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Gilding in Spanish panel painting from the fifteenth and early sixteenth centuries

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ABSTRACT
Pure gold is a soft, malleable, and ductile metal. These characteristics allow it to be hammered into thin leaves and applied to other surfaces, a process known as gilding. This study examines the gilding techniques used in Spanish panel and retable painting from the fifteenth to early sixteenth century, considering gold's intrinsic value and symbolism as well as its role as a painting material. First, historical references and laboratory analyses of panel paintings will be compared and interpreted; second, important technical aspects of gold leaf will be discussed, including its composition and possible origin, its thickness and size, its price, and the different poliments and modes of adhesion used to apply it to the substrate.

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Introduction

Gold is the most precious metal in existence and it has long maintained an important symbolic and social significance:[1] its incorruptibility and luminosity have expressed the perfection of the supernatural and the divine. Because of its rarity and durability, it has served as a monetary standard and a means of hoarding wealth; and its expense has enhanced the status of individuals through its display in the form of jewellery or other precious objects. Gold has proven to be particularly valuable in the production of works of art due to its capacity to convey sumptuousness and reflect light. It is soft, malleable, and ductile – characteristics that have allowed it to be hammered into thin leaf for use in a variety of gilding processes since ancient times. In painting techniques gilding was used on retables and panels, in the illumination of manuscripts, in mural decoration, and in polychrome sculpture. In Spanish retable and panel painting of the fifteenth and sixteenth centuries, gold leaf was applied to articulate or to highlight architectural elements, frames, backgrounds, halos, rays of light, drapery, hair, and other details. Gilding was a very complex technical process, and workshop practices were determined not only by aesthetics and symbolism, but also by economic factors. The availability of gold and resulting price fluctuations directly affected the practice of gilding, which could account for one-third or

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[1]Tatarkiewicz, *Historia de la estética*, 39–41.

Figure 1. A sixteenth-century goldbeater's workshop. Woodcut from Jost Amman's *Panoplia* (Frankfurt: Sigmund Feierabend, 1568).

even one-half of the total cost of a panel or retable. Fine gold needed to be hammered into very thin leaf before gilding, a laborious operation carried out by skilled artisans known as goldbeaters (Figure 1).[2]

Covering a surface with this noblest of metals had an important symbolic dimension: its brilliance was comparable to that of the sun and, likewise, to that of the divine. Given its scarcity and expense, the abundant use of gold could demonstrate a patron's social status. But gold was also a painting material. In the fifteenth-century *Tabula de vocabulis sinonimis*, Jehan le Begue included gold in a list of yellow pigments (*croceus*) used by painters.[3] Artists employed an array of pictorial effects to create contrast and depth, such as lustre, matt, iridescence, the combination of different shades of a particular colour, glazes, and textures. Prior to their being gilded, grounds were prepared in a variety of ways depending on the desired reflectivity (that is, whether or not the leaf was to be burnished) and chromatic effect, as coloured grounds could modify the gold's final tone.

Historical texts and laboratory analysis are the main sources of information concerning the manufacture and use of gold leaf for gilding. Among the various textual sources, extant contracts between commissioners and painters constitute one of the most important, as

[2]The Spanish term for goldbeater varied geographically and chronologically; in the Kingdom of Castile goldbeaters were typically called *batidores* (*batedores*) or *batihojas*, and in the Kingdom of Aragon *batifullas*.
[3]Merrifield, *Original Treatises*, vol. 1, 24.

they indicate how iconography, technical conditions, materials, and prices were determined.[4] Laws, ordinances, and trade documentation can prove valuable, as they may help reveal the social, professional, and economic background of gold leaf production. In addition, technical instructions from medieval and Renaissance treatises on art can be consulted for information regarding facture. However, historical texts cannot be assumed to perfectly reflect contemporary artistic praxis, given the potential for the idiosyncratic techniques of individual artists, professional secrecy, and the oral transmission of knowledge in workshops.[5] In many cases, scientific analysis can help compensate for the scarcity of detailed technical information regarding artistic materials and techniques.

The objective of the present study is to gather technical information on gilding from fifteenth- and sixteenth-century textual sources, and examine it in relation to coetaneous panel painting from Spain. These textual sources will be compared with analytical results from case studies of particular panel paintings, considering technical, economic, and aesthetic aspects. In addition to enhancing our understanding of the technology related to gilding techniques, the results of these comparative studies will help us to reinterpret present available information and raise new questions regarding the use of gold leaf in panel painting. One of the specific questions we will be investigating through these comparative studies is whether there were any noteworthy technical differences in gilding praxis in the kingdoms of Aragon and Castile.

Historical study

Pan de oro (gold leaf)

In the Iberian Peninsula, the term *pan de oro* was commonly used as early as the fourteenth century to refer to the thinnest leaves of gold used in gilding, as well as the manufacture of gold inks and filaments.[6] The use of the Spanish word *pan* (bread) can be traced to the Latin *bractea*, a thin sheet commonly made of metal, and more specifically *bractea panis*, a very thin and flat piece of bread cooked between two iron plates and used to make Eucharistic hosts and wafers.[7] It is quite possible that the thinness and flatness of this bread was associated with that of gold leaf (as well as with other metallic sheets like silver), and thus the term *pan* became widespread in Spanish artisanal jargon, replacing Latin terms like *bractea*, *folium*, and *petallum*. Spanish documentary sources indicate that the term *pan de oro* was well established at the beginning of the fourteenth century; but it is likely that it was first used a century earlier, when goldbeaters started to separate themselves from the guild of the goldsmiths.[8]

[4]There are many more surviving contracts from the Kingdom of Aragon than from the Kingdom of Castile, probably due to the better conservation of their archives.

[5]Long, *Openness, Secrecy, Authorship*, 1–15.

[6]Gold leaf was also used to decorate foods and thus bring splendour to banquets: at the wedding of Princess Beatrice of Navarre and James II, Count of La Marche, in 1406, gold leaf was acquired to gild swans, pigs, and appetisers; Serrano Larrayoz, "La consideración y el ejercicio del cocinero cortesano", 392. Gold leaf was also used in medicinal remedies, usually to fight against the plague; Fores, *Tratado útil y muy provechoso*, fol. 16.

[7]Bear in mind that the Latin term for goldbeater was *bractearius*.

[8]So far the oldest mention of a goldbeater in Spanish vernacular language comes from a 1263 document of León Cathedral, where Pedro Perez, "batedor de oro", appears amongst witnesses; Real Academia Española, Corpus Diacrónico del Español (CORDE), http://corpus.rae.es/cordenet.html (accessed 10 January 2016).

Gilding techniques

Gold is extremely malleable and may be beaten into very thin leaf measuring just a few microns. A relatively small amount of gold could thus be used to gild large surfaces, and it could also be adapted to cover three-dimensional structures such as frames, mouldings, and reliefs. Two primary techniques were used to apply gold leaf to the substrate. The first was water gilding (Figure 2), whereby leaf was applied to the substrate with a water-based adhesive, like glue or gum arabic; in these cases, the gilding

Figure 2. Detail of water gilding with burnished finish and punching decoration (halos). The Descent from the Cross, retable of San Juan, chapel of Santa Teresa, cathedral of Santo Domingo de la Calzada, *c.* 1512.

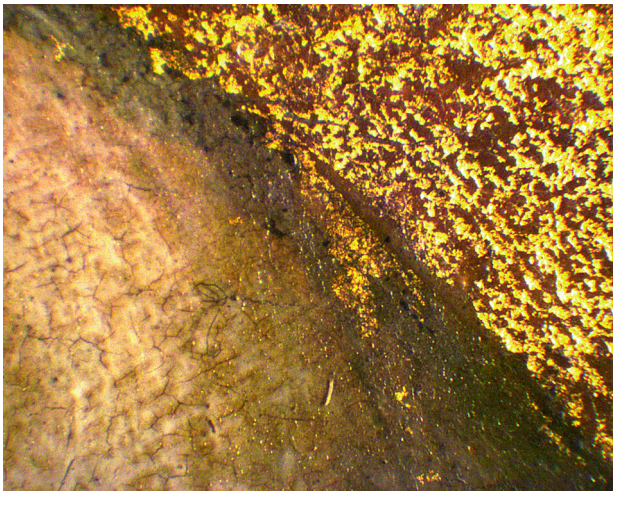

Figure 3. Detail of mordant gilding with matt finish. Nimbus of Santa Leocadia, retable of San Ildefonso, Zamora Cathedral, *c.* 1480.

could thereafter be highly burnished or left unburnished. The second was mordant gilding (Figure 3), whereby leaf was laid over an adhesive mordant, which was normally oil-based; in these cases, the gilding was left unburnished or it was slightly burnished.[9]

The selection of one technique over another depended on the desired visual effect (shiny versus matt) or preferred technical approach (water gilding was executed before painting and mordant gilding after). In both cases, before being gilded the panel surface was always carefully prepared with several layers of white gesso (gypsum, a hydrated calcium sulphate). In water gilding, a layer of bole – a reddish-brown iron-oxide clay – was also applied atop the layer of gesso. Bole served to delimit gilding areas, acted as a cushion for burnishing, and lent the gold a warmer, richer hue once it was burnished.[10] To make the gold leaf adhere to this surface, artists used natural adhesives such as animal glues, glair (egg white), and vegetable gums. Preparatory layers for water gilding could also be made from a mixture of gesso, cinnabar, glue, and other ingredients, such as lead white.[11] In mordant gilding, gold leaf was laid over an adhesive mordant, which normally was oil-based.[12] The most common mixture for this mordant was linseed oil, resin (normally sandarac resin), and a drier such as lead white, verdigris, red lead, or litharge (one of the natural mineral forms of lead oxide). Additives such as ochre, bole, or gesso could be added to give body to the mixture. Gold leaf was laid and pressed over the mordant once the required stickiness had been acquired. The *Compositiones ad tingenda*, which dates to the late eighth century, includes some of the earliest descriptions of both water and mordant gilding.[13] It specifies that in water gilding, the gold leaf was laid with glair directly over a polished layer of gesso and animal glue.[14] In its description of mordant gilding, it states that the mordant was made from a mixture of linseed oil, gum, pine resin, and saffron. This recipe is highly significant because it goes back the beginnings of mordant gilding as early as the eighth century.[15]

[9]Technical details regarding gilding and its decoration can be found in López Zamora, "Estudio de los materiales y procedimientos del dorado", 281–7; Bruquetas Galán, *Técnicas y materiales de la pintura española*, 402–3, 430–7; Alba et al., "Las prácticas artísticas de los pintores 'hispanoflamencos'", 139–40.

[10]Some recipes recommend the use of ochre (*ocrum*, *ocram*), a yellow-brown pigment, instead of bole. Merrifield, *Original Treatises*, vol. 1, 239. In medieval German sculpture there are cases where gold leaf was applied directly over the gesso layer; personal communication with Miguel Gonzalez de Quevedo Ibañez, conservator at the Liebieghaus Skulpturensammlung, Frankfurt. See also Theiss, "Ihr habt dem Mittelalter".

[11]The fifteenth-century *Liber diversarum arcium* describes a layer comprising gesso, lime, gum tragacanth, cinnabar, and glair for gilding wood. The anonymous author of another fifteenth-century recipe advises that gold leaf should be laid only over gesso and never on lime; Clarke, *Mediaeval Painters' Materials and Techniques*, 138–9. A mixture of gesso, cinnabar, and lead white was recommended for gilding on parchment in the third book of *De coloribus et artibus romanorum*, or the "Heraclius" treatise (thirteenth century), and also in the fourteenth-century *Liber de coloribus*. Merrifield, *Original Treatises*, vol. 1, 239; Thompson, "*Liber de Coloribus*", 307. Finally, the fifteenth-century "Bolognese manuscript" includes a treatise (*Segreti per colori*) that calls for gesso, cinnabar, and white lead to be mixed together with aloe juice, glair, honey, and sugar candy. Merrifield, *Original Treatises*, vol. 2, 471.

[12]Cennini notes that gold leaf could be applied over a non-oily ground with mordant characteristics, like garlic juice mixed with bole and lead white; Broecke, *Cennino Cennini*, 198. See also the treatise *Experimenta de coloribus*; Merrifield, *Original Treatises*, vol. 1, 94–5.

[13]Caffaro, *Scrivere in oro*, 100–3, 135.

[14]Sometimes in water gilding, gold leaf was laid directly on a white or coloured gesso or chalk ground. This was very common in manuscript illumination; see Nadolny, "All That's Burnished Isn't Bole", 151.

[15]Clarke, *Mediaeval Painters' Materials and Techniques*, 202.

The thickness of gold leaf

The thickness of gold leaf was crucial as it directly affected the extent of its distribution across a surface and its performance in the gilding process.[16] A few medieval treatises on artistic techniques briefly touch on this issue. Theophilus, in his eleventh- or twelfth-century treatise *De diversis artibus*, describes the process of manufacturing gold leaf and states that goldbeaters should continuously check the thickness of the leaf while beating it in order to make it "completely thin or moderately thick … according to [one's] liking".[17] The gold leaf used in panel painting would have on average a thickness of one to three microns, while a leaf twisted around silk to create gold thread could reach a thickness of ten to fifteen microns.[18] In his well-known treatise *Il libro dell'arte*, Cennino Cennini relates the relative thickness of gold leaf to the particular technique being used (water gilding or mordant gilding), and to the type of surface being gilded.[19] He outlines three categories of thickness: a relatively thick gold leaf, for gilding flat surfaces to be burnished;[20] a thinner one, used to gild frames and foliage, which better adjusts to three-dimensional details; and a very thin gold leaf used in mordant gilding, which would not be burnished and was therefore not in danger of being torn.

Coetaneous contracts from the Iberian Peninsula tend not to specify the thickness of the gold leaf that is to be used, though some refer to *fino* (fine) and *durable* (durable), terms that indicate a concern with thickness. The first term *fino* was commonly related to purity and high quality of gold. Doubts appear in the redudant use of *fino* in some texts. For example, in 1392, the painter Guillén de Leví signed a contract to paint an altarpiece for the Dominican convent at Calatayud, which specified that he was obliged to use "muyt buen oro e muyt fino" (very good and very fine gold).[21] Here either the use of adjective *fino* is redudant in order to describe the high quality of the gold or we could interpret it as "thin", as the adjective *buen* describes quality. A contract from 14 November 1404, which documents Pere Nicolau's retable for the church of San Juan Bautista (Valencia), specifies that the painter was obliged to use "fin or e durable que trobar se puxa" (the best and most durable gold that can be found).[22] Here the term *durable* should be related to the desired thickness of the gold leaf, for if it was too thin, it could become damaged during burnishing.[23]

[16]See the table entitled "Weight of gold used for the beating process and output by square meters obtained with the beaten gold leaves, according to several documentary sources", in Le Gac et al., "The Main Altarpiece of the Old Cathedral of Coimbra", 427.
[17]Theophilus, *On Divers Arts*, 30–1.
[18]Cabrera Lafuente, "Telas hispanomusulmanas", 201; González-Alonso Martínez, *Tratado del dorado*, 125.
[19]Broecke, *Cennino Cennini*, 174.
[20]Cennini uses the term *appannato* to refer to this type of gold leaf. As Broecke notes, this Italian term normally means "frosted" or "steamed up", and she translates it as "matt"; Broecke, *Cennino Cennini*, 174. While this term can indeed be used to describe tarnish, in this case it should instead be translated as "thick" because the author relates thickness to technique and surface; flat areas were normally water gilded and burnished, so in this case the term *appannato* cannot refer to matt gold. That is why Cennini considers it appropriate to obtain no more than 100 leaves from a ducat: otherwise they would be too thin. Moreover, in chapter CLXXII, which discusses gilding glass, he says that leaf should be of "ben fermo oro cioe appannato"; it is quite clear here that this term was related to thickness, and this phrase should thus be translated as "very firm gold, which is thick".
[21]Serrano y Sanz, "Documentos relativos a la pintura" (1915), 148.
[22]Tolosa, Company and Aliaga, *Documents de la pintura valenciana*, 92–5.
[23]Medieval treatises emphasize that burnishing was a delicate process and must be done very carefully so as not to damage the leaf. See e.g. the fourteenth-century *De coloribus faciendis*, in Merrifield, *Original Treatises*, vol. 1, 155.

To our knowledge, the only Iberian text that specifies using gold leaf of two different levels of thickness depending on the gilding technique is the contract Martín Bernat signed in 1493 to paint a retable for the cathedral of Zaragoza.[24] Bernat was required to use "fine gold" for the water gilding of the masonry of the retable and "very fine gold" for the mordant gilding of hair and weapons. Here the only interpretation must be in accordance with Cennini's aforementioned explanation related to the use of a thinner leaf in mordant gilding.[25]

The purity of gold leaf

Closely related to the thickness of gold leaf is its purity. In most contracts of that period it is specified that gold should be of sufficient purity, which was considered to be twenty-three karats or more (twenty-four karats being the maximum purity).[26] Normally, such purity was achieved by refining gold objects (or gold alloys) or by using gold coins. The first process is well documented in recipes to refine gold found in treatises on art technology dating back to the Leyden Greek Papyrus X codex of the third century AD and the medieval *Mappae clavicula* (tenth to twelfth century).[27] The hammering of gold coins to produce leaf for gilding is also described in several treatises on art technology, such as the *Compositiones ad tingenda* and Cennini's *Libro dell'arte*.[28]

Up until the mid-thirteenth century, either Byzantine or Islamic coins were used to make gold leaf, depending on the socioeconomic sphere of influence. The *Compositiones ad tingenda*, for instance, describes the preparation of gold leaf using Byzantine coins. Beginning in the mid-thirteenth century, the florin of Florence (1252) and the ducat of Venice (1284) became the most prestigious gold coins, because of their purity of almost twenty-four karats, with slight variations.[29] Florins and ducats are the coins that usually appear in fifteenth-century painting contracts from the territories of Aragon, Barcelona, and Valencia. In the contract for the painting of the altarpiece of San Pedro de Púbol (Girona) in 1437, the painter Bernat Martorell assumes the obligation to "gild the aforesaid retable with pure gold of Florence, or with florin from Genoa, or with gold of the same purity of the aforesaid coins".[30] Additionally, the 1487 contract for the painting of a retable at Zaragoza Cathedral explicitly requests that "the gold be good and pure, [made] from ducat".[31] The specification of these particular coins is logical given that these territories were under the commercial influence of Italy, and florins and ducats were therefore the common currencies of foreign trade. In the interior of the Iberian Peninsula, however, these foreign coins had little presence in foreign trade and were used mainly to hoard wealth. In the few fifteenth-century contracts from the Kingdom of Castile that survive, gold coins are rarely mentioned as

[24]Serrano y Sanz, "Documentos relativos a la pintura" (1914), 445.
[25]Technically it makes no sense to use gold leaf of the highest purity in mordant gilding.
[26]Twenty-three karats or more was also the lowest purity established at the ordinances of the goldbeaters' guild of the city of Cordoba (sixteenth century); in Córdoba de la Llave, "Los batihojas", 762.
[27]Córdoba de la Llave, "El mito del Dorado", 264–72.
[28]Caffaro, *Scrivere in oro*, 99–101; Broecke, *Cennino Cennini*, 174.
[29]Baldassarri et al., "X-Ray Fluorescence Analysis".
[30]"daurar lo dit retaule de fin aur de Florença o de florí genoví o d'aquell or qui bast a la lliga de la dita moneda"; Post, *A History of Spanish Painting*, 614–16.
[31]"el oro sea bueno y fino, de ducado"; Serrano y Sanz, "Documentos relativos a la pintura" (1914), 442.

sources for beating out gold leaf.[32] From the sixteenth century onwards, however, there are documented examples of Spanish and Portuguese gold coins being used for this purpose.[33]

The advantage of hammering high-quality gold coins into leaf was that there was no need to refine them. Besides, the very small amount of silver they might contain turns the alloy slightly harder and helped goldbeaters obtain thinner leaves, as pure gold is too soft for beating. But there was also a socioeconomic disadvantage, as the excessive use of these currencies could have led to the gradual demonetization of gold coins in the Spanish kingdoms.[34] Today, such a claim might seem slightly exaggerated, but during the sixteenth century it was a widespread belief. The reason was that although gold circulation increased due to a decrease in extraction costs and the discovery of new deposits in America, the international price of gold fell, causing inflation. The proposed solution was the devaluation of gold coin in order to protect foreign trade. This was precisely the moment when criticism arose regarding the use of gold coins in the production of gold leaf, on the grounds that it was harming the economy and commerce. Luis Saravia de la Calle, in his *Instrucción de mercaderes* (1544), warns against hammering coins into leaf as this practice would result in the reduction of gold coins for foreign trade.[35] We can find the same concerns in legislation: in 1537 the courts of Valladolid prohibited gilding (with some exceptions, such as for religious use), not only to avoid the comercialization of gilded objects as if were of pure gold, but also because gold was "disappearing in large amounts"; and in 1559 the courts of Toledo declared that gilding should be controlled because there were "no gold coins left in Spain".[36] It seems that from the seventeenth century onwards, the use of coins for making gold leaf progressively stopped, and other sources of gold and gold alloys were used instead.[37]

The size of gold leaf

A consideration of the size of gold leaf – that is, the square area when beaten – is also essential in gilding techniques. The beating process is the same as that used today by the few remaining goldbeaters. Square gold pieces were hammered while interleaved in sheets usually made of parchment, leather, metal, or paper. Between every few layers, a metal plate of standard size (a kind of mould) was added. This pile was hammered until the gold filled the mould surface and the excess was cut off. This process was repeated

[32]Normally documents just specify the use of fine gold (*oro fino*), but it is quite probable that the source was gold coins minted in Castile, like *doblas* and *ducados*; Berg-Sobré, *Behind the Altar Table*, 57. In 1400, for the gilding of the portal of the chapel of San Blas at Toledo Cathedral, six "doblas castellanas" were purchased at a price of seventy-five *maravedís* each; Sánchez Palencia, "La capilla del arzobispo Tenorio", 33.

[33]For example, on 13 November 1531, the painter Francisco de Cevallos was paid twenty ducats for the gold to be used for the gilding of some phylacteries for the church of Santo Domingo de la Calzada; Moya Valgañón, "Documentos para la historia del arte del archivo", 47. Also, in 1571 Cardinal Juan Mondragón ordered twelve silver chalices with patens to be gilded with "oro de doblón viejo"; Villa-Amil y Castro, *Inventarios de mobiliario litúrgico*, 342. Apart from local gold coins, in Castile Portuguese *cruzados* were also used; Labeaga Mendiola, "Los talleres de platería", 248; Sánchez-Mesa Martín, *Técnica de la escultura*, 44.

[34]Palomero Páramo, *El retablo sevillano del Renacimiento*, 87.

[35]Saravia de la Calle, *Instrucción de mercaderes*, fol. 81v.

[36]Real Academia Española, Corpus Diacrónico del Español (CORDE), http://corpus.rae.es/cordenet.html, search of the terms *Dorar* (n° 1) and *Oro* (n° 3), accessed 21 January 2016.

[37]Le Gac et al., "The Main Altarpiece of the Old Cathedral of Coimbra", 427.

until the leaves acquired the desired thickness.[38] The Spanish term for this metal mould was *caire* or *cayre*. And as each gold leaf took on the size of its *caire*, this term also came to refer to the size of gold leaf in professional jargon. Normally, a goldbeater had to prepare at least two sizes of gold leaf, of both small and large *caire*.[39]

It seems that in the Spanish kingdoms, the size of gold leaf depended on the artisanal tradition of each city. Painting contracts occasionally refer to this question. For example, when the altarpiece of Valencia Cathedral was gilded in 1432, large (*gran caire*) and small (*xich caire*) leaves of gold were purchased.[40] On 26 July 1465, when the painter Samson Florentin purchased gold leaf from Mose Dono, the goldbeater of the city of Ávila, he asked him to prepare the leaves according to the standard size used in the cities of Segovia and Medina.[41] Almost a century later, in 1538, the gilding contract for the grille of the main chapel of the cathedral of Coria specified that the gold leaf should be consistent with the standard *caire* from Salamanca, which produced leaves costing three *maravedís* each.[42]

It is probable that goldbeaters' guild rules controlled these technical aspects, but not much information from the medieval Spanish kingdoms has been preserved on this topic.[43] Nevertheless, the study of some later cases can make up for this lack of information and give some idea of the situation in the past. In 1608, the guild of *guadamacileros* (leather gilders) in Cordoba filed a lawsuit against the guild of goldbeaters.[44] The leather gilders wanted goldbeaters to stop manufacturing small-size gold leaf and to use a larger *caire*. The goldbeaters responded that a large leaf would be too thin and therefore gilding would be a disaster. In 1789 Eugenio Larruga described the goldbeaters guild in Toledo, noting that there were no rules regarding the size and that there were differences in size even with the nearby Madrid.[45]

The cost of gold leaf

The price of gold leaf depended precisely on the three characteristics discussed above: its thickness, purity, and size. Documentary sources from the fourteenth and fifteenth centuries occasionally provide information about cost, whereas data become more abundant from the sixteenth century on. In any case, it is very difficult to carry out a thorough study on the price of gold leaf in the Spanish kingdoms during the late medieval period. First, prices are shown in the common currency of each kingdom and comparisons are problematic as their respective values changed greatly over time. Second, the price of leaf depended on fluctuations in the price of gold, the value of foreign versus local gold coins, and changes in the purchasing power of money. Finally, gilding costs normally included the labour of goldbeating and gold leaf application. It therefore proves

[38]Córdoba de la Llave, "El mito del Dorado." 485–91.
[39]The large *caire* was also used to manufacture silver leaf.
[40]Aliaga Morell, *Els Peris i la pintura valenciana medieval*, 195–9.
[41]León Tello, *Judíos de Ávila*, 141.
[42]García Mogollón, "Precisiones documentales sobre la reja", 144. The *maravedí* was a Spanish currency and account unit used between the twelfth and nineteenth centuries. It is intriguing that in this document the size of the gold leaf is determined by its price rather than measurements.
[43]The ordinances issued in 1397 by the guild of goldbeaters in Cologne fined any member who did not respect the established measurements; Nadolny, "Some Observations on Northern European Metalbeaters", 143–4.
[44]Alors Bersabé, "El gremio cordobés de guadamecileros", 190–3.
[45]Larruga, *Memorias políticas y económicas*, 37.

challenging to estimate cost if a text does not state specifically the price of a single gold leaf.[46] Nevertheless, some observations regarding the cost of leaf can be made.

In general, to determine the cost of gilding a retable, a master painter would calculate about a third of the total cost.[47] The extent of the areas to be gilded was, of course, fundamental to the final price of a retable. The size of the leaf to be used was also reflected in the final price. In the case of the aforementioned altarpiece of Valencia Cathedral (1432), the large-size gold leaf was more expensive (twenty-seven *sueldos* per 100 leaves) than the smaller leaf (twenty-three *sueldos* per 100 leaves).[48] This difference in price is presumably due to the greater amount of gold in the larger leaf, although we must also consider the leaf's thickness. In other cases it is more difficult to explain the difference in price. In 1440 in Pamplona, 600 leaves of fine gold were purchased for forty *groses* per hundred, while, for the same project, another 600 were purchased for four pounds and ten sous per hundred.[49] In this case, the gold leaves were either of different size or of different quality, that is, a more alloyed gold was employed.

Although contracts always specify that gold should be of a high degree of purity (that is, twenty-three karats or more), it was possible to use gold alloys of fewer karats. Cost could be reduced by alloying gold with silver and/or copper to produce leaf of around twenty-two karats, which could then be applied to non-visible areas of a retable. However, it is also possible that artists alloyed gold in order to achieve particular visual effects: adding copper to gold imbued it with a reddish tone, and introducing silver resulted in a paler tone. It is well documented that in northern Europe artists often used gold leaf of different composition for different parts of a retable, but there is not yet evidence of this practice in the Spanish kingdoms.[50] However, some Iberian contracts specify the use of gold leaf substitutions such as *corla*, a yellow-tinted varnish applied over a leaf of tin or silver to give it a golden sheen, or *oro partido*, which was made of gold and silver beaten together and applied as if it were solid gold leaf.[51] And although it has been argued that such substitutes were used to lower the final cost of the retable because gold was too expensive, the few sources we have regarding cost suggest otherwise. In 1467 Cristobal Gostani, a Genoese merchant established in Cartagena, sold 310 leaves of *oro partido* for 620 *maravedís*, that is, two *maravedís* each.[52] In 1488 the cathedral of Segovia purchased 1000 gold leaves for 2250 *maravedís*, or two and one-quarter *maravedís* each.[53] The similarity of the cost of solid gold leaf and *oro partido* in these cases suggests that the latter might have sometimes been selected not merely for economic reasons, and that technical aspects should also be taken into account, including the particular surface being gilded and the desired aesthetic result.

[46]Authors will study the cost of gold leaf and of gilding relative to the entire cost of retables in a future publication.
[47]Normally, the total cost of a retable depended on three elements: the wood and the construction and preparation of the support, the gilding, and the painting and painting materials. This tripartite division is reflected in the payments the donor or patron had to make to the painter: the first when the structure of the retable was finished and grounds were applied, the second when the gilding was finished, and the last when the retable was painted and finished.
[48]Aliaga Morell, *Els Peris i la pintura valenciana medieval*, 195–9.
[49]Idoate and Ramón Castro, *Catalogo de la Sección de Comptos*, 270, 327. The *gros* was a silver coin and the *sou* (or *sueldo*) was an account unit used in Aragon and other Spanish kingdoms.
[50]Nadolny, "Some Observations on Northern European Metalbeaters", 137 and 147–8.
[51]The 1437 contract for Bernat Martorell's painting of the altarpiece of San Pedro de Púbol (Girona) specified that *oro partido* should be used on draperies, and silver leaf with *corla* for the predella decoration; Post, *A History of Spanish Painting*, 614–16.
[52]Torres Fontes, "Genoveses en Murcia", 80.
[53]López Díez, "Judíos y mudéjares en la Catedral de Segovia", 178.

Expertise and gilding practice

When analysing the gilded retables of medieval Spain it is also necessary to consider the artist's level of expertise. Contracts commonly specified that the master was obligated to carry out the work in the best way possible; sometimes existing gilded retables were mentioned as models to be followed. Artists often had to agree to accept a final assessment by experts and guarantee the future conservation of the work. The 1402 contract for the retable of the church of Badules (Zaragoza) stipulated that it should be gilded as well as any other in the city, and that if within the next twenty years any gold became lost or cracked, it was the painter's responsibility to repair it.[54]

In most cases gilding was the most expensive part of retable production, and the master gilder was therefore expected to be an expert at his task, as errors could result in increased cost. During the process of gilding the grille in the main chapel of the cathedral of Coria in 1538, the painter Álvaro Ponte de Trujillo was fired because, according to those in charge of the commission, he did not have the necessary skills to paint and gild it. Not only was his gilding technique deemed to be inadequate, but he was using more gold leaf than any other master and did not know how to prepare a good mordant (*sysa*).[55] Artists were well aware of the expenses and techniques of gilding from the very moment they began work on a retable, and strove to follow technical procedures correctly. Contracts and expense records sometimes mention technical processes related to gilding, like the application of grounds (*aparejado*) and poliments (*embolado*), sizing (*encolado*), and burnishing (*bruñido*) but rarely offer detailed descriptions of them.[56]

A few painting contracts provide valuable technical information regarding grounds. In 1489 Martín Bernat signed a contract to make a retable for the convent of San Agustín in Zaragoza. It specifies that the painter should apply two layers of gesso, paying special attention to the appropriate application of glue over the last and finest gesso layer to ensure that the gilding would have a shiny finish. It also stipulated that bole should be applied in nine layers, so that the gold leaf would not tear while being polished.[57] While contracts do not always supply thorough technical information, we can supplement these gaps in the documentation with the information offered by medieval treatises on art production. For example, with regard to mordant gilding, Cennini emphasized the importance of the type and quantity of the drier, not only because of its effect on the amount of time spent working, but also for aesthetic reasons, as a slow-drying mordant could give a more lustrous appearance.[58] Moreover, because driers were also pigments, the choice of one over another would endow gold with a particular shade.

Finally, the commercial and social relations between painters, goldbeaters and apothecaries is a fertile area of inquiry in need of further research. Considering that individual master painters would usually dominate the retable market in a given city or area of influence, they would have had a close working relationship with the goldbeaters and the apothecaries from whom they purchased their leaf.[59] Contracts were explicit on this

[54]Serrano y Sanz, "Documentos relativos a la pintura" (1916), 463–4. For more details on this topic see also Fernández Somoza, "El mundo laboral del pintor", 41
[55]García Mogollón, "Precisiones documentales sobre la reja", 144.
[56]For more on this topic see Bruquetas Galán, *Técnicas y materiales de la pintura española,* 402–37.
[57]Serrano y Sanz, "Documentos relativos a la pintura" (1914), 450.
[58]Broecke, *Cennino Cennini*, 195–7.
[59]Miquel Juan, "El viaje de artistas y obras de arte catalanas."

subject, and commonly specified that it was the painter who was responsible for buying gold and pigments. In March 1370, for instance, Llorens Saragossa bought gold leaf from the goldbeater Domingo de Gudella for the main retable of the church of Santa Eulalia de Provensana (L'Hospitalet de Llobregat, Barcelona).[60] Other types of documents reveal a variety of interactions between painters and goldbeaters beyond the purchase of leaf. In 1411, the painter Vicente del Port married the daughter of the goldbeater Mateo Simó with a substantial dowry of 4000 *sueldos*.[61] On 30 May 1422, the painter Sancho Villalba signed an apprenticeship contract with the goldbeater Pedro de Campos in order to train his son for the next four years.[62] Finally, three legal documents dated in 1458 state that the painter Francesc Lembrí not only bought gold leaf from the apothecary and goldbeater Gabriel Morell, but Morell was also Lembrí's guarantor in a gilding contract.[63]

Case studies

The following section focuses on some representative examples of gilding on retables and panel paintings produced in the Spanish kingdoms during the second half of the fifteenth century and the first half of the sixteenth.[64] The guiding thread will be the comparison of historical textual sources with analytical results, in order to determine the extent to which extant paintings corroborate the information provided in historical treatises and contracts, and to raise new questions and develop methodological approaches. For the case studies presented here, imaging and spectroscopy-based analytical techniques were used for the characterization of inorganic gilding materials and their application techniques: cross sections of paint layers were characterized by optical microscopy (OM), scanning electron microscopy (SEM) and SEM with energy-dispersive X-ray analysis (EDX). The microscopic analysis of cross-sectioned samples was complemented with infrared reflectography and X-ray radiography for the inner structure of the paintings, as well as with FTIR spectroscopy and fluorimetry for organic binding media.

The first case study concerns the *Virgin of Mosén Sperandeu de Santa Fe* (Museo Lázaro Galdiano, Madrid), a panel painting executed in 1438–39 by Blasco de Grañén from (Figure 4). Luís de Santa Fe commissioned the painting as part of a retable for his father's funerary chapel, Sperandeu de Santa Fe, located within the convent church of San Francisco de Tarazona (Zaragoza). The panel featuring the Virgin was probably the central one of the chapel's lost retable. For the most part, the artist followed standard procedures when applying the gold leaf. The panel's ground is very thick, consisting of three layers of gesso applied with animal glue: the first is light brown gesso reinforced with fabric over its entire surface, the second is similar to the previous one, and the third is a layer of fine white gesso. For the gilding, the artist laid gold leaf over a homogeneous layer of red bole agglutinated with animal glue, and then burnished the leaf. The contract for the retable, which is still preserved, stipulated that the gold should be of high purity, and

[60]Madurell i Marimón, "El pintor Lluís Borrassà", 33–4.
[61]Cerveró Gomis, "Pintores valentinos" (1972), 48.
[62]Cerveró Gomis, "Pintores valentinos" (1964), 128.
[63]Sánchez Gozalbo, *Pintores de Morella*, 116–18.
[64]For larger studies contextualizing Iberian retables in this period, see Kroesen, *Staging the Liturgy*, 2009; Kroesen and Schmidt, eds., *The Altar and Its Environment, 1150-1400*, 2009; Robinson, *Imagining the Passion in a Multi-Confessional Castile*, 2013.

Figure 4. Blasco de Grañén, Virgin of Mosén Sperandeu de Santa Fe, 1438. Museo Lázaro Galdiano, Madrid.

laboratory analysis confirms that the artist followed through on this obligation.[65] One peculiar detail in the gilding of this panel is that the golden background extends under the painted outlines of the figures, and even under the border of the Virgin's cape.[66] This deviation exemplifies how artists could sometimes stray from the standard gilding practices outlined in textual sources, and instead take an individualized approach in accordance with their own creativity, experience, and style.

For another interesting variation on standard gilding technique, we turn to two panels by Pedro Berruguete. The first, which features Christ crucified (*c.* 1493–98), was produced for the retable of the convent of Santa Cruz la Real (Segovia) (Figure 5); the second, which depicts the Mass of St Gregory (*c.* 1500), was painted for the old cathedral of Segovia (Figure 6).[67] In both cases the ground is made of very white gesso and animal glue. The upper layer of fine gesso is slightly yellow due to the high proportion of animal glue

[65]Lacarra Ducay, "Blasco de Grañén", 19.
[66]Gómez, "Estudio analítico de la técnica pictórica", 149.
[67]Gómez et al., "Estudios técnicos de dos obras segovianas de Pedro Berruguete".

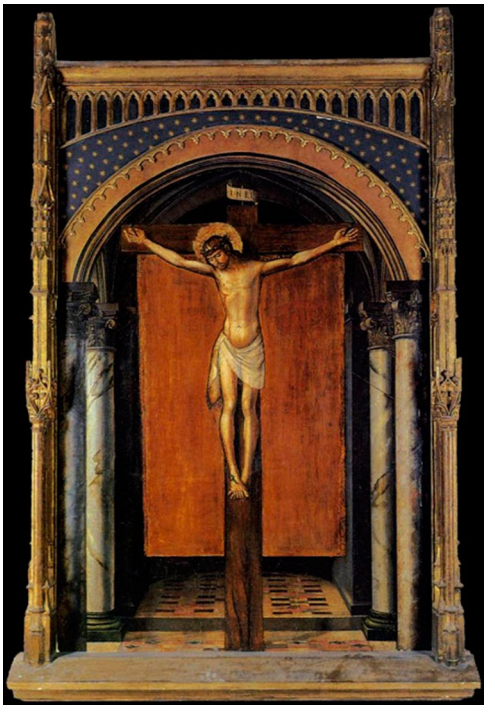

Figure 5. Pedro Berruguete, Christ crucified, *c.* 1493-98. Convent of Santa Cruz la Real (Segovia).

Figure 6. Pedro Berruguete, the Mass of St Gregory, *c.* 1500. Old cathedral of Segovia.

Figure 7. Fernando Gallego, retable of San Ildefonso, *c.* 1480, Zamora Cathedral.

used in the mix. Both panels are gilded with burnished gold leaf in the architectural frames, textiles, halos and other details. What is unusual in these panels is the composition of the bole layer: it is a mixture of a ferruginous clay and vermilion, sized with animal glue. The pigment was probably added to increase the red colour of the bole and provide a warmer tone to the gilding. On the other hand, its use also had some serious disadvantages: because vermilion is harder and has less plasticity than bole, it does not allow for the polishing and compacting of the bole layer. It also prevents the gold leaf from being burnished, and thus also from adhering properly to the bole layer. This may be the reason for the poor state of conservation of the gilding on both of these panels. However, such mixtures of bole and vermilion are present in other paintings, particularly from the workshop of Fernando Gallego.

The retable of San Ildefonso at Zamora Cathedral (*c.* 1480) is one of the few signed works by Fernando Gallego (Figure 7). The retable architecture was decorated using the

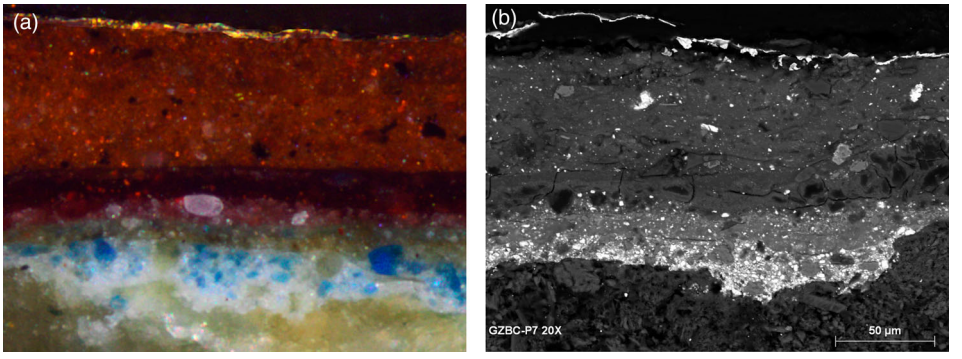

Figure 8. (a) OM photomicrograph of ground, mordant layer, and gold leaf. Retable of San Ildefonso, Zamora Cathedral, *c.* 1480. (b) SEM-BSE image of ground, mordant layer, and gold leaf. Retable of San Ildefonso, Zamora Cathedral, *c.* 1480.

water gilding technique.[68] The bole layer is somewhat less compact than usual and has a reddish colour due to its composition: a mixture of red ferruginous clay with dispersed grains of vermilion (Figure 8a,b). The thickness of this layer is between fifteen and twenty microns, and it is strongly sized with animal glue, which makes it look slightly translucent under a microscope. Mordant gilding was used for details in the narrative scenes, such as rays of light, halos, and the borders of some draperies. The gold leaf was laid over a thick brown and quite compact oil-based mordant. The inorganic materials present in this mordant size are red ochre, lead white, red lead, red lake, vermilion, and carbon black. The surface of the mordant gilding on the details is rougher and presents less continuity than the water gilding on the architecture. In both cases, the gold leaf has a high level of purity, between 23.7 and 23.8 karats, and the remainder is silver.

The retable of the church of Santa María de Trujillo was executed between 1475 and 1490, and most of its twenty-five panels are attributed to Fernando Gallego (as well as two other painters) (Figure 9). It features an abundant use of gold, which is found mainly in the backgrounds of the side panels and in some of the central scenes, as well as in the depictions of brocaded fabric.[69] Both burnished-leaf gilding (i.e., water gilding) and mordant gilding were employed. It is worth mentioning that the predominance of burnished gilding versus mordant gilding varies from one panel to another. In panels where burnished gold is the main technique, the gilding has usually been decorated by punching. The gold leaf was laid over a thin layer (10–15 µm) of an intensely orange-coloured bole. The bole layer is very compact and homogeneous due to a high surface polish to receive the gilding. In addition to the backgrounds, water gilding was also employed on the rays of light emanating from the Virgin and Christ, and on draperies. On various other panels, mordant gilding was applied to a lesser extent on brocade textiles halos. In these cases, the gold leaf was laid over a light brown oil mordant, which was in turn applied over a thin organic layer, highly oily in nature (about 5 µm). In both the burnished gilding and the mordant gilding, the gold leaf is very thin and highly pure.[70]

[68]Gómez and Albar. "Materialidad y técnica en la obra de Fernando Gallego."
[69]Gómez and Jover de Celis, "Fernando Gallego en Trujillo", 52–7.
[70]In the eighteenth century the retable was gilded again in some areas and the gold leaf employed was much thicker than the original leaf used in the fifteenth century.

Figure 9. The retable of the church of Santa María de Trujillo, 1475-90.

Another work attributed to Fernando Gallego is the retable of St Catherine of Alexandria (Santa Catalina) in the chapter house of the old cathedral of Salamanca, dated around 1500 (Figure 10). The artist employed water gilding on the retable's microarchitectural frame, and in the predella where it is used for the backgrounds and saints' halos.[71] The gold leaf was laid over an orange-coloured bole layer approximately twenty microns thick. This layer is not very compact or homogeneous, and consists of ferruginous clay containing titanium dioxide particles. On the panels of the central body of the retable, mordant gilding was only used on the halos of saints. In these cases the gold leaf was laid over a less compact brown-orange mordant layer. Its composition varies in different parts of the retable: that used in the panel depicting St Catherine's martyrdom is a mixture of linseed oil, lead white, ochre, and vermilion, whereas that in the central image of St Catherine enthroned

[71] Albar, Gómez and Bruno, "Estudio técnico del Retablo de Santa Catalina".

Figure 10. The retable of St Catherine in the chapter house of the old cathedral of Salamanca, *c*. 1500.

is a mixture of linseed oil with a very low quantity of pigments and driers. The gold leaf is highly pure (23.6 karats, the remaining 0.4 being silver) and quite thick.

The retable located in the chapel of San Juan Bautista (also known as the chapel of Santa Teresa) in the cathedral of Santo Domingo de la Calzada (La Rioja) is in a late Gothic style and combines panel paintings and polychrome sculptures (Figure 11). Its authorship is

Figure 11. Retable of the chapel of San Juan Bautista/Santa Teresa, cathedral of Santo Domingo de la Calzada, *c.* 1512.

unknown (although the execution of the sculptures is reminiscent of Flemish masters), and it is dated around 1512.[72] Gilding can be found on both the sculptures and panels of the retable. On the sculptures, burnished gold was applied on halos, brocaded drapery, and some relief details, while mordant gilding was applied to the hair of some of the holy figures, such as the Madonna and Child, Saint John, and the angels.[73] Water gilding was aplied over a thin bole layer (*c.* 15 μm) of a light red colour that is well sized with animal glue. In some places, a second layer of gilding can be found over the first one, but in those cases the bole layer is darker and less compact, although similar in thickness. For the matt gilding, the gold leaf was laid over a dark linseed oil mordant, mixed with red ferruginous silicates, red lead, and lead white. Although the mordant layer is thin, its thickness is irregular, varying between ten and twenty-five microns. Mordant gilding was also used over tin leaf on relief brocades. This gilded tin leaf is larger than the gold leaf, with a thickness between twenty and thirty microns. The mordant layer is very thin (5 μm) and it has a brown translucent colour.

[72]Gómez et al., "Estudio científico y técnico de la pintura."
[73]On the main retable of Toledo Cathedral, the hair of all women was gilded, not just the holy figures.

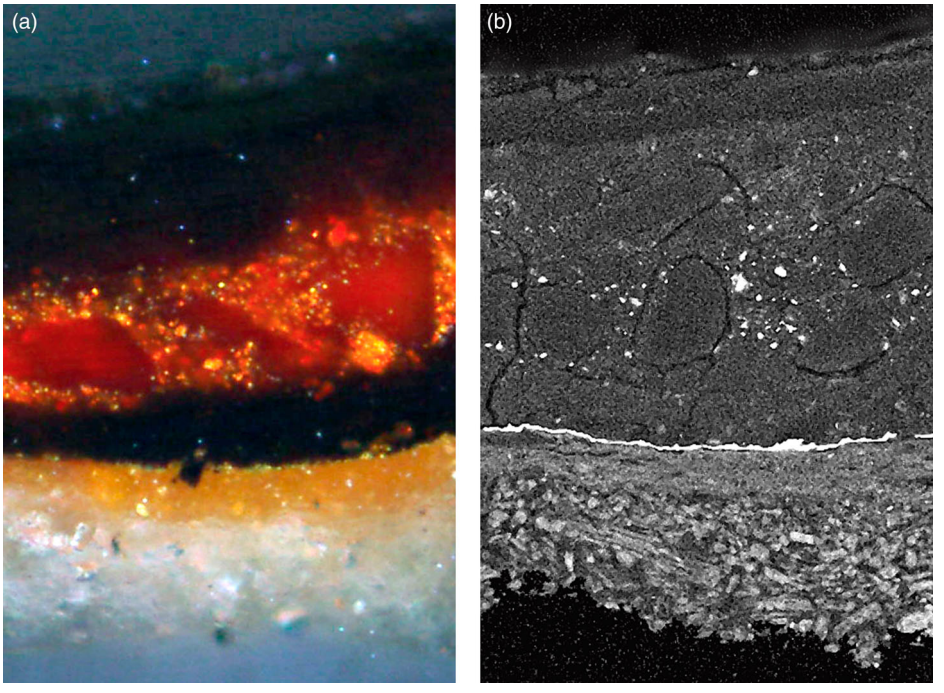

Figure 12. (a) OM photomicrograph of brocade decoration over a layer of burnished gold leaf. Retable of the chapel of San Juan Bautista/Santa Teresa, cathedral of Santo Domingo de la Calzada, *c.* 1512. (b) SEM-BSE image of brocade decoration over a layer of burnished gold leaf. Retable of the chapel of San Juan Bautista/Santa Teresa, cathedral of Santo Domingo de la Calzada, *c.* 1512.

Unfortunately, because it has not been possible to extract a sufficient sample for analysis, the components of this mordant remain unknown. Like its polychrome sculptures, the retable's panel paintings include both burnished and matt gilding. All of the backgrounds and draperies feature burnished gold leaf (1–2 μm) that was laid over a layer of bole sized with animal glue (15 μm) (Figure 12a,b). The gilding technique of the halos depends on their decoration. The halos decorated with punch work were made of burnished gold leaf, while matt gilding was used for those decorated with painted geometric lines (Figure 13a,b). Matt gilding can also be found on some of the borders and brocades of garments. The mordant layer used for matt gilding is between fifteen and thirty-five microns thick, and it is more compact than that used on the polychrome sculpture. The composition of this layer is a mixture of linseed oil, ochre, red lead, and a high quantity of lead white. In this case, we can observe the same characteristic found in Gallego's retable for the church of Santa María de Trujillo: the predominance of one gilding technique over another varies from panel to panel. Also, on the panels where burnished gold is the main technique, punching decoration is present.

Comparative study

The majority of extant contracts for Iberian retables during the fifteenth and early sixteenth centuries belong to the area corresponding to the Kingdom of Aragon. Most of the above case studies of gilding on retables, however, pertain to the Kingdom of Castile. If we compare the stipulations and technical requirements outlined in contracts

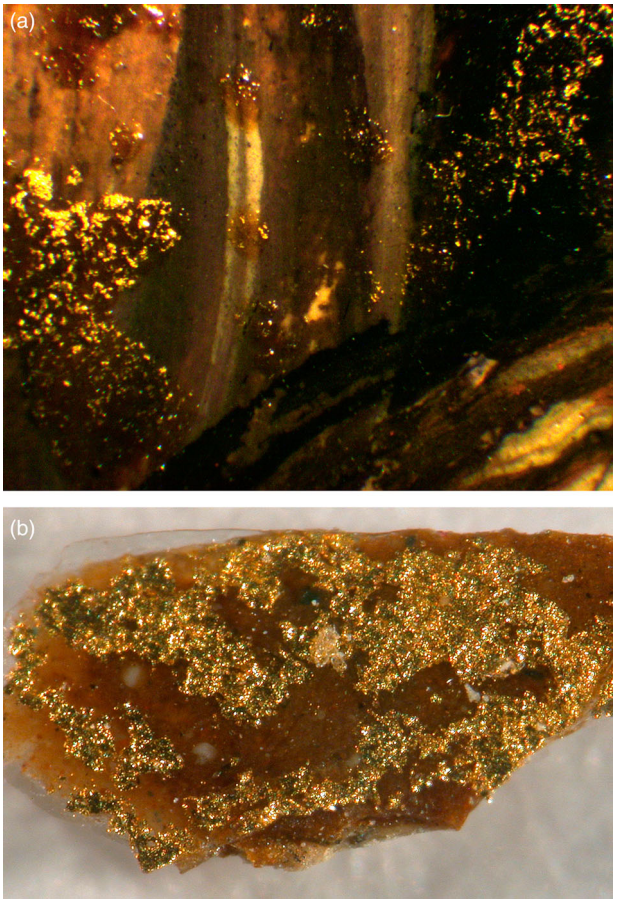

Figure 13. (a) Detail of mordant gilding on nimbus of Mary Magdalene. Retable of St Catherine, chapter house, old cathedral of Salamanca, *c*. 1500. (b) Sample of mordant gilding. Retable of St Catherine, chapter house, old cathedral of Salamanca, *c*. 1500.

with the results of technical analysis, we can confirm that there were no significant differences in workshop practices between these two regions with regard to the gilding of retables. The most outstanding difference is probably the type of coin used to beat out gold leaf: while in the Crown of Aragon (including the Kingdom of Valencia and the County of Barcelona) the gold coins commonly used were of Italian origin, in the Kingdom of Castile locally minted gold coins were used. The advantage of using florins and ducats lay in the fact that their composition was as close to pure gold as was then technically feasible, and, moreover, they had remained stable (i.e. consistently pure) for centuries. Castilian gold coins, by contrast, suffered several alterations to their composition and purity.[74] Therefore it is typical to find gold between 23.3 and 23.6 karats in Castilian retables, while that in Aragonese retables usually exceeds 23.75 karats.[75]

[74]The traces of silver and copper in the composition of the gold can accurately indicate the use of a gold coin that had been devalued. This may explain the composition of the gold in Diego de la Cruz's (fl. 1482–1500) panel painting of Christ between the Virgin and St John; see Alba et al., "Las prácticas artísticas de los pintores 'hispanoflamencos'", 139.

[75]This topic will be discussed in greater detail in a forthcoming publication: Kroustallis, "La técnica del dorado y el retablo de don Álvaro de Luna".

As discussed above, several extant textual sources are very eloquent on the symbolic connotations of gilded retables (such as their articulation of divinity and social status) as well as their aesthetic characteristics (light, brightness, material quality, etc.). But these interpretations tend to elide the importance of gold as a colour in medieval painting and the optical effects of burnished versus matt gilding. These effects rarely survive today in panels and retables because of the state of conservation of the delicate gold leaf: very few examples of burnished gilding still retain their full shine. Moreover, artificial light tends to equalise the appearance of the gold, emphasising brightness but reducing the contrasts, shades, and hues that would emanate from an object imbued with mystical light.[76]

Medieval treatises and contracts make it clear that water gilding was not solely used to imitate a shiny, solid gold surface; that matt gilding was not exclusively used for details after painting; and that cheaper imitations of gold leaf (such as *oro partido* or *corla*) could be used in non-visible areas. It is quite possible that all these gilding materials and techniques were also employed to create pictorial effects of contrast and depth through the juxtaposition of lustrous and matt surfaces, of smooth and textured areas, of strong and diffuse gleams, and of different shades. This is likely to be why mordant gilding and imitations of gold leaf were used mainly in areas where the characteristics of water gilding (solid surface with uniform brightness) were aesthetically unsuitable, as in the depiction of hair and rich textiles. The 1504 contract for the retable of the church of Espera (Seville) stipulated that painters should apply water gilding for backgrounds, but mordant gilding for the "purpuras doradas e orofreses" of the fabrics.[77] In the 1437 contract for the painting of the altarpiece of San Pedro de Púbol (Girona) by Bernat Martorell, it was specified that *oro partido* and silver leaf should be used on *porpres* and silver leaf with *corla* for the decoration of the dust guard.[78] In each of these cases, the references to *purpura*(s) or *porpre*(s) bear no relation to *purpura* or Tyrian purple, the dye extracted from sea snails. On the contrary, it alluded to the plays of light produced by gilding that imitated the iridescence and glow of brocade textile. The so-called *oro partido* was also typically used in the painting of brocades due to its volume and texture. In 1410, the painter Lluis Borrassa objected to a contractual stipulation that pure gold be used on an entire retable, explaining that it was common to use *oro partido* on fabrics.[79] Finally, in 1486 the painter Miguel Vallés signed a contract for a retable for the monastery of Santo Domingo de Guzmán at Estella, in which it was also stipulated that *oro partido* should be used on brocades.[80]

Interpreting laboratory analyses in relation to textual sources on gilding leads to a better understanding not only of the appearance of gold in retables today, but also of the pictorial intentions of its use at the time of production, and the selection of particular gilding techniques to achieve certain effects. On the other hand, this analysis of gilding materials and techniques demonstrates how workshop traditions conditioned artistic praxis. The retables from Santo Domingo de la Calzada and Santa María de Trujillo, for instance,

[76]Miquel Juan, "La novedad de lo desconocido", 520–1.
[77]Bago y Quintanilla et al., Documentos para la historia del arte en Andalucía, 113–15.
[78]"Item, emprès entre les dites parts que les porpres qui serán en lo dit retaule sien d´or partit e d´argent, e los gardapolsos d´argent colrat porpres qui serán en lo dit retaule"; Post, *A History of Spanish Painting*, 615.
[79]Sanpere y Miquel, Los cuatrocentistas catalanes, 142.
[80]Lacarra Ducay, "Miguel Vallés", 511.

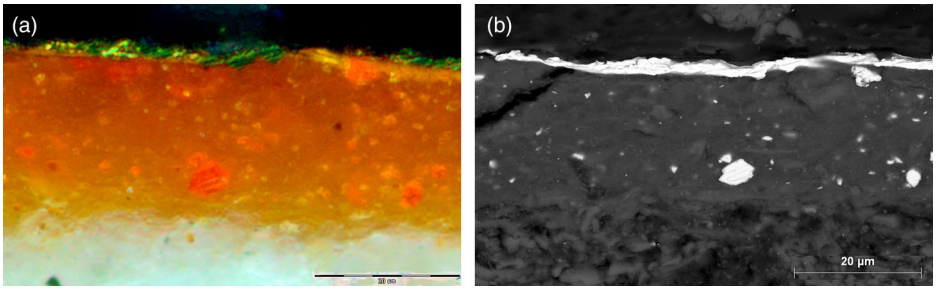

Figure 14. (a) Use of cinnabar by Fernando Gallego to modify the visual characteristics of poliment; OM photomicrograph of ground, bole layer with vermilion particles, and burnished gold leaf. Retable of San Ildefonso, Zamora Cathedral (*c.* 1480). (b) SEM-BSE image of ground, bole layer with vermilion particles, and burnished gold leaf. Retable of San Ildefonso, Zamora Cathedral (*c.* 1480).

demonstrate a tendency to predominantly use one gilding technique (water or matt gilding) on each panel, whereas the common practice was to combine both according to the specific area being gilded (matt gilding for halos, hair, and fabrics, and water gilding for backgrounds and architectural elements). The decision to use a particular gilding technique depended not only on technical characteristics; the master painter also had to think about the final decoration of the gilded areas and the overall visual effect. Water gilding allowed for punch work and painted patterns, while matt gilding only accommodated the latter. This may be seen in the halos of the saints on the retable from Santo Domingo de la Calzada.

Textual sources, like medieval treatises on art technology and painting contracts, make clear the importance of the bole layer in water gilding, as it served as a cushion to burnish gold leaf. But again, it seems that there was also a visual aspect to be taken into account. Pedro Berruguete and Fernando Gallego took the unusual approach of adding vermilion to their bole, as we saw in two of the above case studies (Figure 14a,b). The use of vermilion to modify the colour of the poliment (any preparatory layer for gilding) is also described in some Italian treatises written between the thirteenth and fifteenth centuries.[81] However, in these cases the vermilion was mixed with gesso, and sometimes with lead white, to create a different type of layer for gilding, without bole. It should be noted that the use of cinnabar to modify the visual characteristics of poliment was atypical in painting techniques and its inclusion in medieval compilations of technical prescriptions demonstrates that these were evolving texts that documented not only ancient knowledge, but contemporary artistic practices as well. It is difficult, however, to explain the presence of vermilion in the bole used by Fernando Gallego and Pedro Berruguete. As mentioned earlier, the addition of vermilion could make the bole harder, restricting the potential for the gold leaf to be well burnished and emit a high degree of shine. These two artists either did not know this, or they did and intended to imbue their gold with a warmer and darker tone.[82] The fact that most of

[81] Merrifield, *Original Treatises*, vol. 1, 239, and vol. 2, 469–71; Thompson, "*Liber de Coloribus*", 307; Clarke, *Mediaeval Painters' Materials and Techniques*, 138–9. Ochre pigments are also mentioned in historical sources as layers for gilding, probably in order to indicate the areas where gold leaf would be applied, or to give the impresion of gold in areas where gold leaf has worn off or in areas with reliefs where gold leaf was difficult to lay and burnish.

[82] An explanation for all these cases may be the possibility to use these layers for water gilding but with matt effects, that is, unpolished or only slightly polished.

Figure 15. Detail of mordant gilding in halos with a dull appearance of gold. The Arrest of Christ, retable of the chapel of San Juan Bautista/Santa Teresa, cathedral of Santo Domingo de la Calzada (*c.* 1512).

these recipes are of Italian origin suggests an influence of Italian painting practices in Iberia, an influence that is evident for Berruguete but not for Gallego.[83]

The thickness of the bole layer was crucial for the subsequent burnishing of the gold leaf. During the fifteenth century the bole layer was normally between ten and twenty microns; it contained a large amount of animal glue and was less compact due to its insufficient polishing.[84] It is possible that painters at that time still did not completely understand that a high burnish required a certain thickness of bole. It is alternatively possible that since gold leaf was comparatively thick during this period (*c.* 2 microns), it did not require a thick bole to be thoroughly burnished. When in the sixteenth century gold leaf became thinner, the bole layer became thicker.[85] In any case, some defects observed in gilding during this period are due to an inadequate technique due to the excess of glue, which is very sensitive to variations in humidity and susceptible to the growth of microorganisms. Moreover, a strongly sized bole layer could create tension and ultimately become separated from the ground. This explains why the 1489 contract for the retable of the convent of San Agustín in Zaragoza specified that the bole should be applied nine times, lest the gold leaf tear during the burnishing process.[86]

[83]It seems that Pedro Berruguete travelled to Italy around 1477 and worked in the court of Federico III da Montefeltro in Urbino. In any case, this peculiar use of vermilion in the bole layer needs further study and more comparative data.
[84]These technical problems were solved during the sixteenth century, when the thickness of the bole layer was increased up to thirty microns, allowing for highly burnished water gilding with a very shiny appearance; Carrassón López de Letona, Gómez Espinosa and Gómez González, "Retablo mayor de la iglesia de San Mateo", 121.
[85]Miguel Gonzalez de Quevedo Ibañez (conservator-restorer at the Liebieghaus Skulpturensammlung in Frankfurt), in discussion with the authors, May 2016; see also Theiss, "Ihr habt dem Mittelalter".
[86]Serrano y Sanz, "Documentos relativos a la pintura" (1914), 450.

Oil-based mordant layers are synonymous with matt gilding, but this is a point we must qualify: several textual sources point out that it was possible to get a more or less lustrous appearance using mordant gilding, depending on the drying time. This may help explain the composition of the mordant in some of the above case studies. For example, the mordant layer on the retable of Santo Domingo de la Calzada shows high levels of red lead and white lead: increasing the quantity of driers would accelerate the gilding process, as noted by Cennini, and the gold would ultimately appear very dull (Figure 15).[87]

On the mordant gilding of the retable of St Catherine in the old cathedral of Salamanca, two different mordant layers were identified: the first is a mixture of linseed oil, white lead, ochre, and vermilion, while the second is a mixture of linseed oil with a very low quantity of pigments and driers. In the second case, the slow-drying mordant would give a more lustrous appearance than the fast-drying mordant of the first type. The final appearance of the gilding also depended on precisely when the gold leaf was applied over the mordant. In his treatise *El arte de la pintura*, the well-known Spanish painter and writer Francisco Pacheco (1564–1644) advised that the oil-based mordant needed to be left long enough to dry, so that the gilding would be lustrous and beautiful.[88] The right proportion of the oil component in relation to driers could also increase the shine of matt gilding. Antonio Palomino (1655–1726), the Spanish painter and writer from the Baroque period, notes in his *Museo pictórico* that if the mordant layer is very glossy, then the gilding will be very lustrous, as if it had been burnished.[89] Again, we can see that behind this gilding technique there is an aesthetic component that must be taken into account.

The sizing of the ground layer was also essential to the gilding process. In the two panel paintings by Berruguete described above, the upper of the two layers of fine gesso is slightly yellowish due to the high proportion of animal glue.[90] It is worth nothing that these findings correspond to one of the stipulations in the contract the painter Martín Bernat signed for the retable of the convent of San Agustín in Zaragoza: the contract specified that two layers of gesso should be applied, with the upper layer properly glued so that the gilding would have a shiny finish.[91] Also, the anonymous author of the fifteenth-century *Liber diversarum arcium* recommends that before gilding, the painter should verify the state of the gesso layer by scraping it with a knife. If it is too difficult to scrape, the artist should add water with glair; if it scrapes off too easily, he should add more glair.[92]

There is insufficient evidence to determine whether artists adjusted the thickness of their gold leaf depending on which technique they were using and what sort of area was being gilded, as suggested by Cennini. During the fourteenth and fifteenth centuries in the Spanish kingdoms, gold leaf was on average between one and three microns

[87]Broecke, *Cennino Cennini*, 195–7.
[88]Pacheco, *El arte de la pintura*, 124.
[89]Palomino, *Museo pictórico*, II, 353.
[90]It was very common in painting techniques of that period in the Spanish kingdoms to apply a final coat of glue (normally animal glue) that saturated and sealed the surface of the ground before gilding or painting; Alba et al., "Las prácticas artísticas de los pintores 'hispanoflamencos'", 133.
[91]Serrano y Sanz, "Documentos relativos a la pintura" (1914), 450.
[92]Clarke, *Mediaeval Painters' Materials and Techniques*, 138–9.

(sometimes thicker, but always less than five microns). Technically, it makes sense to use thicker gold leaf for water gilding (as strong leaf prevents tears during burnishing) and thinner leaf for mordant gilding since it was unburnished (to lower the cost). However, laboratory analyses have their limitations. In the first place, the thickness of gold leaf is not equally distributed, as goldbeaters would start hammering from the centre and work their way outwards; secondly, after burnishing the leaf became thinner and more homogeneous; and third, sometimes more than one layer of gold leaf was applied.[93] Therefore, because we can only take average measurements, it is very difficult to corroborate Cennini's statement. It would be worthwhile for scholars to take this aspect into account when taking samples, and to select areas where a correct measurement of thickness is attainable. In this way we might begin to establish a connection between particular gilding techniques and the respective thickness of gold leaf.

Conclusions

The present study demonstrates that gilding is more than a simple shiny surface. In addition to its symbolic and aesthetic dimensions, gilding had a complex variety of technical, professional, economic, and social implications. The current state of conservation of most gilded works and the scarcity of coetaneous textual sources describing the precise appearance of gilding make it difficult to appreciate the play of light, iridescence, shades, and textures originally exhibited by gilding, as well as its relationship to surrounding pigments. The comparative study of historical textual sources and laboratory analysis proves to be a powerful methodological approach that enhances our understanding of the technical and aesthetic possibilities of gilding, as well as the techniques and intentions of particular artists.

Documentary sources and scientific analyses prove that artists chose to use either water or mordant gilding not only for practical purposes, but for aesthetic reasons as well, bearing in mind the ultimate visual effect of each technique and what sort of decoration might thereafter be applied to the gilded surface. Likewise, imitations of gold like *oro partido* were not simply economical substitutes for gold leaf, but could be selected to achieve certain pictorial effects. And although it is important to consider the strong persistence of traditional workshop practices in the gilding process, an artist's creativity and personal experience might lead them to deviate from the standard steps and techniques, as we can see in the works of Pedro Berruguete and Fernando Gallego discussed above.

Analysing the use of gold leaf in painting allows us to consider the origin and cost of gold as well as the manufacture and application of leaf. It should be noted that all these aspects were intertwined and could create limitations for the whole gilding process: accessibility to gold and the fluctuation of the value of coins affected the price of gold leaf, as did the leaf's thickness and size. The master's level of expertise could also impact the final cost of gilding.

Comparative studies of historical textual sources and laboratory analysis also shed light on regional specificities within Iberia. A comparison of painting contracts from the Kingdom of Aragon and surviving panel paintings from the Kingdom of Castile reveals

[93]Theophilus advises that three layers of gold leaf should be applied in water gilding in order to achieve good results; Theophilus, *On Divers Arts*, 31.

that there were no noteworthy technical differences in gilding praxis and traditions in these areas, with the exception of the use of gold coins of different quality.

It is highly significant that the gilding techniques described in medieval treatises on art technology and documentary sources like painting contracts are generally consistent with the results of the laboratory analysis of extant paintings. This underscores the value of textual sources and proves that treatises were not merely compilations of old recipes, but dynamic texts that reflected contemporary artistic praxis.

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Works cited

Alba Carcelén, Laura, Jaime García-Máiquez, María Dolores Gayo García, Maite Jover de Celis and María Pilar Silva Maroto. "Las prácticas artísticas de los pintores 'hispanoflamencos' en la Corona de Castilla en el siglo XV." *Boletín del Museo del Prado* 32, no. 50 (2014): 122–47.

Albar, Ana, Marisa Gómez and Giulia Bruno. "Estudio técnico del retablo de Santa Catalina de Francisco Gallego: Caracterización de los materiales y de la técnica pictórica." in *IX Jornadas Complutenses de Arte Medieval: La formación del pintor y la práctica de la pintura en España (1350–1500)*, eds. Matilde Miquel Juan and Olga Pérez Monzón, Madrid: La Ergástula (forthcoming).

Aliaga Morell, Joan. *Els Peris i la pintura valenciana medieval*. Valencia: Alfons El Magnànim, 1996.

Alors Bersabé, Teresa M. "El gremio cordobés de guadamecileros y su producción durante los siglos XVI y XVII." PhD diss., Universidad de Córdoba, 2013.

Bago y Quintanilla, Miguel de, José Hernández Díaz and Heliodoro Sancho Corbacho. *Documentos para la historia del arte en Andalucía*. Vol. 2, *Documentos varios*. Seville: Universidad de Sevilla, 1928.

Baldassarri, Monica, Gildo de Holanda Cavalcanti, Marco Ferretti, Astrik Gorghinian, Emanuela Grifoni, Stefano Legnaioli, Giulia Lorenzetti, Stefano Pagnotta, Luciano Marras, Eleonora Violano, Marco Lezzerini and Vincenzo Palleschi. "X-Ray Fluorescence Analysis of XII–XIV Century Italian Gold Coins." *Journal of Archaeology* 2014 (2014): 1–6.

Berg-Sobré, Judith. *Behind the Altar Table: The Development of the Painted Retable in Spain, 1350–1500*. Columbia: University of Missouri Press, 1989.

Broecke, Lara. *Cennino Cenninís Il libro dell'arte: A New English Translation and Commentary with Italian Transcription*. London: Archetype, 2015.

Bruquetas Galán, Rocío. *Técnicas y materiales de la pintura española en los siglos de oro*. Madrid: Fundación de Apoyo a la Historia del Arte Hispánico, 2007.

Cabrera Lafuente, Ana. "Telas hispanomusulmanas: Siglos X–XIII." in *V Semana de estudios medievales: Nájera, 1–15 de agosto de 1994*, ed. José Ignacio de la Iglesia Duarte, 199–207. Logroño: Instituto de Estudios Riojanos, 1995.

Caffaro, Adriano. *Scrivere in oro: Ricettari medievali d'arte e artigianato (secoli IX–XI). Codici di Lucca e Ivrea*. Naples: Liguori, 2003.

Carrassón López de Letona, Ana, Teresa Gómez Espinosa and Marisa Gómez González. "Retablo mayor de la iglesia de San Mateo de Lucena (Córdoba)." *Bienes culturales* 2 (2003): 149–63.

Cerveró Gomis, Luis. "Pintores valentinos: Su cronología y documentación." *Anales del Centro de Cultura Valenciana* 49 (1964): 83–136.

Cerveró Gomis, Luis. "Pintores valentinos: Su cronología y documentación." *Archivo de arte valenciano* 43 (1972): 44–57.

Clarke, Mark. *Mediaeval Painters' Materials and Techniques: The Montpellier* Liber diversarum arcium. London: Archetype, 2011.

Cordoba de la Llave, Ricardo. "El mito del Dorado. Elaboración y aplicación del oro en la Península Ibérica (siglos XV-XVI)." *Imago Temporis. Medium Aevum* 8 (2014): 263–96.

Córdoba de la Llave, Ricardo. "Los batihojas y las técnicas de ornamentación en metal (siglos XV–XVI)." in *Estudios sobre historia de la ciencia y de la técnica: IV Congreso de la Sociedad Española*

de Historia de las Ciencias y de las Técnicas, vol. 2, 755–72. Valladolid: Junta de Castilla y León, 1988.

Fernández Somoza, Gloria. "El mundo laboral del pintor del siglo XV en Aragón." *Locus amoenus* 3 (1997): 39–49.

Fores *licenciado*. *Tratado útil y muy provechoso contra toda pestilencia e ayre corupto*. Salamanca: Hans Gysser, 1507.

García Mogollón, Florencio-Javier. "Precisiones documentales sobre la reja de la capilla mayor de la catedral de Coria: Las intervenciones de Hilario Francés, Ursón y Bartolomé de Jaén." *Laboratorio de arte* 17 (2004): 137–72.

Gómez, Marisa. "Estudio analítico de la técnica pictórica: Aplicación a tablas y retablos españoles." in *La pintura europea sobre tabla: Siglos XV, XVI y XVII*, 148–59. Madrid: Ministerio de Cultura, 2010.

Gómez, Marisa, and Ana Albar. "Materialidad y técnica en la obra de Fernando Gallego. El Retablo de San Ildefonso de la Catedral de Zamora." in *IX Jornadas Complutenses de Arte Medieval: La formación del pintor y la práctica de la pintura en España (1350–1500)*, eds. Matilde Miquel Juan and Olga Pérez Monzón, Madrid: La Ergástula (forthcoming).

Gómez, Marisa, and Maite Jover de Celis. "Fernando Gallego en Trujillo: Estudios químicos." *Bienes culturales* 8 (2008): 49–60.

Gómez, Marisa, Pedro Pablo Pérez, Jana Sanyova, Ángela Arteaga, Montse Algueró and Elena González. "Estudio científico y técnico de la pintura y la policromía de un retablo tardogótico anónimo: El retablo de San Juan de la catedral de Santo Domingo de la Calzada." *Informes y trabajos* 13 (2015): 79–98.

Gómez, Marisa, Carmen Vega, Rocío Bruquetas, Tomás Antelo, Ana Albar and Concepción de Frutos. "Estudios técnicos de dos obras segovianas de Pedro Berruguete: La Misa de San Gregorio y Cristo Crucificado." in *Pedro Berruguete en Segovia*, 107–25. Segovia: Diputación de Segovia, 2013.

González-Alonso Martínez, Enriqueta. *Tratado del dorado, plateado y su policromía: Tecnología, conservación y restauración*. Valencia: Universitat Politècnica de València, 1997.

Idoate, Florencio, and José Ramón Castro. *Catálogo de la Sección de Comptos del Archivo General de Navarra: Documentos*. Vol. 44, *Años 1439–1440; Adiciones, 1402–1438*. Pamplona: Editorial Aramburu, 1966.

Kroesen, Justin. *Staging the Liturgy. The Medieval Altarpiece in the Iberian Peninsula*. Louvain: Peeters, 2009.

Kroesen, Justin, and Victor Schmidt, eds. *The Altar and Its Environment, 1150–1400*. Turnhout: Brepols, 2009.

Kroustallis, Stefanos. "La técnica del dorado y el retablo de don Álvaro de Luna." in *Retórica artística en el tardogótico castellano: La capilla fúnebre de Álvaro de Luna en contexto*, ed. Matilde Miquel Juan and Olga Pérez Monzón. Madrid: Silex (forthcoming).

Labeaga Mendiola, Juan Cruz. "Los talleres de platería de Sangüesa (Navarra): El oficio y la organización." *Ondare* 16 (1997): 239–58.

Lacarra Ducay, María del Carmen. "Blasco de Grañén y la pintura del gótico internacional en Aragón." in *La pintura gótica durante el siglo XV en tierras de Aragón y en otros territorios peninsulares*, ed. María del Carmen Lacarra Ducay, 7–72. Zaragoza: Institución "Fernando el Católico", 2007.

Lacarra Ducay, María del Carmen. "Miguel Vallés, pintor de Zaragoza, en Estella (1486–1487)." *Príncipe de Viana* 51 (1990): 505–16.

Larruga, Eugenio. *Memorias políticas y económicas sobre los frutos, comercio, fábricas y minas de España*. Vol. 4. Madrid: Antonio Espinosa, 1789.

Le Gac, Agnès, Ana Isabel Seruya, Michel Lefftz and Adília Alarcão. "The Main Altarpiece of the Old Cathedral of Coimbra (Portugal): Characterization of Gold Alloys Used for Gilding from 1500 to 1900." *ArchéoSciences* 33 (2009): 423–32.

León Tello, Pilar. *Judíos de Ávila*. Ávila: Excma. Diputación Provincial de Ávila, Instituto "Gran Duque de Alba", 1963.

Long, Pamela O. *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*. Baltimore: Johns Hopkins University Press, 2001.
López Díez, María. "Judíos y mudéjares en la Catedral de Segovia (1458–1502)." *Espacio, tiempo y forma: Serie III, Historia medieval* 18 (2005): 169–84.
López Zamora, Eva. "Estudio de los materiales y procedimientos del dorado a través de las fuentes literarias antiguas: Aplicación en las decoraciones de pinturas castellanas sobre tabla." PhD diss., Universidad Complutense de Madrid, 2007.
Madurell i Marimon, Josep Maria. "El pintor Lluís Borrassà: Su vida, su tiempo, sus seguidores y sus obras, II". *Anales y Boletín de los Museos de Arte de Barcelona* 8 (1950): 9–387.
Merrifield, Mary P. *Original Treatises on the Arts of Painting*. 2 vols. New York: Dover Publications, 1967.
Miquel Juan, Matilde. "La novedad de lo desconocido: Las aportaciones foráneas como elemento de lujo y ostentación en los retablos medievales valencianos." in *Mercados del lujo, mercados del arte: El gusto de las elites mediterráneas en los siglos XIV y XV*, ed. Sophie Brouquet and Juan Vicente García Marsilla, 503–26. Valencia: Universitat de València, 2015.
Miquel Juan, Matilde. "El viaje de artistas y obras de arte catalanas en el Mediterráneo medieval (siglo XV)." in *Els catalans a la Mediterrània medieval: Noves fonts, recerques i perspectives*, ed. Lluís Cifuentes i Comamala, Roser Salicrú i Lluch and M. Mercè Viladrich i Grau, 55–77. Rome: Viella, 2015.
Moya Valgañón, José Gabriel. *Documentos para la historia del arte del archivo catedral de Santo Domingo de la Calzada, 1443–1563*. Logroño: Instituto de Estudios Riojanos, 1986.
Nadolny, Jilleen. "All That's Burnished Isn't Bole: Reflections on Medieval Water Gilding Part 1: Early Medieval to 1300." in *Medieval Painting in Northern Europe: Techniques, Analysis, Art History*, ed. Jilleen Nadolny, 148–62. London: Archetype, 2006.
Nadolny, Jilleen. "Some Observations on Northern European Metalbeaters and Metal Leaf in the Late Middle Ages." in *The Materials, Technology, and Art of Conservation: Studies in Honor of Lawrence J. Majewski on the Occasion of His 80th birthday, February 10, 1999*, ed. Rebecca Anne Rushfield and Mary W. Ballard, 134–60. New York: Conservation Center of the Institute of Fine Arts, 1999.
Pacheco, Francisco. *El arte de la pintura*. Madrid: Cátedra, 1990.
Palomero Páramo, Jesús Miguel. *El retablo sevillano del Renacimiento: Análisis y evolución (1560–1629)*. Seville: Diputación Provincial de Sevilla, 1983.
Palomino, Antonio. *El museo pictórico y escala óptica*. Vol. 2. Madrid. Aguilar, 1988.
Post, Chandler R. *A History of Spanish Painting*. Vol. 8, *The Aragonese School in the Late Middle Ages*. Cambridge, MA: Harvard University Press, 1941.
Robinson, Cynthia. *Imagining the Passion in a Multi-Confessional Castile: The Virgin, Christ, Devotions, and Images in the Fourteenth and Fifteenth Centuries*. State College, PA: Penn State University Press, 2013.
Sánchez Gozalbo, Ángel. *Pintores de Morella: Datos para la historia de la pintura valenciana de los siglos XIV y XV*. Castellón de la Plana: Sociedad Castellonense de Cultura, 1943.
Sánchez-Mesa Martín, Domingo. *Técnica de la escultura policromada granadina*. Granada: Universidad de Granada, 1971.
Sánchez Palencia, Almudena. "La capilla del arzobispo Tenorio." *Archivo español de arte* 48 (1975): 27–42.
Sanpere y Miquel, Salvador. *Los cuatrocentistas catalanes: Historia de la pintura en Cataluña en el siglo XV*. Vol. 1, *Primera mitad del siglo XV*. Barcelona: L'Avenç, 1906.
Saravia de la Calle, Luis. *Instrucción de mercaderes muy provechosa*. Medina del Campo, 1544.
Serrano Larrayoz, Fernando. "La consideración y el ejercicio del cocinero cortesano en Navarra durante la Baja Edad Media." *En la España medieval* 31 (2008): 357–412.
Serrano y Sanz, Manuel. "Documentos relativos a la pintura en Aragón durante el siglo XV." *Revista de archivos, bibliotecas y museos* 31 (1914): 433–58.
Serrano y Sanz, Manuel. "Documentos relativos a la pintura en Aragón durante el siglo XV." *Revista de archivos, bibliotecas y museos* 32 (1915): 147–66.

Serrano y Sanz, Manuel. "Documentos relativos a la pintura en Aragón durante el siglo XV." *Revista de archivos, bibliotecas y museos* 34 (1916): 462–92.

Tatarkiewicz, Wladyslaw. *Historia de la estética*. Vol. 2, *La estética medieval*. Trans. Danuta Kurzyka. Madrid: Akal, 1990.

Theiss, Harald. "'Ihr habt dem Mittelalter seine Aura genommen': Die experimentelle Farbrekonstruktion einer spätmittelalterlichen Skulptur." in *Die grosse Illusion: Veristische Skulpturen und ihre Techniken*, ed. Stefan Roller, 88–119. Frankfurt: Liebieghaus Skulpturensammlung, 2015.

Theophilus. *On Divers Arts: The Foremost Medieval Treatise on Painting, Glassmaking and Metalwork*. Trans. John G. Hawthorne and Cyril Stanley Smith. New York: Dover, 1979.

Thompson, Daniel Varney. "*Liber de Coloribus Illuminatorum sive Pictorum* from Sloane MS. No. 1754." *Speculum* 1 (1926): 280–307.

Tolosa, Lluïsa, Ximo Company and Joan Aliaga. *Documents de la pintura valenciana medieval i moderna*. Vol. 3, *1401–1425*. Valencia: Universitat de València, 2011.

Torres Fontes, Juan. "Genoveses en Murcia (Siglo XV)." *Miscelánea medieval murciana* 2 (1976): 71–168.

Villa-Amil y Castro, José. *Inventarios de mobiliario litúrgico*. Madrid: Nueva Imprenta de San Francisco de Sales, 1907.