SYMONÉE MARIE SOBRAL HINCKLEY

Licenciada em Conservação e Restauro

The Aesthetic Treatment of a Painting on an 18th Century Coach

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Supervisor: Doutora Leslie Anne Carlyle, Associate Professor, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa
Co-supervisor: Doutora Isabel Pombo Cardoso, Investigadora, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa

Júri:

Presidente: Doutoura Maria João Seixas de Melo
Arguente(s): Doutura Carolina Barata
Vogal: Doutora Leslie anne Carlyle

FACULDADE DE CIÊNCIAS E TECNOLOGIA
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RESUMO

O objectivo principal desta tese foi o estudo e tratamento de uma pintura a óleo do painel superior traseiro de um coche do século 18 pertencente ao Museu Nacional dos Coches (MNC), Portugal. A pintura é uma representação simbólica da Monarquia Portuguesa e do Escudo das Armas Reais. Todas as figuras, incluindo a Monarquia, estão vestidas com roupas clássicas. Em relação ao seu aspecto estético, a pintura estava significativamente comprometida. Áreas consideráveis do verniz encontravam-se baças, em vez de brilhantes, e as intervenções anteriores não tinham as cores saturadas, sobressaindo-se em relação às áreas em redor. No centro da pintura, nas junções dos painéis, separados no passado, antigos preenchimentos e retoques eram visíveis. O preenchimento da junção apresentava uma fissura de dimensões consideráveis, estando associada à perda de algumas áreas da antiga reintegração cromática. Os restantes preenchimentos foram realizados sobre os pregos. Estes divergiam das áreas em redor, tanto a nível da textura como de saturação de cor. Fissuras nestes preenchimentos e em redor eram visíveis.

Tendo em consideração que o coche contém um total de 11 painéis, que foram analisadas como parte deste trabalho, esta tese focou-se nas seguintes quatro áreas:

- Estudo da história, materiais e técnicas das pinturas sobre o coche, com base na análise bibliográfica de 5 tratados com foque na construção e decoração de coches. Estes datavam entre 1858 e 1903, sendo publicados em França, Inglaterra e Estados Unidos da América.
- Avaliação e identificação dos materiais e técnicas das pinturas utilizando análise estratigráfica e métodos analíticos, com o apoio do Laboratório HERCULES. Dada a restrições de tempo, as análises focaram-se no painel superior traseiro. Para obter alguma comparação entres as várias pinturas, μ-EDXRF foi efectuada em quatro dos painéis laterais;
- Avaliação do estado de conservação do Painel Superior Traseiro para formular uma proposta para o tratamento estético;
- Realização do tratamento do Painel Superior Traseiro sobre a supervisão do Instituto José de Figueiredo.

O estudo de tratados de pintura em coches revelou que era comum ocorreram danos nestas pinturas. Como resultado, era esperado que estas pinturas fossem recorrentemente removidas e substituídas. Sendo assim, embora o coche seja do século 18, as pinturas actualmente presentes, poderão ser de séculos posteriores. Após analise do painel com μ-EDXRF, μ-FTIR, μ-Raman e SEM-EDS não foram detectados elementos ou pigmentos específicos de épocas posteriores ao século 18, excepto nas áreas de intervenção. Os pigmentos identificados nas camadas pictóricas da pintura foram: branco de chumbo, vermelhão, ocres (hematite e goethite), terra verde e amarelo de Naples, bem como sulfato e carbonato de cálcio associados às cargas utilizas.

O tratamento estético efectuado permitiu restituir o brilho do verniz assim como saturar os antigos retoques. Os retoques foram reintegrados de modo a estarem em consonância com tonalidade do verniz da pintura. O tratamento permitiu reduzir o impacto visual dos mesmos, deixando estes de ser o foco da pintura.

Palavras-chaves: Coche do Infante D. António; coche do século 18; pinturas sobre coche; tratados de pinturas sobre coche; materiais e técnicas; tratamento estético; Museu Nacional dos Coches; Instituto José de Figueiredo; Laboratório HERCULES.

ABSTRACT

The main objective of this thesis was the study and treatment of an oil painting on the upper back panel of an 18th century coach in the collection of *Museu Nacional de Coches* (MNC), Portugal. The painting is a symbolic representation of the Portuguese Monarchy and of Royal Power depicted by a female figure sitting on a throne with her right arm resting on the Portuguese Royal Shield of Arms. All the figures, including the Monarch, wear classical costume. The aesthetic appearance of the painting was significantly compromised. Large areas of the varnish were matt rather than shiny, and previous re-integrations were not saturated in colour, standing out from the original. In the centre of the panel, the join between two horizontal planks had separated and had been filled and reintegrated. The fill had developed a large obvious crack, with associated losses to the reintegrated paint on the fill. Infilling which had been applied over nail heads in other areas on the panel were disturbing since they were also cracked and had an uneven texture compared to that of the original painting.

The coach has a total of 11 painted panels, which were also examined as part of this work. This thesis project focused on four main areas:

- The study of the history, materials and techniques of the paintings on the coach. This involved research on 5 treatises on coach construction and decoration dating from 1858s to 1903, published in, France, England and United States,to evaluate the materials and methods recommended;
- The evaluation and identification of the materials and techniques for the paintings using stratigraphic analysis and analytical techniques. This was carried out with the support of Laboratório HERCULES. Due to time constraints, analysis was focused on the Upper Back Panel. For comparison of the materials present, μ-EDXRF was also carried out on 4 of the side panels as well as the Upper Back Panel;
- The full evaluation of the condition of the Upper Back Panel in order to develop an aesthetic treatment strategy;
- The execution of the treatment of the Upper Back Panel with the supervision of the Instituto José de Figueiredo.

The study of coach painting treatises revealed that it was common for paintings on these vehicles to become damaged. As a result it was expected that paintings would be routinely removed and replaced. Therefore although the coach may have been constructed in the 18th century, the current paintings could be from later centuries. After analysis of the upper back panel using μ-EDXRF, μ-FTIR, μ-Raman and SEM-EDS it was found that no elements or pigments specific to an time after the 18th century were present, except in areas of intervention. The materials original to the paintings which were identified during this thesis include: lead white, vermilion, ochres (hematite and goethite), green earth and Naples yellow; as well as the fillers, calcium sulphate and calcium carbonate.

The aesthetic treatment undertaken was successful in restoring gloss to matt areas of varnish along with re-saturating previous re-integrations and overpaint. Previous colour re-integrations were also retouched and the surrounding varnish colour re-integrated such that the visual impact of the discordant previous treatments was reduced and no longer became the focus of the painting.

Keywords: Coche do Infante D. António; 18th century coach; paintings on coach; treatises on coach painting; materials and techniques; aesthetic treatment; Museu Nacional dos Coches; Instituto José de Figueiredo; Laboratório HERCULES.

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Note: Unless otherwise stated, all images were taken by the author throughout the realization of this project.
Before Treatment Photographs were done between September 2015 to March 2016.
During Treatment Photographs were taken between March 2016 and June 2016.
After Treatment Photographs were taken June 2016.
All photographs can be found in the accompanying CD at the end of the thesis.

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INDEX ACRONYMS

GC-MS……..Gas chromatography – mass spectrometry

IJF……..Instituto José de Figueiredo

MNC……Museu Nacional dos Coches

OM.....Optical Microscope

SEM-EDS…..Scanning electron microscopy with energy-dispersive X-ray spectroscopy

µ-EDXRF……Micro energy disperseive X-ray Flourescence

µ-FTIR ……Micro Fourier transform infrared spectroscopy

1. Introduction

The focus of this project is the study and aesthetic restoration of an oil painting on the upper back panel of an 18th century coach belonging to the collection of the Museu dos Coches (MNC). This was a collaborative project between the Faculdade Ciências e Tecnologia, University Nova Lisboa (FCT-UNL), the Museum (MNC), the Laboratório José de Figueiredo (LJF) and Laboratório Hercules.

This painting depicts various figures of which the most prominent is the one representing the Portuguese Monarchy. To understand the materials and techniques used, cross-sections were taken from the painting and analyses were performed. The techniques used were µ-EDXRF (performed *in situ*); SEM-EDS, µ-Raman and µ-FTIR (on the samples). Cross-sections and µ-EDXRF analysis from the coach's other paintings were also done for comparison. For further information, treatises on coach paintings were also consulted.

The decision in studying the Coche do Infante D. António, in particular the upper back panel, was due to this painting presenting what appeared to be mostly aesthetic disturbances. Taking into consideration the allotted timeframe of the project, along with other factors, it was considered that the nature of this painting, could be treated with an aesthetic intervention. The intervention was supervised by the IJF.

1.1. Coaches and their History

A coach is characterized, and thereby differentiated from other horse drawn vehicles, for having its body suspended over its carriage parts [1]. With regards to their origin, there is some disagreement among authors as to who is truly responsible for its invention. Fuller in 1828 brings up this very matter in his, *An Essay on Wheel Carriages*, and states that since the name has been adapted with 'little variation' there is difficulty is resolving the question by etymology [1]. According to Pereira (1988), in his work he attributes it to the small town of Kotzee in Hungary, where, as he claims, it also got its name [2]. Such an assumption, as explained by Straus (1912), is not unreasonable considering that two later carriages, the *Berlin* and *Landau,* were named after the towns where they were first made [3]. However, he also states that according to early accounts being 'fragmentary and obscure' it is not feasible to determine when and where the first coach was made. Nevertheless, it is known that in the start of the 17th century coaches were beginning to be in common use. [1-3]

During the 17th century, the French, as explained in Libourel's *The French Art of Carriage Building* (2012) developed improved coach models [4]. The *carrosses modernes* (see Fig. 1), the modern coach, as they came to be known, is attributed to Jean Le Pautre around the 1600's [4]. The changes made were to both the carriage parts, specifically the axle system, and the body. In regard to the axle system, Libourel mentions two key developments: the installment of two crane neck iron arches (see Figure 2) under the front wheels and a reduction of diameter of the same wheels. These adaptations gave these coaches a higher degree of maneuverability, permitting 90º angles. As a result, this facilitated their use on tight city streets. [4]

In regard to the body with the possibility of now using coaches with more ease within cities, they quickly became a symbol of status and wealth [2,4]. As emphasized by Pereira (1988), modern coaches became a representation of the European Courts during ceremonies [2]. They were no longer considered a mere means of transport but as a work of art as well, or as Libourel in "*The Modern State Coach"* phrases it, "the state coach was a vehicle intended to display royal pomp and grandeur" [5, p.230]. He goes on to explain that such rich ornamentation included motifs, which were "sculpted in bas-relief instead of simply painted" and "brilliant gilding that covers the entire piece, including the wheels" [5, p.231].

After the Industrial Revolution, tastes varied and passed largely from the French model to an English one, which was of much less grand decoration; a coach more fitting for daily use [3].

1.2. Coaches in Portugal

Not much is known about the use of coaches in Portugal prior to the 17th century as few records of their use exist [6]. Despite this, one pre-17th century coach has managed to survive: the coach of Filipe II (aprox.1619). According to Pereira (2016), in a conversation with the author at the MNC, this coach is believed to have been offered to the Portuguese King of that period, Sebastião, by his uncle Fillipe II [6].

Two possible reasons exist as to why there are few references to coaches in Portugal; the first is that, as mentioned above, until the 17th century coaches were not in common use. The second case, as stated by Pereira (1988), is that Portugal was not an important European political center before the 17th century. After the restoration of its independence from Spain in 1640, Portugal was gradually able to re-establish its political power and influence reaching its peak during the 18th century [2]. As mentioned by Pereira (personal communication 2016), one of the reasons behind Portugal's growth in wealth was the gold coming from Brazil, and that King, João V avoided wars [6]. The means by which the country could express it's power and wealth was by investing in the creation of coaches for Portuguese embassies, such as the Coach of the Crown (1715) for Paris as ordered by the Portuguese King João V, according to Pereira (1988) [2].

As was previously mentioned, coaches after the 17th century followed the French *carrosse modern,* of which the oldest example in Portugal is the Coach of Maria Francisca de Sabóia (17th century). [7]

Despite tastes changing over time and their wider use in Portugal after the 18th century, old examples belonging to the Royal House and Religious collections were conserved and occasionally used for ceremonial purposes. In 1905, Queen Amélia d'Orleões e Bragança, Princess of France established the *Museu dos Coches Reaes* (the Royal Coach Museum), the first of its kind in the world [8]. With the fall of the Portuguese Monarchy in 1910 ownership of the coaches passed to the new government. In 1911 the museum was renamed to what it is known as today, the *Museu Nacional dos Coches* (the National Coach Museum, MNC). [8]

1.3. The Coach of Infante D. António (Prince Anthony)

1.3.1. Historical Context

The Coach of Infante D. António (Figure 1), as explained by Pereira (1988), is named based on the traditional belief that it had once belonged to Prince Anthony, brother of King João V. [2]. According to its dossier in the MNC's inventory, its origin is assumed to be Portuguese and it is dated between 1710 and 1757 (according to the presumed owners' biography) [9]. Very little is known about this coach, as documentary references to it are rare. In Botto's work *Promptuario analytico dos carros nobres da Casa Real Portugesa e das carruagens de gala* (1909), he notes only vague references to the existence of a Prince Anthony's coach [10]. However, if the current coach in the MNC's collection did indeed belong to the 18th century Prince Anthony, according to Botto (1909) it was most likely made for the Jornada do Caia in 1729, which marked the exchange of princesses between Portugal and Spain [10]. If this is the case, contrary to popular belief, it is possible that it is of French craftsmanship instead, as commented by Raúl Leite[1], as some coaches for the Jornada de Caia were ordered from France. In order to clarify the coach's origin, a thorough artistic and historical study is required.

Figure 1: Coche do Infante D. António. Right side view. (Dossier Photo [9])

Some uncertainty currently exists concerning when the coach became an official part of the MNC's collection. Botto (1909), did an extensive study on the first coaches exhibited by the Queen in 1905, but

[1] Raúl Leite, Senior Paintings Conservator at the LJF, Personal Communication October 2015.

this coach was not one of them [10]. Although it's date of acquisition is 1920, according to the *dossier* [9], this date does not correspond to the day it began being displayed, as explained by Rita Dargent at MNC [11]. According to the MNC's history, ever since it was established, it has had problems with space, which has limited the number of coaches that could be on display [8]. In 1944, this situation led to expanding the museum's original building, the Picadeiro Real, by adding a new room [8]. It is likely that the Coach of Infante D. António was only officially put on display at the MNC sometime after that year, especially since previous museum catalogues prior to that decade make no mention of this coach.

According to a conversation with Pereira (2016), coaches belonging to the Royal Collection were sometimes offered to the Patriarch when they were no longer being used by the Royal Family [6]. It is possible, as theorized by Pereira (2016), that Anthony's Coach could have been one of various coaches given to the Patriarch, eventually becoming assimilated into the MNC's collection [6]. If this were the case, it may explain why there is not much information on the coach.

Today, the coach resides in MNC's new building inaugurated in 2015 [9].

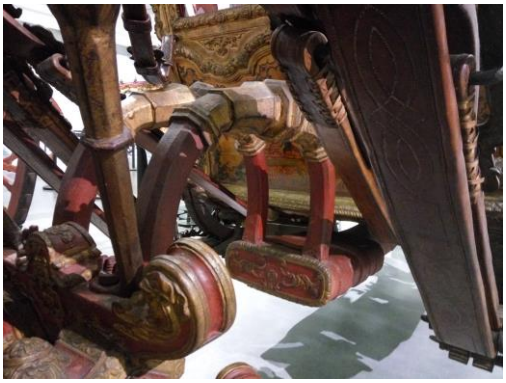


Figure 2: *Coach's crane neck and some more examples of leather straps.*

Figure 3 :*Example of the suspension system underneath the body.*

1.3.2. General Description

The following information on the construction and decorative elements for the *Coach of Infante D. António* is taken from the Museu dos Coche's dossier for this coach [9]. It stands approximately 270 cm tall, 630 cm long and 200 cm wide (Figure 1). This coach follows the *carrosse moderne*[2] style, which was evident upon examination of the crane neck (Figure 2) characteristic of this style as mentioned above. The coach body is closed and, like all vehicles of this type, is suspended over the carriage parts by a suspension system, in this particular case, by leather straps which are called main braces (Figures 2 & 3). The carriage parts, at some point during its use were painted red and present various decorative elements, mainly around the coachman's seat at the front, and between the rear wheels, with molded bronze and carved wood. Understanding when certain decorations or painting were applied to the carriage parts would be important to comprehending the coach's history, as will be mentioned in Section 2, damages occur often to these vehicles and consequently their décor.

Figure 4: *Examples of the carved and gilded wood on the coach body.*

The coach body has two doors, each in the center of the sides and seven windows, one in the front and three on each side. The exterior of the coach body is richly decorated by carved and gilded wood in shapes of leaves, flowers and sometimes faces (Figure 4). These carvings do not cover the whole coach, for on all the sides, there are various oil painted panels, around which these carvings act as frames (Figure 5). There are 11 panels on the coach, representing various allegorical and symbolic

[2] According to Liborel this style was introduced in the 17th century and used until the 18-19th century [4]

figures alluding to the Portuguese Monarchy, to Royal Power, and to the Four Corners of the World, among others such as Prosperity, Affability, and Providence. The panels are very similar in style, varying only in the figures being represented except for the upper back panel, which will be described below.

The interior of the coach is lined with a worn embroidered red fabric, which follows similar stylistic design as the outer wooden carvings of the body, as pointed out by Rita Dargent [11].

1.3.3. Description of the Back Panel

The panel in this study[3] (Figure 5, see also Appendix I Figure I.1) is a depiction of the Portuguese Monarchy, represented as a woman sitting on a throne with her right hand resting on the Portuguese Royal Shield of Arms. The Monarchy is garbed in a classic white robe with a red mantle running over her right arm and onto her lap. According to Chevalier (2004) red is a colour of power, blood and fire [12]. When joined with white, the two are the colours associated to Jehovah, God of Justice and Wisdom, a being of supreme power [12]. The Monarchy possess both colours, perhaps this was done to compare the Portuguese Royal Family and Royal Power to that of a supreme power, to emphasize the figure's importance and role. However, as mentioned, the God for which these colours are generally employed, is Jehovah, known as a Just and Wise being, perhaps the intention was to portray the Portuguese Monarchy as one of Justice and Wisdom as well.

As can be seen in Figure 5, the Monarchy is surrounded by other figures. These have been identified in the coach's *dossier* as warriors, gods and muses [9]. However, no justification for these attributions was given. As a means to understand their meaning along with confirming their correct attribution, the painting was shown to the Historian João Castel-Branco Pereira [6].

Pereira's first observation was on the manner in which the figures are organized in the painting. The Monarchy in the upper center holds the position of most importance, however some of the figures such as the women next to the Monarchy have their faces turned with their attention on the two soldiers on the right side of painting. These two in turn, appear to be pointing at the woman on the bottom right of the painting. This same woman is holding onto a child as if attempting to protect it while gazing towards the Monarchy. In Pereira's opinion, the scene of the painting appears to be of a judgement, mentioning the possibility of it being a representation of a biblical story such as the Judgement of Solomon. According to the bible (1 Kings 3:16-28) King Solomon was asked to judge which of two women claiming to be the mother of a child was the real one. However, the painting has only one woman, so it may be depicting some other judgement [6]. The depiction of the Monarchy as a judge would emphasize the symbolic depiction of 'wise and just God.'

Figure 5: Upper Back Panel of the Coach before treatment (author's image).

The soldiers appear to be classic warriors (based on their costume, for example the helms and armor). The only other figures identified aside from the Monarchy were two cupids on the bottom of the panel to the left of the woman and child. They appear to refer to the God of Love, since they are shown with a bow,

[3] Due to the timeframe and the scope of this project, it would not have been possible to undertake a full treatment of the whole coach. As such, it was opted to focus on the upper back panel. Aside from time constraints, another motive behind this decision is because no thorough studies have been done on any of the coaches in the MNC, as such any full treatment on any coach could influence the understanding of future studies on their materials and techniques and their relation to the others in the museum.

quiver and arrows visible upon close observation, symbols of this god as described by Chevalier (1982) [12].

Unlike the other panels (see Figures in Appendix II) where the figures are painted over a flat gilded surface, this painting is much more elaborate. Rather than 'flat', the figures appear to be inserted into a perspectival 'space'. This can be seen in the floor as the tiles get smaller towards the Monarchy and in the background, where the Monarchy and the other figures appear to be in an open courtyard surrounded by clouds and bushes. The upper corners, where the sky would normally appear is gilded, similarly to the other panels. Pereira also noted the possible symbolism behind the scenery: there is a separation between the top and bottom figures, in other words, the checkered floor may be representing Earth and everything on and above the clouds is Heaven [6]. This seems to further emphasize the Monarchy's importance and divinity.

Aside from an iconographic study, another means of dating a painting is through the analysis of the style of clothing. According to Xénia Ribeiro and Dina Dimas[4] from the *Museu dos Trajes*, this is an allegorical painting, which follows a neo-classic style rather than clothing from a specific era. As they explained, neo-classic representations can date from the 18th century till the beginning of the 19th. While the style does fit the time the coach was created (18th century) the clothing does not provide direct assistance in discovering whether the painting is original or could have been made at a later date, possibly replacing an earlier panel.

[4] Personal communication 31 August 2016 Xécia Ribeiro and Dina Dimas, Artes Historians, Museu dos Trajes.

2. Treatises on Coach Painting

2.1. Methodology

Coach or carriage[5] paintings are meant for a functional object exposed to the outdoors. As such, for them to maintain a certain durability required for such conditions, it is only natural that particular care is given in the selection of materials used during construction not necessarily found on other types of paintings (e.g. portraits and other indoor paintings), as discussed by Arlot (1860) a coach painter [13]. To understand what materials were most commonly used in coach painting and the reason why, a study on various coach treatises was done.

Table 1: List of search terms used in the three languages.

English	Portuguese	French
Coach	Coche	Carrosse
Carriage	Carruagem	Chariot
Horse-Drawn Vehicles	-	Véhicules hippomobiles
Coach Treatise	Tratados sobre Coches	Traité sur Carrose
Painting On Coach	Pinturas sobre Coches	Pientures sur Carrosses
Coach Painting Treatise	Tratados sobre Pinturas em Coches	Traité sur les Peintures de carrosserie

The first step of the study involved looking for coach treatises in Portugal at the *Biblioteca Nacional de Portugal*[6] and the MNC's library as well, however none were found to be present at either library.The search then spread out to two online library archives: the French National Library[7]; and the Archive[8], an online access to digitized archives from European, American and Canadian Libraries. From these two sources, with the use of the terms in Table 1, five treatises on carriage painting were found. More carriage treaties on other topics (such as their history, prices and construction) were also discovered in the process (see Appendix III. Bibliographical Sources Researched), however they are not the focus for this study as they do not discuss the process of painting.

As previously mentioned, all the treatises were found online and are therefore digital copies of books present in libraries in other parts of the world. The five treatises include: The *Manuel complet du peintre en équipages* by Gastellier (1858) [14] an original French manuscript. *A Complete Guide for Carriage Painters,* by Arlot translated from French into English by Fesquet in 1871 to which was added an appendix [13]. However, the original French manuscript, *Guide complet du peintre en voitures* (1860) [15] was at times consulted to confirm the original French terms with the other French treatise, despite the translated version being mostly used to facilitate comprehension. The third treatise was, *The Carriage Painters Manual* by Gardner (1877) [16], an original English manuscript from the United States. *A Practical Treatise on Coach-Building* by Burgess (1881) [17] was an original treatise from England and at last, *The Practical Carriage and Wagon Painting,* 3rd Edition by Hillick (1903) also from the United States [18]. Within these treatises, the focus of the study was given to: the preparation layers, the *gilding*, the varnishing, re-painting and re-varnishing of the panels.

Paint layers were not considered due to the style of painting in these treatises being different from the style present on the *Coche do Infante D. António*. As seen in the example shown in figure 6, the paintings done during that era were most commonly solid backgrounds with monograms or ornamental designs [15-18] rather than allegoric figures like the coach being studied. It is likely that if a more traditional painting

[5] In English the term carriage is used generically for horse drawn vehicles [1].
[6] Portugal's National Library
[7] French National Library: http://gallica.bnf.fr/
[8] The Archive: https://archive.org/

method was to be used that they would resort to other artistic treatises. A list of all the pigments mentioned in the treatises may be found in Appendix IV, Table IV.10.

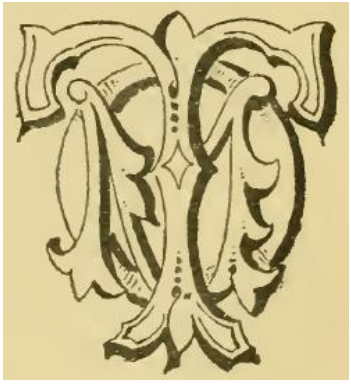


Figure 6: Example of a monogram as designed in Burguess' (1881) treatise [17, p.215].

2.2. Preparation and Ground Layers

According to Stols-Witlox (2014), the term "preparation layers" refers to all of the layers that are present between the support and the paint layers (e.g. size and ground) [19, p.67]. In all the English written treatises, instead of preparation, they have used the term foundation [16-18], however, in this thesis these layers will be mentioned as preparation to maintain coherence with what most conservators are familiar with. In turn, these may be divided into three different steps or 'layers', although some of the treatises vary in terminology and process. As such, instead of a general term, these will be referred to as the 1st, 2nd and 3rd stages. The only treatise to present merely two stages rather than three is Gastillier's (1858) [14].

For more detailed information on each preparation stage's recipes and method of application see Tables IV.1-5 in Appendix IV.

2.2.1. 1st Stage of Preparation – Filling of wood pores

In Gardner's (1877), Burgess' (1881) and Hillick's (1903) treatises, this layer is called the priming [16-18]; while in Gastillier's (1858) and Arlot's (1860) it is '*couche de impression'* [14,15]. In an English translation of Arlot's treatise by Fesquet (1871), he translated this into priming as well [13]. In all of the treatises, the role of this 'priming layer' is to fill the wood pores, or as put by Hillick (1903), it is the 'agent required to go into and saturate the minute cells and pores of the wood (…) sealing them against moisture' [18, p.18-20]. This step also prepared the surface of the wood to receive subsequent layers of preparation and paint (as stated by Gastillier (1858) [14], p.7).

In Stols-Witlox's (2014) study on historical preparation layers for paintings, those meant to "stiffen or fill pores in different surfaces" are referred to as size layers [19, p.72]. However, as mentioned above the treatises refer to this stage as priming rather than size layers. According to Stols-Witlox (2014), the term priming was sometimes reserved for "oil-based pigmented ground layers" [19, p.73]. As seen by Stols-Witlox (2014) sizes used on panel paintings during the 17-19th centuries were primarily animal glue based [19], as such it is likely that the treatises are using the term priming for this stage due to the fact it is oil based (see below).

To summarize, according to the Treatises, at least one layer of 'priming' was applied over the surface in order to properly fill the wood pores [13-18]. The composition of this layer in all the treatises is the same: linseed oil and lead white [13-18] of which according to Hillick (1903) the first coat should have plenty of oil, 'with just enough pigment to stain the oil' [18, p.19].

In Gastillier's (1858) and Arlot's (1860) treatises, they both add turpentine to their recipe and dryer [14,15] although the first states it should only be in winter [14]. They also call for a second coat of priming, Arlot notes that it should be 'poorer' in oil than the first [15, p.16]. According to these authors the application of this second coat will give the best results in the end. [13-15]

2.2.2. 2nd Stage

Unlike the first stage, naming for the second stage varies considerably as does the procedure. Gastillier (1858) and Arlot (1860) both refer to *couches de apprêt* [14,15], which according to Stols-Witlox are also general terms for the preparation layer ([19], p. 68). However, in Fesquet's (1871) translation of Arlot's treatise he calls these layers 'filling coats' [13,15]. Burgess' (1881) calls the layers of this stage 'lead colour' [17] and both Gardner (1877) and Hillick (1903) call them 'lead coats' [16,18]. For the last three authors,

the process is very similar and will be discussed together, whereas the French treatises during this stage are considerably different. Also, as noted above, this is the last stage in Gastillier's (1858) treatise.

The English treatises have, two to three coats applied to the surface. In Burgess (1877) they are composed of lead white, linseed oil and dryer [17]; similarly in Gardner (1881) they are a mixture of lead white, oil and Japan[9] (a drier) [16]. In Hillick (1903) the first layer is linseed oil, lead white and turpentine, and for the second layer Japan is added to the first mixture [18]. Hillick (1903) calls for only two layers to be applied [18], the others each have three [16,17]. In between each application the surface is to be smoothed by sanding or pumicing (rubbing with pumice stone) [16-18].

During this stage, the French treatises apply more coats: Gastillier (1858) in his second and final phase applies a total of eight layers [14], while Arlot (1860) only applies six [15]. In both, the mixture is composed of yellow ochre, lead white, linseed oil and essence of turpentine; although in different proportions [14,15]. Once layers have dried they are then smoothed by pumicing, between layers and at the end [14,15]. According to Gastillier, the reason for the use of so many layers of preparation (2 *couches de impression* and *8 couches d'apprêt*), is to not only insure that it will fill the cavities of the wood as well as be able to support the friction of the pumice stone; a process which occurs not only throughout the preparation layers but will happen during the varnishing phase as well (see below) [14].

2.2.3. 3rd Stage

For Arlot (1860), the third and final stage consists of two layers of 'puttying up' as translated by Fesquet (1871) [13,15]. Holes and dents are filled with a varnish putty (hard varnish with white lead or zinc white) which is applied over the whole surface [15]. Between the two coats of 'puttying up' a guide coat (a thin usually red coat) is to be laid on to aid in pumicing the surface: as the coloured coat disappears the surface will be smoothed [15]. After Arlot's second 'puttying up' layer has been smoothed, the surface is ready to receive paint. Although Gastillier (1858) doesn't have a 3rd stage, he does mention guide coats in a negative light; he doesn't think they are necessary for pumicing, as such they are a waste of material [14, p. 31].

Once again the English written treatises are different from the French, and their terminology is not exactly the same between them. Burgess' (1881) calls the layers of this stage 'filling coats' [17], as does Fesquet (1871) in his translation of Arlot [13,15]. These consist of filling-up[10] stuff: lead white, turpentine, Japan gold size[11] and bottoms of wearing varnish[12] [17]. Burgess (1881) states that five layers are to be laid on the surface [17]. He also notes, that these should be kept from lapping over the edges of the panels [17].

In both Gardner (1877) and Hililck (1903) these layers are called rough stuff [16,18]. The composition of this in Gardner (1877) is a filler of ground slate, with lead white, Japan, rubbing varnish and turpentine [15]. Hillick (1903) gives a variety of possible recipes, the materials can be seen in Table IV.5 in Appendix IV. According to Gardner (1877) and Hillick (1903) three to four coats are to be laid on and then rubbed down with the aid of a guide coat [16,18].

2.3. Gilding

For a surface to receive gold, silver or another metallic leaf, as Gastillier (1858) states, it must have a sticky enough surface for it to adhere [14]. To get the gold leaf to 'stick' to the surface of the panel, a liquid, gold size or mordant, must be applied [15,16,18]. In some cases, such as ornamental gilding, only specific

[9] Gastillier gives composition to a japan: asphaltum and linseed oil [12, p.68], other japans may be the same.
[10] It's likely that the 'filling-up stuff' is the same as Gardner's filling, in other words, ground slate due to sharing the same term "filling".
[11] Burgess' japan gold size is made up of: asphaltum, litharge (or red-lead) and linseed oil (p.110).
[12] See footnote 22 in Appendix IV

areas are intended to receive gold leaf. To ensure the leaf does not stick to surfaces not meant to be gilded, material can be applied to prevent adherence [15,16,18]. Gardner (1877), directs that the area be dusted with whitening [16]. According to the *Pigment Compedium* (2008) whitening is composed of calcium carbonate [20, p.80].

Gastillier (1858) mentions a different method: before gilding, 15 to 20 coats of shellac must be applied over a hardened and polished white lead ground [14]. Once the shellac has dried it too is to be polished to a glass-like surface after which it is ready for gilding [14]. The body is placed in a heated workshop where the mordant (yellow button of gold[13] and linseed oil, see Table IV.6 and corresponding footnote in Appendix IV) is coated over the shellac after which the gold leaf may be laid on [14]. Gastillier (1858) also describes a method for retouching gilding which involves using a thin coat of clay over the panels before the mordant may be laid, for this adds colour to the leaf [14]. The gold leaf, according Gastillier (1858) should only be laid on when the mordant 'is at the point of drying', for only then it is ready to receive the gold [14, p.96].

After the laying on the gold leaf, the surface may be carefully cleaned, and if there were areas where the mordant was not applied, the gold leaf will not have stuck to the panel and may be cleared from the surface leaving behind the desired ornamental design [14,15,18].

For further information on gilding see Table IV.6 in Appendix IV.

2.4. Varnishing

In general, two different varnishes were called for in the treatises: rubbing varnish and finishing varnish [15-18]. According to Carlyle (2001), the varnish most commonly used for coaches was a copal oil varnish [21]. The only treatise to discuss the resin used in one of the varnishes, the rubbing varnish, was Gastillier (1858). It was made up of the resin *gomme dure Calcutta* in linseed oil (1:1) and essence of turpentine [14]. Augerson (2011) states that Zanzibar copal was sometimes sold under the name g*omme dure Calcutta*, due to being exported from this location to other places in the world [22], Although the other authors do not specify the type of varnish, it is likely they are all referring to a copal oil varnish since they all describe similar qualities and use (see below) as well as similar names (e.g. finishing varnish, wearing varnish etc.) as recipes discussed in Augerson's (2011) article of which all use copal [22].

As the name suggests, rubbing varnishes are to be rubbed in order to produce a polished and glossy surface, "like glass" (Gastlillier (1858) [14], p.63). Arlot (1860) states that three coats should be applied, the first thinner than the rest to ensure it flows easily to cover all the surface [15]. He notes between each coat the varnish must be rubbed with a pumice stone [15]. Unlike the others, Burgess (1881) mentions another varnish to be applied after the rubbing varnish. It is called a 'hard drying varnish', which, according to him, is meant to level the surface preparing it for the finishing varnish [17, p.110].

The final varnish was the final layer or coat in the whole process of painting the carriage. Arlot (1860) explains that finishing varnishes are "always of the best quality and very fat," he notes that "they are more easily laid on than the rubbing ones' [15, p.21]. As explained by Leslie Carlyle, a fat varnish is a thick and glossy varnish[14]. Since the final varnish is not heavily rubbed, just slightly polished if at all, this indicates that it is not the same exact composition as the rubbing varnish [15-18]. Arlot (1860) observed that it is easier to apply than rubbing varnish [15]. None of the treatises identifies the resin used for the finishing varnishes, however as discussed above, according to research done by Augerson (2011) these were copal resin based [22].

For further information see Table IV.7 in Appendix IV.

[13] Gastillier (1858) in his treatise, calls for use of a yellow pigment by the name of "*jaune bouton d'or"* [14, p.95-96] which translates into Yellow Button of Gold. According to *The Pigment Compendium* this pigment is a zinc chromate hydroxide first produced around 1800, and is most commonly known as Zinc Yellow. [20, p.406, 414-415].

[14] Leslie Carlyle Personal Communication March 2017

2.5. Re-painting and Re-varnishing

As can be imagined, through use, coaches become dirty and damaged. It is one of the reasons why a good varnish is of utmost importance, to protect the surface of the coach (and any painting) as best as possible as it must endure rain or frequent cleaning [15,17]. A non-oil based varnish would most likely not withstand the same trials as does the copal-oil varnish.

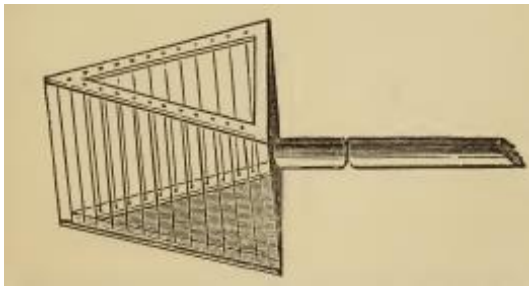


Figure 7: Example of the tool used for furnacing as shown by Gardner (1877) [15, p.67].

Regardless of all the care taken, damages are inevitable. These are foreseen in all the treatises, since it appears to be a common and acceptable practice to not only re-varnish but also to re-paint the panels. Re-varnishing is similar to that of regular paintings, the damaged varnish is removed by means of solvents and new ones are applied [15-18]. As copal varnishes are not known to being very soluble, as seen by Carlyle (2001) [21], it is possible, that the method mentioned in the treatises either involves powerful solvents over considerable period, or that the final varnish (the Finishing Varnish) is made up of a less durable and more soluble resin than copal. However according to Augerson's work, finishing varnishes were also copal based, but since their composition is different from other copal varnishes (e.g. hard drying varnish) this could influence the ease at which they can be removed [22].

Regarding the paintings, or paint coats, when these layers are considered sufficiently damaged they are completely removed. The treatises give various methods for removing paint and preparation layers from a panel's surface, however it appears that the preferred method is 'furnacing' [15,16,18]. According to Arlot (1860), 'if there are cracks or blisters that go as far as the foundation coats (…) the old paint must be burned off by means of the furnace' and new coats laid on [15, p.39]. Gardner (1877) explains the furnace process quite clearly: the coach painter is to use a 'sheet-iron and heavy wire' (shown in the Figure 7). The center of this tool is filled with ignited charcoal which will allow the user to '"burn off" a body very quickly and well' [16, p.67-68]. This for paintings on wood panel, as some coaches have paintings over leather or papier mache.

The implications of this, indicate that, although a coach, such as the *Coche do Infante D. António* was built in the 18th century, the paintings we see on its panels today could be from a much later date. According to Botto (1909), even during the 18th century, the Portuguese King had four painters and restorers within the Royal house whose function was to maintain and repaint the royal collection including the coaches [10]. He also notes that there may be retouching and repainting on some of the coaches within the MNC from this era [10], however there are no known records as to which coaches were treated in the past.

3. Analytical Strategy

The main objective in the technical examination of the *Coche do Infante D. António's* was to understand the condition of the paint layers on the coach, specifically in the painting to be treated, the upper back panel (see Section 5), and the materials and techniques used. Accessibility to the upper back panel presented limitations therefore it was necessary to carefully consider each analytical method with regard to the questions to be answered, as well as the viability of it being used in such conditions. The objective was to select and use techniques that would allow the collection of as much information as possible through the least invasive or destructive means to the object.

The first step, photographic documentation, was carried out by Luís Piorro. These images were supplemented by normal and macro-photographs taken by the author (Appendix I for Before Treatment images and Appendix V for equipment details). The following imaging methods were used: Normal Light (NL), Raking Light (RL), Ultraviolet Light (UV), Infrared Reflectography (IRR) and X-Radiography (see Appendix I). The first three (NL, RL and UV) provide information on the painting's surface [23]. According to Macbeth (2012), Raking Light will allow a better understanding of irregularities on the surface, caused by artistic techniques, such as impasto, and can emphasize an area of damage by highlighting indentations or bumps, or reveal previous interventions (such as infills) [23]. Macbeth explains that Ultraviolet Light allows better observation of overpaint as these frequently fluoresce differently from original materials [23]. UV photography of the panel could therefore give more information on why the varnish gloss is uneven (see varnish condition in Section 5). X-Radiography and IRR, unlike the others, are techniques that can be used to penetrate the surface layers. IRR, is used primarily to reveal the use of preparatory drawings or transfers [23], while X-radiography penetrates even further revealing the support [23]. This permits a study of not only the condition of the support but of the layers underneath the paint as well, as damages (e.g. cracks) or losses can be revealed, indicating areas of previous intervention which may not have been visible on the surface [23]. Since it was not possible to remove the panel from the coach to observe it on the reverse, the x-radiograph was the only means to be able to study the support.

The second step involved instrumental analysis of the painting's materials (e.g. pigments, binders, and mixtures) and techniques (e.g. the method of application). The first step was to analyze the paint *in situ* with a portable μ-EDXRF (see Appendix V.2) under the direction of António Candeias (Laboratório Hercules) and Ana Machado (LJF) with the author assisting and learning the technique. μ-EDXRF identifies the elements present within the "sample" area [24]. Although this analytical technique does not allow the exact identification of pigments present within the painting, it can indicate possibilities to be confirmed in subsequent analysis, as certain elements are very characteristic of specific pigments (e.g. Hg is characteristic of the pigment vermilion). μ-EDXRF was also used to establish if the general results over all the painting were consistent to distinguish areas of original paint from overpaint.

The third step involved the removal of cross-sections from the coach panels with emphasis on the upper back panel, the focus of this work. Taking into consideration that the painting did not present many areas of loss to remove cross-sections from, it was decided to remove a limited number of samples, to ensure the painting wouldn't be damaged unnecessarily as well as to respect the Museum's ethical stance on limited sampling. To establish where to take the samples, a Sample Strategy was created (see below). Cross-sections were observed under an Optical Microscope (OM) and further instrumental analysis to identify their materials was carried out with SEM-EDS, μ-Raman and μ-FTIR. Townsend & Boon (2012) detail the characteristics of the different analytical techniques: SEM-EDS like μ-EDXRF, identifies the elements present in the sample, however, this method also provides the location of the elemental information with SEM-EDS mapping [24]. This technique also indicates the concentration and location of a particular element in the sample aiding in the separation and identification of layers [24]. μ-Raman and μ-FTIR are techniques that identify compounds thereby aiding in the identification of specific pigment(s), binder(s) and varnish(es) that are present [24].

3.1. Sampling Strategy

Cross-sections were taken from carefully selected locations to answer specific questions as well as to identify the materials present.

3.1.1 Overall Sampling of the Coach

Although the main focus of this thesis is the upper back panel, in order to understand its relationship with the coach and how paintings were made on such an object, samples were taken from all of the panels.

Sampling began with the other panels in order to build an understanding of their stratigraphy before reaching the upper back painting. The priority was the study of their stratigraphy, to see if all of the panels presented the same layers. Since these panels each present a similar decorative scheme such as a painted green border and red stripes (Figure 8), for comparison samples were taken from the same decorative features on each painting. One of the areas sampled from every panel was the green border.

Figure 8: An example of the green border and 'red stripes' found on every panel (except upper back).

3.1.2. Sampling of the Upper Back Panel

With regard to the upper back panel, sampling was guided by the following questions:

The first and most basic question was, what is the original stratigraphy of the decorative panel? How was it made? Was the whole panel gilded or only in certain places?

Cross-sections what may be untouched areas on both the image and the gold background were obtained. These cross-sections would not only give information but would serve as the basis for comparison with all the other samples to follow.

The next set of questions were about previous treatments and alterations: what type of infill was used over the join? Does the infill cover original paint? Are the areas of previously treated gold background done with gold leaf or paint?

Regarding the alterations on the gold background, some samples were taken from previous treatments. For the infill used[15], various samples were taken from different locations: from the edge of the crack in the panel which is believed to have no original material underneath; and closer to the border of the previous treatment of the painting which may or may not be over original paint.

The last question was: why are there drastic differences in matt and gloss over the final surface finish (varnish)? Was this a result of the number of varnish layers or because two different types of varnishes were used? To answer this question, samples were taken from both glossy and matt areas.

The exact locations of the samples are shown in Figure V.6 in Appendix V.

3.2. Coach Panel/Painting Identification Codes

While examining the *Coche do Infante D. António*, it became apparent that identifying which decoration, in this case the oil painted panels, being referred to and its location could easily become confusing. When studying an object whether by visual observation, photographs, cross-sections or through analytical

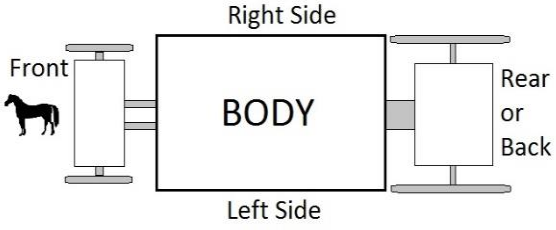


Figure 9: Simplified coach schematic from bird's eye view identifying the sides.

[15] No documentation has been found about this previous intervention.

techniques, it is extremely important to know the precise location of the information. Even though this thesis focuses on the Upper Back Painting, the other paintings were also examined and taken into consideration for future studies; this necessitated the development of a coding system to quickly distinguish the paintings. Although designed for this case study, the coding system was planned with the intention of creating a location format for use in future studies of the other coaches and vehicles in the MNC.

The code was designed to shift from the general to the specific, for example, identifying first the coach then the decorative panel in question. Therefore, the MNC inventory number for the coach appears at the beginning of the code. The next step was to establish an individual code for each decorative panel.

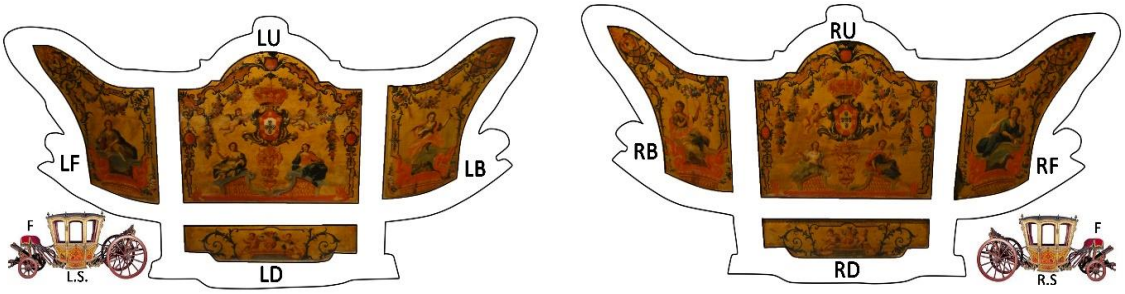


Figure 10: *The identification codes designated for the panels on the left and right sides of the coach*

To maintain consistency with the museum, their method of orientation for the four sides of the coach was adopted: the "front" corresponds to same direction as the horse (where the coachman's seat is) which means that the left and right sides will match the horses' left and right flanks, as seen in Figure 9. The code uses the first letter of each direction as its identifier, for example F for Front. However, since both Right and Rear begin with the same letter, this was resolved by using the synonym for rear: Back. As a result, the location identifiers are: F (front), B (back), L (left) and R (right). The next characters in the code allow a more specific identification by indicating where the decorative panel is located, as many of the sides have more than one. In this coach, the sides with the most painted panels are the left and right sides, each with four distributed symmetrically as can be seen in Fig. 10.

Table 2*: Summary list of the identifiers decided for the code.*

IDENTIFIER	
1st – Side of the Coach	**2nd – Location of panel on the Side**
F Front of Coach	**F** Side, area closest to the Front of the coach
B Back of the Coach	**B** Side, area closest to the Back of the coach
R Right Side of the Coach	**U** Upper, panel above
L Left Side of the Coach	**D** Down, panel below

As can be seen in these figures the right and left sides have two paintings on their lateral edges and two in the center, one above the other. In the case of the lateral paintings, as can been seen in the images below, these are closest to either the front or the back of the coach.

Therefore, it was decided that the same terms, front and back, could be applied. For example, the lateral painting on the left side of the coach towards the front would be labeled as LF while the lateral painting towards the back would be LB. For the two center paintings, the letter C could have been used, however as there were two paintings in the center the same code could not be used for both. A third identifier could have been added, but to keep all the codes the same, a different solution was found in order to maintain a two-letter system. Since there were only two panels on
either side above and below one another, they were referred to as the top and bottom panels on the left (or right) side. Once again, to avoid having back and bottom beginning with the same letter, the panel locations were designated: Up (U) and Down (D) to refer to top and bottom.

Table 3: List and meaning of all the codes for the coach's

Inv. #	Code	Meaning	Side
V0016	FD	Front Side Down	Front
	RF	Right Side Closest to the Front	Right Side
	RU	Right Side Center Upper	
	RD	Right Side Center Down	
	RB	Right Side Closest to the Back	
	LF	Left Side Closest to the Front	Left Side
	LU	Left Side Center Upper	
	LD	Left Side Center Down	
	LB	Left Side Closest to the Back	
	BU	Back Side Upper	Back
	BD	Back Side Down	

The use of up and down works just as well on the back (rear) of the coach, as this side presents two paintings one on the upper half and the other on the lower. The front is a unique case, having only one painting on the lower half as the upper part of the front consists of a window. After the MNC coach inventory number, the next set of identifiers is therefore: F(front), B (back), U (Upper) and D (downwards). They are summarized in Table 2.

Table 3 illustrates the codes for each decorative panel. Beginning with the coach's inventory number (e.g. V0016-BU) this served as the basis for photographic, analytical, and sampling codes. Figure 11 is a schematic of how they are used.

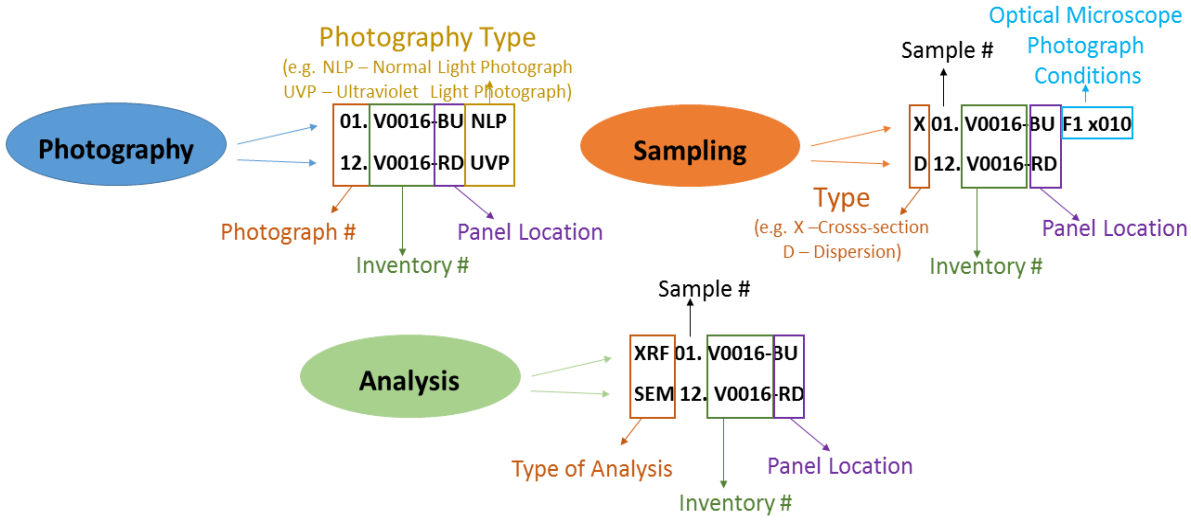


Figure 11: Examples of the codes as applied.

4. Characterization of Materials and Techniques

4.1. Summary of the Results from the Coach's Panels

Concerning μ-EDXRF results of the coach's various panels, they appear to be consistent among one another in regards to the elements found in similar colours. None of the elements identified with this technique presented any specific element which could indicate the use of a pigment solely from an era after the 18th century, except for in areas where retouching is evident. For detailed information regarding the μ-EDXRF results see Appendix V.2.

The examination of the cross-sections under the Optical Microscope (OM) showed that the panels vary in their stratigraphy. Figures 12, 13 and 14 show cross-sections from different panels with differing stratigraphy (Figure V.6, Appendix V.3 for sample map locations). This could indicate that they have been altered at different periods in time and/or by different people, which would correspond to what was discussed in the treatises (Section 2) where decoration could be completely removed and repainted [13,15,17]. None of the panels compares directly with the upper back panel (Figure 14). Of all the samples, the one in Figure 13 (see larger format Figure V.16 in Appendix V) is unique in that contains two distinct paint layer systems. In the UV image, above the yellow layers there is a layer of gilding and fluorescing material which could be resin from a varnish, on top of which are new layers of what appears to be ground, gilding and varnish. This could be evidence to the existence of a previous painting underneath the one seen today, further emphasizing the practice of altering coach paintings over time.

Elemental and pigment analysis of all the cross-sections could reveal simulates between them, despite the varying stratigraphy system (different ground layers). However, this work was beyond the scope of this thesis which concentrates on the upper back panel.

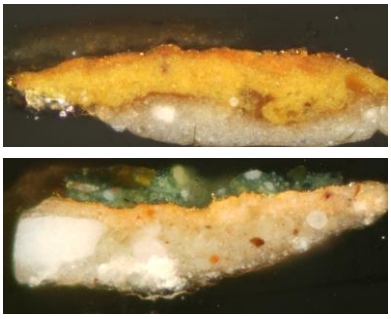


Figure 12: Cross-section **24-V0016-LD** (top), and cross-section **14-V0016-RU** (bottom).

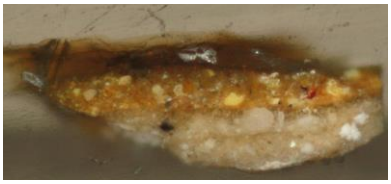


Figure 14: Cross-section **37-V0016-BU** (from the upper back panel).

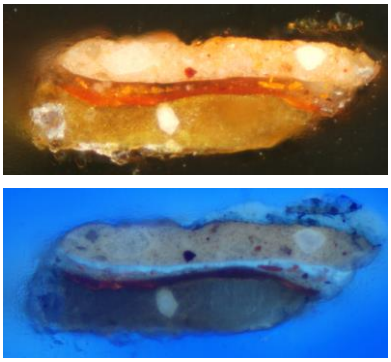


Figure 13: Cross-section **34-V0016-BU,** crossed-polarized light (top) and ultraviolet light (bottom)

4.2. Characterization of Materials and Techniques of the Back Panel

4.2.1. Wood Support (Panels)

Without removing the panel from the coach, a complete analysis of the wood support is difficult. However, information can be gained through X-Radiography (see Figure I.5 in Appendix I). Thanks to Luís Piorro at the IJF, an x-radiograph was made of the panel in situ (see Appendix V for technique details). In the x-radiograph it is evident that the panel was created by joining two horizontal planks, as see in Figure 15, where the join is highlighted in blue. These appear to be held in place on the reverse with nails (black dots Figure 15.a) using what appears to be three vertical wooden bars (see Figure 15.a), which are, according to Doherty and Wollet (2009), known as battens [25]. Battens are wooden bars which are sometimes placed perpendicular to the grain on wooden supports to help prevent warping and other distortions from humidity from occurring [25,26]. By observing the x-radiograph, it was possible to determine that the wood grain of the panels runs horizontal, confirming that the battens are in this case perpendicular to the grain.

On either side of each batten, six smaller vertical blocks of wood are also visible in the x-radiograph (Figure 15.b). These, like the vertical battens, appear to have been nailed into the two planks. They are situated such that they extend on either side of the join, most likely to reinforce it.

By examining the x-radiograph of the area at the very top of the painting (Figure 15.c), another line can be seen, a second join, indicating that the support is made up of three pieces of wood. As observed in the x-radiograph, the nails in the vertical battens do not continue into this area. However, nails along this piece are visible in the x-radiograph (Figure 16). Without removing the panel from the structure of the coach it is not possible to confirm the exact function of the nails on the uppermost piece of wood.

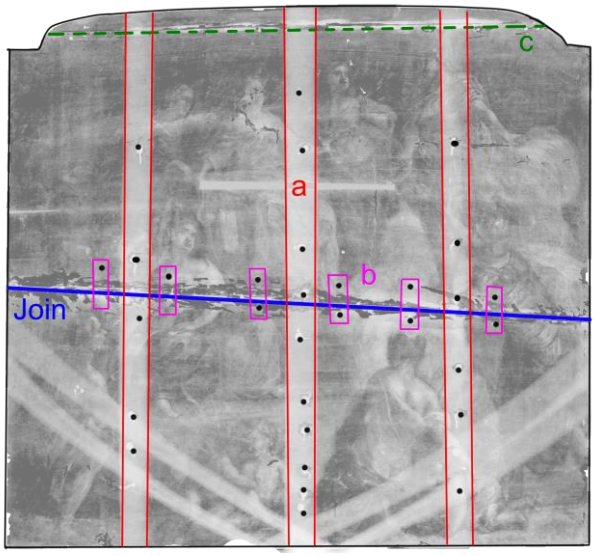


Figure 15: Schematic of the panels construction according to what was observed with the x-radiograph.

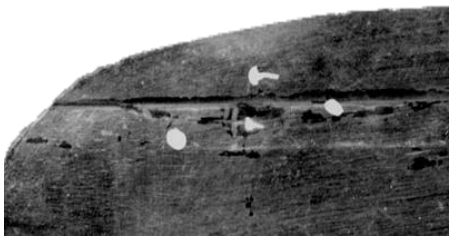


Figure 16: Example of the nails along the 'join' on the top. (Luís Piorro, LJF, Jan. 2016)

4.2.2. Preparation Layers and Gilding

According to the treatises discussed in Section 2, it can be expected that various preparation layers would have been applied to the panels prior to painting. Although it was not possible to observe the preparation layers by looking along the edges of the panel (these were hidden behind the decorative framing elements), some observations could be made based on the x-radiograph and cross-sections (see Appendix I and V). In the x-radiograph white streaks were seen, likely brushstrokes made during the application of the preparation layers (see Figures I.5a in Appendix I). Upon closer examination of the x-radiograph, some of these were in reality a line of 'dots' or rather preparation material which had filled the pores in the wood grain (see Figure I.5a in Appendix I). As stated in the treatises the objective of the first preparation layers or 'priming' was to seal the pores with a mixture of linseed oil with a little addition of lead white [13-18]. This radio-opaque material in the woodgrain, could be an indication that the preparation of the panel was done in a similar manner as discussed in the treatises.

μ-EDXRF (see Appendix V.2) analysis revealed that every area investigated shows the presence of calcium (Ca) and lead (Pb). which could indicate the use of lead white and calcium carbonate or sulphate in the preparation layers. As seen in Section 2, the presence of Pb is not unexpected as this appears to be the main pigment/filler coach painters used for their preparation layers.

The treatises mention 2-3 'stages' of preparation, composed of various layers in each [13-18]. As found by Carlyle (2012) when studying preparation layers in cross-sections, the different applications are not always distinguishable, especially if they are composed of the same materials and proportions [27]. Cross-sections from the panel (see Appendix V.3), revealed two distinct grounds under the Optical Microscope. This suggests that the techniques and materials used for the panel were similar to those mentioned in the treatises, as at least '2 stages of preparation' are present. According to SEM-EDS (see Appendix V.4 Elemental and Pigment Analysis) and μ-Raman analysis the upper ground layer is composed of lead white and calcium carbonate. The bottom ground layer contains lead white, calcium carbonate and calcium sulphate (see Appendix V.4). This suggests that the techniques and materials used for the panel were similar to those mentioned in the treatises, as at least '2 stages of preparation' are present. (see Appendix V, Table V.6).

In addition, and as seen in Section 2, the treatises mention linseed oil as the primary binder for not only the ground as well as the paint [13-18] AND μ-FTIR analysis of the painting's binder identified it as an oil (Appendix V.5). Although the exact type of oil was not possible to confirm with μ-FTIR.

Aside from linseed oil, lead white was the other main component for the grounds discussed by the treatises (Section 2) [13-18]. Although in this painting the preparation layers are not solely made up of lead white, as seen above, Fesquet (1871) mentions the use of other materials for cheaper work, such as pumice stone [13]. Despite not specifically indicated, it is possible some coach painters rather than pumice stone added chalk and gypsum instead.

One cross-section, S6, the gilding sample, presented a reddish third layer between the top layer of ground and gold leaf. According to the literature [20, 28] this layer is most likely bole, a clay-based preparation layer for the gilding. SEM-EDS of this layer revealed the presence of Mg, Si, Al, Fe, typical elements present in clays. Analysis with μ-Raman, confirmed the presence of Haematite also a compound found in clays, indicating that this layer is indeed a bole layer.

SEM-EDS revealed that the leaf in the gilding (S6), consists primarily of gold.

4.2.3. Painting Method and Materials for the Upper Back Panel

During initial observation, it was assumed that as gold was an expensive material, that this painting, unlike the others (see Appendix II), was only gilded in the corners visible (see Figure 5). This was confirmed through the cross-sections as the ones from the painting did not reveal the presence of gold leaf except for the one from the gilding (see Appendix V.3 for cross-section images of all panels). μ-EDXRF analysis also showed elemental gold (Au) restricted only to areas where the gold was meant to be visible, rather than being continuously applied underneath the painted areas as is the case with the other panels (see Appendix V.2 for μ-EDXRF analysis).

Figure 17: Detail of the paintings smooth surface, with little impasto evident.

The artist appears to have laid on the paint layers in a fluid state, as there is little evidence of raised paste-like brushwork (see Figure 17). Although there were not many cross-sections taken, some of the samples (S1 & S2, see Appendix V.3) show that the artist used more than one layer of paint for the white and green floor tiles, indicating that a base colour was used followed by the individual tile colour.

In determining the pigments present on the painting, as very few cross-sections were taken, μ-EDXRF was the only technique available for analyzing each colour area. Similar colours consisted of the same elements, although sometimes with varying intensities. Elemental results for each area can be found in Appendix V.2 along with the μ-EDXRF sample map. Every area investigated shows the presence of calcium (Ca) and lead (Pb). Since μ-EDXRF does not just analyze the upper layers but includes the lower layers and even the support (although this does not show in μ-EDXRF), elements from the ground are included. In some areas, such as the whites and pinks, the presence of lead is most likely also in the paint layers; this was confirmed by μ-Raman analysis (see Table V.7 in Appendix V). Although μ-EDXRF is a technique that only identifies elements, it is possible in some cases to still determine the main pigment. For example, the reds, flesh tones and pinks all have mercury (Hg), a key element for the pigment vermillion (HgS) [20] suggesting that vermilion is present in these areas. As for the blues, greens and yellows, the presence of iron (Fe) is a strong indication that iron based pigments such as, earths and ochres and perhaps Prussian Blue were used.

It would be of interest to properly identify the blue pigment used in the painting, in particular the blue area in the royal shield of arms, as some blue pigments are specific to certain time periods and may help confirm if the painting could be later than the 18th century since it was not uncommon for coach paintings to be altered and replaced. In regards, to the possibility of Prussian Blue having been used due to the

identification of iron with μ-EDXRF this pigment was developed in the early 1700's [22]. This pigment is also mentioned by the treatises (see Table IV.11 in Appendix IV).

4.2.4. Varnish

On first observation, the varnish showed glossy and matt areas (see Section 5 for varnish condition), however UV photography of the panel does not indicate a difference in fluorescence and it seems to have been applied uniformly (see Figure I.4 in Appendix I). To better understand what could be causing this difference in the varnish's surface, samples were collected from both areas, revealing two distinct layers of varnish, the bottom layer has a brighter blue fluoresce than the top layer (see S3, S4 and S5: Figures V.10, V.11 and V.13 in Appendix V). In both cross-sections the varnish was separated from the paint and then analyzed with μ-FTIR (by Catarina Miguel, Laboratório HERCULES). A sample of a varnish drip from the upper back panel was also analyzed by μ-FTIR (Vanessa Otero and Prof. Maria João, FCT-UNL). All three spectra were the same, indicating the whole panel contains the same varnish(es). μ-FTIR of the varnish identified the presence of both diterpenoid (e.g. rosin, sandarac and copal) and triterpenoid (e.g. mastic and dammar) resins (see Appendix V.5).

As discussed in Section 2, copal based varnishes were those supposedly used on coaches [14, 21] and as seen in the spectrum diterpenoid bands are present, which could indicate the possible use of copal. However, as seen, triterpenoid bands were also present. As it was not possible to separate the two layers of varnish for μ-FTIR analysis, the diterpenoid and triterpenoid resins could be each in their own layer. For example, perhaps a copal varnish was first applied (being the bottom layer of varnish) and then later on a mastic was placed above (being the top layer). Another possibility is that both layers of varnish are a mixture of the two resins. Another possible scenario could be that no copal is present on the painting, as seen in Section 2, it was not uncommon to remove the varnish or even the whole painting in order to add another. If this did occur, at a time the coach was no longer in use, it is plausible that rather than applying a copal oil varnish, a less durable non-oil based varnish was applied as it was no longer necessary to protect the coach from outdoor conditions.

As μ-FTIR was not able to identify the exact resins used, it will be necessary to analyze the varnish with another technique such as GC-MS (gas chromatography-mass spectrometry).

4.2.5. Summary of Past Intervention Materials (Infill and Reintegration)

The fill material used along the central join of the back panel was identified as calcium carbonate by μ-Raman. As for the pigments used for reintegration, μ-EDXRF analysis determined the presence of barium (Ba), chrome (Cr) and zinc (Zn). These elements were not present in the original painting. Chrome yellow ($PbCrO_2$) was identified in the paint over the infill in the join with

μ-Raman (Sample S7 and see Table V.8 in Appendix V). According to *Pigmentum* (2004) chrome yellow was first recognized as a possible pigment in 1804 [18].

The presence of barium and zinc in the retouching could be related to the yellow pigments barium chromate and zinc chromate, or the white materials barium sulphate and zinc sulphate. Barium chromate was first used around 1809 and zinc chromate in 1825-1829 [21]. Carlyle notes that zinc white was reported to not function well when in an oil medium [21] and barium white was used primarily as a filler or additive to lead white [21]. It is therefore most likely that the barium and zinc may

Table 4: List of all pigments and fillers* identified in the cross-sections.

Identified Pigments: μ-Raman		
Paint Layers	Yellow	Naples Yellow
		Yellow Ochre (Goetite)
	Red	Vermilion
		Red Ochre (Hematite)
	White	Lead White
		Calcium Carbonate*
		Calcium Sulfate*
Retouching	Yellow	Chrome Yellow
		Yellow Ochre (Goetite)
	White	Lead White

be related to the yellow pigments (barium chromate and zinc chromate), despite not yet identified in μ-Raman or μ-FTIR.

As previously discussed in Section 2, during the 18th century, the time of this coach, the Portuguese King had paint restorers in employment at the Royal house [10]. In Botto's (1909) opinion, it would not be surprising if coaches at the MNC were found to have alterations from this century [10], however as chrome yellow was only available in the 19th century, this restoration could not have been from the 18th century, but it could be from the 19th century or after. Regardless, this does not nullify the possibility that earlier interventions may have occurred during the earlier lifespan of the coach, they were perhaps removed to be replaced with another intervention, or as discussed by the treatises the whole painting could have been replaced leaving little trace of any former image.

5. Condition Report

Overall, the *Coach's Upper Rear Panel* presented aesthetic problems associated with the opaque blemishes in the varnish coating and previous treatment(s). The most notable include the unsaturated colours associated with former reintegrations, and the cracking in the current infill. This cracking is most likely a result of the separation between the join and surrounding cracks in the wood panel.

5.1. Original Support: Panel

Figure 18: Crack on the Monarch which is from the support (raking light). (Luís Piorro , LJF, Ja. 2016)

The original support is approximately 102 cm (width) x 85.3 cm (height). In general, the support appears to be in an overall good and stable condition. Although cracking is visible on the surface, this is in the infill material and not the support (see previous treatment condition below). However, observation of the x-radiograph revealed that there are cracks in the wood support along the join in the center and the nails (see Figures I.5, I.5b, I.5c and I.7 in Appendix I).The cause is possibly from the nails in the wood. According to Rivers and Umney (2003), nails exert stress on the surrounding wood, and as it is not a material that fluctuates the same way as wood with climatic changes, it too may keep the wood near them from properly responding [28]. The tension, when strong enough leads to the wood cracking. Another cause for cracking, especially along the center join, could be also from the battens, which according to Rivers and Umney (2003) prevent the freedom of movement needed for fluctuating wood, forcing it to stay in place [28]. Cracks will then occur due to the tension [28].

Another crack in the support is in the central figure, the Monarch, running along her face through to her torso. Unlike the other cracks mentioned, this one is not hidden underneath past interventions (see Appendix I, Figures I.2, I.3 and the damage map I.7); it is visible without needing to observe the x-radiograph. Under Raking Light (see Figure 18, and Figure I.2b in Appendix I) it became evident that this particular damage has a deformation, or indentation, to it. Part of the wood has been pushed into a lower plane causing a shadow which is visible in raking light. This damage may have been caused by some sort of blow as this would have induced enough stress on the wood to make it crack.

5.2. Ground Layers

The ground layers appear to adhere well to the support, showing no evidence of flaking. However, in the x-radiograph (see Figure III.5, Appendix III) large losses are seen along the panel join; a common problem due to the wood movement, according to the literature [26,28,29]. More losses can be seen at the top of the painting where the upper panel has cracked, this would have consequently caused ground and paint losses. According to close analysis of the x-radiograph, smaller areas of loss all seem to match up to locations where nails are present or smaller cracks have formed (see damage map Figure I.7 in Appendix I). Losses in ground and paint layers all seem to correspond to areas of damage (mostly cracks) indicating that this is not a problem with the inherent stability of the ground and paint.

5.3. Pictorial Layers and Gilding

The paint layers appear to be in good condition, and are well adhered to the ground, since there is no evidence of flaking (see damage map Figure I.7 in Appendix I). Some of the original paint has been covered by overpaint, where previous losses have been treated (see previous intervention map Figure I.8 in Appendix I). The gilding in some areas appears to have an uneven discoloration (see Figure I.1d, Appendix I), this will be discussed below.

As previously discussed, one of the questions was whether this painting was original to the coach or added at a later date. One method of finding an approximate date for a painting is through pigment analysis, as there are certain pigments which were introduced around specific dates. However, according to *Pigmentum* (2004) all of the pigments identified were in use during the 18th century [20], matching the date of the coach. Since the pigments employed were in use during the centuries following the time of the coach, unfortunately their identification did not prove useful as a means to date the painting.

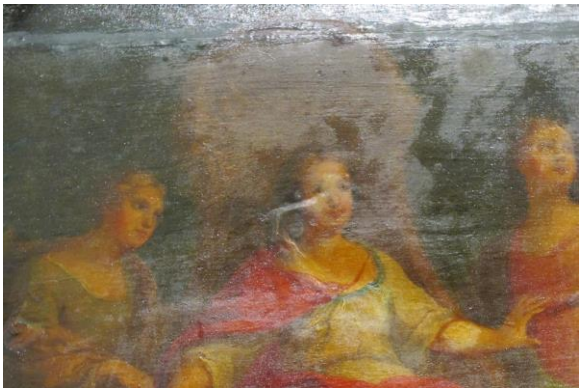


Figure 19: Example of large matt areas in the varnish layer

5.4. Surface Coating: Varnish

Regarding the varnish the first problem to be noticed is the uneven surface gloss (Figure 19). All locations of disturbances in the varnish as well as other damages can been see on the damage map in Appendix I (Figure I.7). According to Raúl Leite, these before the inauguration the surface was coated with a Talens Retouching Varnish to restore the gloss but as seen, the effect was only temporary.

The varnish surface varies from high gloss to very matt areas. Matt areas range from thin vertical and horizontal lines (see damage map, Appendix I) to large blotches (particularly over the Monarchy, Figure 19). There are two probable reasons for the matt areas, and, as understanding it was important for the final treatment, this will be discussed here as well as Section 8 (the Treatment).

The first possible cause, is that the surface in the matt areas has been disturbed influencing the way that light is reflected off those areas, causing what is known as *lightscattering* [30]. This can occur because of friction from another object against the varnish, such as getting scraped or by aggressive cleaning [30]. This effect will be discussed in more depth in the Section 8.

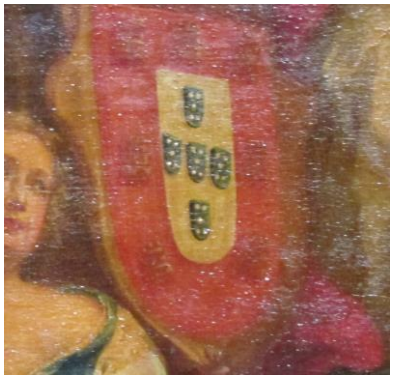


Figure 20: Detail of Royal Shield of Arms.

The second cause could be a difference in varnishes, perhaps one area has an extra layer of varnish. It is possible that it is not even varnish; it could be a different substance altogether that could be triggering *lightscattering* by not having the same refractive index as the varnish [30]. However, under UV light (see Figure I.4 in Appendix I), the matt and shiny areas have the same fluorescence. This is an indication that the surface varnish is most likely the same in these areas. This raised the possibility that if there is a difference in the varnish which is influencing the way light interacts with the materials it may be in the lower varnish layer.

Another aspect to mention in terms of the varnish condition is it has yellowed, changing the final tonality of the image, which is evident more on some colour areas than others. For example, the white center of the Royal Shield of Arms and the Monarch's white robe (Figure 20): rather than a light and pure white, both areas appears with a yellow-brown stain over the white. Yellowed or yellowish-brown tonality in natural resin varnishes is not unusual, as these tend to discolor over time even though they are usually applied in a clear uncoloured state [28,30].

5.5. Previous Treatment: Infill and Reintegration

Losses to the ground and paint layers had previously been treated by infilling and then reintegrated (see Figure I.8 in Appendix I). As noted above, μ-Raman analysis of samples from the infill along the join (see Figure 21) revealed that the infill was made from calcium carbonate [32]. As seen in Raking Light (see Figures I.2a and I.2c in Appendix I), the infill is uneven with the surface of the painting, creating edges

around the fill material where it meets the surface of the paint. Where the infill has been applied over nails, there are occasional mounds from the nail heads which protrude from the surface (see Figure 22). The infill over the join has a crack that runs all along from one edge to the other. The crack reaches a maximum width of 0,5 cm and a minimum of approximately 0,2 cm. Cracking in the infill is likely to have been caused by the movement of the wood in response to changes in relative humidity and temperature [28,32].

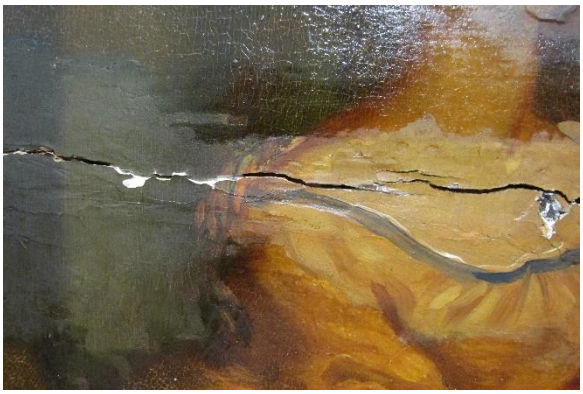


Figure 21: Detail of fill and retouching along the join.

The retouching over the infill was dull with unsaturated colours compared to the original. In nearly all areas of retouching, there is overpaint, where the retouches cover original paint (Figure 22). Retouching over the gilding was done with gold paint, as is evident in UV photography and in cross-sections. UV photographs from the right side of the painting show what appears to be brush strokes over the gilded area (see Figure I.4 and I.4b in Appendix I) indicating the application of gold paint. The gilded surfaces in the upper left and right corners of the image appear to have discoloured (although this is difficult to observe in some areas due to the discoloration of the varnish). However, it is clearly evident in some places that discoloration must be from the gold paint retouches, for example: the left and right edges of the painting show uneven patches of brown each of which correspond to differences in fluorescence and the brush strokes seen under UV (Figure I.4 in Appendix I).

Figure 22: Detail of an uneven fill over an area with a nail.

Overall, the condition of the previous treatment in terms of aesthetic appearance is poor: the retouching materials have significantly different saturation and gloss to that of the painting and do not match in terms of texture, colour and brushwork. Furthermore, the previous infill along the join is structurally unsound as the infill has cracked.

6. Discussion on treatment approaches

Although it is impossible for a restorer to bring any object back to its absolute original state, he, or she can aid in preserving its authenticity. This concept is defined by Cesare Brandi in 1963 (*Theory of Restoration*), as cited by Auffret (2011): once an object has been created it begins to live a life, it is only considered original at the moment of creation [33, 34]. According to Philippot (1966) it is impossible to 're-establish the original state of a painting (..) only reveal the present state of the original materials' [35, p.392]. Although never restored to its precise 'original form' this does not mean that the work is any less authentic [33-35]. Authenticity, as expressed by Brandi (1963) and Auffret (2011) is affected by the object's second time period, when changes occur through natural alterations or human interventions [33,34]. When discussing an object's authenticity, its history, its overall aesthetic appearance, and its function as well as the artist's original intention, are just some examples that must be taken into account when considering any treatment [34-37]. In general, within conservation and restoration in the 20th and 21st centuries, authors discuss the importance of how certain values will influence final treatment decisions, usually requiring compromise. While treatments are designed to improve specific values, as explained by Taylor & Cassar (2009); they can, decrease other values. For example, retouching to restore pictorial unity (its aesthetic value) may reduce the value of historical evidence [36]. The authors consulted [34, 36-38], indicate that there is no method in conservation and restoration that will fit all scenarios, in other words each object, in terms of its condition, context and values associated with it, is unique, and therefore each treatment option must be evaluated with this in mind, while following ethical guidelines.

The discussion throughout Section 7 will elaborate on the considerations and the reasons behind decisions regarding the treatment for the upper back panel.

6.1. The Cleaning of Paintings

In general, one of the first issues to consider in the treatment of paintings, is whether or not a painting should be cleaned. Cleaning as explained by Ruhemann (1968) consists of three stages: the removal of surface dirt (surface cleaning), the removal of varnish and finally the removal of old retouchings [39]. Léo Van Puyvelde (1932), saw these stages somewhat differently: the three operations involved are 'simple removal of dust', surface cleaning and then varnish removal [40]. In general, dust and surface dirt are both considered part of surface cleaning [41].

Of the three stages, the one most discussed in the conservation literature is the removal of a painting's varnish, which will be discussed below.

6.1.1. The Cleaning/Removal of Varnish

One of the authors to have discussed varnish removal in considerable detail is Gerry Hedley, whose ideas, expressed in the articles *On Humanism, Aesthetics and the Cleaning of Paintings* (1985) [42] and *Long Lost Relations and New Found relativities: Issues in the Cleaning of Paintings* (1990) [36] have been used by other authors, such as David Bomford in his *Picture Cleaning: Positivism and Metaphysics* (2012) [43].

A painting varnish, as explained by Hedley (1985), has two functions: to protect the surface, and to alter the final saturation, tonality and gloss of the image [42]. Over time natural resin varnishes yellow due to changes in their chemical structure as well as accumulations of grime on their surface and/or between layers, progressively obscuring the image [36,42]. Hedley (1990) states that eventually the appearance of the varnish, will reach a stage of obscurity where "cleaning is widely felt to be necessary" [36]. However, as discussed in both of his articles, the removal of varnish is not a straightforward practice, a work of art cannot be treated as a mere physical object [36,42]. Paintings play cultural and aesthetic roles in society, and as he said in his 1985 article, during the process of cleaning, their "very meaning may be at stake" [42, p152]. Hedley makes it clear that the decision to remove a varnish and by how much, is not to be taken lightly.

In general, there are three approaches to the cleaning or removal of a painting's varnish: total, partial and selective [36,42,43]. Both Hedley (1985 &1990) and Bomford (2012) discuss all three methods, however Hedley is more detailed in his discussion, as such he will be the main reference for their summarized description and discussion here.

According to Hedley (1985 & 1990) total, or complete cleaning, as the term implies, is the practice of removing all of the discoloured varnish, and at times, previous interventions, as long as this will cause no damage to the paint surface [36, 42]. This approach is in Hedley's (1985) opinion "practically straightforward" as it "views all discoloured varnish and over-extensive, or poor quality, retouchings as unwanted later accretions" [42, p.159]. Total cleaners, as Hedley (1985 &1990) explains, give priority to the true condition or state of the painting [36,42], and they believe the biggest change the painting has suffered "has been their obscuring by yellow varnish resulting in a loss of form and colour with the imposition of a false harmony" [42, p.159]. However, by revealing the paint and the condition of the original materials, Hedley (1985) warns, one should not assume the artist's intent is being made known [42] for the paint materials may have altered over time as well shifting in tonality (this will be discussed below under selective cleaning). The main argument against total cleaning is the claim that it endangers the surface of the painting by removing all the varnish thereby exposing the paint directly to solvents, and interferes with the taste for the 'antique look' [36,42].

Partial cleaning, similarly to total cleaning, removes varnish from the surface, however as explained by Hedley (1985 & 1990), this approach is intended to leave a uniform film of varnish over the surface with the original paint concealed [36,42]. Hedley (1990) notes that practitioners of this approach often feel that varnishes have the "dual function of harmonising the relationships of colour and space within a painting while acting as a signifier of the age, the antique character, of the work" [36, p.174]. As seen above, this approach solves one of the arguments against total cleaning. In 1968 Ruhemann had argued against partial cleaning claiming that it is just as dangerous as total cleaning and that it is "rarely feasible to leave an even layer" and this will consequently influence the final aesthetic [39, p.214]. This approach unlike total cleaning is also considered to be subjective: as Hedley (1990) points out, the "degree of age", or the thickness of the film left on the painting depends on the conservator's taste [36, p.174].

The third and final approach discussed by Hedley, selective cleaning, is based on the assumption that paintings have changed over time, (a potential problem not addressed with total cleaning) [36,42]. According to Hedley (1990), a completely cleaned work may reveal "changed colour and spatial relationship"', which is the fundamental concern for selective cleaners [36, p.175]. The focus in selective cleaning is pictorial unity: maintaining the balance of the painting during the cleaning, removing more or less varnish in a manner that will maintain the "colour and spatial relationships" of the painting [36, p.175]. Of the three approaches, Hedley (1985) considers selective cleaning to be the most subjective, "the end result resides in the mind of the restorer and is transposed to the painting (…) different cleaners would clean the same painting differently" [42, p.158].

According to both Hedley (1985 & 1990) and Bomford (2012), neither approach is more correct than the other [36,42,43], however as Hedley (1990) states, "this does not mean that any approach to cleaning is equally valid" [36, p.176]; it depends on the circumstance of the individual painting. Hedley (1985) states that each painting is "allegedly specific and must be regarded as an isolated case" [42, p.153], a cleaning approach for one painting may not be appropriate for the circumstance of another painting. Regardless of the approach decided, Hedley (1985 & 1990) and Bomford (2012) state that the removal of a painting's varnish will inevitably influence all the other stages of the intervention [36,42,43], indicating that any cleaning decision for any painting must be decided with great care and consideration.

6.1.2. Removal of Previous Interventions (Reintegration/Overpaints and Infills)

When a painting is restored, it is usually in a manner intended to bring back pictorial unity in order to improve its aesthetic value [39,44-47]. Methods for restoring a painting's image generally require infills and colour re-integration [39,44]. If done well, these will re-establish harmony between the original and the

changed or damaged areas. However, a badly executed retouching, as Poulsson (2008) points out, can have a “profound effect” on the object, rendering the retouching “more distracting than the damage itself” [44, p.81]. Poulsson goes on to state that when this occurs the retouchings are generally removed [44, p.87]. As seen above, Ruhemann (1968) considers the removal of previous retouching the third cleaning stage [39, p.189] and Hedley (1990) refers to it as part of a total cleaning [36].

However, what would occur with these retouchings if varnish removal were not to happen? Some authors, such as Goltz and Stoner (2012) [45], address the possibility of still being able to remove retouches without resorting to full varnish removal as retouchings are at times on the surface of the painting [45- 47]. Goltz and Stoner (2012) also include a second option: rather than remove unsatisfying retouches, some restorers decide to maintain them, opting to improve their appearance instead [45]. This last option will be discussed in further detail below.

7. The Treatment Decision – Aesthetic Vs. Full Treatment

Before deciding on the final treatment of the back panel on the coach, various options were discussed and evaluated with Leslie Carlyle Associate Professor (FCT-UNL) and Raúl Leite, Senior Paintings Conservator (LJF).

7.1. Cleaning of the Back Panel's Surface and Varnish Removal

If a full treatment were to be executed, this would include removing surface dirt followed by the removal of the varnish and previous interventions [39,42]. The removal of previous interventions will be discussed separately in the next section.

One reason for not cleaning or removing material from the back panel is because of the fact it cannot be considered as an individual object for it is just one decorative part of a larger whole: the coach itself. As such, any changes to the painting will consequently affect how it relates to the other painted panels and to the coach's gilded woodwork. Like the back upper panel, all of the other panels are covered with varnish with a similar level of discoloration, which through µ-FTIR was confirmed to be made up of the same composition (see Appendix V.5). If the varnish of the back panel were to be cleaned off, its final appearance would differ from the others, setting it apart from the rest of the coach. For an object of this type, to ensure aesthetic harmony between all of its parts, removal of the varnish would have to be done on all of the other panels as well, to guarantee that they maintain the same general appearance [41]. Aside from this, there is the further issue of the appearance of this coach being in harmony with the MNC's coach collection, as many other coaches in the museum appear to present similar varnish characteristics as the *Coche do Infante D. António*. In terms of a full restoration for the whole coach, it was also felt that not enough information was yet understood about the current state of all the panels, especially since the treatises indicated that coaches were often repainted and re-varnished over time. Removal of varnish, be it total, partial or selective, could also put at risk losing important historical information regarding the MNC coaches and their treatment as a collection. Further investigation comparing the materials and technique used in this coach and others in the collection, would be necessary to properly distinguish the original from the non-original as well as if all coaches have the same varnish. However, as Smith (2008) notes, museums often find it difficult to allocate extensive time and resources on investigating and realizing complex interventions on objects in their collections [48].As discussed above, Hedley (1985 & 1990) identified three approaches to cleaning [36,42], however Bomford (2012) in his work brings up a forth option 'which is to do nothing' [43]. Of all the cleaning approaches, this is one of the least discussed, and the most minimalist of them all. In conservation and restoration, there is always the option to decide not to do anything. Sometimes it may be best to leave things untouched as future generations could have better solutions and materials for the problem. Despite Hedley (1990) not being explicit about this fourth option, he does state that "we are in a period of minimalist conservation", in other words, conservators are tending for their treatments to interfere as little as possible with the object [39, p.74]. The upper back painting of the coach does indeed have a discolored varnish, however removal of the varnish would impact the appearance of the whole coach, as the other panels have the same gloss and final varnish tonality (discoloration). This would also affect possible material connections with other coaches present in the museum. As such a decision to maintain the upper back panel's varnish was opted to maintain the harmony of the whole and historical information. As discussed above, aside from discoloration, the other disturbing aspect of the varnish are the matt areas, the solution for which will be discussed below in the section on Treatment Materials and Techniques.

Since a full restoration of the back panel was not warranted it was decided to follow, at least in part, Bomford's (2012) suggestion to do nothing [40]. While Ruhemann's (1968), observation that surface cleaning can brighten up a painting just as well "as the removal of the varnish itself, and sometimes more" [39, p.189], it was nevertheless decided for the same considerations of harmony for the coach overall, that surface cleaning of the back panel would not be undertaken as part of this project.

7.2. Removal of the Back Panel's Previous Interventions (Infill and Reintegration)

In regard to the previous interventions present on the panel, these, as Poulsson (200) and Goltz & Stone (2012) recognize, constitute a significant distraction when reading the image [44,45]. In an ideal situation, these interventions would be removed, however, when taking into consideration the extent of the losses that would be revealed (see Figures I.5 and I.7 in Appendix III) their removal would result in significant change which may alter the harmony of the whole coach and require more resource than allocated for this project. In terms of the reintegration of missing details, especially along the joint, according to the authors consulted [39,44,49] if not enough information is available to establish connections between the loss and the original it is best to avoid subjective recreations. Until the current overpaint is removed it is not possible to assess the degree of re-integration required.

While the current infill does have a substantial crack, it was determined that this could be repaired, leaving a base for aesthetic treatment since the rest of the fill is structurally intact and appears stable. As such, it was decided to maintain the previous interventions, opting to improve their current appearance through retouching which will be discussed in more details in the following sections. Another advantage in retaining old interventions, as discussed by Gotlz and Stoner (2012), is that this maintains the painting and the coach's history [45] which could be of importance in the future in order to compare information between the various coaches in the museum.

7.3. Retouching of the Image (Aesthetic Treatment)

As stated previously, the back panel is a decorative part of a larger piece. Its appearance is currently being jeopardized by the condition of the varnish, overpaint and infills. The orientation of the coach in its current position on display at the MNC, presents the back panel in full view of the public not only from various directions but from a considerable distance as well. It was a factor in choosing to treat this panel: to focus on improving the overall harmony and integrity of the image.

Hedley (1985) refers to a treatment which seeks to improve a painting's appearance (e.g. colour balance, retouching of losses etc.), as an aesthetic intervention [42]. Hedley states that in the treatment of paintings any subjective decisions (or subjective intervention as he also calls it) are best left for the retouching phase and not the cleaning, as there is more control over the modifications and they are also reversible [42]. Since surface cleaning and varnish removal will not be undertaken all subjective decisions during this panel's treatment were as Hedley proposes, during the retouching stage only.

8. Treatment

As the previous interventions were not removed, the new retouching was carried out, as suggested by Goltz and Stoner (2012), directly over the former [45]. With regard to the matt areas of varnish, it was decided to re-saturate these areas with a new varnish. The techniques and materials employed during the treatment are discussed in the next section.

The treatment of the painting was carried out under the supervision of Raúl Leite, Senior Paintings Conservator (LJF). At the time of writing, all infilling and varnishing has been performed, however only the left half of the previous intervention along the joint has been retouched. It is intended that treatment will be completed by the author.

Before the treatment began, to facilitate accessibility to the back panel, the two leather straps[16] which were suspended from the coach body and crossed to attach to the back of the suspension, were removed[17] by Lina Falcão (MNC) with the help of Rita Dargent (MNC) and Isabel Cardoso (FCT-UNL). Throughout the treatment, it became necessary to re-adapt the method of access to the panel as it became apparent certain positions were not the most suitable for such delicate work.

Figure 23: Example of crack area with completed infill. This image also shows and area with unsaturated retouching.

8.1. Infilling the crack in the previous fill

Although the previous infill material (see Section 5) consisted of calcium carbonate, Raúl Leite recommended using wax-resin to fill the existing crack in the previous fill after evaluating the pros and cons. He reasoned that the previous chalk infill failed since it could not withstand the movement of the wood along the join. According to López-Fuster (2012) wax-based fills are known for being "somewhat flexible", capable of handling the potential stress present within a wooden panel [32, p.599]. By using this wax-resin it is anticipated that the separation in the fill material which occurred in the previous restoration will not reoccur. The wax-resin prepared by Raul Leite consists of beeswax, dammar resin and elemi gum (7:2:1), with the addition of the filler kaolin and white spirit as needed (see Appendix VI for complete recipe).

Wax-resin requires heating to achieve a malleable consistency before being applied to the crack with a small heated spatula. The fill material was applied in layers, as discussed by López-Fuster, (2012) this ensures proper filling by slowly building up the material to the desired needs [32,]. In the first application, the wax-resin was liquid to ensure that it would penetrate as far as possible into the crack. Raúl Leite explained that if the fill were not applied deep enough into the existing crack there would be a higher risk of it cracking or coming loose in the future.[18]

Remaining within the lacunae's boundaries when infilling is considered ethical practice today [32,45]. Therefore, it was this was observed during the current infilling even though the area being treated was not original. Limiting the wax-resin fill to the edges of the crack, also reduces the surface area that will later need to be retouched. Wherever wax exceeded the boundary of the crack, the excess was carefully removed with a #15 scalpel.

[16] These two straps do not aid in supporting the weight of the body, they are secondary supports for reducing the amount that the body swings during travel.
[17] Leather straps were removed on the 16th of May 2016.
[18] Personal communication during execution of the treatment. May 16 2016.

While filling, the wax was smoothed wherever necessary in order to match the height of the surrounding surface. This was done by removing the excess wax with a scalpel, or by re-heating the wax surface with the spatula. In some areas, it was difficult to adjust the level of the wax fill with the rest of the painting as the height on one side of the crack could be slightly higher or lower than the other.

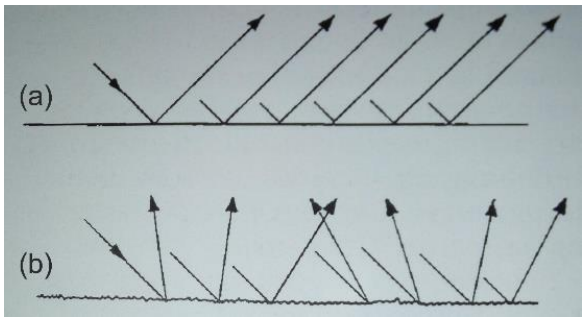


Figure 24: Example of specular reflection from two different surfaces (a) glossy and (b) matt. The (b) diagram illustrates light scattering. Rivers (2003) [28,p.587]

8.2. Varnishing

As discussed previously (Section 5), various matt areas are present in the varnish which disturb the harmony of the image. In addition, the previous retouching is very matt with the colours unsaturated compared with the original paint (Figure 23).

No conclusive evidence was found with µ-FTIR analysis of a chemical difference between the matt and glossy areas of varnish (see Appendix V.5). It is therefore most likely that the difference in gloss is a result of light scatter in the matt areas. As explained by Elias (2006) and de la Rie (2010) the gloss of a varnish is affect by the smoothness or roughness of the surface which influences the manner in which light is reflected off the surface [31,50]. With a rough surface, one with more surface variation, the angles of reflection are increased resulting in *lightscattering* (see Figure 24), an effect which can make a surface appear more matt and white [31,50]. de la Rie et al (2010) states that this effect can be minimized by applying a varnish with an appropriate reflective index such that the surface is re-saturated allowing the light to reflect in a more coherent [31].

It was decided that the matt areas could be resolved by applying another coat of varnish on top of them. However, as the dull retouchings also required re-saturation it was also necessary to consider their situation before proceeding.

According to Raúl Leite, a previous attempt to re-saturate the retouching was done not long before the new museum's inauguration using a commercial product, Talens Retouching Varnish. However, as he noted, the colours soon became dull again. In order to prevent this from happening, a test with three different varnishes was performed on the right side of the treatment area along the main crack (see Figure 26). The varnishes chosen by Raúl Leite were Laropal A81 (25g in 40ml Shellsol A and 60ml Shellsol D40, WPV), and Talens Retouching Varnish and Talens Rembrandt Picture Varnish – Glossy (see Appendix VI.2). The following week, it was observed that of the three used, Talens Rembrandt Varnish – Glossy was the one which retained the most saturation. Because this varnish was the thickest of the three, it is possible that it did not penetrate as much, remaining at the surface [51]. Talens Rembrandt Varnish – Glossy was analyzed by µ-FTIR to identify the resin and other ingredients used, see Appendix VI for results.

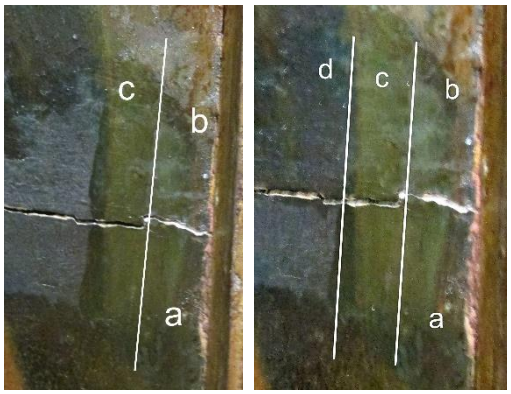


Figure 25: After the application of Laropal A81 (A) on top of the crack, of Talens Picture Varnish (B) on bottom half of the crack and Talens Rembrandt Varnish –Glossy (C), to the left of A and B on both halves of the crack. Result after a week (right).

The varnish was first applied by brush in a single layer over the new fill and the surrounding old retouches, re-saturating their colours. A layer of varnish was also applied on other previous retouches. For the matt areas, a layer was laid on locally wherever necessary and allowed to dry, and if required, a second coat of varnish was brushed on (see Appendix VI for map of areas varnishes). The results of the varnishing can be seen in Figure 26 and the During Treatment Images (Appendix VI).

8.3. Retouching

Figure 26: Area over the Monarchy that used to have a large area of matt varnish (see Section 5).

It was decided that all retouching would be done with a binder consisting of Laropal A81 resin (using either 10g or 15g in 40ml Shellsol A and 60ml Shellsol D40) with dry pigments, utilizing the technique of pointillism. Pointillism, according to Bailão (1989) is a retouching technique that was inspired by 19th century painters adopting the "decomposition" of colours[19] [51]. Color is achieved by applying tiny dots on the surface of the painting without mixing them, since mixture takes place in the perception of the viewer once distant from the surface [52]. The reason for the selection of this technique by Raúl Leite, was to differentiate the current work, not only from the painting, but from the previous intervention as well. Sozzani (2010) [46], states that retouches should be left with a slight difference from the original, such as a slightly lighter tone or a lower level in the infill in order for them to be identified, at least by professionals. Although pointillism was adopted to distinguish the intervention from the original and past interventions, it was also decided to leave the tone of the retouching slightly different from the original to allow it to be distinguishable through tonality as well (especially since at a distance the pointillism is not visible).

As noted above, Goltz and Stoner (2012) point out that some conservators work on top of retouchings in order to adjust their appearance to better work with the rest of the painting [45]. Considering the only new area is that of the crack infill, the majority of the work performed was done in accordance with the practice described by Gotlz and Stoner.

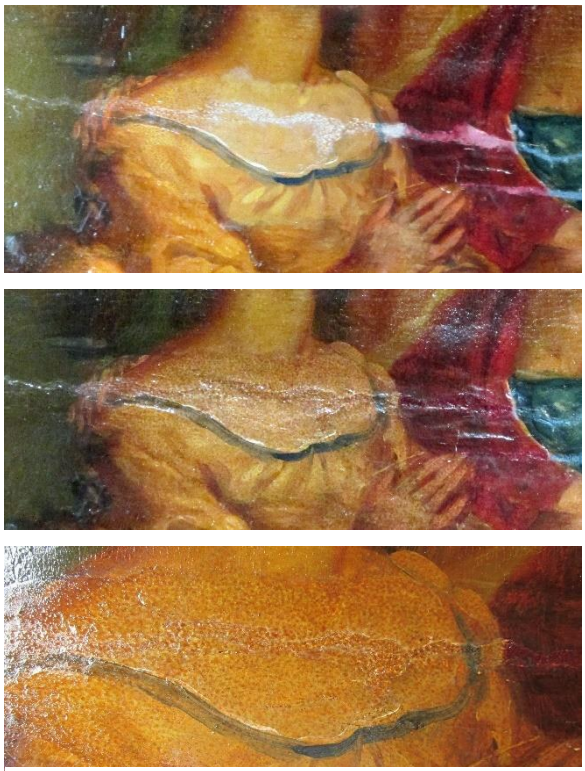


Figure 27: Example of the effect of pointillism glaze to imitate the varnish tone, the top is before the glaze and the middle image is after. The bottom image is a detail of the retouching.

Although the varnish aided in adjusting the saturation in the previous retouching, in some areas it was still possible to distinguish a difference between the retouching and the original. In this case, it was due to differences in tonality. Rául Leite suggested that this was most likely because these areas did not have a yellowed varnish on top. To give these areas of previous retouching on the join this missing tone, pointillism was performed with a mix of goldish, yellowish-brown and goldish-red transparent dots. By doing this it was possible to give the effect of the discolored varnish as a glaze over these areas, thus altering their final tonality to bring them into harmony with the painting (see Figure 27).

For retouching on the wax-resin, after isolating with the same varnish for saturating the colours, a lighter base colour of the same retouching material was first applied, the colour being based on the surrounding areas. The rest of the retouching was then done until the final desired result was achieved (see During Treatment images in Appendix VI).

[19] The painters instead of painting in a solid fashion would make up their figures etc. with dots which when seen at a distance would appear to be one wholecolour, while when close the individual dots are noticeable.

9. Conclusion

Differences regarding the method and materials used for the upper back panel and the other panels on the coach were revealed as a result of this thesis project. Although pigment analysis of the back panel did not reveal pigments from a date later than the 18th century, cross-section comparison of all panels showed variations between their stratigraphy which could be an indication of alterations to the panels during different eras. As stated in the treatises [13-18], it was common for coach paintings to be removed and then repainted which could explain the variations between the panels on the coach as well as, why in one sample (from a side panel) paint layers appear to correspond to a previous painting underneath the current one.

Although the back panel had been in poor condition, previous treatment appeared to have resolved most of the damages, aside from the crack within the infill along the join between the two wooden planks making up the panel. At the time of this intervention, the previous treatment exhibited serious aesthetic problems, such as unsaturated colour in the retouches as well as significant differences in gloss in the varnish also affecting the previous retouches. μ-FTIR analysis of the matt and glossy varnish areas confirmed that they were chemically the same indicating that the cause was most likely *lightscattering.* Taking into consideration that these aesthetic alterations were the most disturbing aspects upon observing the painting it was decided that the painting's intervention would be an aesthetic one. Another reason behind the aesthetic treatment was any other treatment, would influence not only the overall harmony of the coach as well as the coach's harmony with that of the MNC's collection, along with the possibility of removing important historical and material information for comparison with other coaches.

The most challenging aspect of the intervention was the position of the painting, as this made it difficult to perform certain movements associated with the treatment. Although the previous intervention was left on the surface, altering the saturation of the colours and the disturbed areas of varnish was found to have positive results, successfully bringing back harmony to the image.

10. Final Remarks

During this project, it was apparent that little scientific research regarding coach painting materials and techniques have been carried out. Future research on this subject is needed as this would aid other studies allowing easier comparison between scientific finds.

One way of adding to research in this area would be the continuation of the analytical study of the cross-sections from the coach side and front panels since this was beyond the scope of this thesis. It would be of interest for not only comparing between the panels, but as well as for building information on materials used for coach paintings in general.

As a limited number of samples were taken from the back panel, not all colours were identified using μ-FTIR and μ-Raman. It would be of interest to identify the blue used in the shield as some blue pigments are specific to certain time periods and may help confirm if the painting is original or post 18th century.

As there is little historical information on the coach, it would also be of interest to study the object as a whole rather than just the paintings. Perhaps with a study of the techniques used on the coach's carriage more may be revealed on where it was made and by whom. With regard to the painted panels, each could be studied in depth from a historical point of view. In doing so, a thorough search for similar paintings, drawings and other artistic work could reveal relevant information on the date, author or meaning of the images on these panels.

11. References

[1] Fuller, T. 1828. *An Essay on Wheel Carriages: Containing a Concise view of their Origin and a Description of the Variety now in use*. London: Longman, Rees, Orme, Brown and Green.
[2] Pereira, J. 1988. *Viaturas de Aparato em Portugal*. Lisboa: Bertrand Editora.
[3] Straus, R. 1912. *Carriages & Coaches: Their History & Their Evolution*. London: Martin Secker.
[4] Libourel, J.L. 2012. The French Art of Carriage Building. In: *Le Château de Versailles À Arras Roulez Carrosses!*, trans. by K. Berri. Paris: Skira Flammarion, p. 236-239.
[5] Libourel, J.L. 2012. The Modern State Coach. In*: Le Château de Versailles À Arras Roulez Carrosses!*, trans. by K. Berri. Paris: Skira Flammarion, pp. 230-231.
[6] Personal Communication 25 October 2016 & 26 January 2017 with J. Castel-Branco Pereira, Historian and author of Viaturas de Aparato em Portugal [2].
[7] Coche de D. Maria Francisca de Sabóia. 2016. Museu Nacional dos Coches. [online] [Accessed 30 May 2016]. Availaible at: <http://museudoscoches.pt/pt/explore/colecao/t-detalhe/?c=coche-de-d-maria-francisca-de-saboia>.
[8] Missão. 2016. Museu Nacional dos Coches. [online] [Accessed 30 May 2016]. Availaible at: <http://museudoscoches.pt/pt/museu/#missao>.
[9] Coches do Infante D. António Dossier File, MNC Document. Access given by R. Dargent, Técnica Superior da DGPC. Museu Nacional dos Coches.
[10] Botto, J. 1909. *Promptuario analytico dos Carros nobres da Casa Real Portuguesa e das Carruagens de Gala*. Vol. 1. Lisboa: Imprensa Nacional.
[11] Personal Communication 25 January 2016 with R. Dargent, Técnica Superior da DGPC. Museu Nacional dos Coches.
[12] Chevalier, J. & Gheerbrant, A. 1982. *Dictionnaire des Symboles: Mythes, Rêves, Coutumes, Gestes, Formes, Figures, Couleurs, Nombres*. Edited Edition. Paris: Robert Laffont/Jupiter.
[13] Arlot, M. 1861. *A Complete Guide for Carriage Painters* , trans. by A.A Fesquet .1871. to which is added an appendix. Philadelphia: Henry Carey Baird. [accessed 6 June 2016 February 2016]. Available at: <https://archive.org/details/completeguidefor00arlo>
[14] Gastellier, M. 1858*. Manuel Complet du Peintre en Équipages*. Paris: Typographie D'Émile Allard. [accessed 12 February 2016]. Available at: <http://gallica.bnf.fr/ark:/12148/bpt6k9404124/f119.item.r=manuel%20du%20peintre%20en%20%C3%A9quipages.zoom>
[15] Arlot, M. 1860. *Guide Complet du Peintre en Voitures*. Paris: Au Bureau du Mercure Universel [accessed 6 June 2016]. Available at:<https://archive.org/details/bub_gb_0mdX_7PKdagC>
[16] Gardner, F.B. 1877. *The Carriage Illustrated Painters' Manual*. New York: S.R. Wells & Co. [accessed 20 November 2015]. Available at: <https://archive.org/details/carriagepainters00gard>
[17] Burgess, J.W. 1881. *A Practical Treatise on Coach-Building*. London: Crosby Lockwood and Co. [accessed 20 November 2015]. Available at: <https://archive.org/details/practicaltreatis00burg>
[18] Hillick, M.C. 1903. *Practical Carriage and Wagon Painting*. 3rd Edition. Chicago: Press of the Western Painter. [accessed 10 December 2015]. Available at: <https://archive.org/details/practicalcarriag00hill>
[19] Stols-Witlox, M. 2014. Historical Recipes for Preparatory Layers for Oil Paintings in Manuals, Manuscripts and Handbooks in North West Europe, 1550-1900: Analysis and Reconstructions. PhD Thesis. University of Amsterdam. Volume I.
[20] Eastaugh, N., Walsh, V., Siddall, R., & Chaplin, T. 2004. *Optical Microscopy of Historical Pigments. The Pigment Compendium.* Volume 1. London: Butterworth-Heinemann.
[21] Carlyle, L., 2001. *The Artist's Assistant: Oil Painting Instruction Manuals and Handbooks in Britain, 1800-1900*, *with Reference to Selected Eighteenth-century Sources*. London: Archetype Publications.
[22] Augerson, C. (2011). Copal Varnishes Used on 18th and 19th Century Carriages. *Journal of the American Institute for Conservation*, 50:October, p.14–34. Avaliable at: <https://doi.org/10.1179/019713611804488928>
[23] Macbeth, R. 2012. The Technical Examination and Documentation of Easel Paintings. In: J.H. Stoner & R. Rushfield, eds. *Conservation of Easel Paintings*. London: Routledge, p. 291-305
[24] Townsend, J. & Boon, J. 2012. Research and Instrumental Analysis in the Materials of Easel Paintings. In: J.H. Stoner & R. Rushfield, eds. *Conservation of Easel Paintings*. London: Routledge, p. 341-365.
[25] Doherty, T & Wollet, A.T. 2009. *Looking at Paintings: A Guide to Technical Terms*. Revised Edition. Los Angeles: The J. Paul Getty Museum.
[26] Ackroyd, P. 2012. The Structural Conservation of Paintings on Wooden Panel Supports. In: J.H. Stoner & Rushefield, eds*. Conservation of Easel Paintings*. Oxon, England: Routledge, p. 453-480.
[27] Carlyle L. 2012. Exploring the grammar of oil paint through the use of historically accurate reconstructions. In: J.H. Stoner & R. Rushfield, eds. *Conservation of Easel Paintings*. London: Routledge, p. 33-38.
[28] Rivers, S. & Umney, N. 2003. *Conservation of Furniture*. London: Butterworth Heinemann.
[29] Stols-Witlox, M. 2012. Grounds, 1400-1900, including: Twentieth-Century Grounds by Ormsby, B and Gottesgen, M. In: J.H. Stoner & R. Rushfield, eds. *Conservation of Easel Paintings*. London: Routledge, p. 161-188.

[30] de la Rie, E., Delaney, J.K., Morales, K.M., Maines, C.A., and Sung, L. 2010. Modification of Surface Roughness by Various Varnishes and Effect on Light Reflection. *Studies in Conservation*, 55, p.134-143.
[31] Derrick, M.R., Stulik, D., & Landry, J.M. 1999. *Infrared Spectroscopy in Conservation Science*. Scientific Tools for Conservation, The Getty Conservation Institute, Los Angeles
[32] López-Fuster, L. 2012. Filling. In: R. Rushfield & J. Stoner eds. *Conservation of Easel Paintings*. London and New York: Routledge. p. 586-606.
[33] Brandi, C. 1963. *Teoria del restauro*. Roma: Edizoni di Storia e Letteratura. [Rockwell, C. trans. English translation, 2005. Theory of restoration. Roma: Instituo centrale per il restauro: Firenze: Nardini.]
[34] Auffret, S. 2011. *The Role of Conservation in the Preservation of the Authenticity of Furniture*. In: ICOM Committee for Conservation, 16th Triennial Conference, Preprints. Lisbon
[35] Philippot, P. 1966. The Idea of Patina and the Cleaning of Paintings. In: D. Bomford and M. Leonard, eds. *Issues in Conservation of Paintings*. 2004. Los Angeles: The Getty Conservation Institute.p.391-395
[36] Hedley, G. 1990. Long Lost Relations and New Found Relativities: Issues in the Cleaning of Paintings. Reprinted in: C. Villers, ed. *Measured Opinions*. 1993. London: United Kingdom Institute for Conservation, p.172-178.
[37] Taylor, J. & Cassar, M. 2008. Representation and Intervention: The Symbiotic Relationship of Conservation and Value. In: D. Saunders, J.H. Townsend, S. Woodcock, eds. *IIC Conservation and Access, Congress Contributions*. London. p. 7-11.
[38] Nardi, R. 2008. Conservation for Preservation: A Key for Protecting Monuments. In: D. Saunders, J.H. Townsend S. Woodcock, eds. *IIC Conservation and Access, Congress Contributions*. London. p. 22-26.
[39] Ruhemann, H. 1968. *The Cleaning of Paintings*. London: Faber and Faber.
[40] van Puyvelde, L. 1932. The Cleaning of Old Paintings. In: D. Bomford and M. Leonard, eds. *Issues in Conservation of Paintings*. 2004. Los Angeles: The Getty Conservation Institute. p.73-79
[41] Personal Communication 19 January 2016 with L. Carlyle, Associate Professor, Department of Conservation & Restoration, Faculty of Science and Technology New University of Lisbon.
[42] Hedley, G.1985. On Humanism, Aesthetics and the Cleaning of Paintings. Reprinted in: C. Villers, ed. *Measured Opinions*. 1993. London: United Kingdom Institute for Conservation, p. 152-166.
[43] Bomford, D. 2012. Picture Cleaning: Positivism and Metaphysics. In: R. Rushfield & J. Stoner eds. *Conservation of Easel Paintings*. London and New York: Routledge. p. 481-491.
[44] Poulsson,T. 2008. Ethics of Retouching. In: *Retouching of Art on Paper*. London: Archetype Publications. p. 65-80.
[45] von der Goltz, M & Stoner, J.H. 2012. Considerations on Removing or Retaining Overpainted Additions and Alterations. In: R. Rushfield & J. Stoner eds. *Conservation of Easel Paintings*. London and New York: Routledge. p. 481-491.
[46] Sozzani, S. 2010. Pushing the borders of retouching and reconstruction: can enough ever be too much? In: *Mixing and Matching*, Approaches to Retouching and Paintings. London: Archetype Publication. p. 125-141.
[47] Te Marvelde, M. Abraham, L. Grenvenstein-Kruse, A. & Putten, H. 2011. Two Treatment Approaches to one Dutch Militia Group Portrait. In: *ICOM Committee for Conservation, 16th Triennial Conference, Preprints*. Lisbon.
[48] Smith, S. 2008. Access at any cost? Strategies to maintain conservation standards and expertise at the V&A. In: D. Saunders, J.H. Townsend, S. Woodcock, eds. *IIC Conservation and Access, Congress Contributions*. London. p.205-208.
[49] Digney-Peer, S., Thomas, K., Perry, R., Townsend, J., and Gritt, S. 2012. The Imitative Retouching of Easel Paintings. In: R. Rushfield & J. Stoner eds. *Conservation of Easel Paintings*. London and New York: Routledge. p. 607-657.
[50] Elias, M., de la Rie, E.R., Delaney, J.K, Charron, E., and Morales, K.M.. 2006. Modification of the surface state of rough substrates by two different varnishes and influence on the reflected light. *Optics Communications*, 266, p.589-591.
[51] von der Goltz, M., Proctor, R.G., Whitten, J., Mayer,L.,Myers, G., hoenigswald, A. and Swicklik, M. .2012. Varnishing as part of the conservation treatment of easel paintings. In: R. Rushfield & J. Stoner eds. *Conservation of Easel Paintings*. London and New York: Routledge. p. 635-657.
[52] Bailão, A. 1989. As Técnicas de Reintegração Cromática na Pintura: revisão historiográfica. *Ge-conservación*, p.45-63.

Appendix I – Before Treatment Photographs of the Upper Back Panel

Figure I.1: Overall photograph of the upper back panel with Normal Light.

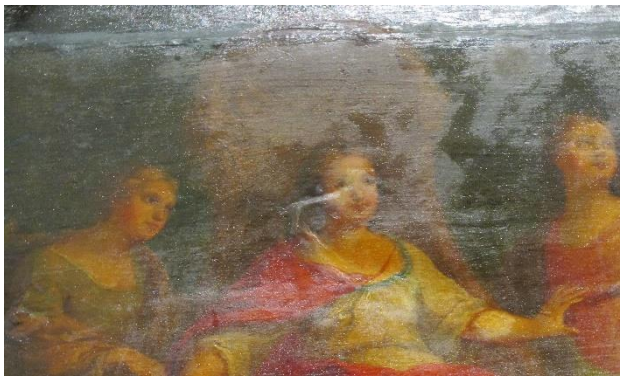


Figure I.1a: Shows the matte and glossy areas in the varnish around the Monarchy's head.

Figure I.1b: Detail of join on left side showing the wide crack in the infill used in the previous treatment and unsaturated colours from the previous reintegration.

Figure I.1c: Feet of upper far right male figure showing cracking in the wood panel (around area of nail application) and of the infill (through the arm).

Figure I.1d: Top right corner gilding showing discolored areas of gold.

Figure I.1e: Detail of varnish drip on top left corner under normal light (right) and its location (left).

Figure I.2: Overall Raking Light from Right Side. (Photo by Luís Piorro, LJF, Jan. 2016)

Figure I.2a: Raking light detail of join. The uneven surface of the infill can be seen, which shows that it does not match the texture of the surrounding paint. (Photo Luís Piorro, LJF, Jan. 2016)

Figure I.2b: Detail of the Monarchy with raking light reveals the presence of the crack in the wood with more clarity than Normal Light. (Photo Luís Piorro, LJF, Jan. 2016)

Figure I.2c: Raking light detail of crack in the wood panel and area of previous infill over a nail hole (right side). (Photo Luís Piorro, LJF, Jan. 2016)

Figure I.3: Overall Raking Light from Left Side). (Photo by Luís Piorro, LJF, Jan. 2016)

Figure I.4: Overall Ultraviolet Light. Previous retouching material fluores~~cen~~ces differently from the varnish (Photo by Luís Piorro, LJF, Jan. 2016)

Figure I.4a: UV detail of the Monarchy's head showing dark areas over the shoulder and face due to the difference in fluorescence of the previous repairs. (Photo Luís Piorro, LJF, Jan. 2016)

Figure I.4b: UV detail of top right corner gilding showing the discolored areas of gold paint which was brushed on during the previous treatment. (Photo Luís Piorro, LJF, Jan. 2016)

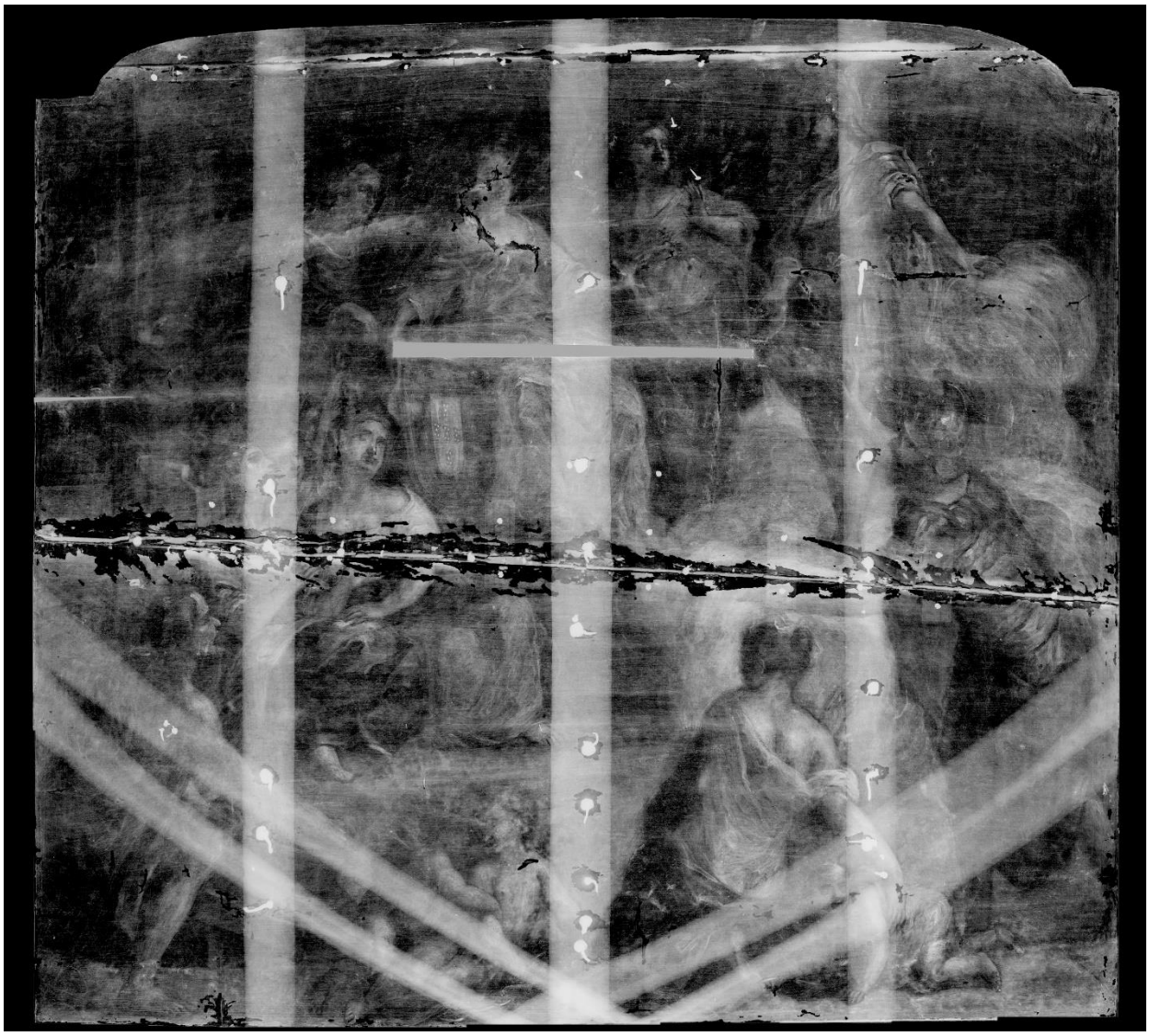


Figure I.5: X-radiography of the upper back panel. Extent of ground loss is visible as darker areas in the x-radiograph. The grey bar is a result of the method of x-radiograph used. Not a single image was done, but a collection of various sections. The grey bar represents an area that was not caught by the x-radiograph. (Photo by Luís Piorro, LJF, Jan. 2016)

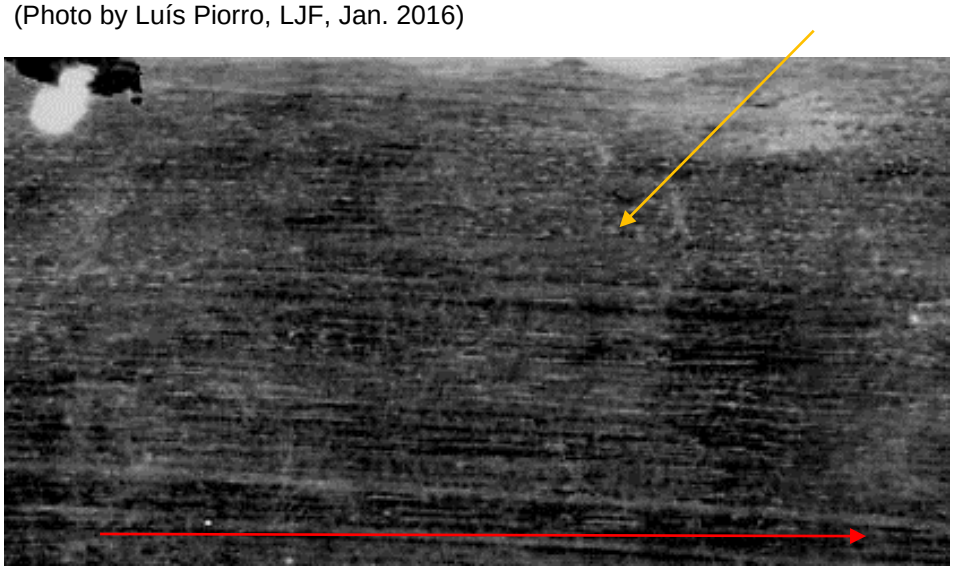


Figure I.5a: Detail in the x-radiograph with another view of grain pattern (horizontal, red arrow). Radio opaque material that appears to be in the pores (white dots, yellow arrow gives example). (Photo Luís Piorro, LJF, Jan. 2016)

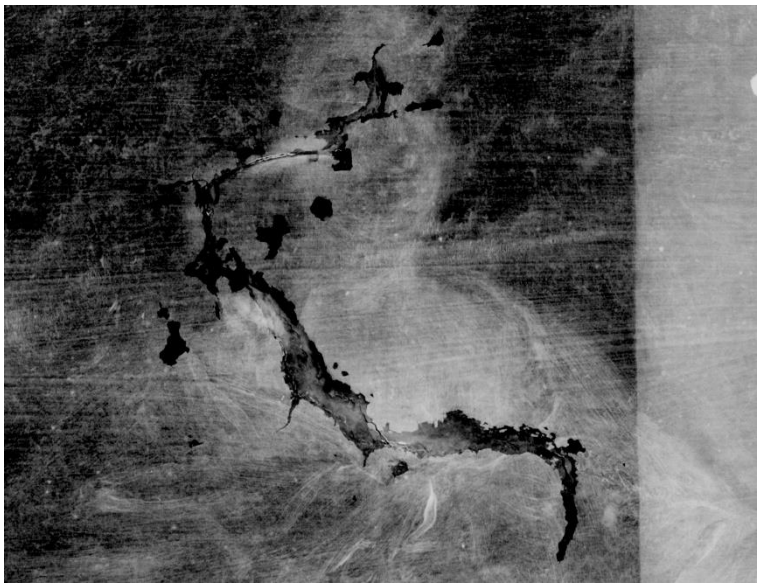


Figure I.5b: Detail of the Monarchy in the x-radiograph. Evidence of damage along the face and torso is evident. There is cracking in the wood along with loss of ground and paint layers. (Photo Luís Piorro, LJF, Jan. 2016)

Figure I.5c: x-radiograph detail of crack in the wood panel passing around a nail. Note the extensive loss of ground along the join underneath the infill. (Photo Luís Piorro, LJF, Jan. 2016)

Figure I.6: Overall Infrared Reflectography. (Photo by Luís Piorro, LJF, Jan. 2016)

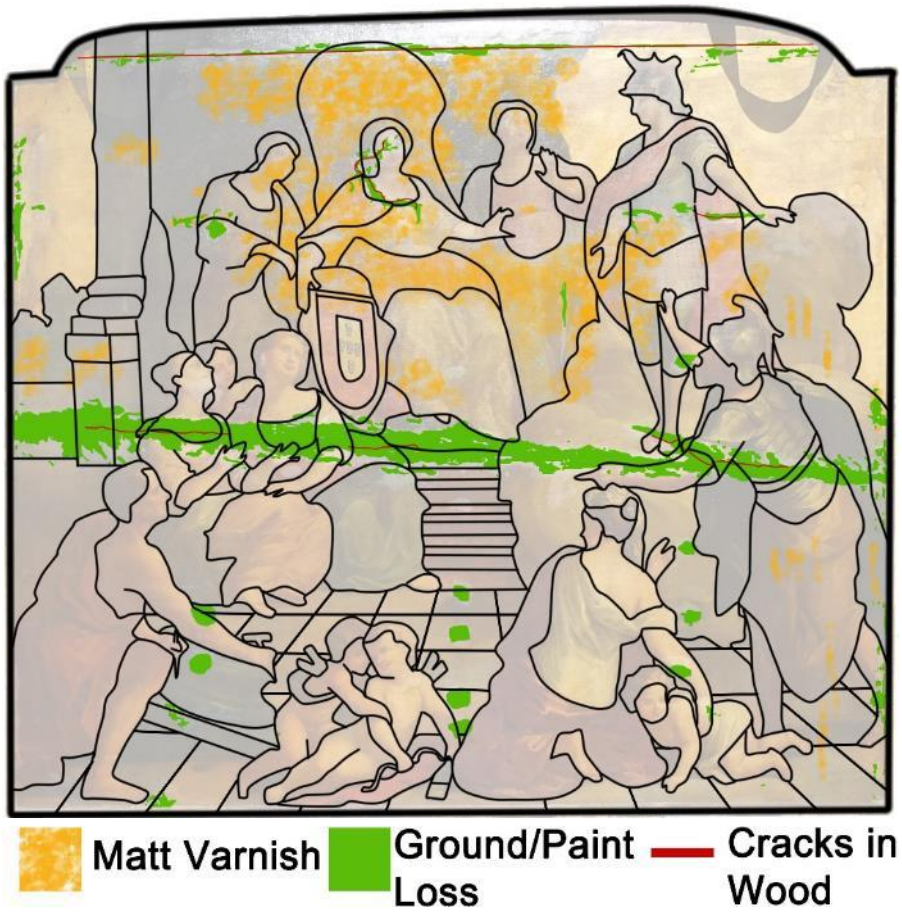


Figure I.7: Map of damages and disturbances present on the panel and painting. Mapping losses and wood cracks were done by observing the x-radiograph as the previous interventions cover these (Figure III.8).

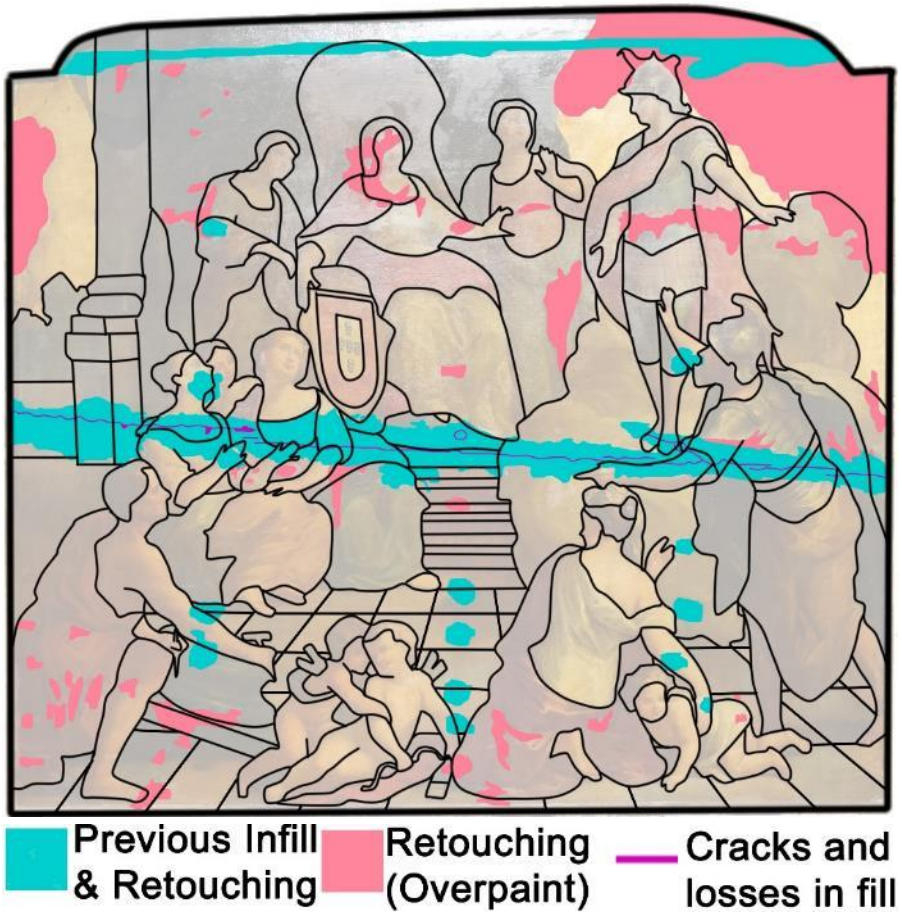


Figure I.8: Map of previous interventions on the painting. Some have been identified to clearly contain both infilling and overpainting (blue), however other areas may not include infilling only retouching (pink). All retouching appears to go over original surface, andis therefore called overpaint.

Appendix II – Overall Photography of all other Panels (Informal)


Figures II.1 (Left) & II.2 (Right): Panels on the left & right sides of the coach


Figures II.3 (Left) & II.4 (Right): Panels on the lower back of the coach (left) and front (right).

Appendix III – Bibliographical Sources Researched on Carriage Treatises

The following details the treatises consulted during this project. The format of presentation echoes the annotated bibliography in Carlyle's *The Artist's Assistant: Oil Painting Instruction Manuals and Handbooks in Britain, 1800 -1900, with Reference to Selected Eighteenth-century Sources (2001).*

EIGHTEENTH CENTURY SOURCES

FELTON, WILLIAM

1794 (Vol. I), **1796** (Vol. II) A Treatise on Carriages; comprehending coaches, chariots, phaetons, curricles, whiskies, etc. Together with their proper harness. In which the fair prices of every article are accurately stated. By William Felton, coachmaker, No. 36, Leather-Lane, Holborn. London: Printed for and sold by J. Derett, Piccadilly; R. Faulder, New Bond-Street; J. Egerton, White-Hall; J. White, Fleet-Street; W. Richardson, Cornhill; A. Jameson, Long-Acre; and all other Booksellers in Great Britain and Ireland.

Language: English

Location: Archive.org (online library resource)

Contents: Describes the many parts which make up coaches and other horse drawn vehicles along with some illustrated examples. Mostly mentions the prices of the many parts and steps in carriage making, depending on their richness. The end of the second volume has a glossary made by the author of carriage terms.

Author: Felton was a London coachmaker. In the spring of 1803 he constructed the body for a steam-powered vehicle meant for transporting passengers, however it never became a commercial success. The body he designed allowed the accommodation for 8 people whereas the typical coach was just 6.[1]

Reference: [1] Brogden, T. 2003. *Richard Trevithick's London Steam Carriage 1803*. [Accessed 20 October 2016] Available at: <http://www.steamcar.net/brogden-1.html>

GARSAULT, FRANÇOIS-ALEXANDRE-PIERRE DE (1693-1778)

1756 - Traité des Voitures, pour servir de supplement au nouveau parfait maréchal. Avec la construction d'une berline nouvelle, nommée L'Inversable. Par Garsault, Paris, chez Leclerc, Libraire, Grand'Salle du Paais, à la Prudence. Avec approbation & privilege du roi.

Language: French

Location: BnF, www.gallica.bnf.fr (online library resource)

Author: Garsault was a French botanist, zoologist as well as a painter[2]. He was also a member of the French Academy of Sciences according to the BnF's records[2]. The same library contains various manuscripts of the author on a variety of subjects, such as art and plants[3].

Contents: Discusses the history and the many parts that make up various types of horse drawn vehicles. A small reference is made regarding their final aesthetics (gilding, painting and varnishing) but not the process.

References: [2] Bibliothèque Nationale de France [Accessed 25 October 2016]. Available at: <http://data.bnf.fr/14548897/francois-alexandre-pierre_de_garsault/#other-pages-databnfr>

[3] Bibliothèque Nationale de France [Accessed 25 October 2016]. Available at: <http://data.bnf.fr/14548897/francois-alexandre-pierre_de_garsault/>

NINTHEENTH CENTURY SOURCES

ANON.

1897 Haney's Trade Manuals. Sign, Carriage & Decorative Painting. Including full instructions in fresco painting, a practical treatise on car painting, and much valuable practical information. New and Enlarged Edition. New York: Excelsior Publishing House, McKeon & Schofield, Proprietors, 110-112 West 26th Street.

Language: English

Location: Archive.org (online library resource)

Contents: As the title suggests it contains summaries and tips regarding the materials and methods on the practice of outdoor painting, especially of the decorative type.

Notes: Due to the wide range in content very few pages' address carriage painting leading to their information being heavily condensed and summarized. It was difficult to fully comprehend what the author intended with each step and as such this manuscript was not used in conjunction with the others selected.

ARLOT,? (First name unknown).

1861 Guide Complet du Peintre en Voitures, par Arlot Peintre en équipages Ex-Maitre peintre pendant onze années chez M. Eherler, carossier

à Paris. Et Illustré par A. Guillon, architecte en voitures. Paris. Au Bureau du Mercure Universel.

Language: French

Location: Archive (online library resource)

Author: According to Fesquet's introduction in the English Translation (1871), Arlot was a French coach painter of great expertise working mainly in Paris.

Contents: Arlot's treatise describes how to prepare the "foundations" (the groundwork) for new bodies, indicating what are to him the best materials to use and the process in which to apply them (how to properly lay and pumice etc.) The author also gives suggestions on how to apply transparent colours along with how to varnish the surface. These processes he mentions for both the body and the carriage parts, as well as what to do when they get old or damaged (repainting and revarnishing). Arlot discusses the many materials (colours, liquids, dryers etc.), specifically their use and qualities. The author also discusses some ornamental techniques.

1871 A Complete Guide for Coach Painters. Translated from the French of M. Arlot, Coach Painter, for eleven years foreman painting to M. Eherler coach maker Paris, by A.A. Fesquet, chemist and engineer. To which is added an appendix, containing information respecting the materials and the practice of coach and car painting and varnishing in the United States and Great Britain. Philadelphia: Henry Carey Baird, Industrial Publisher, 406 Walnut Street. London: Sampson Low, Son, & Marston, Crown Building, 183 Fleet St.

Language: English (Translated from French) except appendixes.

Translator: Adolphe Amdée Fesquet (1833-1894) was born in France. He was a chemist and engineer, who received his degree at the renowned engineering school in Paris the École Centrale des Arts et Manufactures. In 1865 he moved to Philadelphia, Pennsylvania working as a chemical engineer and French translator.[4]

Location: Archive (online library resource)

Notes: The contents of the treatise are the same as above, the editor has added articles and notes from London and the United States on some of their practices or comments on materials.

References: [4]University of Pennsylvania. A.A Fresquet drawings and notebooks. [Accessed 11 September 2016] Available at: <http://dla.library.upenn.edu/dla/pacscl/ead.html?showall=sort&fq=date_facet%3A%221850-1900%22&id=PACSCL_HSP_FI7280>

BURGESS, JAMES W.

1881 A Practical Treatise on Coach-Building Historical and Descriptive. Containing full information of the various trades and processes involved, with hints on the proper keeping of carriages, etc. With fifty-seven illustrations. By, James, W. Burgess. London: Crosby Lockwood and Co. 7 Stationers' Hall Court, Ludgate Hill

Language: English

Location: Archive.org (online library resource)

Contents: Most of Burgess's treatise covers how to build carriages, however there is a chapter dedicated to painting and varnishing where he discusses how to build up the painting from the ground up until varnishing. In the part on painting in terms of decoration, the author, rather than explain how to paint, has focused on colour theory and mentioned which are most frequent for carriages.

FULLER, ?. (First name unknown)

1828 An Essay on Wheel Carriages; containing a concise view of their origin, and a description of the variety now in use; with comparative observations on the safety of those upon two and four wheels, and remarks on the dangerous construction of the present stage coaches. To which are added, observations on the mechanical power and operation of wheels, etc. etc. By T. Fuller, coach builder, Bath; inventor of the patent shafts for two-wheel, carriages, and the patent locking for those with four.

Language: English

Location: Archive.org (online library resource)

Contents: History on the origin and evolution of coaches and other horse drawn vehicles.

GARDNER, FRANKLIN.B.

1877 The Carriage Painters' Illustrated Manual, containing a treatise on the art, science and mystery of coach, carriage, and car painting, including the latest improvements in fine painting, gilding, bronzing, staining, varnishing, polishing, copying, lettering, scrolling, and ornamenting. With an appendix, containing useful suggestions, receipts, etc.; a list of the principal varnish makers and dealers; a correct list of carriage and wagon-makers in New York City. Adapted to the wants of every painter. By F.B. Gardner, practical

New York coach and ornamental painter. New York: S.R. Wells & Co., 737 Broadway.

Language: English

Location: Archive.org (online library resource)

Editions: 1871, 1877, 1886

Author: According to the preface Gardner has practiced the art of carriage painting since the 1850's and it is with the many years of experience that he created this treatise to help his fellow craftsmanship.

Contents: Gardner in his treatise discusses the carriage painters shop along with how to properly care for ones' materials and tools. He also describes how to prepare and apply the ground for the painting, along with some decorative techniques and the use of colours. The author also gives the reader an account of how to remove old paint from the surface, so as the painter may repaint it and how to re-varnish damaged varnish.

GASTELLIER, ? (First name unknown)

1858 Manuel complet du peintre en équipages, contenant tout ce qui a rapport à cette profession, par M. Gastellier, Peintre, Exerçant depuis trente-quatre années consecutives, soit comme ouvrier, soit comme contre-maitre, soit pour son compte personnel. Paris, Typographie D'Émile Allard, Rue D'Enghien, 14.

Language: French

Author: According to the preface the author was a carriage painter. At the time he wrote this treatise he had 34 years of experience in the art. The reason he wrote this work was due to health reasons he decided to take advantage of his inability to practice to share his knowledge and experiences to benefit the education of younger carriage painters.

Location: BnF, www.gallica.bnf.fr (online library resource)

Contents: The author in his writings wanted to inform the reader of the proper processes and materials to use in preparing the groundwork for the carriage painting (carriage parts and the body); the different background colours and their methods of application; how to varnish the coach; as well as explain his own observations and judgements regarding the liquids, pigments and other merchandises that are used in the area. The author also has notes on how to repaint, revarnish and regild the carriage.*BRICE, THOMAS & GASTELLIER*

1870 Le carnet du peintre en voitures oubrage a l'usage des carrossiers illustre de soixate échantillons de peintures. Exfremant les plus belles peintures exécutées depuis quarante ans avec tente comprenant: une description d'essemble sur la des voitures, l'ordre et le nombre de couches pour l'execution de craque peinture, des matiéres et leurs proportions pour les peintures ou ells sont mélangées. Par Brice Thomas et Gastellier. Seconde Édition. Paris: Brice Thomas, Boulevard Haussmann, 164 et les principaux libraires de la France et le L'Etranger.

Language: French

Authors: Brice Thomas was born in 1820; his complete name is Pierre-Brice-Marc-Antoine Thomas. He apprenticed as a wheelwright and in 1858 founded Guide du Carrossier to teach carriage manufacturing.[5]

Gastillier (see above)

Location: BnF, Gallica (online library resource)

Editions: 1st edition date unknown, 1870 (2nd)

Notes: Written by Brice Thomas and Gastellier, based on Gastellier's (1858) Manuel complet du peintre en équipages. It was meant to serve as supplement or companion to the previous treatise.

Contents: Most of the information is the same as Gastillieir's treatise but more concise, focusing on key points for each process and step. It does not go into as much depth on materials and recipes as the former, always referring to Gastillier's previous book for further information.

References: [5] Le Guide du Carrossier. [Accessed 12 September 2016] Available at: <https://www.abaa.org/book/880445944>

TWENTIENTH CENTURY SOURCES

GILBEY, SIR WALTER (1831-1914)

1903 Early Carriages and Roads. By, Sir Walter Gilbey, Bart. Illustrated. London. Vinton & Co., Ltd., 9, New Bridge Street, E.C.

Language: English

Location: Archive.org (online library resource)

Author: Sir Gilbey was an English wine-merchant and philanthropist. His father was the owner of the daily coach between Bishop's Stortford and London, which he frequently was the driver of as well.

Contents: All the information is historical, regarding the evolution and use of carriages.

Most of the information is focused on their usage and history in England.

HILLICK, MAYTON CLARENCE (1859 -?)

1903, 3rd Edition Practical Carriage and Wagon Painting. A treatise on the painting of carriages, wagons and sleighs, embracing full and explicit directions for executing all kinds of work. Including painting factory work, lettering, scrolling, ornamenting, varnishing, etc. With many tested recipes and formulas. Profusely Illustrated. By M.C. Hillick. Chicago, U.S.A: Press of the Western Painter.

Language: English

Location: Archive.org (online library resource)

Editions: 1898, 2nd edition year unknown, 1903, 1906

Author: Hillick is identified by the editor of the 3rd edition to be one of the most notable carriage painters of the country.

Contents: Discusses carriage painting by not only describing the various materials as well as their chemical properties and how best to prepare and use them. Also, talks about the process and materials for gilding, varnishing and what to do with damaged or old paintings.

MARIE, FREDERICK

1911 Carriage Painting. A Series of Practical Treatises on the painting of carriages and wagons, embracing full directions for the practical execution of all kinds of carriage and wagon painting, including striping, lettering, scrolling, ornamental work, varnishing, transfer ornaments, applying gold leaf etc. Each treatise is followed with Test Questions for the Student. By, F. Maire, author of “Modern Painter’s Cyclopedia”, “Exterior Painting”, “Graining and Marbling”, etc. Illustrated. Chicago, Frederick J. Drake & Company Publishers.

Language: English

Location: Archive.org (online library resource)

Notes: Written as a manual for students, including questionnaire at the end of each section. The author references Hillick frequently mentioning most of the same procedures, materials and recipes as found in his book.

Appendix IV – Summary of information gathered from treatises regarding carriage painting

Appendix IV.1 – Preparation Layers

Table IV.1: Summary of the preparation layers for coach painting as described by Gastillier (1858).

***Manuel complet du peintre en équipages (*Gasteillie 1858)**			
Preparation Layers			
1st Couches d'impression		**2nd Couches d'apprêts**	**"Mastic" (Putty)**
Materials	Lead white mixed with pure linseed oil and essence of turpentine (p.7)	1 part unwashed yellow ochre 2 parts powdered lead white (1/20 of which mixed with ochre) 2/3 pure linseed oil 1/3 essence of turpentine (p.18) Author does not specify reference for quantities.	Oil Based Putty: "Blanc Espange" (Spanish White[20]) and raw linseed oil. vermilion, lampblack or yellow ochre may be added to tint.
Application	Apply two layers, the first is to be thinner (by adding more oil, according to the author) than the second. To be placed as smooth as possible on the surface.	8 coats of this are to be laid on, and sanded smooth when dried (between layers and at the end). 3 days should be given between each coat to properly dry. Number of coats allows the wood cavities to be filled as well as to support friction of the pumice stone during the polishing phase of the final varnish. (p.18-19)	According to the author, this putty is made by grinding filler material (the whiting) into a good paste with the linseed oil. It may be tinted to match the base colour of the coach. It is to be used in areas of defects during pumicing, and to fill nail holes. (p.40-42)

Table IV.2: Summary of preparation layers for coach painting as described by Arlot (1871).

***A Complete Guide For Coach Painters* (Arlot 1871)**			
Preparation Layers			
1st Stage – Priming (Size Layers)		**2nd Stage – Filling Coats**	**3rd Stage – Puttying Up**
Materials	'white lead ground in linseed oil, thinned with turpentine and with a very small quantity of dryer' (p. 15)	'Linseed oil (2/3) and essence of turpentine (1/3), add 3 parts of yellow ochre (…) and to the paste obtained, 1 part of white lead' (p.13)	'the filling of holes and dents in bodies is made with a varnish putty' (p.17) Varnish putty: 'hard varnish, white lead or zinc white (…) a certain proportion of yellow ochre' (p. 20) Guide Coat: red ochre, linseed oil and turpentine (p.17) Disguise Coat: dark lead (lead with lampblack) in oil. (p.19)
Application	'First coat must have plenty of oil (…) to fill the pores' (p.15) 'To obtain best results (..) give a second coat of white lead, somewhat poorer in fatty oil [than] the former' (p.16)	Applied once priming has been 'well set' (p.16) '6 filling coats are generally sufficient for wood (…) recommend laying filling coats every other day in summer and every three days in winter' (p.17)	1st Puttying Up: Used to adjust 'defects and irregularities' of the filling coats by puttying them up. Is followed by the guide coat to aid pumicing with a pumice stone of 'medium coarseness and grit' (p. 17-18) Last Puttying Up: Disguise coat is laid so 'that it helps the last puttying up and levelling (…) will disappear during pumicing'. (p.19-20) Between each pumicing the surface is to be dusted.

[20] According to the Pigment Compendium Blanc d'Espange or Spanish White is chalk. [1, p.356]

Table IV.3: Summary of preparation layers for coach painting as described by Gardner (1877).

***The Carriage Painters Manual* (Gardner, 1877)**			
Preparation Layers			
	1st Stage – Priming (Size Layers)	**2nd Stage – Lead Coats**	**3rd Stage – Rough Stuff**
Materials	Keg lead with raw linseed oil (p.22) Note: Keg lead is white lead prepared and ground in oil. Author uses keg to distinguish this lead from dry white lead (p.22)	Lead coat: Keg lead with raw linseed oil (2 parts) and Japan (1 part) (p.34) Putty: "Hard Drying Putty" (p.35) Made by mixing "dry white lead with Japan and rubbing varnish equal parts" (p.35)	Rough stuff: "Three parts filling (ground slate), two parts dry white lead, one part keg lead; mix with Japan two parts, rubbing varnish one part; dilute with turpentine" (p.33)
Application	According to the author, it should be applied in a manner to fill every nail-hole and crack as best as possible, rubbing it into the grain of the wood. After a few days of drying, the layer is to be sandpapered lightly, smoothing the grain and removing any lumps of lead (p.30-31)	Three coats should be applied as smooth and evenly as possible. Between each coat, after drying for a few days, it will be hard enough to "putty up" (fill any defects or holes). Once putty is dry the surface is to be sandpapered and then the next coat may be applied. (p.31-32)	"Three coats of this is now put on (…), each coat being allowed time to dry hard. Then to enable us to see, when rubbing that the surface is level we "stain" the whole with the lampblack mixed in Japan and turpentine". Surface is rubbed with lump pumice stone and water" (p.32-33, 36)

Table IV.4: Summary of preparation layers for coach painting as described by Burgess (1881).

***A Practical Treatise on Coach-Building* (Burgess, 1881)**			
Preparation Layers			
	1st Stage – Priming (Size Layers)	**2nd Stage – Lead Colour**	**3rd Stage – Filling**
Materials	Priming layer, as indicated by the author should be composed of the 'best pure keg lead and oil, with only a small quantity of drier'. (p.111)	These layers are composed of the same materials as the priming as the priming, but with less oil. (p.111) Putty 'hard stopper': Dry lead white and Japan gold size[21] (p.112)	'2 parts filling-up stuff, 1 part lead white, 2 parts turpentine, 2 part japan gold size and ½ part bottoms of wearing varnish'[22] (p.112)
Application	According to the author, priming is also known as "slushing" and is applied in a very fluid consistency to fill the pores and grain. It is left to dry for at least a week then sandpapered. (p.110-111)	According to the author, 3 coats should be laid on and the nail holes puttied up. Between each coat a few days are given for it to dry and the surface is sandpapered before the next coat.	According to Burgess, a total of five layers are applied, in order to cover every 'portion of the surface'. Once hardened, the surface is rubbed down using pumice stone and a bit of water.

[21] According to Burgess (1881) Jappaners' gold size is made with asphaltum, litharge (or red-lead) and linseed oil. (p.110)

[22] According to *Copal Varnishes used on 18th and 19th century* Carriages, wearing varnish is believed to be a darker copal for application over darker colours [2, p.9]. According Carlyle's research, as sited by Stols-Witlox in *Conservation of Easel Paintings,* bottoms of varnish is the residue of varnish left in the pot after it has been made [3, p.178]. As such, bottoms of wearing varnish may be the bottom residue of a regular wearing varnish.

Table IV.5: Summary of preparation layers for coach painting as described by Hillick (1903).

***The Practical Carriage and Wagon Painting* (Hillick, 1903)**			
Preparation Layers			
	1st Stage – Priming (Size Layers)	**2nd Stage – Lead Coats**	**3rd Stage – Rough Stuff**
Materials	Author refers to 5 different recipes for priming, all of them consist of white lead and raw linseed oil. Variations in the recipes are in the addition of lampblack or yellow ochre (both for tinting); coach japan or rubbing varnish (or both in one case). (p. 18)	"First lead": White (keg) lead, linseed oil and turpentine. "Second lead","Flat lead", "dead lead": white lead, turpentine, oil and japan (p.19-20)	Once again, the author refers to a lot of different recipes, 7 in total. The possible fillers are: white lead and/or filler (English[23] or whiting[24]). The possible binders are: rubbing varnish, japan and/or bottoms of wearing varnish. (p.24-25)
Application	"Should contain just enough pigment to stain the oil (…) apply the priming smoothly and in a uniform film" The priming (the mixture of a liquid with the addition of a little pigmented filler) is the "agent required to go into and saturate the minute cells and pores of the wood (…) sealing them against moisture" (p.18-19)	Per the author the first lead is applied over the priming after it has been sandpapered. Once the first lead has dried it too is to be sandpapered. The second lead coat is applied, with less oil than the first coat. Once dry the surface is sandpapered again. (p.19-20)	Per the author, each coat is laid on in the opposite direction of the last (horizontal then vertical etc.). "Four coats should suffice (…) a guide coat is to be used over rough stuff (…) made a bit with yellow ochre or venetian red and thinned down considerably thinner than the stuff, with turpentine". Coatings are then rubbed down with stones and/or bricks. Even if guide the coat disappears it doesn't mean the surface is completely smooth. (p.24-26)

Appendix IV.2 - Gilding

Table IV.6: Summary of gilding materials and techniques mentioned in the treatises.

Gilding		
Treaty	**Materials**	**Application Technique or other comments**
Manuel complet du peintre en équipages (Gasteillie 1858)	Shellac over lead white ground and then the gilding mixture. Mixture: Yellow Button of Gold[25] and Linseed Oil (p.95-96)	Historical Method: According to the author, gilding on coach panels was done by first applying 15-20 coats of shellac over a hardened and polished lead white ground. About four coats of shellac could be given a day. Once it has hardened it was to be polished with pumice and cloth until a bright surface was achieved. Afterwards, the carriage body was to be placed inside a heated workshop where the gilding mixture was to be coated over the layers of shellac and it would be ready to receive the gold leaf and then the varnish. (p.80-81)
A Complete Guide For Coach Painters (Arlot 1871)	1.) Gold Size 'mixed with English varnish, a small quantity of japan, white lead, and chrome yellow, makes an excellent mixture for gilding' (p.70) 2.) House gilder mixture: gold size and 'an addition of white lead and chrome yellow ground very fine with linseed oil' (p.72)	'Under coats must be entirely hard, and the work done in a perfect manner (…) This mixture must be used quite dry (....) may receive gold 12 hours after it has been laid down (…) when gilder has delivered his work to the painter (…) must wash it with plenty of water, taking care not to scratch the gold (…) better to wait three or four days before washing' (p.72) 'Gilt panels require a well-polished white ground, composed of several coats of white lead. Shellac varnish is laid over, and polished again when dry. Afterwards (…) gilding mixture is spread, and receives gold (…) then two coats of varnish No. 2, a polishing, and the finishing varnish' (p.95)

[23] The English Filler mentioned is probably ground slate as another author (Table II.3) mentions a filler by a similar name and calls it ground slate. According to the *Pigment Compendium* ground slate was commonly used as "inert filler for the preparation of stopping and filling" materials for woodwork [1, p.350].
[24] According to the *Pigment Compedium* (2008) whitening is composed of calcium carbonate (p.80).
[25] Author calls this pigment in his treatise "*jaune bouton d'or"* which a type of yellow. Direct translation into English would be Yellow Button of Gold, which according to *The Pigment Compendium* is zinc chromate hydroxide first produced around 1800. It is most commonly known as Zinc Yellow. [1, p.406, 414-415]

Table IV.6: Cont. Summary of gilding materials and techniques mentioned in the treatises.

Gilding		
Treaty	**Materials**	**Application Technique or other comments**
The Carriage Painters Manual (Gardner, 1877)	1.) 'English Gold Size' is considered by the author as 'being the best for the use of gilding. (p.59) However, the following can be made if necessary 1.) 'English varnish and Japan in equal parts' (p.59)	According to the author, before proceeding with the gilding the surface must be rubbed smooth. (p.59) To prevent gold leaf from sticking onto the surface where the size isn't applied the author suggests the use of 3 different techniques: the first, making of a pounce bag with whitening and pounce/dusting over surface; 2nd suggestion is washing the job with a little starch water and the 3rd is by rubbing the surface with a cut potato. (p.59-60) The size is applied to the desired areas to gild and left to dry until "tacky" to the touch, to which the gold leaf may now be applied. (p.60)
The Practical Carriage and Wagon Painting (Hillick, 1903)	1.) Quick size: Gold size japan, 5 parts; fat oil, 1 part. With a dash of japan ground chrome yellow, this size will dry to safely leaf over in ½ hour. 2.) Medium quick size: Gold size japan, 4 parts; fat oil, 2 parts. 3.) Four-hour size: Gold size japan and fat oil, in proportions of 2/3 japan to 1/3 oil. 4.) Over-night size: Fat oil with a few drops of gold size japan added. (p.85)	Per the author 'slow drying size works better and affords a more satisfactory job of gilding than does the quicker mixture'. (p.85) 'If it is desirable to varnish a job of gilding the same day the leaf is laid, and it is feared that the leaf will brush mark, it is a good plan to give the gold a light coat of thin shellac, going over the work very quickly. The shellac will protect the leaf without in any way harming it.' (p.149)

Appendix IV.3 – The Varnishing of Carriage Paintings

Tables IV.7: Summary of varnishing materials and techniques mentioned in the treatises.

Varnishing		
Treaty	**Varnishes**	**Application Technique or other comments**
Manuel complet du peintre en équipages (Gasteillie 1858)	"Vernis nº2 à polir" – Polishing Varnish (The varnish to be polished, before the final varnish) "Vernis à finir" – Finishing Varnish (The last varnish put on to give the final shine)	How to make polishing varnish: Boil linseed oil over a low and steady fire and without introducing harmful products allow it to become less fatty. Afterwards, allow it to rest for approximately 10 hours. In a copper pot over the fire place crushed "gomme dure Calcutta" (Copal Resin). Crushing the resin beforehand will facilitate its cooking and melting. Stir the resin with an iron spatula until it has thoroughly melted together after which it is ready to receive the previously "defatted" linseed oil. The adequate proportions are 1 pound of oil per 1 pound of resin. The mixture should be cooked together between 10 to 15 minutes and stirred from time to time. When removed from the fire, let it rest for 10-15 minutes before adding the turpentine as too much heat may cause it to ignite. 3 pounds of turpentine should be added per pound of gum. It should be added in small quantities and slowly at a time, always being stirred with a spatula. Leave in the boiler over night but covered, transferring the substance to bottles the following day. After 3-6 weeks the varnish will be ready for use. (p.60-64)

Tables IV.7: Cont. Summary of varnishing materials and techniques mentioned in the treatises.

Varnishing		
Treaty	**Varnishes**	**Application Technique or other comments**
A Complete Guide for Coach Painters (Arlot, 1871)	Rubbing Varnish (p.27) Finishing Varnish (p.31)	According to the author, once the surface of the painting is prepared the first coat of rubbing varnish may be laid on, this must be thin and flow easily. Once this coat has dried, it is to be rubbed with pumice dust, a rag and water. After the surface has dried, the second coat of rubbing varnish must be rapidly laid and plenty of varnish may be used with this coat, 'taking care to avoid runs and gatherings'. Like the first coat it is allowed to dry and it may now be polish by used of powdered pumice stone and water, rubbed with a woolen rag. (p.27) 'Finishing varnishes are always of the best quality and very fat, they are more easily laid on than the rubbing ones'. (p.31)
The Carriage Painters Manual (Gardner, 1877)	Author prefers the use of "Noble & Hoare's hard drying varnish" and "Harland's wearing body-varnish" mixed in equal parts	Varnish is applied on the inside of the panel in a heavy coat after which it is leveled off. On the outside of the panel, varnish is laid in a very heavy but even manner, beginning in horizontal strokes followed by vertical ones. The process repeats itself and the last movement should always be vertical. Author mentions a last step, one of polishing, even though it is "a thing of the past". A job must be finished as "smoothly and cleanly as possible with American finish varnish". It is then left to stand for ten days before it will be ready to polish. Polishing is done by rubbing down the surface with pumice stone, this is cleaned off and rubbed once more with rotten stone ground fine "until the marks of the pumice stone are all obliterated". The next step is rubbing rotten stone and oil on the surface "until a gloss appears". The last step consists of using whiting "mixed with the sweet oil will produce a good polish (…)" and cleaned off with soft silk. This will produce a "glossy surface, superior to varnish in point of wear – but not in looks".
A Practical Treatise on Coach-Building (Burgess, 1881)	Rubbing Varnish: 'required to dry firmly in (…) two to five days (…) have not much oil in their composition' Hard Drying Varnish Finishing Varnish (p.110)	According to the author, rubbing varnish is the first varnish to be applied after the painting is completed, and it 'should not be rubbed until the fourth or fifth day after being laid'. Following the rubbing varnish, the hard drying varnish will enable the painter to 'level his work down, and prepare for the last coat', the finishing varnish. Finishing Varnish is a different nature from the last two varnishes as it should be laid to achieve 'great brilliancy'. As stated by Burgess, it must also possess 'an elasticity or oily nature that will resist' climatic changes. (p.110)
The Practical Carriage and Wagon Painting (Hillick, 1903)	Rubbing Varnish (p.46) Finishing Varnish (p. 50)	According to the author, the first varnish applied is the rubbing varnish, 3 coats in total. Once it has dried, or hardened sufficiently, 'surfacing should ensue', which is the rubbing of the varnish with pulverized pumice stone and cloth. Water should be used to carefully clean the surface of any residues and then dried. (p. 46-48) The last coat of varnish is with the finishing varnish. (p. 50) The author does not inform the reader what specific varnish (aside from the terms "rubbing" and "finishing") to use, hence there is no indication as to what type of resinous material they are to be composed of.

Appendix IV.4 – Summary of all materials mentioned in the treatises and their uses

As can be seen in Table IV.8, all the treatises use white lead in all the steps for the preparation layers (or foundation as called by the authors). Another common ingredient is linseed oil however, this does not seem to be in use for the third step, being replaced by Japan, a type of gold size which is a drier. Japan is made up of asphaltum and linseed oil, in Gastellier's treatise (p.68). Pigments aside from white lead are also there as additional filler(s), tinting agents (to add color such as ochre) or as a replacement pigment for lead (e.g. zinc white). With regard to varnishing, four out of the five treatises mention at least one of the same type of varnish, Finishing varnish; and three of the five call for Rubbing varnish.

Table IV.8: List of materials mentioned in treatises for use in preparation layers.

	"1st Stage" of Preparation					"2nd Stage" of Preparation					"3rd Stage" of Preparation			
	1858	1871	1877	1881	1903	1858	1871	1877	1881	1903	1871	1877	1881	1903
Turpentine														
Japan														
Japan Gold Size														
Linseed Oil														
Dark Lead														
Filling (Ground Slate)														
Lampblack														
White Lead														
Whiting														
Yellow Ochre														
Zinc White														
Bottoms of Wearing Varnish														
Hard Varnish														
Rubbing Varnish														

Table IV.9: List of materials mentioned in treatises for gilding.

Gilding Materials	Treatises			
	1858	1871	1877	1903
Fat oil				
Gold Size				
English Gold Size				
Japan				
Japan Gold Size				
Linseed Oil				
Chrome Yellow				
White Lead				
Yellow Button of Gold				
English Varnish				
Rubbing Varnish				
Shellac				

Table IV.10: List of materials mentioned in treatises for use in varnishing.

	Varnishing				
	1858	1871	1877	1881	1903
Turpentine					
Linseed Oil					
Copal Resin					
Hard Drying Varnish					
Finishing Varnish					
Rubbing Varnish					
Wearing Varnish					

Table IV.11: List of pigments for paint colours mentioned by the treatises.

	Pigments	Treatises				
		1858	1871	1877	1881	1903
RED	Carmine					
	Chinese Vermilian					
	Dutch Pink					
	English Purple					
	English Vermilian					
	Florence Lake					
	Indian Red					
	Italian Pink					
	Light Red					
	Madder Lake					
	Mauve Lake					
	Munich Lake					
	Prussian Red					
	Red Lake					
	Red Lead					
	Rose Madder					
	Scarlet Lake					
	Venetian Red					
	Vermilian					
	Victoria Lake					
Yellow	Chrome Yellow					
	French Yellow Ochre					
	Golden Ochre					
	Kings Yellow					
	Lemon Chrome					
	Lemon Yellow					
	Medium chrome yellow					
	Naples Yellow					
	Orange Chrome					
	Orange mineral					
	Solferino Lake					
	Yellow Lake					
	Yellow Ochre					

Table IV.11: Cont. List of pigments for paint colours mentioned by the treatises.

	Pigments	Treatises				
		1858	1871	1877	1881	1903
White	Cremnitz White					
	English Filling					
	White Lead					
	Whiting					
Blue	Antwerp Blue					
	Blue Black					
	Brunswick Blue					
	Chinese Blue					
	Cobalt Blue					
	Flora Blue					
	Indigo					
	Prussian Blue					
	Ultramarine Blue					
Green	Chrome Green					
	Emerald Green					
	Fine Green (Vert Fin)					
	Light Chrome Green					
	Medium Chrome Green					
	Paris Green					
	Terraverde					
	Verdigris					
Brown	Burnt Sienna					
	Burnt Umber					
	Gold Bronze					
	Raw Sienna					
	Raw Umber					
	Vandyke Brown					
Black	Asphaltum					
	Brown Ochre					
	Ivory Black					
	Lampblack					

References used in Appendix IV:

[1] Eastaugh, N., Walsh, V. Chaplin, T. and Siddal, R. 2004. Pigment Compendium: A Dictionary and Optical Microscopy of Historical Pigments. New York: Routledge.

[2] Augerson, C. 2011. Copal Varnishes Used on 18Th- and 19Th-Century Carriages. Journal of the American Institute for Conservation, 50(October), p. 14–34.

[3] Stols-Witlox, M. 2012. Grounds, 1400-1900, including: Twentieth-Century Grounds by Ormsby, B and Gottesgen, M. In: J.H. Stoner & R. Rushfield, eds. Conservation of Easel Paintings. London: Routledge, p. 161-188

Appendix V – Material Analysis
Appendix V.1 – Instrument Description

Photographic Documentation: Standard light and raking photography were performed with a high resolution digital camera Nikon D2x, Nikkor 28-70mm 1:2 8D. A tungsten light bulb of 500W was used for raking light and for ultraviolet light, two lamps with three blacklight bulbs each. These images were taken by Luís Piorro (LJF) in January 2016.

Other images were taken by the author with a Canon PowerShot SX160 IS, 5.0-80mm.

Infrared Reflectography: The reflectograms were obtained by using a high resolution infrared reflectography camera (Osiris) with an InGaAs array sensor with a 0.05 mm resolution, allowing a wavelength response from 900 to 1700 nm, and equipped with a 16x16 cm2 tile system which allows an image size of 4096x4096 pixels. The camera comes with a longpass filter Schott RG850, allowing the transmission of infrared wavelength and blocking the undesired shorter wavelength until 850 nm. This camera has a 6 element Rodagon lens with focal length of 150 mm and aperture range of f/5.6 to f/45. Reflectograms were recorded with a working distance (front of body camera to painting) of 170 cm, and focus (front of body camera to lens) of 20 cm, an f/11 aperture and diffused illumination at 1000 lux by reflectors with 2×1000 W Tungsten Halogen VC – 1000Q Quartz Light. Images by Luís Piorro (LJF).

X-radiograph: X-radiography was performed with an X-ray generator Yxlon Smart160E X-ray tube operating at 40 kV, 6 mA for 50-300 s, 40 kV, 6 mA for 600 s and 60 kV, 6 mA for 600 s, at the invariable distance from the object of 2 m. The image contrast was improved by increasing the exposure time and the penetration depth was improved by increasing the beam energy.

The digital image capture devices were reusable medium-sized 55 photo-stimulated phosphor plates (37 cm x 43 cm), that after being radiated, were scanned by means of computer imaging software via the SCANNA Durr NDT - CR 35sec. scanner. Taken by Luís Piorro (LJF) in January 2016.

Optical Microscope (OM): The optical microscope used is an Axioplan 2ie Zeiss microscope equipped with transmitted and incident halogen light illuminator (tungsten light source, HAL 100); UV light (mercury light source, HBO 100 illuminator); and a digital Nikon camera DXM1200F, with Nikon ACT-1 application program software, for microphotographs. Samples were analyzed with 10x ocular lenses and 5x/10x/20x/50x objective Epiplan lenses (giving a total optical magnification of 50x, 100x, 200x, and 500x).

For the incident light the samples were analyzed under crossed polarised light; and for UV light the Zeiss filter set 05 [BP 395-440, FT 460, LP 470] and set 2 [BP 300-400, FT 395, LP 420] were used. The scales for all objectives were calibrated within the Nikon ACT-1 software.

Energy Dispersive X-ray Fluorescence (μ-EDXRF): X-ray fluorescence spectra were obtained using a Bruker Tracer III-SD Handheld X-Ray Fluorescence Spectrometer, belonging to HERCULES. Operating with a rhodium (Rh) X-ray tube and palladium (Pd) slits, and a 10mm2 XFlash SDD (Si) peltier cooled detector, with 145 eV resolution at 100,000 cps.

Elemental compositions of the lateral panels were obtained from independent spots (and in some cases an average of three) analyzed with a tube voltage of 15 kV and a current intensity of 55μA and live time 120s. Elemental compositions of the Upper Back Panel were obtained from the average of three independent spots, analyzed with a tube voltage of 15 kV and a current intensity of 55μA and live time 60s and 10s. Some of the analyses were done with the addition of a titanium (Ti) filter.

Analysis was done with the aid of António Candeias (HERCULES) and Ana Machado (LJF).

μ-Raman: Micro-Raman microscopy was carried out using a Labram 300 Jobin Yvon spectrometer, equipped with a He-Ne laser of 17 mW power operating at 632.8 nm and an external laser of 50mW power operating at 532 nm. Spectra were recorded as an extended scan. The laser beam was focused with a 506 Olympus objective lens (50x). The laser power at the surface of the samples was varied with the aid of a set of neutral density filters (optical densities 0.3, 0.6, 1).

Fourier Transform Infrared Spectroscopy (μ-FTIR) - HERCULES: An infrared spectrometer Bruker Hyperion 3000 equipped with a single point MCT detector cooled with liquid nitrogen and a 15x objective

lens was used. The spectra were collected in transmission mode, in 50–100 µm areas, using a S.T. Japan diamond anvil compression cell. The infrared spectra were acquired with a spectral resolution of 4 cm-1, 32 scans, in the 4000-650 cm-1 of the infrared region. Analysis was by Catarina Miguel at HERCULES.

Fourier Transform Infrared Spectroscopy (µ-FTIR) – FCT UNL: Infrared spectra were acquired using a Nicolet Nexus spectrophotometer coupled to a Continumm microscope (15xobjective) with a MCT-A detector cooled by liquid nitrogen. The spectra were collected in transmission mode, between 4000 – 650 cm-1, resolution setting 4 cm-1 and 128 scans, using a Thermo diamond anvil compression cell. The spectra are shown as acquired, without corrections or any further manipulations, except for the removal of the CO2 absorption at ca. 2300-2400 cm-1. Analysis was by Vanessa Otero and Prof. Maria João.

Scanning Electron Microscope with Energy-dispersive X-ray Spectroscopy (SEM-EDS): Pressure Scanning Electron Miscroscope HITACHI S-3700N, operated with a accelerating voltage of 20kV and chamber pressure 40Pa. Chemical microanalysis was done in the same conditions, using a Bruker XFlash 5010 Silicon Drift Detector (SDD) with a resolution of 129eV at Mn Kα. Analysis realized was by Luís Dias and Sara Valadas at HERCULES.

Appendix V.2 – µ-EDXRF Anlysis

Appendix V.2.1 – Results on Upper Back Panel (BU)

Figure V.1: Areas of µ-EDXRF analysis on Upper Back Panel (BU).

µ-EDXRF analysis on the Upper back panel was done by collecting, in general, an average of 3 points per area and/or colour. Due to the weight of the equipment, along with the positions required to reach each point of analysis, the first point in each new area analyzed was done with 60 seconds. The other two were then collected with just 10 seconds, however, this was only done if their spectrums were the same as the first (the 60 second analysis).

Once µ-EDXRF analysis was completed, each individual spectrum was carefully observed and compared with one another, to verify whether variations did occur within the same area of analysis; if areas of similar

colour had the same elements or not; and the difference between the previous retouching material and the original surface.

About Table V.1's μ-EDXRF results, the first element on the upper line is the element thought to be providing the main colour. Elements on the bottom line are believed to belong to the ground. Elements in bold refer to higher intensity peaks, elements in brackets are residual peaks.

Table V.1: List of the elements identified from each area on the Upper Back Panel (BU).

Area	Panel	Color Tested	Elements Present
1	BU	Green	Fe, (Mn), (Hg) Ca, **Pb**
2	BU	White	**Pb**, Fe, (Mn), (Hg) Ca, **Pb**
3	BU	Skin	Hg, Fe, **Pb**, (Mn) Ca, **Pb**
4	BU	White	**Pb,** Fe, (Hg), (Mn) Ca, **Pb**
5	BU	Yellow	**Fe**, (Hg), (Mn), Ca, **Pb**
6	BU	Green	Fe, (K), (Mn), (Hg) Ca, **Pb**
7	BU	Green	Fe, (Mn), (Hg), Ca, **Pb**
8	BU	Green Intervention	**Fe**, Cr, Ba, Mn, **Zn**, **Pb** Ca
9	BU	White	**Pb,** Fe, (Mn) Ca, **Pb**
10	BU	Pink	Hg, **Pb,** (Mn), Fe Ca, **Pb**
11	BU	Green	Fe, (Hg), (Mn) Ca, **Pb**
12	BU	Red	**Hg,** Fe, (Mn) Ca, **Pb**
13	BU	Blue	**Pb,** Fe, (Mn) Ca, **Pb**
14	BU	Pink	(Hg), **Pb,** (Mn), **Fe**, Ca, **Pb**
15	BU	Brown	**Fe**, (Mn), (Hg), Ca, **Pb**
16	BU	Red	**Hg, Fe**, (Mn), Ca, **Pb**
17	BU	Blue	Fe, (Mn) Ca, **Pb**
18	BU	Blue Intervention	**Fe**, **Zn**, **Pb** Ba, Cr, Mn Ca
19	BU	Green	**Fe**, **Pb,** (Mn), (Hg) Ca, **Pb**
26	BU	Brown	**Fe**, (Mn), (Hg) Ca, **Pb**
27	BU	Brown Intervention	**Fe**, Ba, **Cr**, Mn, Zn, Sr **Ca**, **Pb**
28	BU	Brown	**Fe**, (Hg), (Mn) Ca, **Pb**
29	BU	Green	Fe, (Hg), (Mn) Ca, **Pb**
30	BU	Pink	(Hg), **Pb,** (Mn), **Fe**, Ca, **Pb**
31	BU	Red	**Hg, Fe**, (Mn) Ca, **Pb**
32	BU	White	**Pb,** Fe, (Mn) Ca, **Pb**
33	BU	Blue	Fe, Hg, (Mn) Ca, **Pb**
34	BU	Yellow	**Fe**, (Hg), (Mn) Ca, **Pb**
35	BU	Red	**Hg,** Fe, (Mn) Ca, **Pb**
36	BU	White	**Pb, Fe**, (Hg), (Mn) Ca, **Pb**
37	BU	Red	(Hg), **Fe**, (Mn) Ca, **Pb**
38	BU	Red Intervention	(Hg), Ba, Cr, **Fe**, Zn, **Pb**, **Ca**
39	BU	White	(Hg), **Pb, Fe**, (Mn) Ca, **Pb**
40	BU	White Intervention	**Pb**, Ba, **Cr**, Mn, **Fe**, Zn **Ca**
41	BU	Grey	**Pb, Fe**, (Mn) Ca, **Pb**
42	BU	Green	Fe, **Pb,** (Mn) Ca, **Pb**
43	BU	Red	**Hg,** Fe, (Mn) Ca, **Pb**
44	BU	Pink	Hg**,** Pb, **Fe**, (Mn) Ca, Pb
45	BU	Green	**Fe**, (Mn) Ca, **Pb**
46	BU	Yellow	**Fe**, (Mn) Ca, **Pb**
47	BU	Green	Fe, (Mn) Ca, **Pb**
48	BU	Pink	Hg**, Pb,** Fe, (Mn) Ca, **Pb**

Appendix V.2.2 – Results on other panels

Figure V.2 (Left): µ-EDXRF analysis spots on the right side of the coach, the top middle panel RU
Figure V.3 (Right): µ-EDXRF analysis spots on the right side of the coach, the panel towards front RF.

Figure V.4 (Left): µ-EDXRF analysis spots on the left side of the coach the panel towards the front LF.
Figure V.5 (Right): µ-EDXRF analysis spots on the left side of the coach the upper middle panel LU.

The same method of organization was used for these µ-EDXRF tables as well, except for separating the ground elements onto a bottom line. As no other analytical methods were used there was no means of knowing which elements on these panels belong with certainty to the ground.

As can be observed, the XRF of the right and left side panels present similar elements to the Upper Back Panel, such as: mercury (Hg) found in the pigment vermilion, used in areas with red or pinkish tones as well as skin colour; lead (Pb), in all areas, most likely lead white and possibly in the ground or as mixtures for certain colours (e.g. pink); and iron (Fe) which is most prominent in areas of green, blue and yellow which could indicate to the use of ochres.

Table V.2: Elements identified on the top middle panel on the right side (RU).

Area #	Panel	Colour	Identified Elements
1	RU	Green	Fe, **Pb,** Au, Cu, Ca, (Mn), (Cr)
2	RU	Red	**Hg**, **Pb**, Fe, Ca (Mn), (Au)
3	RU	Reddish Brown	**Fe, Pb**, Ca, Au, (Mn)
4	RU	Blue	Fe, **Pb**, Au, Ca, (Mn)
5	RU	Grey	**Pb**, Fe, Au, Ca, (Mn)
6	RU	Blue	**Fe, Pb**, Au, Ca, (Mn)
7	RU	Pink/Red	**Hg, Pb**, Fe, Ca, (Mn), (Au)
8	RU	Pink/Red Restoration	Hg, **Fe**, Ca, Ba, Zn, Pb, (Mn), (Cr)
9	RU	Green	**Fe, Pb**, Au, Ca, Zn, (Mn), (Cr)
10	RU	Greyish Green	**Pb**, Au, Fe, Ca, (Mn)
11	RU	Red	(Hg), **Pb, Fe**, Au, Ca, (Mn)
12	RU	Light Blue	Fe, **Pb**, Au, Ca, (Mn)
13	RU	Green	**Fe**, **Pb**, Au, Ca, (Mn)
14	RU	Red	**Hg, Pb,** Fe, Ca, (Au), (Mn)
15	RU	Gilding	Au, **Pb**, Fe, Ca, (Mn)
16	RU	White	**Pb**, Fe, Au, Ca, (Mn)

Table V.3: Elements identified on the front panel on the right side (RF).

Area #	Panel	Colour	Identified Elements
1	RF	Red	**Hg, Pb,** Ca, (Fe), (Mn)
2	RF	Brown	**Fe, Pb,** Ca, (Mn), (Hg)
3	RF	Light Green	Fe, **Pb**, Ca, (Mn)
4	RF	Blue	Fe, **Pb,** Ca, (Mn)
5	RF	Skin	Hg, **Pb**, Ca, Fe, (Mn)
6	RF	Pink	(Hg), **Pb**, (Fe), (Au), (Mn)
7	RF	Brown	**Fe, Pb,** Hg, Ca, (Mn)
8	RF	Gilding	Au, **Pb**, Fe, Ca, (Mn)

Table V.4: Elements identified on the front panel on the left side (LF).

Area #	Panel	Colour	Identified Elements
1	LF	Red	Hg, **Pb,** Fe, Ca, (Mn)
2	LF	Brown	Fe, **Pb**, Hg, Ca (Mn)
3	LF	Green	Fe, **Pb**, Ca, (Mn)
4	LF	Reddish Brown	**Hg, Pb, Fe**, Cu, Ca, (Mn)
5	LF	Dark Blue	**Fe, Pb**, Ca, (Mn)
6	LF	Grey	**Pb**, **Cu**, Fe, Au, Ca, (Cr), (Mn)
7	LF	Green	Fe, Pb, Cu, Au, Ca, (Mn)
8	LF	White	Pb, Fe, Cu, Ca, (Au), (Mn)

Table V.5: Elements identified on the top middle panel on the left side (LU).

Area #	Panel	Colour	Identified Elements
1	LU	Blueish Grey	**Fe, Pb, Zn,** Ca, Cr, (Mn),
2	LU	Gilding	**Au, Fe, Pb,** Ca, Cu (Mn)
3	LU	Gilding Restoration (more pale in colour)	**Cu,** Au, **Pb, Fe,** Zn, (Cr), (Mn), (Ca)
4	LU	Skin	(Hg), **Pb**, Fe, Ca, (Au), (Mn)
5	LU	Skin Restoration	(Hg), **Pb, Fe, Zn**, Ca, (Mn), (Cr), (Au)
6	LU	White	**Pb, Fe**, Au, (Mn), (Ca)
7	LU	Dark Blueish Green	**Fe, Pb**, Au, Cu, (Mn), (Ca)
8	LU	Dark Blueish Green Restoration	**Fe, Pb, Cu,** Au, Zn, Ca, Cr, (Mn)
9	LU	Red	**Hg, Pb,** Au, Cu, Fe, Ca, (Mn)

Appendix V.3 – Cross-sections

Appendix V.3.1 –Upper Back Panel (BU) Cross-sections

All cross-section images were taken with an Optical microscope with Crossed-Polarized Light and Ultraviolet Light. In one case (S6), Plane Polarized Light was also used as it reveals with clarity the layer of gilding. Some of the cross-sections were also analysed with SEM, the corresponding image can be seen here, while the elemental result will be in Analytical Result section below.

Figure V.6: Map of cross-sections from the Upper Back Panel (BU). V1 is a varnish drip sample.

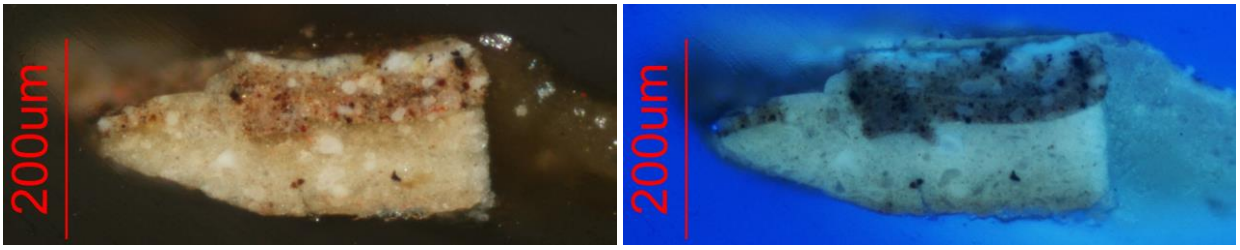


Figure V.7: S1 (34.V0016.BU) left showing a white ground & two paint layers (pinkish followed on top with a whitish one). Varnish layers are visible in UV.

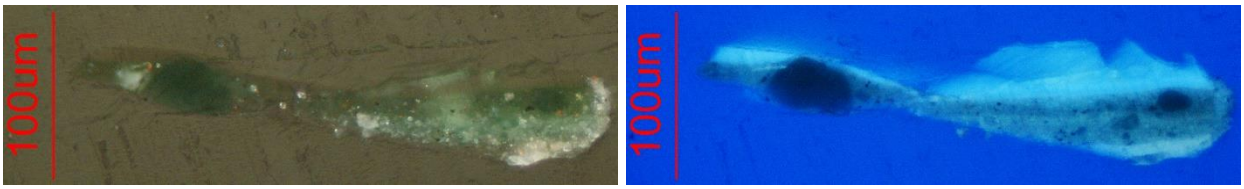


Figure V.8: S6 (40.V0016.BU) shows green paint layer, a little residue left of the ground (white on bottom). UV light seems to distinguish two varnish layers. Green paint layer was analysed in FTIR, see below.

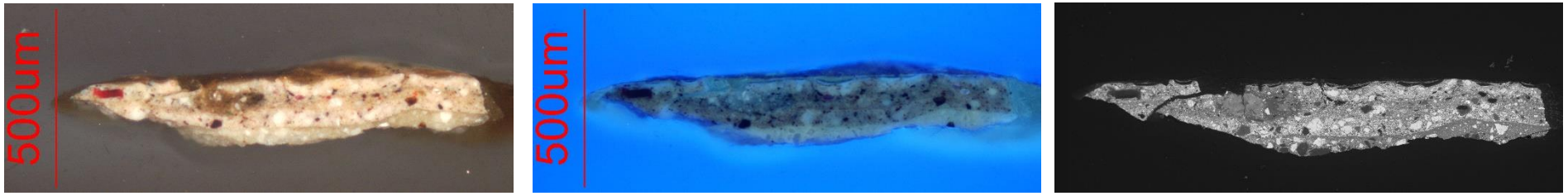


Figure V.9: S2 (35.V0016.BU) showing a bit of the top layer of ground (white layer on the bottom), the paint layer and in the UV the varnish layers. SEM aids in distinguishing the layers by the difference in grain size of the various materials used in each layer, as well as the variation within the black-and-white tones (heavier elements are whiter and lighter elements darker).

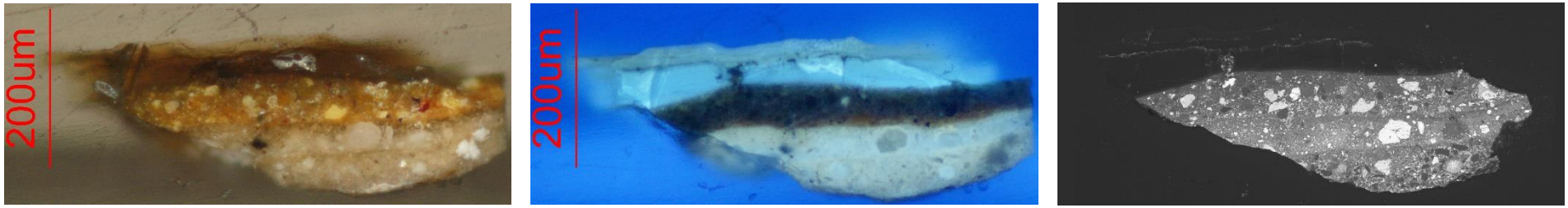


Figure V.10: S3 (37.V0016.BU) showing two distinct ground layers, a yellow paint layer, and in UV two layers of varnish. SEM image shows slight differences between the two ground layers, the upper most be lighter than the bottom layer.

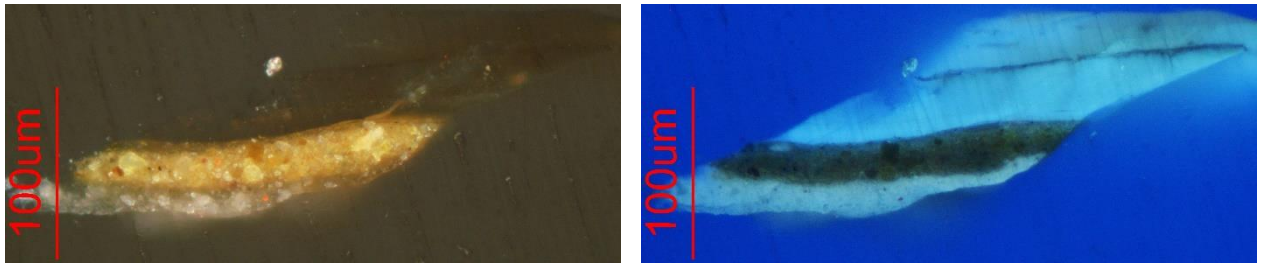


Figure V.11: S4 (38.V0016.BU) similar to **S3** with yellow paint layer and two layers of Varnish (UV) however only has the top layer of ground. UV shows what is most likely a layer of grim between the two varnish layers.

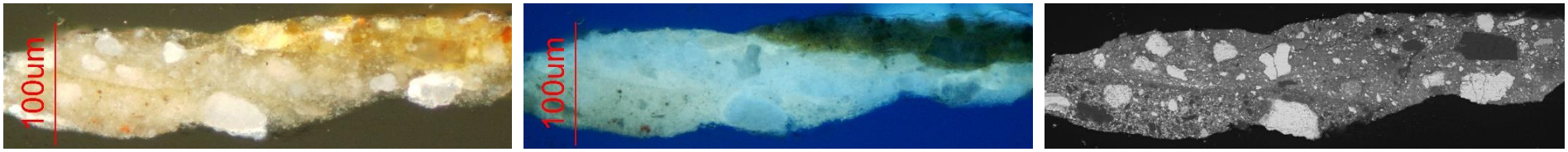


Figure V.12: S5 (39.V0016.BU), shows two distinct ground layers and a yellow paint layer. Ground and paint layers were separated from the varnish layers during sample mounting, see figure below. SEM reveals large rectangle shaped grain in the yellow paint, which doesn't show in OM images, most likely silica (e.g.quartz).

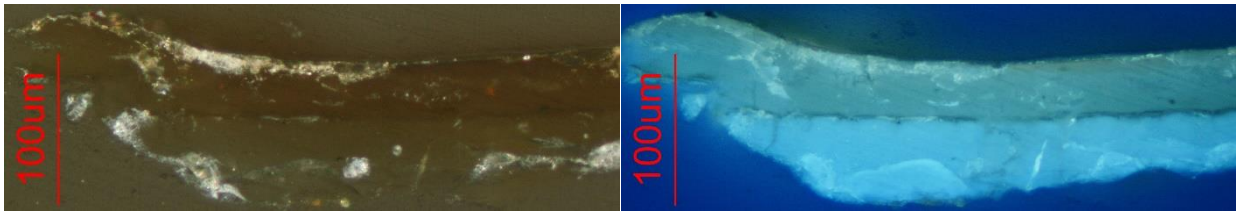


Figure V.13: S5 (39.V0016.BU), shows two distinct layers of varnish in UV

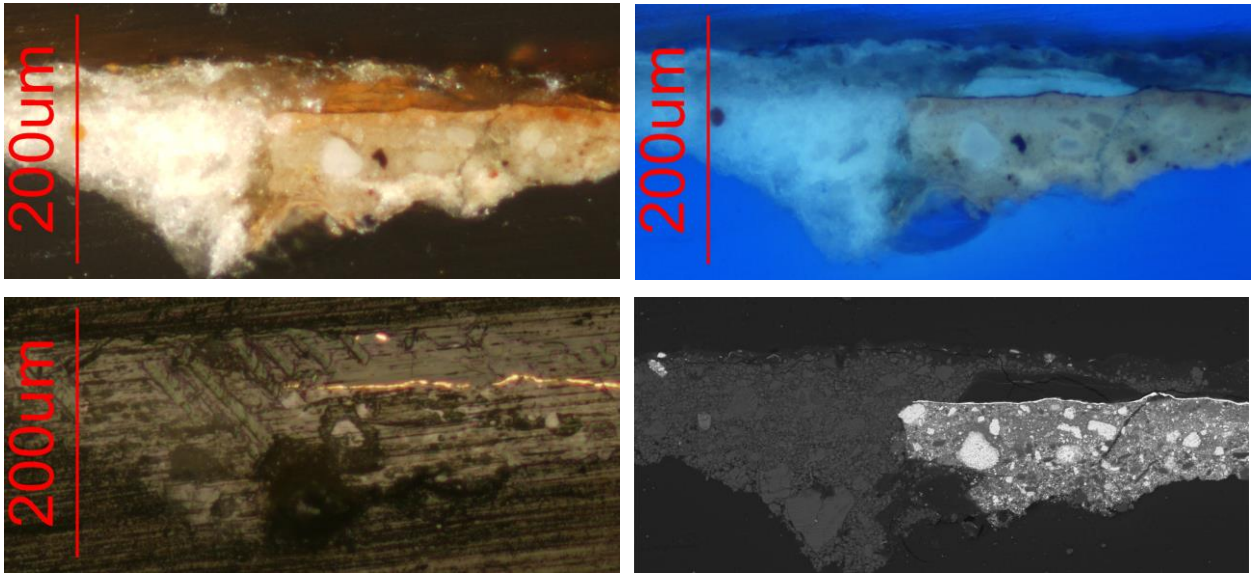


Figure V.14: S8 (48.V0016.BU) shows on the left infill material, and on the right the ground layer, with a thin layer of bole before the gilding. Gilding is visible in the Plane Polarized Light image (bottom left). SEM (bottom right) shows a clear difference between the ground and fill, fill is darker (indication of no heavy metal pigments like lead white).

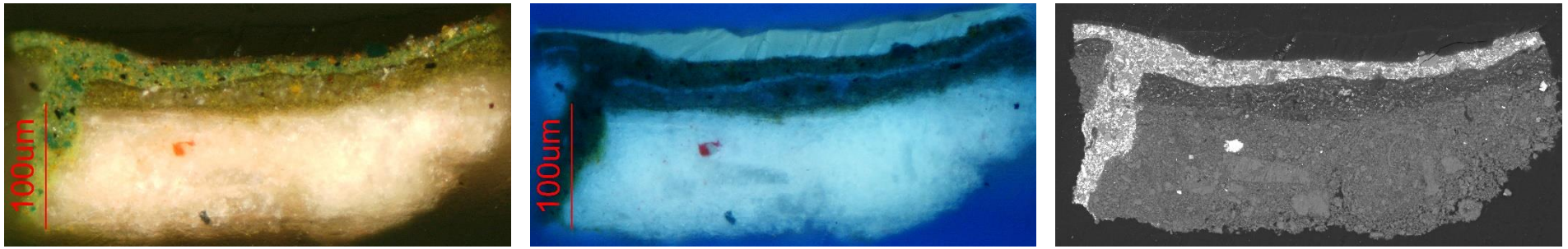


Figure V.15: S7 (41.V0016.BU) shows infill used on the join (white layer on bottom), with two distinct green paint layers. UV shows only one layer of varnish. Which may indicate that the second layer of varnish was applied after the pervious infill and retouching, or that a similar varnish to what is on the painting was placed afterwards on the previous treatment.

Appendix V.3.2 – Other Panels Cross-sections

These images were also taken in the Optical Microscope, with Normal and UV light. As all the panels have a gilded background, polarized light was also used to clearly distinguish the gold leaf or gold paint.
Although cross-sections maps identify all of the samples taken during the project, only one from each panel is demonstrated here as an exemplification of the variation in the ground layers. All cross-section OM images can be found in the CD accompanying the thesis.

Figure V.16: S16 (06.V0016.RB) has a yellow layer on the very bottom, which is a previous ground. This is deduced from the fact that there is a layer of varnish between half of the sample, over which a new ground (white one) was applied along with new gold leaf. It's likely that the former painting was either painted over, or removed before a new one, however this residue remained.

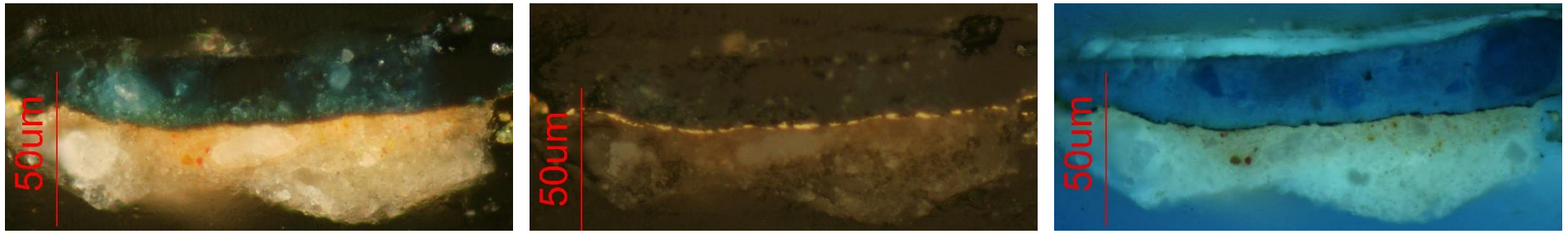


Figure V.17: S10 (03.V0016.RD) from same panel as **S9** (images above) shows same type of ground layer followed by the bole, gilding and blue paint layer. UV seems to show two layers of varnish, the top layer with a darker fluorescence.

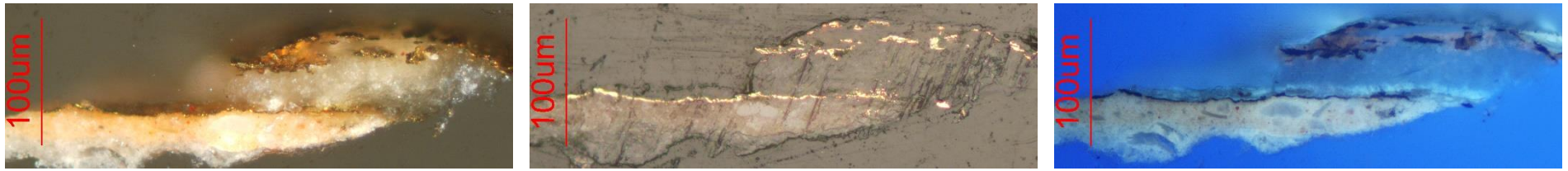


Figure V.18: S13 (16.V0016.RF) as area of gilding sample shows no paint layer. Has a white ground and yellowish bole. The gilding is gold leaf as seen in the Polarized image, appears as a thing single line. Over the previous varnish (visible in UV), gilding retouching is present. This is most likely gold paint as it is not as thin as the gold leaf underneath, as well as broken up.

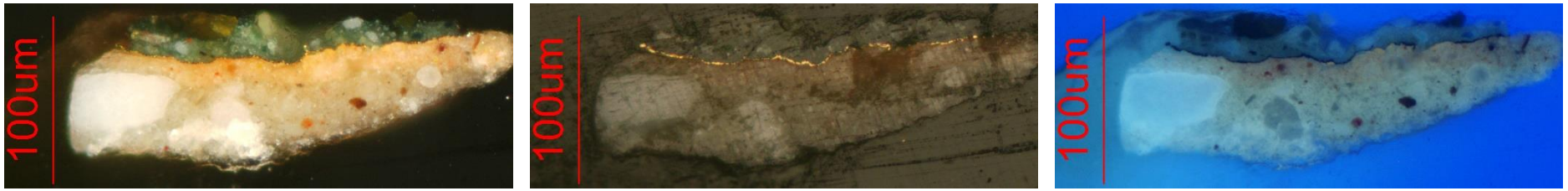


Figure V.19: S14 (08.V0016.RU) also shows white ground layer along with bole before the application of gold leaf (visible in Polarized light). Only one distinct paint layer is present which is green.

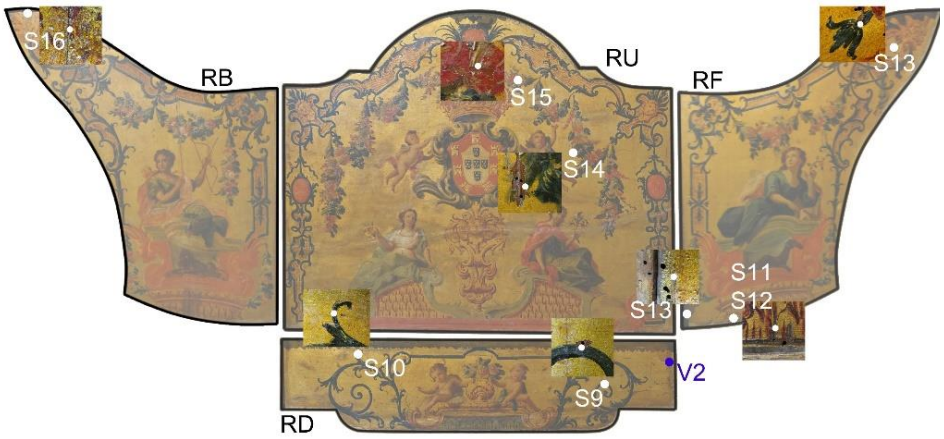


Figure V.20: Cross-section map for samples from the right side panels. The sample V2 was of varnish drip for μ-FTIR analysis

Figure V.21: Cross-section map for samples from the left side panels.

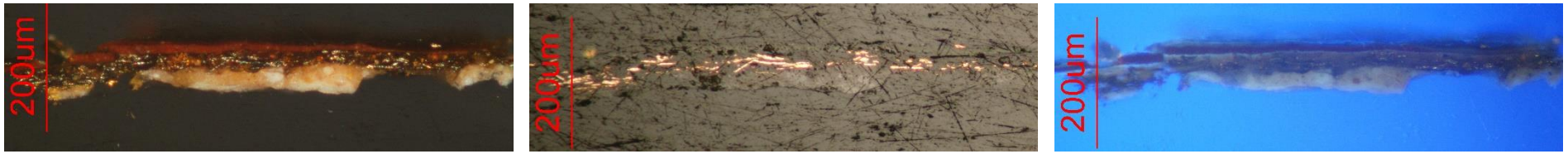


Figure V.22: S18 (12.V0016.LF) shows what may be two layers of ground, a white layer on the bottom followed by a yellowish bole. As seen in Polarized and UV images, the layer of gold (above the bole) is not gold leaf but gold paint due to its appearance. Over the gold is a red paint layer. In UV thin layer of varnish appears to be visible.

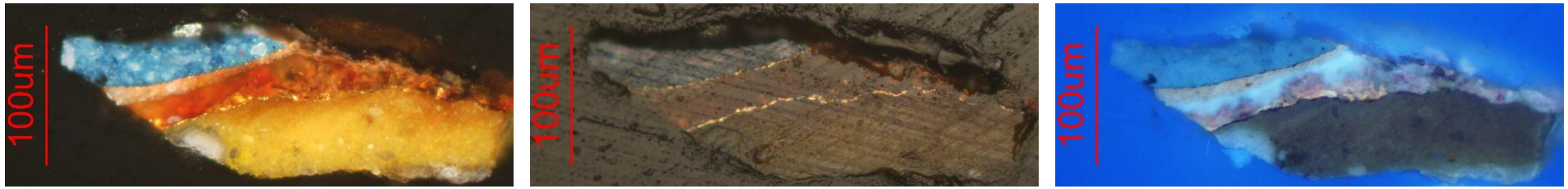


Figure V.23: S20 (15.V0016.LU) appears to have two ground layers, residues of what would be the bottom white ground layer can be seen on the bottom right, the layer above is a yellow ground. Two distinct applications of gold leaf is present (visible in polarized light), one over the yellow ground layer, the other over what may be paint layer (a red one). Above the upper gold leaf is another paint layer, this one blue. As seen in UV light, between the red paint layer and the upper gold leaf and blue paint layer is a layer of varnish. It is likely that the second gold leaf and blue paint layer are later alterations to the painting.

Figure V.24: S23 (24.V0016.LD) shows two layers of ground, the bottom layer is white followed by a yellow layer. Over the ground is a layer of gold leaf. UV image distinguishes a layer of varnish over which is either thing dark layer of grime or retouching.

Figure V.25: S25 (27.V0016.LF) also appears to have two layers of ground, the first is white and the second yellow. The gilding is also gold leaf followed by a red paint layer. UV image shows what seems to be two layers of varnish over the paint.

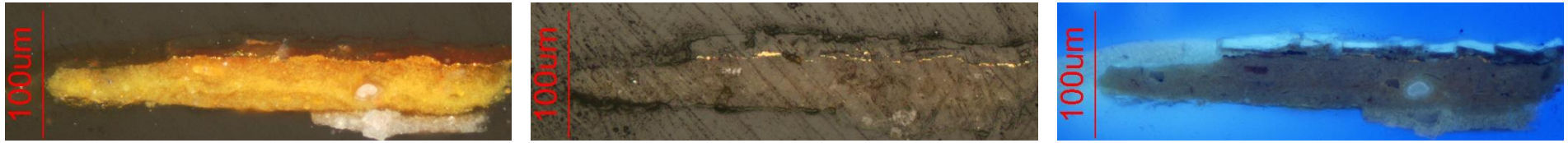


Figure V.26: S26 (29.V0016.FD) shows two layers of ground, white followed by yellow, over which is the gold leaf. Two layers of varnish appear to be visible in the UV image.

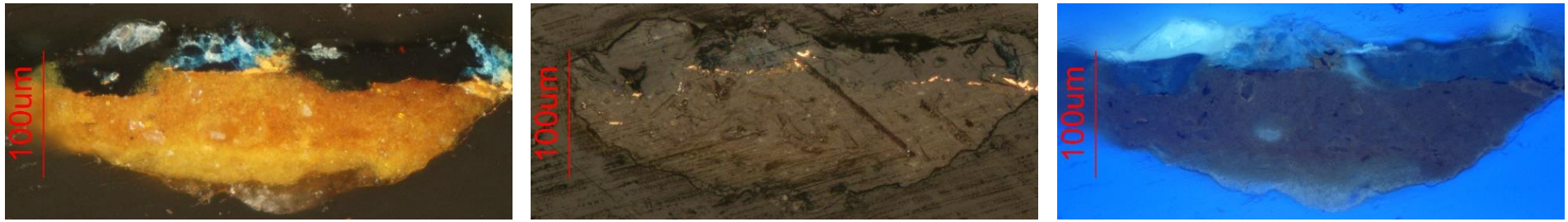


Figure V.27: S30 (32.V0016.BD) appears to have two layers of ground, the bottom is yellow while the one above is a bit of a darker yellow or orange. Presents a layer of gold leaf between the ground and the blue paint layer. UV image shows some residue of varnish.

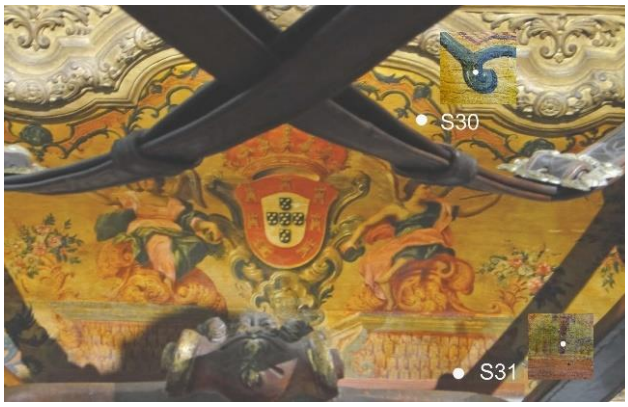


Figure V.28: Cross-section map for samples from the lower back panel.

Figure V.29: Cross-section map for samples from the lower front panel

Appendix V.4 – Elemental and Pigment Analysis

In regards to SEM-EDS analysis of the ground layers, cross-sections **S2, S3, S4, S5** and **S6** revealed the elements calcium (Ca) and lead (Pb) in the upper layer of ground. For the cross-sections containing the lower layer of ground (**S3, S5** and **S6**), lead and calcium was also present along with sulphur (S). In cross-section **S6** the layer of bole is made up of Fe, Mg, Si and Al.

SEM-EDS analysis of the paint layers revealed the elements Pb, Sb, Na, Al, Ca, Mg, Fe and Si in cross-sections **S2, S3, S4** and **S5** in with varying percentage among the elements from sample to sample. Cross-sections with yellow layer (**S3, S4** and **S5**) had higher amount of Fe. In cross-section **S6**, the gold leaf is made up of gold (Au), silver (Ag) and copper (Cu).

Table V.6: µ-Raman and SEM results of the Ground Layers from Upper Back Panel (BU).

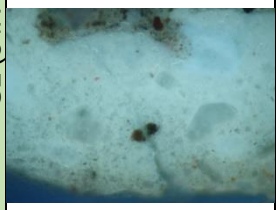
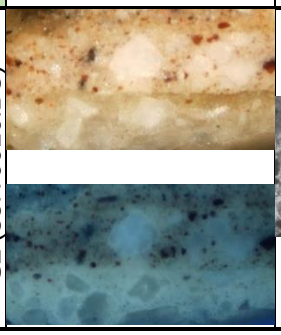
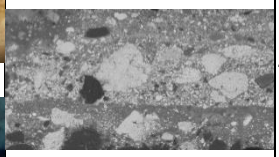
		Original Ground Layers						
		OM (NL & UV)	SEM	G.L.	SEM - EDS	µ-Raman		Identified Pigments
						Wavenumber (cm^{-3})	Assign.	
TILES	**S1** (34.V0016.BU)[1]		N.A.	2nd	N.A	1050vs	$v_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						1085vs	$v_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
				1st	N.A	1050vs	$v_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						1008vs;	$v_s(SO_4^{2-})$	Calcium Sulfate Dihydrate (Gypsum) $CaSO_4.2H_2O$
						1085vs	$v_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
	S2 (35.V0016.BU)[2]			2nd	Ca, **Pb**	1050vs	$v_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						1085vs	$v_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$

Table V.6: Continuation.

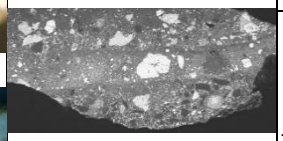
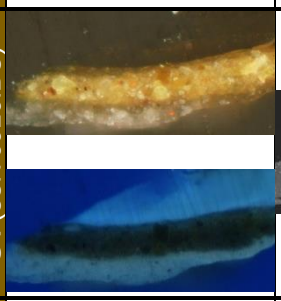
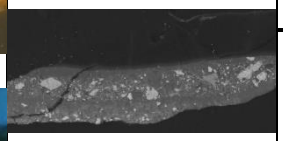
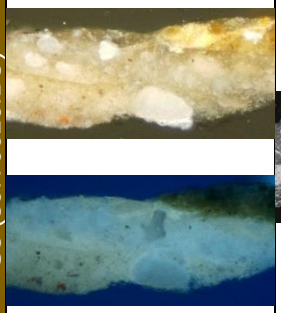
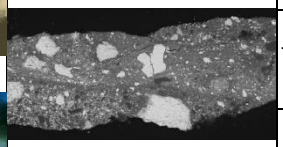
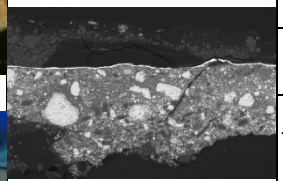
		Original Ground Layers						
		OM (NL & UV)	SEM	G.L.	SEM - EDS	μ-Raman		Identified Pigments
						Wavenumber (cm^{-3})	Assign.	
Matt Varnish Area	**S3** (37.V0016.BU)			2nd	Ca, **Pb**	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						1085vs	$\nu_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
				1st	S, **Ca,** Pb, (Mg)	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						416m; 1008vs; 1136m	- $\nu_s(SO_4^{2-})$	Calcium Sulfate Dihydrate (Gypsum) $CaSO_4.2H_2O$
						1085vs	$\nu_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
Shiny Varnish Area	**S4** (38.V0016.BU)			2nd	Ca, **Pb,** (Fe)	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						1085vs	$\nu_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
Shiny Varnish Area	**S5** (39.V0016.BU)			2n	Ca, **Pb**	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						1085vs	$\nu_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
				1st	S, **Ca,** Pb	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						416m; 1008vs; 1136m	- $\nu_s(SO_4^{2-})$	Calcium Sulfate Dihydrate (Gypsum) $CaSO_4.2H_2O$
						1085vs	$\nu_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
Gilding	**S8** (48.V0016.BU)[3]			Bole	Mg, Si, Al, Fe	299vs, 408 m	- δ_g (Fe-O)	Hematite A-FeOOH
				2n	Ca, **Pb**	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						1085vs	$\nu_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$
				1st	S **Ca** Pb	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						416m; 1008vs;1136m	- $\nu_s(SO_4^{2-})$	Calcium Sulfate Dihydrate (Gypsum) $CaSO_4.2H_2O$
						1085vs	$\nu_s(CO_3^{2-})$	Calcium Carbonate $CaCO_3$

Table V.7: μ-Raman analysis of the Paint Layers from Upper Back Panel (BU).

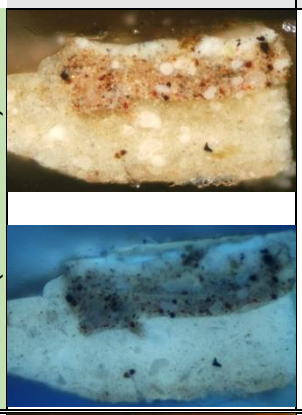
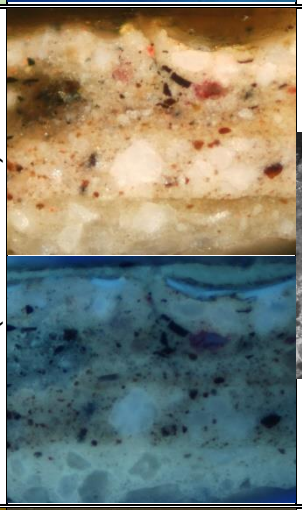
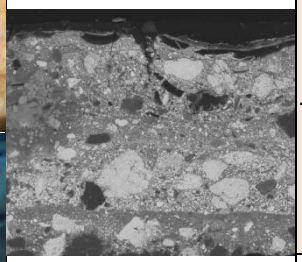
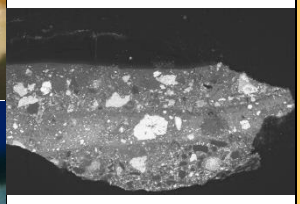
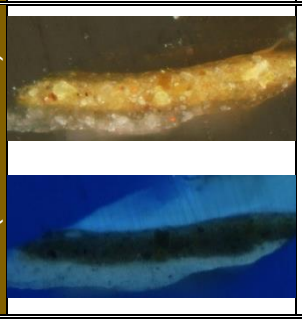
		Original Paint Layers						
		OM (NL & UV)	SEM	P.L.*	SEM-EDS	μ-Raman		Identified Pigments
						Wavenumber (cm^{-3})	Assign.	
Tiles	**S1** (34.V0016.BU)[1]		N.A.	2nd	N.A.	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
				1st	N.A.	253vs; 342m	δ(S-Hg-S) ν(Hg-S)	Vermilion HgS
						291-299vs; 409m	- δ_s(Fe-O)	Hematite α-Fe_2O_3
						1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
	S2 (35.V0016.BU)[2]			3rd	Pb, Na, Al, Ca	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
				2nd	Ca, Mg, Al, Si, P, Pb, Fe, Hg	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
						253vs; 285w; 342m	δ(S-Hg-S) ν (Hg-S)	Vermilion HgS
						408m	δ_s(Fe-O)	Hematite α-Fe_2O_3
				1st	Ca, Pb	1050vs	$\nu_s(CO_3^{2-})$	Lead White $2PbCO_3.Pb(OH)_2$
Matt Varnish Area	**S3** (37.V0016.BU)			1st	**Pb**, Sb, Fe, Si, Al, Ca, Mg, K	131vs; 294-298m; 351w; 515m	Lattice Pb-O Stretching - -	Lead (II) Antimonate (Naples Yellow) $Pb_2Sb_2O_7$
						245vw; 299m; 395s;	- δs (Fe-O)	Goetite (Yellow Ochre) α-FeOOH
Shiny Varnish Area	**S4** (38.V0016.BU)			1st	**Pb**, Fe, Ca, K, Sb, Si, Al, Mg	131vs; 294-298m; 351w; 515m	Lattice Pb-O Stretching - -	Lead (II) Antimonate (Naples Yellow) $Pb_2Sb_2O_7$
						245vw; 299m; 395s;	- δs (Fe-O)	Goetite (Yellow Ochre) α-FeOOH

Table V.7: Continuation

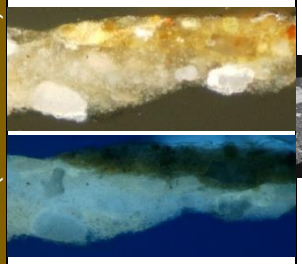
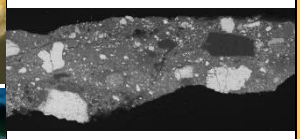
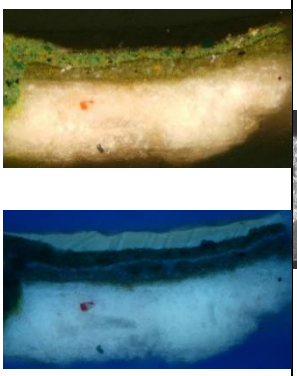
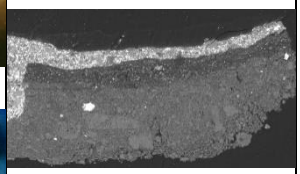
	Original Paint Layers						
	OM (NL & UV)	SEM	P.L.*	SEM-EDS	μ-Raman Wavenumber (cm^{-3})	μ-Raman Assign.	Identified Pigments
Shiny Varnish Area **S5** (39.V0016.BU)			**1st**	**Pb**, Al, Si, K, Sb, Ca, Fe, Mg	131vs; 294-298m; 351w; 515m	Lattice Pb-O Stretching - -	Lead (II) Antimonate (Naples Yellow) $Pb_2Sb_2O_7$
					131vs; 294-298m; 351w; 515m	Lattice Pb-O Stretching - -	Lead (II) Antimonate (Naples Yellow) $Pb_2Sb_2O_7$
					245vw; 299m; 395s;	- δs (Fe-O)	Goetite (Yellow Ochre) α-FeOOH

Table V.8: Raman analysis of the infill and retouching from **S7** of the Upper Back Panel (BU).

Non Original Ground Layers						
OM (NL & UV)	SEM		SEM-EDS	μ-Raman Wavenumber (cm^{-3})	μ-Raman Assign.	Identified Pigments
		**Inpainting**	**Pb**, **Ca**, Cu, Al, Si, Cr, Ba, Fe, Zn	245w; 299m; 395s	- δs (Fe-O)	Goethite (Yellow Ochre) α-FeOOH
		Inpainting	**Pb**, **Cr**, Cu, Al, Si, Ca, Ba, Fe, Zn	338w; 360s; 372m; 403w; 841vs	-	Chrome Yellow ($PbCrO_4$)
		Infill	Ca	1085vs	$V_s(CO_3^{2-})$	Calcium Carbonate (Chalk) $CaCO_3$

Appendix V.5 – μ-FTIR Spectra Analysis

Pigment analysis of green paint layer from S6 (Figure V.29)**:**

Since μ-Raman analysis of the green pigment (from **S6**) was inconclusive, despite hinting to the possible presence of green earth with the band at 145, a sample was analyzed in μ-FTIR to confirm this observation. According to the spectrum obtained from the green pigment, it was possible to identify that it was indeed a green earth. Aside from being pigment with iron (identified with μ-EDXRF in green areas of the painting) it like ochres also contains quartz (Si-O), is a silicate based mineral. Green earth as explained by Ospitali, et al (2008) is composed of octahedrally coordinated cations Al. Fe^{II}, Fe^{III} and Mg between two layers of silicate [1]. The authors also state that green earth can be made up of celadonite and/or glauconite. The most notable band present in this spectrum is that at 973 cm^{-1} which according to the authors is associated to the octahedral structure (in-plane Si-O stretching modes) of the mineral celadonite (■, in spectrum) [1]. Further comparison with their study revealed other bands attributed to celadonite present in S6's spectrum, such as: 3600 cm^{-1} and 3559 cm^{-1} the minerals O-H stretch; 3530 cm^{-1} is another O-H stretch from the mineral [1], however this band is also attributed to one of lead white's O-H stretch (see below) [2]. The

band at 1070 cm^{-1} is also attributed to the in-plane Si-O stretching modes, while the band at 839 cm^{-1} is from the minerals octahedral O-H bending modes [1].

Comparison with spectra found in *Artists' Pigments: A Handbook of Their History and Characteristics Vol. I,* the spectrum obtained for the green pigment is very similar to their spectra of green earth [3, p.159].

As can be seen in Figure V.29, other components are present, such as the pigment white lead (◇) at 1411 cm^{-1} (CO_3^{2-} stretch) and 678 cm^{-1} (CO_3^{2-}). Another white lead band could be possibly at 3532 cm^{-1} in association to it's O-H stretch, however this as seen above could be in reference to green earth's O-H stretch. Also associated to white lead is the band at 1538 cm^{-1} attributed to the COO^- asymmetric stretch from the formation of a metal carboxylate (lead soap, ○ in spectrum).

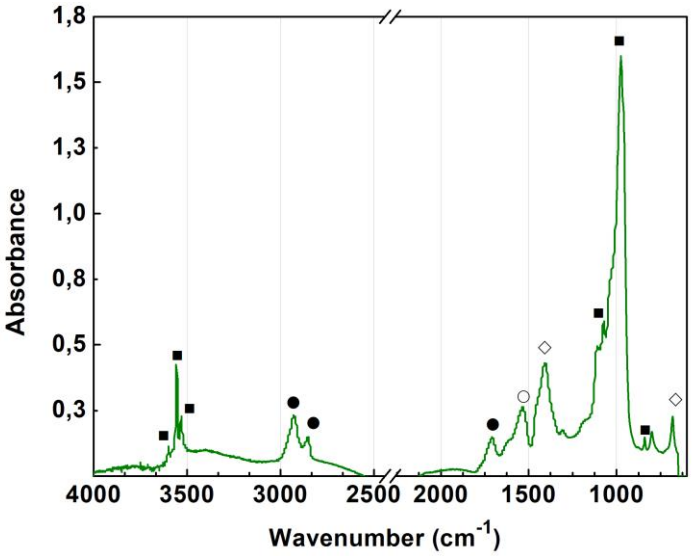


Figure V.30: μ-FTIR spectras of the green pigment

Binder (Figure V.29): The binder was identified as drying oil (• in spectrum) through the characteristic asymmetric and symmetric stretching modes of CH_2 groups at bands at 2930 cm^{-1} and at 2855 cm^{-1}, respectively. The band at 1710 cm^{-1} is a C=O stretch associated with carboxylic acid (✳ in spectrum) which is formed as oil dries. [2]

Varnish (Figure V.30)**:** μ-FTIR analysis of the Upper Back Panel's varnish revealed bands respective to natural resins. Analysis of the matt and glossy areas on the same panel presented the same spectra indicating that both areas contain the same varnish. A third comparison was done with a varnish sample from one of the side panels (RD), it's spectra was also in accordance to the previous. In other words, the varnish on all the panels on the coach is the same.

In regards to the identification of the resin used, bands from both diterpenoid and triterpenoid resins are present. The bands at 2935 cm^{-1} and 2875 cm^{-1} are the asymmetric and symmetric CH stretch for methylene groups, of which closest resembles those noted for diterpenoid resins such as rosin, sandarac and copal. Some diterpenoid resins, present another peak related to CH stretches (asymmetric or symmetric) or the methyl group, however neither of these are present in this spectrum [2].

Another band by which resins types can be differentiated is by the strong carbonyl stretch between 1715-1695 cm^{-1}. In the case of this spectrum, this band is at 1708 cm^{-1} which is characteristic of triterpenoid resins, such as mastic. Diterpenoids tend to be below 1700 cm^{-1} [2].

The remaining bands, between 1456 and 840 cm^{-1}, also belong to either diterpenoid or triterpenoid resins. The bands 1456 cm^{-1}; 1354 cm^{-1} and 1313 cm^{-1} are all C-H bending, the first belonging to that of a triterpenoid and the last two a diterpenoid. The bands 1238 cm^{-1}, 1180 cm^{-1} and 840 cm^{-1} are C-O stretching, the first of a diterpenoid and the last two of a triterpenoid [3]. The last band, about 3420 cm^{-1} is the O-H stretch, present in both types of resins [2].

With the present FTIR spectrum, it is not possible to identify the exact resin present as

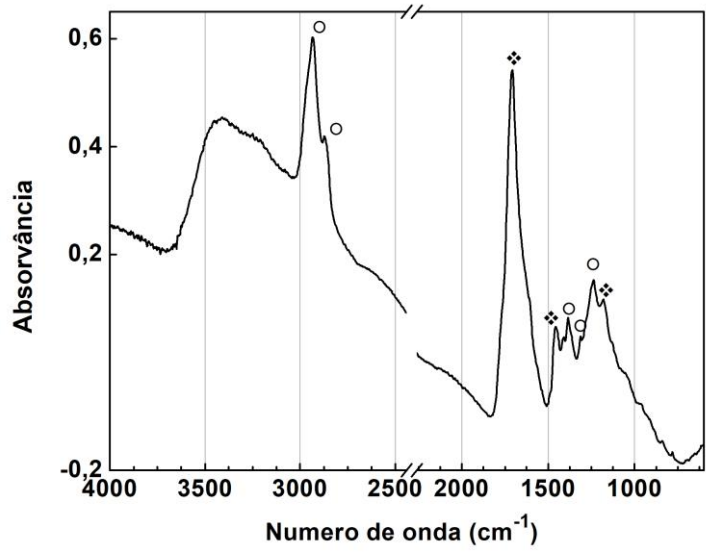


Figure V.31: Varnish spectrum of the paintings varnish, showing both diterpenoid (○) and triterpenoid (❖) resin bands.

only some bands from each family are present, the others most likely masked, mixed or overlapped by each others bands.. As seen in the UV OM images of the cross-sections two distinct varnish layers are visible, however it was not possible to separate each layer for FTIR analysis. As such, it is possible that one layer is a diterpenoid and the other a triterpenoid, or both layers are a mixture of each.

Due to the presence of diterpenoid bands, one of the resins used could have been copal as this was the most used varnish for coaches [2]. According to Carlyle (2001), some copal's were mixed with other resins, such as colophony (rosin) and sandarac, diterpenoids, or mastic a triterpenoid [4].

References used in Appendix V:

[1] Ospitali, F., Bersani, D., Di Lonardo G., & Lottici, P.P. 2008. 'Green earths': vibrational and elemental characterization of glauconites, celadonites and historical pigments. *Journal of Raman Spectroscopy*, 39: p.1066-1073.

[2] Derrick, M. R., Stulik, D., Landry, J. M. 1999. *Infrared Spectroscopy in Conservation Science, Scientific Tools for Conservation.* Los Angeles: Getty Conservation Institute.

[3] Feller, R.L. ed. 1986. *Artists' Pigments: A Handbook of their History and Characteristics*. Vol.1. Washington, DC: National Gallery of Art, Vol.1, p.141-168.

[4] Carlyle, L. 2001. The Artist's Assistant: Oil Painting Instruction Manuals and Handbooks in Britain, 1800-1900, with Reference to Selected Eighteenth-century Sources. London: Archetype Publications.

Appendix VI – Treatment

Appendix VI.1 – Wax-Resin Recipe26,27

Raúl Leite prepared the wax-resin infill with the following:

- 2 parts of Dammar Resin (with 1 part Gum Elemi) were melted together first;
- the melted resin mixture is poured into a container of Beeswax (7 parts), thereby melting it, and stirred until a homogeneous material is obtained;
- chalk and synthetic varnish (Talens Picture Varnish) can be added while stirring until the desired qualities were acquired; these ingredients were optional, to be added only when required
- the mixture is then poured out onto a flat surface to cool;
- when it is semi-solid, incisions can be made to cut it into individual pieces.

Appendix VI.2 – Commercial Product (Rembrandt Talens) vs. Laropal A81

Since the complete and precise ingredients for commercial products such as Talens Rembrandt Varnish are not indicated by the maker, conservators are unaware of what exactly is being applied to an object. Despite being convenient products, as they are premade ready for use, they have their potential consequences. In this case, the main concern is how the 'unknown' materials will react with the previous ones on the object. Negative reactions are their possible irreversibility and aiding in the acceleration of an objects degradation. Due to this, it is of utmost importance that tests be carried out prior to any intervention to verify any materials compatibility with the object, be it a commercial product or not.

Although it was decided to apply a commercial varnish on the painting's varnish to resaturate the matt areas, this wasn't considered to present future problems as solubility tests showed the two have different sensitivities, indicating the Talens Rembrandt Varnish could be removed without affecting the current varnish. However, the main concern is not with the paintings varnish, but with its paint layers. As the painting is completely varnished, this commercial varnish was not going to be directly on any layers of paint.

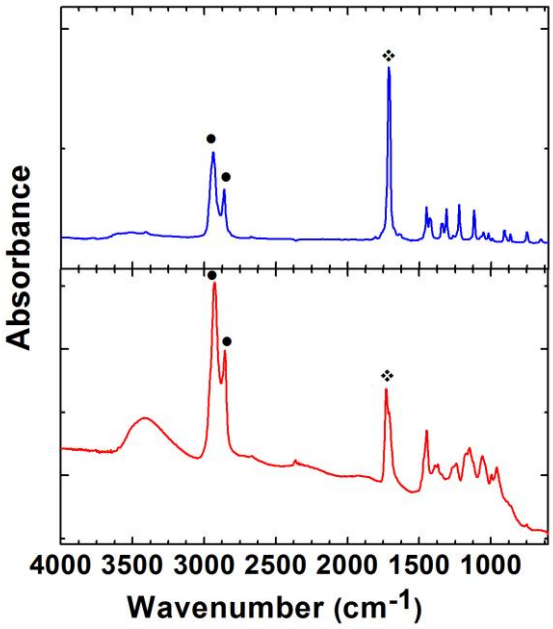


Figure VI.1: FTIR spectras of Rembrandt Talens (red) and cyclohexanone (blue).

In order to understand what some of the Talens Rembrandt Varnish's components might be it was analyzed with μ-FTIR along with the other product used (Laropal A81 an urea-aldehyde resin) [2]. Comparison of both spectras showed that the commercial varnish used does not contain the same resin, Laropal A81. According to Horie (2010) and *Painting Conservation Catalog*, Talens Rembrandt Varnish is composed of a cyclohexanone, a Ketone resin [1,2]. Over time the formulation has varied yet remained a cyclohexanone in its base [1]. The latest one to be used as its base resin is Laropal K80 [1]. Rembrandt's spectrum shows some similarity between that of a Laropal K80, however in order to confirm the use of a cyclohexanone a sample was also analyzed as can be seen in Figure VI.1. According to Professor Maria João, the presence of cyclohexanone cannot be confirmed as Rembrant Talens Varnish C=O stretch (❖) and C-H stretches (•) do not match [3]. The deviation of the C=O stretch, 1705 cm^{-1} for cyclohexanone and 1730 cm^{-1} in the varnishes spectrum, could be a result of the auto-oxidation of the varnish as explained by some authors [4]. In regards to its C-H stretches, as explained by Professor Maria João, these appear to be similar to that of an oil's in regards to the different relation between the C-H and C=O bands between both spectras [3]. As seen in the commercial varnish, the C-H stretches are more intense than the C=O where as in the cyclohexanone it is reversed. According to literature, previous tests have shown that castor oil was used as a plasticizer in

[26] Filipe, E. and Murta, A. 2009. The use of Wax-Resin in Conservation Treatments of Gilded Surfaces. *E_Conservation,* 11: 83-93

[27] In Filipe's and Murta's recipe elemi gum, chalk and varnish aren't mentioned, however their recipe is just a base. Some conservators, such as Raúl Leite, add other materials in order to achieve specific qualities.

previous formulations [1], which may explain why the bands are similar to oil. Horie (2010) also indicates that cyclohexanone resins, such as Laropal K80, are the product of a cyclohexanone or methyl-cyclohexanone with a catalyst such as formaldehyde [2, p.182]. The reaction of formaldehyde in the creation of the resin may be a reason as to why it does not appear similar to a cyclohexanone in FTIR, or the fact it was with methyl-cyclohexanone instead [2,4]. To better identify the exact substances in the commercial varnish GC-MS analysis is necessary.

If the varnish applied is indeed a cyclohexanone product, a Ketone Resin, a downside to its use is the fact it is said to become insoluble and yellow over time as stated by Horie (2010) [2]

References:

[1] Samet, W. ed. 1998. Painting Conservation Catalog: Varnishes and Surface Coatings. Volume 1. Paintings Specialty Group of the American Institute for Conservation.
[2] Horie, C. V. 2010. *Materials for Conservation: Organic Consolidants, Adhesives and Coatings*, 2nd ed. Oxford: Butterworth-Heinemann.
[3] Personal Communication (March 6 2017) Professor Maria João Director of the Conservation and Restoration Department at the University of Lisbon.
[4] Doménech-Carbó M.T., et al. 2008. Study of ageing of ketone resins used as picture varnished by FTIR spectroscopy, UV-Vis spectrophotometry, atomic force microscopy and scanning electron microscopy X-ray microanalysis in *Anal Bioanal Chem*

Appendix VI.3 – During Treatment Photographs

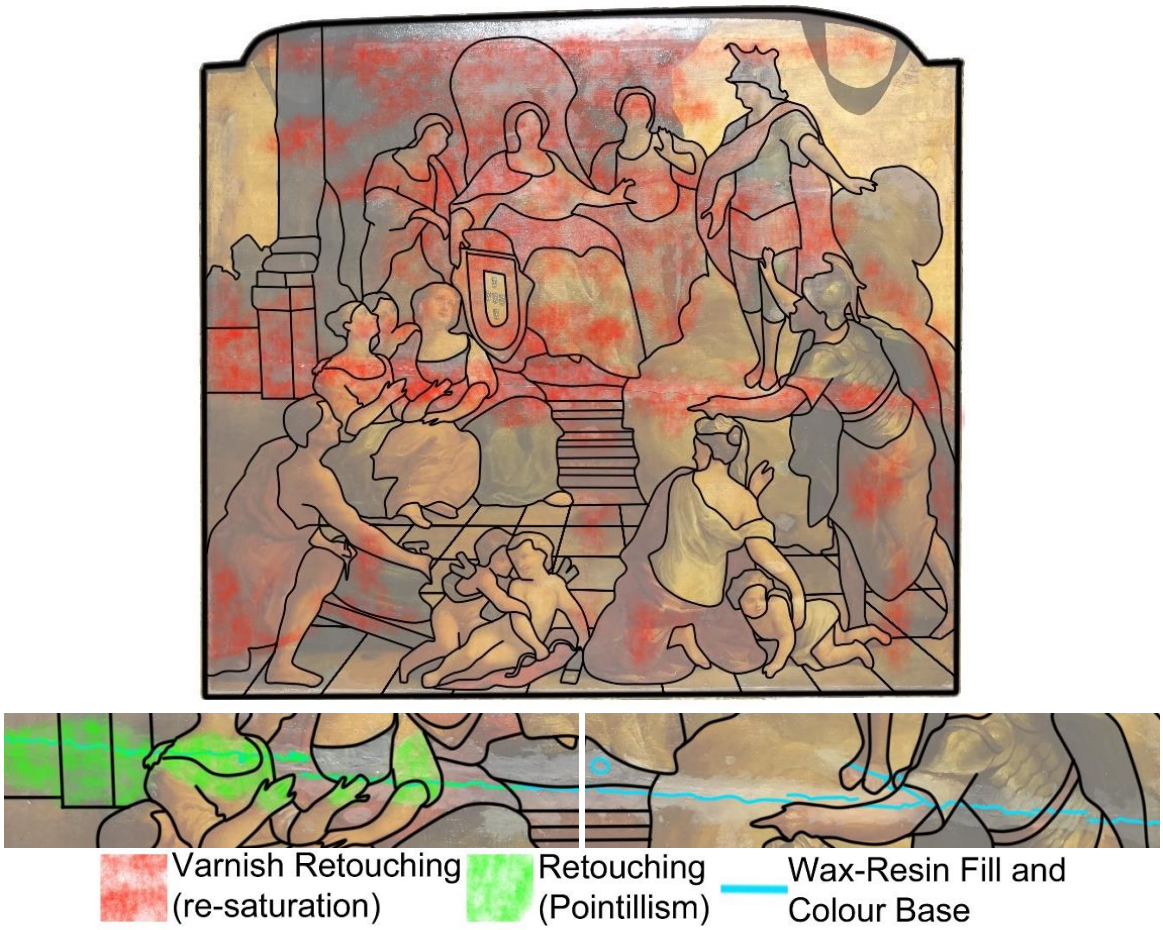


Fig. VI.2: Maps of the treatment done during this project.

VI.3: Result and appearance of the painting after the varnishing. The varnish was applied after the wax-fill.

Figure VI.4: Crack in previous infill after being filled with the wax-resin and varnished with isolating varnish, including resaturation of previous retouching (compare with before treatment images).

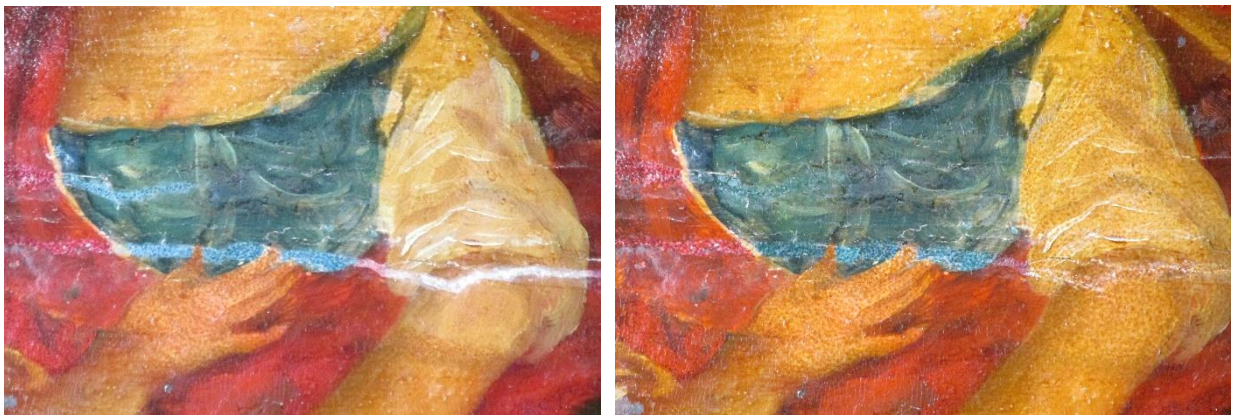


Figure VI.5: Various stages of retouching – base colour and beginning of pointillism retouching (left); the final pointillism with the imitative varnish pointillism glaze (right).


Figure VI.6: Details of glaze pointillism from Figure VI.5. In these two cases the pointillism was done over the previous retouching to give a final tone similar to that of the overall varnish.

Appendix VII – After Treatment Photographs

Figure VII.1 Overall appearance of the Upper Back Panel after the treatment undertaken up until July 2016 when only the left half of the previous fill has been completed (compare with treatment map above).

Figure VII.2: Detail of join retouching to where it has been done (July 2016).