the painting occupies a special position in Abildgaard's oeuvre, which is otherwise characterized by his use of multiple techniques, often within the same painting. (Filtenborg, 2014). Apart from the issue of painting method, the changes made during its execution indicate that *The Wounded Philoctetes* in the SMK collection is the original, and perhaps only, autograph version of the composition.

Conclusions

This technical study aimed to characterize the palette of Nicolai Abildgaard in *The Wounded Philoctetes* using MA-XRF complemented by other non-invasive techniques such as FORS and X-radiography. While the palette of the painting included pigments traditionally employed in the eighteenth century (calcium carbonate, lead white, Prussian blue, vermilion, bone black, Naples

Figure 5. Visible light image of a detail with the arrow quiver in the painting (left) and MA-XRF elemental map obtained for gold (Au L_α line).

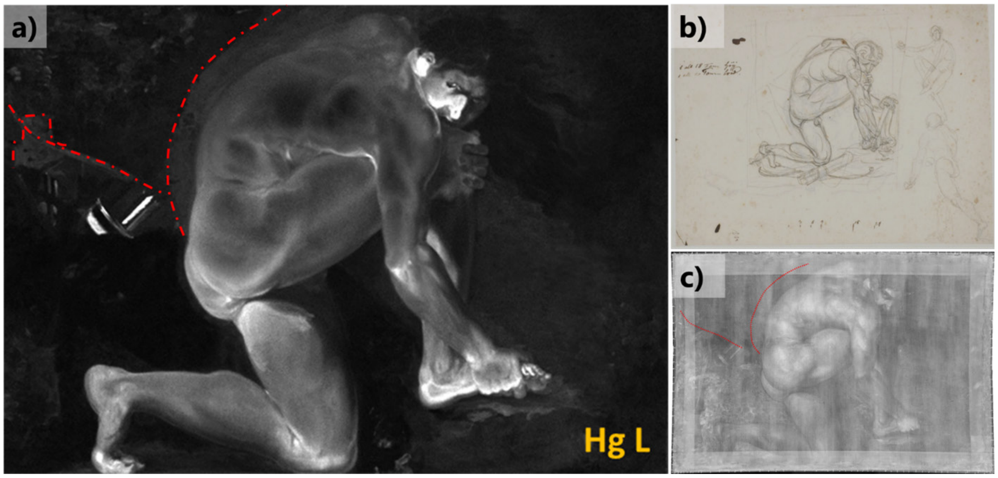

Figure 6. MA-XRF elemental distribution maps obtained for Hg-L_α line associated to the use of vermilion (a); Preliminary drawing of The Wounded Philoctetes (1774 – 1775) National Gallery of Denmark, KKSgb3601. SMK Photo (b); and X-ray radiography (c). The changes are indicated with a red dotted line in (a and c).

yellow, and iron-based earth pigments including, but not limited to, red iron oxide, umber and green earth), this study has also revealed the unexpected use of powdered gold, an expensive material, rarely, if ever, found in technical studies of eighteenth-century easel paintings. In addition to the identification of the pigments, the MA-XRF elemental maps also render changes made during the execution visible, supporting interpretations regarding the applied painting methods and the status of the work in Abildgaard's oeuvre . With the apparent employment of a controlled academic method, unusual in his practice, the adjustments and changes are indicative of the significance of this early painting for the artist and demonstrate its autograph nature.

In general, while MA-XRF provides enough information to trace the distribution of the different pigments and changes in the composition with a degree of detail, it lacks the specificity required for the unambiguous identification of all materials employed as well as the stratigraphy of the painting. This case study demonstrates the effectiveness of the combination of non-invasive, imaging techniques along with a minimally-invasive approach (in this case a cross section from a previous investigation) in order to fully understand the nature and spatial distribution of pigments used in paintings.

Competing interests

The authors declare that they have no competing interests.

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