The wooden gilded and polychrome Baroque altarpieces and ceilings of Portuguese churches offer a unique opportunity to study the relationship between historical documentary sources and physical evidence from surviving pieces. This project involved three elements. First, researching the archives surviving from the 17th and 18th Centuries - primarily ecclesiastic account books and contracts - made between the Portuguese Church and the artists they employed...

Isabel Pombo Cardoso

18th Century church altarpieces in the Algarve, Portugal: A comparison of the historical documents to the results of the microscopical analysis
These reveal the pigments and other materials used in the decoration. The second concentrated on extensive analysis of paint samples from art objects. Finally, comparison of these, together with supplementary research on trade, economy, society, geology and pharmacology of the period, which looks to achieve significant new understanding of artists’ practices and palettes, the relationship between artists and allied artisans, trade patterns of pigments, and the chemical identity of terms used historically.

**Drawing on two extant financial accounts for a group of altarpieces in the Algarve, this article explores the comparative interpretation of the historical record and analytical results from various forms of microscopy on samples taken from the paintings. In particular, questions of interpretation of historical terminology will be discussed, as well as issues connected with the structure of workshops employed to carry out commissions and the supply of materials used for them. The possible impact of political and socioeconomic changes in the period will also be considered.**

**Historical Background**

The richly decorated interiors of the churches of this period are a consequence of the Counterreformation in Portugal. The manner of their actual construction however, is closely tied to political and economic circumstances of the period. These ceilings and altarpieces, as integral components of a decorative formula for interior spaces, were created during the 17th and 18th Centuries, mainly between 1650 and 1740. In terms of decorative arts, this period corresponds to the first phase of the Baroque in Portugal, where this emergent style exhibited peculiar national characteristics. This artistic style started experimentally in the late 16th Century, flourished during the following century, losing its dominance when the country began receiving Italian influences again around 1735. It survived until the end of the 18th Century owing mainly to the strength of traditional and regional influences. The ‘National Baroque’, as it is known, was strongly subject to regional and vernacular adaptations and influences.

The merger of the Portuguese and Spanish crowns under Spanish control (1580-1640) and consequent warfare and socio-economic upheaval (1640-1668) led to the isolation of the country from foreign influences. During this period - in contrast to the previous centuries when, owing to maritime expansion, Portugal was one of the most active and influential countries in Europe - a decline in various spheres, including the artistic, is noticeable, especially when compared with Spain, then living its Golden Age. Curiously, this decline did not affect the decorative arts. On the contrary, it is possible to grasp the emergence of something which is known, in Portuguese historiography, as the ‘National Baroque Compact’: one of the most interesting and rich artistic expressions in Portuguese history (‘compact’ in this case refers to the comprehensive unity of the decoration). This development, just recently appreciated by art historians, occurred in the country as well as the colonies – e.g. Brazil and India.

This style rapidly became dominant as it allied two important elements: a spectacular final result combined with a relatively low cost. Although this latter may seem surprising, these works were in fact made by an evolving group of ‘painter/gilders’, who had a lower professional status, and consequently cost less, than canvas painters. Canvas painters, so sought after during the previous artistic period, Mannerism, when their paintings were the central element of the altarpieces, started to have difficult times. Additionally, contemporary contracts indicate that
the painter/gilders frequently gilded and painted not only the altarpieces, as they had done in previous periods, but also ceilings, columns, arches, choirs and even, occasionally, tiles.

Methodology

Documentation
The starting point for the documentary research was the ecclesiastic account books and contracts. These occasionally refer to the materials used to decorate altarpieces and ceilings and their prices, the quality, quantity and provenance of material purchased for a specific work, as well as practices used in the execution of individual features. Contracts and account books could also provide some important information about the artists, their organisation, and other social groups involved.

The core examples discussed here are two published account book documents, listing payments made to purchase different materials used in the polychromy and gilding of the two surviving altarpieces from the south of Portugal (Algarve): Santa Teresa altarpiece from the Nossa Senhora do Carmo Church, and Nossa Senhora do Rossário altarpiece from the Faro Cathedral. The document related to the Santa Teresa altarpiece provides information about the name of the materials (gold, different pigments, different gessos, oil, eggs, water, coal, etc) and the prices paid, the total salary paid to the artists and finally, two interesting references to money paid to a merchant and the source of the material used to produce the size glue, Lisbon. The second list is less detailed concerning materials, although it gives more information about the artists involved in this decoration work, specifically their names, their professional grade and differences in salaries.

Additionally, other contemporary documentation is being studied, including painting treatises, anonymous recipes, dictionaries, economic reports, pharmacopoeias and travel descriptions. This is crucial in understanding different aspects of the research, since they refer to various aspects of materials, technology, practices, terminology or social groups involved in the process of decorating these objects. Some other material evidence is also being examined: a series of ceramic containers; brushes and chunks of pigments used to paint a church in 1700, and a private company that still produces and extracts pigments apparently using traditional techniques and sources.

Analytical Methodology
Samples from the churches are being extensively analysed in order to identify the materials present, find indications of production technology, explore painting practices, detect possible forms of physical and chemical ageing and determine the provenance of materials. Polarised Light Microscopy (PLM), Raman Spectroscopy, and Scanning Electron Microscopy with Energy Dispersive spectrometer (SEM-EDX) are the core techniques used, along with others that may be suitable depending on the sample and on the research question. The techniques were selected because each one provides unique and complementary information.

Comparison of results
Since the altarpieces are very similar it is readily possible to establish important points of comparison.

How they are constructed
The altarpieces are made of carved wood which is then gilded and painted. The wood is first prepared by applying several layers of a white inert material (gesso) mixed with animal glue (size). Next, several layers of a very fine coloured material (bolus) are applied. At this point the surface is ready for paint or gilding. Grounds can have several layers of a coarse gesso on top of which are applied several layers of a fine gesso, or be just single-structured grounds. These grounds may be modified with additional layers that create other effects, such as lightening some colours.
The workshops

The group of ‘artists’ that usually decorated the altarpieces were the gilders (also known as ‘tempera painters’). Gilders were not considered to be artists, but rather ‘mechanical’ craftspeople; in practice this meant that they had to submit to a Guild. The Guilds and workshops had a very rigid structure with strong roots dating from medieval times and were run by a master. In the shop there were usually two or three assistants and an apprentice. The apprentices learned in a workshop for four to six years, and had to pay the master, who in turn was obliged to teach them their craft. After these years of learning they could take a practical exam in front of a jury – composed of masters of the same profession. If approved, the apprentice could then ask for a license from the city council conferring a right to practice; at this point they were the equals of other masters. The gilders had to be good at their craft, and their work had to be perfect. The novice had to be able to execute a piece of work that the master could carry out in just a few days. Thus the masters were very strict in selecting their apprentices and were very satisfied with the work they did. The gilders were divided into different ‘degrees’, each with its own specific work. The lowest degree was that of ‘painter’, followed by ‘distructor’, ‘plater’, and finally the degree of ‘master’. The gilders were subject to a strict Guild structure and were allowed to work only in their own workshops. The workshops were the usual place of residence of the masters, who did not have a regular income and were often in financial difficulties. In these workshops the masters usually had only a few assistants and a few apprentices who worked for them. The workshops were the usual place of residence of the masters, who did not have a regular income and were often in financial difficulties. In these workshops the masters usually had only a few assistants and a few apprentices who worked for them.
stage the apprentice becomes an assistant. This rigid organisation aimed to protect the interests of the craft. In practice, it preserved and imparted the craft’s traditions at the same time.

There was also a fair mobility of artists between Portugal and Italy and Spain. Traditionally Portuguese artists went to those countries to learn with scholarships; some important Italian and Spanish artists went to Portugal during the 15th and 16th Centuries, attracted by the lively cultural and economic environment. Mobility was also influenced by the 60 years of Spanish control and the natural proximity of the two countries.

**Studies**

The studies presented here are still in progress, but already reveal special insights.

**Gesso layers**

**Information from the documentation**

The contracts made between the artists and the Church mostly inform us of the gold used and its quality, but they also often refer to the preparation layers. Specifications include the materials, the required quality, the number of layers, the final quality of the work of art, and the artist who is to prepare it; all aimed at durability, and thus high quality, of the gilding and polychromy. It is clear from the documentation, that the ground was considered a very important phase of the gilding and painting work. These texts also reveal that the people involved in the process knew the technical advantages of a good ground, with the use of several layers of gesso grosso (coarse gesso), several layers of gesso mate (fine gesso) and several layers of bolus, this ideally making a total of fifteen layers overall.

The account book documents give information about the materials used, prices (sometimes giving purchased quantity) and occasionally the provenance of the gesso. With documentation such as this, it is possible to confirm the information contained in the contracts about using different gessos. Additionally we learn that gesso mate is much more expensive than gesso grosso, and about quantities purchased and the great variation in prices. This price variation might be related to the provenance of material or to the amount purchased, however to reach correct conclusions it will be necessary to examine additional documentation. Furthermore, it is possible to observe not only differences in pay due to career
grade (master, assistant and apprentice), but also within the same grade, the latter probably due to differences in experience as well as skill.

The studied treatises’, testament to the tradition of a double-structured ground of gesso grosso and gesso mate, differ in their opinion of the number of layers that make a good gilding ground. Additionally, they point to gesso grosso being produced by burning natural gypsum and gesso mate by slaking gesso grosso in water for several days.

**Information from the analytical work**

Examination of the dispersions, under PLM, from the Algarve altarpieces showed the presence of gypsum (CaSO₄.2H₂O) and anhydrite (CaSO₄). Particles differed greatly in size, which might indicate the existence of gesso grosso and gesso mate. The SEM analysis revealed that all the altarpieces had a twin-layered ground, both of calcium sulfate, but having clear differences of particle size and shape. EDX analysis of the trace elements was particularly interesting, the Algarve samples consistently revealing the same trace elements: silicon, aluminium and magnesium.

These results might indicate that artists from the same region were using gesso from the same source. These primary results will be used for the future LA-ICP-MS comparative analysis of works from the different regions, and will be compared to reference samples hoping to trace the provenance of the gesso.

Water molecules are known to be significant in the structure of gypsum (calcium sulfate) molecules; therefore their removal represents a change in the hydration levels as well as in its structure. Raman Spectroscopy can distinguish structural changes as well as dehydration in minerals, and it is therefore able to distinguish the different hydration phases of calcium sulfate. In fact, the Raman analysis revealed anhydrite (anhydrous calcium sulfate, CaSO₄) in the lower layers of the gesso and gypsum (calcium sulfate with two water molecules, CaSO₄.2H₂O) in the upper layers. This information, when related to the other analytical results, points to a hypothesis subsequently clarified by the additional documentary sources and literature review: that the gesso grosso is anhydrite and the gesso mate, gypsum.

**Discussion of the results**

**Materials and Painting Practices**

There is agreement between the different documentary sources and analytical results: anhydrite and gypsum were used to produce a double-structured gesso ground. Materials and practices are identical for all the studied works from Algarve with no difference between workshops. Note here that the apprenticeship structure ensured traditions were passed on and thus preserved. The use of these two products and the way they were applied seems to be a well established tradition within Portugal. This is reinforced by all the written sources, which, in addition to describing materials and practices, refer to the two key reasons for using these: the quality and durability of the final work. Other practical reasons for the use of the gesso grosso should be mentioned. Gesso grosso is coarse, with uneven particles, and is a cheaper and of lower quality gesso. Its application is also cheaper as the large particles more easily fill the irregularities of the wood.

**Function of the material and layers**

The documentation mentions the importance of double-structured gesso grounds, good adhesive, and a number of successively finer layers of material - the last being bolus - relating to the quality of the gilding. The ground layers seek to provide a very smooth surface for gold leaf so that it can reflect light without scattering.

The other function of the ground layers relates to the durability of the gilding. Using several layers of the two different gesso materials mitigates the
The greater amount of the natural polymer results in greater flexibility of the gesso grosso layers, which can therefore better accommodate the natural movements of wood without cracking and are thus stronger.

destructive effect of the natural movement of the wood. This was clearly understood as the documentation, which frequently demands the use of the two gessos, implies. Greater durability can be explained by the physical properties of the gessos and the physical and chemical property of the glue.

Production technology of the gessos

How were they produced and were natural products used? The literature always refers to the use of gypsum transformed into one of its derivatives, bassanite (\(\text{CaSO}_4\cdot\frac{1}{2}\text{H}_2\text{O}\)), commonly known as plaster of Paris. This means that the natural gypsum is historically described as a product that is burned, in kilns, with the objective of obtaining plaster of Paris, due to its setting property when remixed with water. There is also a common confusion as the name plaster is used both for gypsum (a calcium sulfate product) and for lime plaster (a calcium carbonate product).

Natural gypsum, processed gypsum, bassanite, and anhydrite are all calcium sulfate products in different hydration phases. Burning natural gypsum at different temperatures gradually produces: bassanite \(\text{(CaSO}_4\cdot\frac{1}{2}\text{H}_2\text{O})\) the hemihydrate phase (by losing 1.5 water molecules) – around 130°C; soluble anhydrite \(\text{(CaSO}_4)\) by losing the remaining half water molecule (the soluble anhydrite which easily regains water molecules and still has setting ability) - below 300°C; and insoluble anhydrite \(\text{(CaSO}_4)\), which has lost the setting properties but maintains the ability of regaining the water molecules if soaked for a long time in water – below 600°C.

The hydration of the anhydrite makes it regain the two lost water molecules and return to gypsum, but now called processed gypsum. The main difference between plaster of Paris (bassanite) and processed gypsum and anhydrite is the setting characteristic. Bassanite mixed with water sets very quickly (about 15 minutes) and becomes a hard material. Both insoluble anhydrite and processed gypsum have mostly lost that setting ability. Production of processed gypsum and anhydrite used in Portuguese grounds probably followed this pattern. Natural gypsum is burnt to produce insoluble anhydrite (between 300°C and 600°C), which is then ground and used for the first layers – gesso grosso. Additionally the burning process makes the calcium sulfate easy to grind.

Gesso grosso is in turn used to produce processed gypsum by being soaked in water and beaten for a period that varies, depending on the author of the treatises, from ten to thirty days, resulting in a finer and purified material, gesso mate. No literature is known that refers to the burning of gypsum with the aim of obtaining the two products - processed gypsum and anhydrite. The occurrence of anhydrite is always considered to be an accident resultant from the over-burning of the hemihydrate phase.
due to poor temperature control in the primitive gypsum kilns. However, I consider it very implausible that the production of anhydrite would not be a conscious process, bearing in mind the extensive use of this material in Portugal and therefore the existence of a demand for it.

Foreign influences on the painting practices

The literature review indicates a division between the traditions of Southern and Northern Europe. These studies particularly refer to the use of gypsum in Southern Europe due to the availability of gypsum in the South of Europe. The North of Europe used calcium carbonate as a result of its ready availability. Portugal followed the Southern tradition using anhydrite for the gesso grosso and processed gypsum for the gesso mate. Curiously, information provided by the two main producers and sellers of calcium carbonate and calcium sulfate in Portugal (SIVAL, S.A. and Comital, S.A.), indicates the scarcity and poor quality of calcium sulfate in Portugal, especially when contrasted with the quantity and quality of calcium carbonate in Portugal.

In contrast to other countries in Southern Europe, Portugal, apparently, does not have generous supplies of gypsum. This fact might indicate that the tradition received from Spain and Italy, both with good supplies of gypsum, was more important than the availability of the material in Portugal. However, calcium sulfate extraction might have been enough for the national needs. Documents and historical information is being searched in order to re-evaluate this anomaly.

Economic framework of production and trade

The primary documentation shows that some artists were buying the two types of gessos already prepared. So these materials might have been prepared by manufacturers or the vendors. The treatises, though, seem to indicate that gesso mate was made by the artists themselves. This apparent contradiction might indicate that all knew how to produce the gesso mate but just manufacturers or vendors knew how to burn natural gypsum (none of the treatises refers to how to produce gesso grosso). Some documents just refer to the purchase of gesso (with no reference to type). This might be an indication of the purchase of gesso grosso.
Sometimes simply referred as gesso, which would afterwards be transformed in gesso mate by the artists. This subject needs further study.

The account book from N. Srª. do Carmo church refers to retalhos (parchment clippings) coming from Lisbon and payments to a merchant for his trips. It is possible to infer, from this and other primary documentation, that merchants played an important role in the distribution of some of the painting products. Both treatises and primary documentation refer to the production and to the purchase of retalhos, which seems to indicate that the retalhos size was produced by the artists. This hypothesis is plausible because retalhos size, an organic product, tends to deteriorate fairly quickly.

As different historical studies of works of art from this time indicate clear southern stylistic influences it is likely that the same influences affected materials and painting practices. The study of the gesso layer points to the idea that the workshops all chose to use the same materials and the same techniques resulting from the southern tradition (due to the mobility of the artists between the southern countries). The rigidity of the guild structure and the way knowledge was transferred within it seemed to contribute to conservatism in materials and techniques.
It is important to note the fact that Portugal is a Catholic country and therefore received strong influences from other Catholic countries, mainly guidelines from Rome. Moreover, during this period, the 'fight' between Catholics and Protestants was particularly intense.

**White intermediate layer**

One of the documents refers to the purchase of coarse lead white and fine lead white. The former is cheaper than the latter. The altarpieces are mainly gilded with just some polychrome – e.g. flesh and draperies. PLM and SEM of two altarpieces showed the presence of a white layer in flesh paint samples. This layer is always on top of the bolus and under the flesh colour. Analysis showed it to be coarse particles of white lead mixed with calcite. Therefore, what was called 'coarse lead white' is in fact a mixture of lead white with calcite – a cheap material. The interesting question now is to know who was making this mixture: the artists the producers or the sellers?

The application of this layer only in some areas could evidence the use of a cheap material to block the reddish bolus and receive bright colours. Finding this layer seems to indicate a practice but as it was detected in just two of the nine studied...
artworks its justification will only be understood after examining other samples. It is also possible that the calcite was used as an extender and this produced a cheaper, lower quality, lead white. It was also common to obtain different qualities of lead white during its production, the lower quality one (coarser) being used for this function.

Rom and maquim
One of the documents refers to the purchase of two pigments, rom and maquim, that present interesting questions. Portugal’s isolation and strong relations with the colonies are important realities that certainly influenced the history of these decorations.

The case of maquim (a lead tin yellow pigment) is interesting because this pigment was abandoned in Europe in the early 17th Century, substituted by Naples yellow (lead antimony oxide). However, several documents from the end of the 18th Century still refer the purchase of maquim. A possible explanation of a later abandonment of this pigment can be Portugal’s natural isolation as a peripheral country and a forced one given its war with Spain. This could have created ‘pocket’ areas within Portugal where this pigment was still used.

The case of rom, seems to correspond also to a particularity of Portuguese history – the maritime expansion and cultural and commercial relations with foreign countries - an adaptation of a material that was used in India. So far no foreign references to this material have been found. Portuguese dictionaries briefly describe it as being yellow with Indian provenance. The aim is to find this pigment (as indicated by the documentation) on artworks in order to characterize it and understand if it is a known pigment with a different terminology elsewhere, or conversely, if it is an unusual pigment which should then be fully characterised.

Conclusion
This research has so far had new and interesting results. For example: the conscious choice of materials can be scientifically explained; the influences of the social structure of the guilds on the use of materials, practices and learning processes; the dichotomy of foreign influences and isolation of Portugal; and the questions related to terminology, unknown materials and adaptations of materials imported from the colonies. The aim is to obtain a comprehensive and global piece of work that could clarify issues related to materials, practices, production, trade, provenance, and terminology of these Portuguese artworks and to integrate the results within its singular historical context and to determine similarities with or particularities from other foreign regions.

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