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RESEARCH ARTICLE

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Two Sculptures, One Master? A Technical Study of Two Rare Examples of Polychrome Sculptures Associated with "the Master of Saint Catherine of Gualino", Italy, Fourteenth Century

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ABSTRACT

Between the 1960s and 1990s art historian Giovanni Previtali identified a group of polychrome wood *trecento* sculptures from the Umbrian-Abruzzo region of Italy as the work of one hand. He named his artist the *Maestro della Santa Caterina Gualino* after one of the pieces considered to epitomize the style he had identified. Previtali's attribution has since been universally accepted in art historical publications and catalogs. This study tests this assertion through scientific analysis of two of the sculptures named in the group. A team from National Museums Scotland, Edinburgh and the Isabella Stewart Gardner Museum, Boston compared a statue of the Madonna and Child (Edinburgh) and Saint Agnes (Boston) using a variety of analytical tools. Cross-references were made to three other sculptures in the group to which access was gained. The results of this analysis highlight the challenges of testing stylistic associations in the laboratory. Despite taking a scientific approach to data collection and collation there is still much scope for subjectivity in interpretation. Rather than providing a conclusion, our work has opened the door wider still for multiple interpretations, illustrating the limitations of analysis in supporting definitive statements about the authorship of Medieval polychrome sculpture.

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RÉSUMÉ

Entre les années 1960 et 1990, l'historien de l'art Giovanni Previtali a identifié un groupe de sculptures en bois polychrome datant du trecento de la région italienne Ombrie-Abruzzes comme étant l'œuvre d'une seule main. Il a nommé son artiste le Maestro della Santa Caterina Gualino, d'après l'une des pièces considérées comme incarnant le style qu'il avait identifié. L'attribution de Previtali a depuis été universellement acceptée dans les publications et catalogues d'histoire de l'art. Cette étude évalue cette assertion à travers l'analyse scientifique de deux des sculptures citées dans le groupe. Une équipe des National Museums Scotland à Édimbourg et du Isabella Stewart Gardner Museum à Boston a comparé une statue de la Vierge à l'Enfant (Édimbourg) et de Sainte Agnès (Boston) à l'aide de divers outils analytiques. Des références croisées ont été faites sur trois autres sculptures du groupe dont l'accès a été obtenu. Les résultats de cette analyse mettent en évidence les difficultés à évaluer les associations stylistiques en laboratoire. En effet, malgré l'adoption d'une approche scientifique de la collecte et de la collation des données, il reste encore beaucoup de place pour la subjectivité dans l'interprétation. Plutôt que de fournir une conclusion, notre travail a ouvert la porte vers de multiples interprétations, illustrant les limites de l'analyse pour étayer des déclarations définitives sur la paternité de la sculpture polychrome médiévale. *Traduit par Lucile Berthelot.*

RESUMO

Entre as décadas de 1960 e 1990, o historiador da arte Giovanni Previtali identificou um grupo de esculturas de madeira policromada so século XIV da região da Úmbria-Abruzzo, na Itália, como obra de uma mão. Ele nomeou seu artista de Maestro della Santa Caterina Gualino em homenagem a uma das peças considerada como sintetizadora do estilo que ele havia identificado. Desde então, a atribuição de Previtali tem sido universalmente aceita em publicações e catálogos de história da arte. Este estudo testa essa afirmação por meio da

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análise científica de duas das esculturas nomeadas no grupo. Uma equipe dos Museus Nacionais da Escócia, Edimburgo e do Museu Isabella Stewart Gardner, em Boston, comparou as estátuas da Madona e do Menino (Edimburgo) e Santa Inês (Boston) usando uma variedade de ferramentas analíticas. Foram feitas referências cruzadas a outras três esculturas do grupo as quais se teve acesso. Os resultados desta análise destacam os desafios de testar associações estilísticas em laboratório. Apesar de adotar uma abordagem científica para a compilaçãode dados, ainda há muito espaço para subjetividade na interpretação. Mais do que uma conclusão, nosso trabalho abriu ainda mais as portas para múltiplas interpretações, ilustrando as limitações da análise em sustentar afirmações definitivas sobre a autoria da escultura policromada medieval. *Traduzido por Francisco Vieira.*

RESUMEN

Entre las décadas de 1960 y 1990, el historiador del arte Giovanni Previtali identificó un grupo de esculturas de madera policromada del *trecento* procedentes de la región italiana de Umbría-Abruzo como obra de una sola mano. Nombró a su autor como el *Maestro della Santa Caterina Gualino* por una de las piezas consideradas epítome del estilo que había identificado. Desde entonces, la atribución de Previtali ha sido universalmente aceptada en las publicaciones y catálogos de historia del arte. Este estudio pone a prueba esta afirmación mediante el análisis científico de dos de las esculturas nombradas en el grupo. Un equipo de los Museos Nacionales de Escocia, en Edimburgo, y del Museo Isabella Stewart Gardner, en Boston, comparó una estatua de la Virgen con el Niño (Edimburgo) y Santa Inés (Boston) utilizando diversas herramientas analíticas. Se hicieron referencias cruzadas con otras tres esculturas del grupo a las que se tuvo acceso. Los resultados de este análisis ponen de manifiesto los desafíos que plantea la comprobación de asociaciones estilísticas en el laboratorio. A pesar de haber adoptado un enfoque científico en la recopilación y cotejo de datos, sigue habiendo mucho margen para la subjetividad en la interpretación. Más que ofrecer una conclusión, nuestro trabajo ha abierto aún más la puerta a múltiples interpretaciones, ilustrando las limitaciones del análisis a la hora de apoyar afirmaciones definitivas sobre la autoría de la escultura policromada medieval. *Traducción y revisión: Vera de la Cruz y Ramón Sánchez; revisión final: Amparo Rueda e Irene Delaveris.*

1. Introduction

In 1965 art historian Giovanni Previtali attributed a group of *trecento* polychrome sculptures to an Umbrian artist he dubbed the Maestro della Santa Caterina Gualino, or the "Master of Saint Catherine of Gualino," basing his attribution on similarities in style and technique that he saw both in the carving and in the visible polychromy. The majority of these sculptures were in devotional settings in Italy; over the course of the next 30 years, he expanded his group to twelve, including a Madonna and Child in National Museums Scotland (NMS) Edinburgh, and a statue of Saint Agnes at the Isabella Stewart Gardner Museum (ISGM) Boston (Figure 1).

The Gualino grouping is still universally accepted and has been augmented by art historians identifying other pieces matching the style (Palozzi 2014) though none has been subjected to (published) scientific scrutiny. This may be due to the fact that many of the pieces are still in use in churches. Today we are fortunate not only to have access to those two pieces found outside Italy but also to have the tools to be able to look beyond appearance and consider the materials and methods of construction.

This article was prompted by the conservation and publication of the first technical examination of one of Previtali's group: the NMS Madonna and Child sculpture (de Bellaigue et al. 2017) (Figure 1a). The results of this work revealed an elaborately decorated piece commensurate with other *trecento* sculpture but far removed from its modern-day appearance. Other elements of manufacture such as the discovery of an underdrawing marked directly on the wood drove the decision to expand and develop the study by carrying out a full technical analysis of Saint Agnes.

In order to understand the significance of the data from the two sculptures within the context of the wider group associated with the "Gualino Master," a visual examination of three more sculptures was made to which close access had been granted: two Enthroned Madonnas displayed together at the National Museum of Abruzzo (MUNDA) in L'Aquila and the eponymous St. Catherine herself, belonging to a private collection (Figure 2).

With the aim to understand more fully the relationship between the works ascribed to the "Master of Saint Catherine of Gualino," the information obtained through this technical study will be discussed in parallel with recent studies of contemporaneous polychrome sculptures in Europe. Is Previtali's hypothesis borne out by the new evidence? Can authorship be "proven" using analytical techniques? Can the hand of an

Figure 1. (a) Front and reverse of NMS Madonna and Child, © National Museums Scotland. (b) Front and reverse of ISGM Saint Agnes, © Isabella Stewart Gardner Museum.

Figure 2. (a) *Madonna and Child,* early fourteenth century, polychrome wood, 133 cm H × 38 cm W, accession number: A.1950.323, © National Museums Scotland. (b) *Saint Agnes*, early fourteenth century, polychrome wood, 131 cm H × 27.3 cm W, accession number: S30s37, ©Isabella Stewart Gardner Museum. (c) *Saint Catherine of Gualino,* 1300–1350, polychrome wood, 139 cm H × 31 cm W, National catalog code: 0100211697. Courtesy of General Catalog of Cultural Heritage. (d) *Di Carlo Enthroned Madonna and Child*, 1300–1350, polychrome wood, 116 cm H × 35 cm W, Courtesy of Museo Nazionale d'Abruzzo. (e) *Sant Omero Enthroned Madonna and Child,* 1300–1350, polychrome wood, 110 cm H × 29.5 cm W, accession number: OPA 1222. Courtesy of Museo Nazionale d'Abruzzo.

individual as opposed to a group or regional style be pinpointed? And finally, what more can be learned about *trecento* polychrome sculpture and its production through this study?

2. Background

When Saint Agnes was acquired by Isabella Stewart Gardner in 1897, it was described as "school of Pisa" by the Italian Florentine dealer Stefano Bardini from whom she purchased it. By 1935 Saint Agnes was however thought to be French (Longstreet and Carter 1935). The provenance for the NMS Madonna and Child is known with certainty only from 1933 when Michael Sadler, an art collector, bought it from the London sculpture dealer Sir Sydney Burney, at which point, like Saint Agnes, it was thought to be French. Three decades later both statues were reattributed by Giovanni Previtali to the Umbrian-Abruzzo regions of Italy and to the hand of the "Master of St Catherine of Gualino"; an attribution which first appears in print in a 1976 article entitled "An Italian Hypothesis for Two Saint Agnes Sculptures at Fenway Court" (Previtali 1976).

Previtali's first paper to introduce his "Master" outlined the stylistic similarities of a group of pieces found in Umbria and Abruzzo (Previtali 1965). As a student of Roberto Longhi who had identified specific evidence of an Umbrian style in painting, Previtali sought to define that style within the sculptural record. Like his mentor, Previtali was a connoisseur, relying on close scrutiny, through which he discovered and revealed links between hitherto unappreciated sculptures in unexpected geographical locations. He pinpointed other masters he also considered to be influenced by an Umbrian artistic tradition, a tradition previously unnoticed, dismissed as lesser versions of Sienese or Florentine art, or credited to influences from the South and the Kingdom of Naples.

Not only was the geographical area of study unusual so was his appreciation of polychrome wood within the traditions of art historical study, dominated by painting and by more exalted statuary of stone or bronze (Syson 2018). He identified an Umbrian style in the stone bas-reliefs of Orvieto Cathedral, and saw it translated into wood and paint by his "Gualino Master." He also singled out other wooden sculptures and masters from the Abruzzo rather than Umbrian region, such as the "Madonna of la Fossa." These works he saw as evidence of a stylistic spread he saw originating from Umbria, influenced by contact with France and French artifacts during the Avignon Papacy.

It is this interest in geographical origins, rather than a deeper analysis of his grouping of the sculptures under one master, which seems to have dominated art historical scholarship on the subject since. Abruzzo was traditionally considered culturally depressed so despite the cluster of "Gualino" sculptures located here, Previtali thought it implausible that his master might originate from there. On stylistic grounds, the link to Orvieto was recently supported by Luca Palozzi who posited that the "Master of Saint Catherine of Gualino" had trained first as a stone carver, evidenced by the fine finishing techniques on the wood in which he sees close links to stone carving (Palozzi 2014). The physical location of at least five "Gualino" sculptures, situated not in Umbria but in Abruzzo, suggests to Palozzi an itinerant sculptor working first in Umbria and moving on to Abruzzo. However, these Umbrian origins have recently been challenged by Lucia Arbace whose research leads her to believe that the socio-economic conditions of the region and the availability of raw materials could have produced this "quality" of artistic production, positing Teramo origins for the master (Arbace 2019). This re-evaluation of the region's artistic potential is equally supported by Stefania Paone who argues for an Abruzzian style of its own (Paone 2011).

Perhaps this focus on region is unsurprising within the Italian context where artistic flowering is heavily associated with certain areas of production. And perhaps the fact that the existence of the "Gualino Master" has not been directly questioned, is due to the strength of visual evidence. However, in the broader European context, interdisciplinary studies exploring the concept of the anonymous master, originally identified stylistically during the twentieth century, have become increasingly common (Peters 2013; Debaene 2020) and are reflective of changing perceptions of the creative process in polychrome Medieval sculpture. The development of conservation science and the ability to look beneath the surface has enabled such an approach.

For Previtali, for whom it would seem that the physical location of the sculptures was secondary to the stylistic similarities he identified, a close analysis of these stylistic attributes is certainly justified; analysis enabled by new techniques and lab-based assessment. Returning to his writing therefore, Previtali describes: "… the same elongated forms, the same sharp profile, the same soft drapery that falls in simple folds; the same light, clinging fabrics through which the forms of the body beneath can be discerned, sheathing it like fine skin" (Previtali 1965, 19). His identification of similarities extended from the carved form to the polychrome surface: singling out for example, "unforgettable flame red" which he found on one Virgin's mantle and on the NMS Madonna's tunic (Previtali 1984, 37). He considered a "close

Table 1. Summary to key attributes of the sculptures attributed to "the Master of Saint Catherine of Gualino," Italy fourteenth century. + = present; – = not present; ? = unverifiable.

List of attributes	Saint Agnes	NMS Madonna and Child	Di Carlo Madonna and Child	Di Sant'Omero Madonna and Child	Saint Catherine
Poplar wood	+	+	?	?	?
Nailed wooden additions	–	+	+	+	+
Underdrawing	?	+	?	?	?
Partial linen covering	+	+	+	?	+
Straight nose and elongated head	–	+	+	+	+
Deeply carved facial features	–	+	+	–	+
Lack of carved chest and waist modulation	+	+	+	+	+
Deeply carved mantle and tunic folds	+	+	+	–	+
Black lines with vermilion diamonds or jewels	+	+	+	?	–
Straight neckline	–	+	+	+	–
Painted in mantle on shoulders	+	–	–	–	+

collaboration" between the painting and the carving to be a common trait of Umbrian art, and this was epitomized in his Master who was able to be "… both a great sculptor and a superb colorist" (Previtali 1965, 19). It was with these attributes in mind that the cross examination of the NMS Madonna and Child and the ISGM Saint Agnes was undertaken.

3. Analytical methods

A combination of analytical techniques was used on the ISGM Saint Agnes and the NMS Madonna and Child sculptures to gain insight into the date, construction, carving, and possible presence of underdrawings. These included wood identification and radiocarbon dating, visible and ultraviolet induced fluorescence photography, infrared reflectography (IRR), X-ray radiography, and computed tomography scanning (CT). The high level of overpainting visible on both sculptures, combined with the need to identify the original levels of polychromy, meant that micro-samples had to be taken. The identification of the original polychromy was undertaken with cross-section paint analysis, using a combination of Raman Spectroscopy, scanning electron microscopy (SEM) and Fourier transform infrared (FTIR) microscopy. Additional information was also obtained using radiocarbon dating of the paint binder. Due to the separate location of the two sculptures, analytical instrumentation and techniques available to each institution were used in this work. Details on the Analytical Methods can be found in Appendix 1.

4. Results

In the following sections, the structure and polychromy of Saint Agnes will be described and then compared with the data gathered on the NMS Madonna and Child taking into account any similarities and differences perceived on the figure of Saint Catherine, and the MUNDA statues. The similarities and differences described below are summarized in Table 1.

4.1. Wood analysis and carving

Radiocarbon dating confirms that the wood of both sculptures is dated to the fourteenth century (Wileman 2016; Henderson 2021) (Table 2). Saint Agnes is carved entirely from one trunk of poplar wood (Alden 2019) and is carved on three sides. The reverse of the sculpture is a flat surface which has been hollowed out from just below the shoulder line in order to reduce weight and lower the risk of shrinkage and cracking (Stiberc 2014). Curved tool marks are evident where the wood has been removed, perhaps those of an adze – the hollowed area is roughly of the same width down the length of the piece and slightly rounded at the top at a depth of roughly 80 mm. The back reveals many knots in the wood. There are two wooden dowels positioned in parallel by the shoulders and two more at slightly different heights in the lower half. There is also a drilled hole on the proper right side at the base which could have accommodated an additional dowel. These may have been used for attaching the piece to a backing – possibly setting within a reredos or tabernacle (Paone 2011). Similar holes were noted on the reverse of the Di Carlo statue.[1] Saint Agnes is standing on a wooden

Table 2. Radiocarbon results gained from wood sampled from Saint Agnes and Madonna and Child sculptures.

Object	Material	AMS lab code	^{14}C age ± σ [yrs BP]	Calibrated date (95.4 % probability)
NMS Madonna and Child	Wood	OXA-34377	704 ± 28	1260–1306 & 1363–1385
Saint Agnes	Wood	OXA-40645	658 ± 16	1286–1318 & 1359–1389

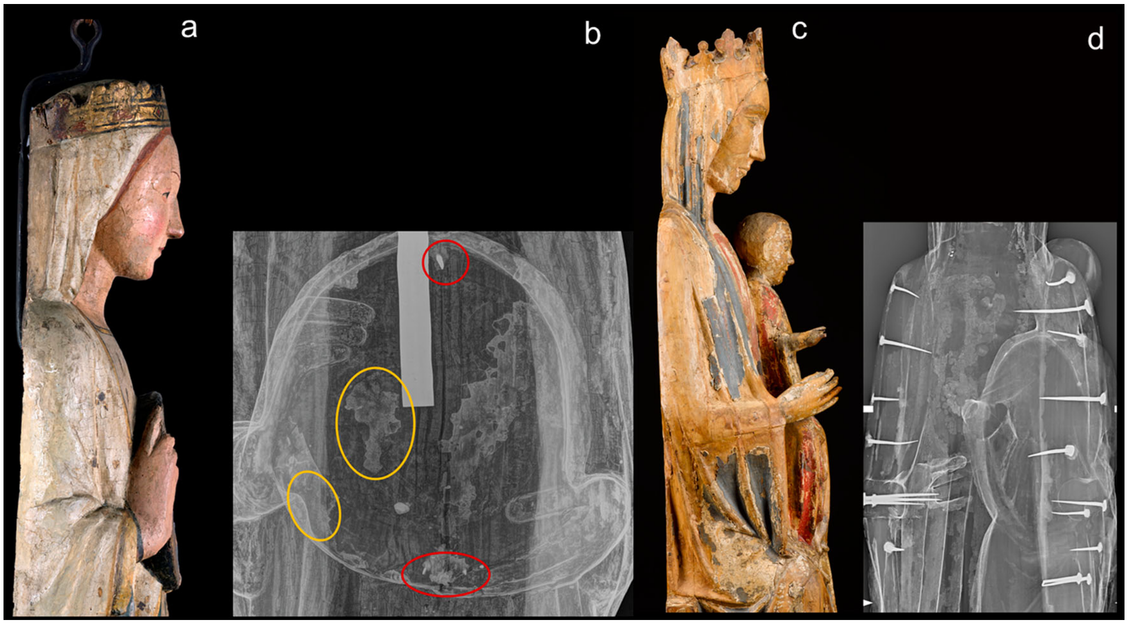

Figure 3. (a) Saint Agnes in profile. (b) En-face projected radiographic image highlighting nail points – red, and linen – yellow. (c) NMS Madonna and Child in profile. (d) En-face projected radiographic image highlighting nail points. © ISGM, © National Museums Scotland.

base, assumed from the style to be of far later provenance.

Saint Agnes holds a medallion depicting the Lamb of God. This is probably also carved from the same trunk as no joints or differences in grain are visible in the x-ray radiographs and the medallion protrudes no further than other parts of the figure. There are, however, several nail shafts evident in the x-ray radiographs with one near the top of the medallion and two near the base. These may be associated with a repair to a significant crack rather than a means to secure a separate piece of wood (Figure 3).

The front of the sculpture is delicately carved with the definition of facial features and drapes in the cloth finely depicted. The layers of paint reduce the crispness of the carving and it is not possible to see evidence of the type of tools employed. When considering the depth of the carving, the eyes and mouth seem to be relatively low in detail with reliance on the painted surface to create these features (Figure 4). The mantle on the shoulders is equally painted in, with no indication of form in the wood. There is little modulation of form on the chest area. The folds of the clothing on the lower parts of the body are carved with some depth, e.g., the proper right sleeve has been deeply hollowed out. Though detailed with fingernails, the hands are cruder. This may be the result of repairs as there is much evidence of insect damage on the medallion and the hands on the x-ray radiographs.

An application of linen is visible underneath the paint on the shoulders at the edge. The linen is also apparent on the x-ray radiographs in patches on the medallion but not apparent elsewhere (Figure 3). It may be that the linen was only applied over edges and knots, or it may be that the density of overlying pigment concealed it.

Unlike Saint Agnes, the NMS Madonna and Child is edged with additional strips of wood where the girth of the poplar tree was not great enough to allow for the carving of the broader seated figure and throne (Skinner 2016; de Bellaigue et al. 2017). Nails were the primary means of attaching the additional wood, albeit the Christ Child's proper right hand is a separate piece attached with a mortise and tenon joint evident in the x-ray radiography (Figure 3). Nail heads were noted on exposed edges of the thrones on both of the MUNDA Virgins therefore it is assumed that similar strips were added to the core trunk. Even the more diminutive standing figure of Saint Catherine was augmented on the shoulders and arms increasing the breadth of the sculpture slightly.

The NMS Madonna and Child is also carved on three sides only, with a flat back, but the exception to this is the head which is carved almost entirely in the round; this is also the case on the MUNDA sculptures. This is probably due to the inclination of their heads, rendering the reverse more visible, unlike the more upright poses of Saint Agnes and Saint Catherine. When comparing the backs of the sculptures, the method of wood removal appears slightly different. The hollowing of the NMS Madonna and Child starts from a lower point halfway down the back and is more angular than curved, with a gradual tapering toward the top.

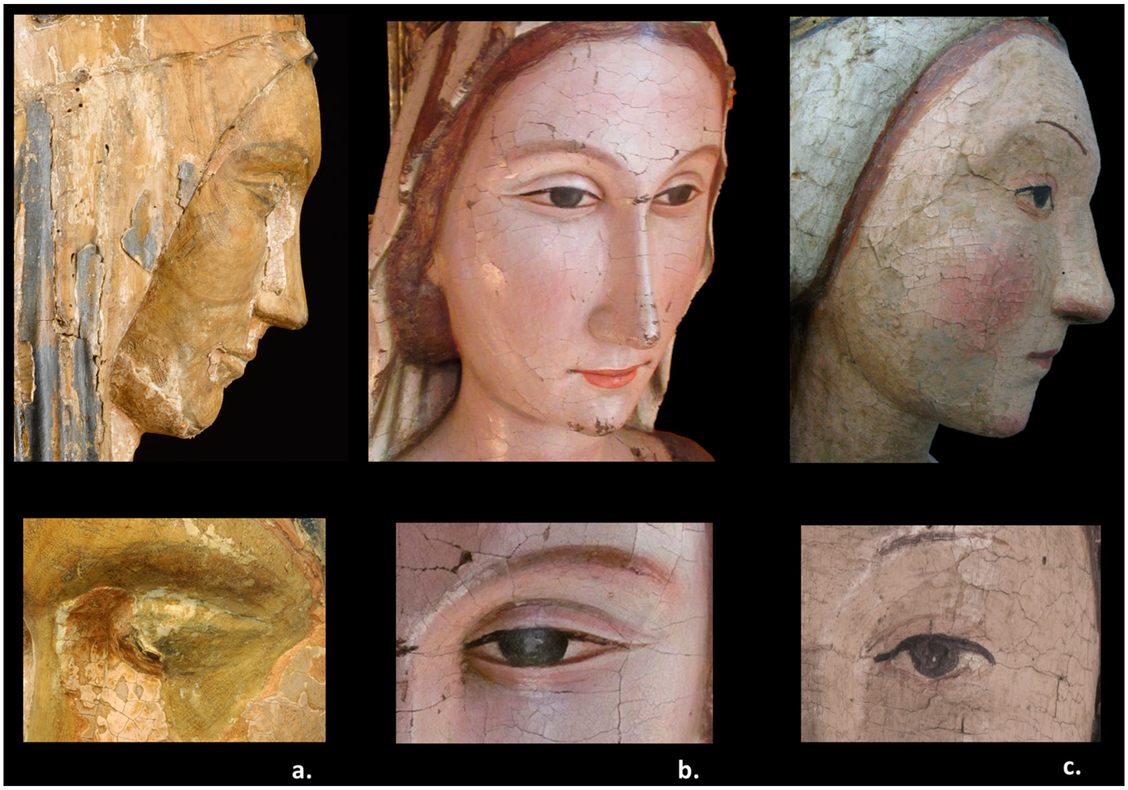

Figure 4. (a) Profile of NMS Madonna's head and detail of proper left eye. (b) Profile of Saint Catherine's head and detail of proper left eye. (c) Profile of Saint Agnes's head and detail of proper left eye. © National Museums Scotland, © ISGM.

The tool marks are straighter than on Saint Agnes, suggesting a flatter blade, and the surface is less rough than that of Saint Agnes (Figure 1a,b). On Saint Catherine the hollowing out is similar to that of the NMS Madonna and Child, starting halfway down the back and with an angular form that tapers toward the top. The chisel marks on the reverse of Saint Catherine have been painted over and are hard to see. Though visible in the online image, the reverse of the di Carlo piece cannot be seen in enough detail to make meaningful comparisons (https://www.europeana.eu/et/item/281/PM_ABR_3D_0009) and the backs of both the MUNDA statues were hidden from view at the time of the visual inspection.

The underside of the Madonna and Child has a rectangular hole on the proper left side which may be evidence of the securing method to the workbench. The top of the sculpture is coated in polychromy so any corresponding fixing point is obscured. It was not possible to look at the underside of any of the other pieces under consideration here.

The NMS Madonna and Child both wear mantles with tunics beneath. The NMS carving appears to be generally deeper and more detailed in places than that of Saint Agnes: For example, the eyes and mouth are deeply gouged in the corners; the form of the mantle on the shoulders is carved in, and the veil around the face is carefully scalloped (Figure 4). The fingers of the proper right hand are particularly delicate, though without fingernails. The folds of the clothing are deeply cut in, and the form of the Christ Child's mantle is indicated around the neck with the marks of a fine finishing tool, including the carving in of a border band and tightly pulled-in waist on the tunic. Repeating straight lines of tooling are also visible, for example on the chin of the Madonna, possibly from a rasp.

In contrast to this, in other areas, the wood was left less finished: On the Christ Child's head for example there are broader chisel marks where the smoothing and finishing does not seem to have occurred, similarly on the Madonna's proper left hand. It is possible that the proper left side of the sculpture was never intended to be as visible as the right. The CT data also shows a large crack running radially through Christ's head from the heart wood which has been filled with a dense material: Perhaps this weakness was the reason this side was left to the painters to finesse due to the risk of further cracking during carving.

When comparing the Madonna and Child and Saint Agnes with the MUNDA pieces, the Madonna and Child is extremely similar in carving technique to the MUNDA Di Carlo statue. Though it is not possible to

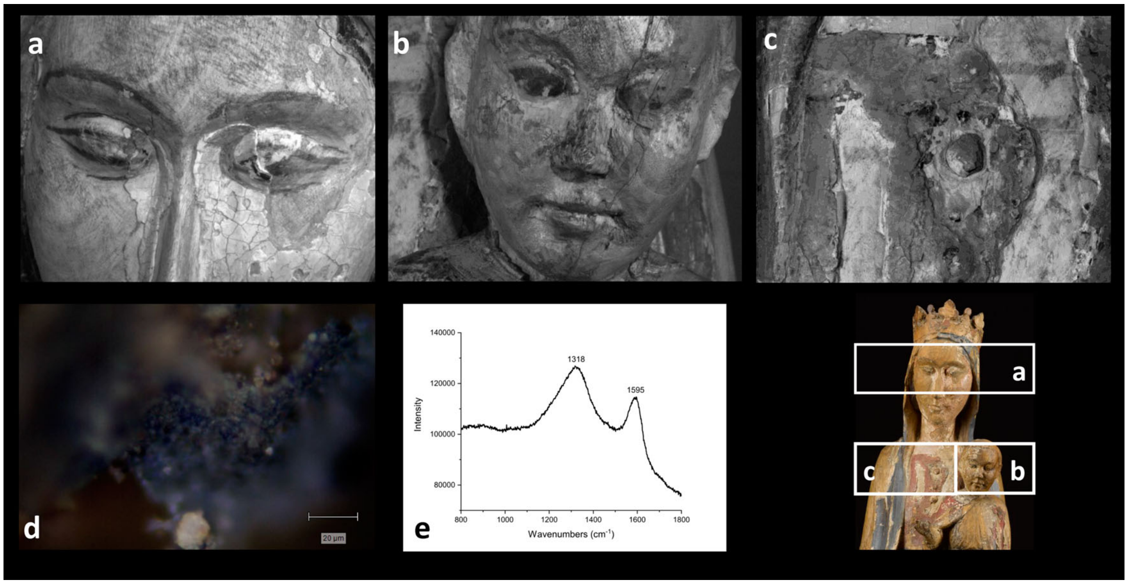

Figure 5. IRR detail of (a) Virgin's face; (b) Jesus's face; (c) Virgin's chest; (d) black pigment sample from Virgin's proper left eye observed under microscopy; (e) Raman spectra displaying the characteristic vibration bands of a carbon black pigment (1358, 1595 cm^{-1}). © National Museums Scotland.

see the detailed tool marks because of the polychromy, the depth of the folds, the shape of the nose, the corners of the mouth are all closely related. Intriguingly, the Madonna's proper left hand is also less fine than the proper right.

The MUNDA di Sant'Omero piece, though of a very similar composition, is carved less deeply in the clothing and appears to have a less finished surface though again the straight noses and overall head shapes are similar. Though the surface at first glance appears to be missing much of its polychromy, there is still a covering of gesso over most of the surface, obscuring tool marks.

The Madonna's crown is more ornate than that of Saint Agnes with tall projections. Saint Catherine's smaller crown is more similar to that of Saint Agnes.

Saint Agnes and Saint Catherine have much in common besides the fact that they are both standing figures. The folds of their mantles cluster at the wrist, and though the shape of the drapery on the lower half is different, it has a similar depth, ending abruptly and obscuring the feet. In both cases the mantle is indicated over the shoulders in the paint and not the wood while the veils are carved in. Nonetheless, Saint Catherine shares similarities with the Madonna and Child as well; the straight nose, the gouges at the corners of the mouth and deep set eyes, and also aspects of the veil, scalloped around the sides of the head (Figure 4). All five figures are similar in the lack of modulation on the chest and at the waist.

As with Saint Agnes, there is a layer of linen evident in some areas beneath the gesso of the NMS Madonna and Child. The MUNDA di Carlo statue also has areas of linen visible beneath the paint though none was noted on the MUNDA Di Sant'Omero Madonna and Child.

4.2. Underdrawing

During conservation treatment of the NMS Madonna and Child, black lines were uncovered underneath the original polychromy running across the Virgin's chest area and other demarcations delineated the eyes of both figures. Though not entirely clear to the naked eye, the use of IRR established with certainty that these were intentional marks made directly on the wood (Figure 5). Further analysis of a micro-sample by Raman spectroscopy revealed the presence of two broad bands centered at ca. 1318 and 1595 cm^{-1}, indicating the use of a graphite pigment (Coccato et al. 2015). There is no visible underdrawing that can be observed on Saint Agnes, either by IRR and UV-induced fluorescence photography. It may be that there is no preparatory drawing present, but it could simply be undetectable due to the thick layers of paint covering the entire surface of the sculpture. It was not possible to conclude whether an underdrawing was used on the other three statues due to the state of surface preservation and obscuring layers of restoration.

4.3. Paint analysis

The study of the polychromy is based on the analysis of fourteen samples taken from Saint Agnes (A1-14) and

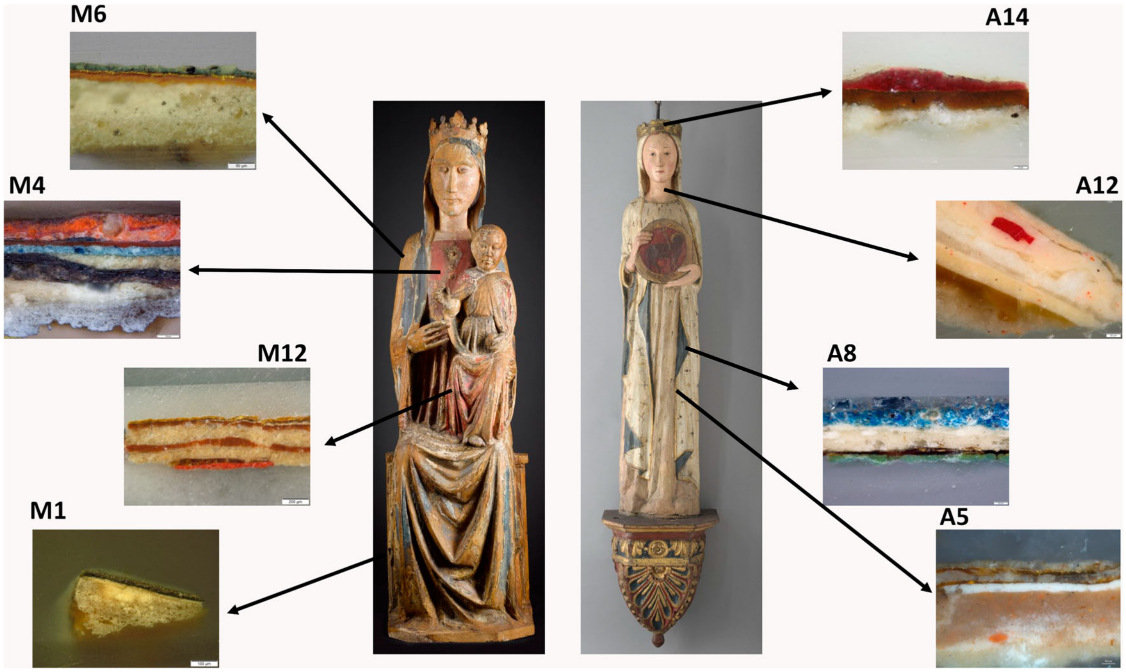

Figure 6. Locations of sampling and microscopic images revealing the stratigraphy of samples A5, A8, A12 and A14 from Saint Agnes and M1, M4, M6, M12 from NMS Madonna and Child. © National Museums Scotland.

twelve samples taken from the NMS Madonna and Child (M1-12). Figure 6 displays the location and stratigraphy of a sub-set of samples across both sculptures discussed in the following sections. For detailed information on the location of each of the samples and detailed analytical data, please refer to SI-1 in Supplemental Information for the detailed data set.

4.3.1. Ground layers

The investigation of the paint samples revealed two types of ground layers used for both sculptures (Table 3). The samples analyzed from the NMS Madonna and Child present a single white ground layer, composed of traditional gesso (gypsum and anhydrite), with inclusions rich in carbonate (dolomite) and strontium (possibly celestine). It was not possible by FTIR analysis to confirm the presence of a protein size in the ground layer, but this was observed in several cross-sections by fluorescent staining (de Bellaigue et al. 2017). In some places, an additional layer of lead carbonate had been applied between the gesso and the paint layers (M1, M5, Table 4). In comparison, Saint Agnes differs in the ground composition as two distinct layers are to be observed. The first two ground layers were identified as calcium carbonate, superimposed by calcium sulfate, followed for most of the samples by a

Table 3. Discussion of the ground layer compositions obtained on Saint Agnes and NMS Madonna and Child sculpture by SEM-EDS and FTIR analysis. © National Museums Scotland.

Sculpture & layers	Method	Laboratory data	IR bands Interpretation	Ground layer
Saint Agnes				
1	EDS	**Ca**		Chalk $CaCO_3$, with coccolith fossils
	FTIR	1400, 871 cm^{-1}	Carbonate – $\nu(CO_3^{2-})$	
2	EDS	**Ca, S, Mg**		Gypsum $CaSO_4.2H_2O$, anhydrite $CaSO_4$
	FTIR	1102, 674 cm^{-1}	Sulfate – $\nu(SO_4^{2-})$	[inclusions of dolomite $CaMg(CO_3)_2$, traces chalk (coccolith fossils)]
		3533, 3398 cm^{-1}	Water – ν(O-H)	
3	EDS	**Pb**		Lead white $2PbCO_3.Pb(OH)_2/PbCO_3$ in siccative oil
	FTIR	1045, 1398 cm^{-1}	Carbonate – $\nu(CO_3^{2-})$	
		1521 cm^{-1}	Carboxylate – $\nu(COO^-)$	
		1725 cm^{-1}	Drying oil – ν(C=O) ester	
		2928, 2856 cm^{-1}	Drying oil – $\nu(CH_2)$	
		3534 cm^{-1}	OH – ν(O-H)	
Madonna and Child				
1	EDS	**Ca, S, Mg, Sr**		Gypsum $CaSO_4.2H_2O$, anhydrite $CaSO_4$
	FTIR	1102, 674 cm^{-1}	Sulfate – $\nu(SO_4^{2-})$	[inclusions of dolomite $CaMg(CO_3)_2$ and/ or celestine ($SrSO_4$)]

Table 4. Discussion of the materials identified in the brocades and glaze layers on Saint Agnes and NMS Madonna and Child sculpture by SEM-EDS and FTIR analysis. © National Museums Scotland.

Type of layer	Method	Laboratory data	IR bands	Interpretation	Sample ID
Gilding	EDS	**Fe, Si [Au]**			
	FTIR	1027 cm^{-1}	Ochre – ν(Si-O)	Gold over red bole ($Al_2Si_2O_5(OH)_4$) and Fe_2O_3, FeO(OH)) in protein and/or lipidic binder	M4
		1550, 1650 cm^{-1}	Amides I and II – ν(C=O)		
		2928, 2856 cm^{-1}	Drying oil – ν(C-H)		
		3618, 3645, 3689 cm^{-1}	Ochre – ν(O-H)		
Lead white	EDS	**Pb**			
	FTIR	1398, 1045 cm^{-1}	Carbonate – ν(CO_3^{2-})	($2PbCO_3.Pb(OH)_2$/ $PbCO_3$) in siccative oil	A5, A6, A10, A12, M1
		1521 cm^{-1}	Carboxylate – ν(COO^-)		
		1720 cm^{-1}	Drying oil – ν(C=O ester)		
		2928, 2856 cm^{-1}	Drying oil – ν(C-H)		
		3534 cm^{-1}	ν(O-H)		
Brocades	EDS	**C, O [Sn, Au]**			
	FTIR	1550, 1650 cm^{-1}	Amides I and II – ν(C=O)	Protein and/or lipidic binder	A5, A6, A10, A12, M1, M6
		1725 cm^{-1}	Drying oil – ν(C=O ester)		
		2928, 2856 cm^{-1}	Drying oil – ν(C-H)		
Red lakes	EDS	**C, O [Al]**			
	FTIR	1550, 1650 cm^{-1}	Amides I and II – ν(C=O)	Pink/ red lakes in protein and/or lipidic binder	A11, A12, A14, M12
		1725 cm^{-1}(weak)	Drying oil – ν(C=O ester)		
		2928, 2856 cm^{-1}	Drying oil – ν(C-H)		
Green glazes	EDS	**C, O [Cu, (Cl)]**			
	FTIR	1619, 1558 cm^{-1}	Acetate – ν(COO^-)	Copper acetate in lipidic binder (residual atacamite in A8)	M6, A8
		2928, 2856 cm^{-1}	Drying oil – ν(C-H)		
		3444, 3333 cm^{-1} (weak)	ν(O-H) (only in A8)		
Green glazes	EDS	**C, O [Cu]**			
	FTIR	1580 cm^{-1}	Carboxylate – ν(COO^-)	Copper carboxylates in lipidic binder	A4
		2928, 2856 cm^{-1}	Drying oil – ν(C-H)		

thin white layer identified as lead carbonate as shown in Figure 7. SEM-EDS analysis confirmed these observations and showed the presence of large inclusions of quartz and calcium-magnesium (dolomite) in the gesso layer, and coccolith fossils characteristic of the use of chalk. From FTIR analysis, siccative oil appears to be present in the lead carbonate layer with the C–H absorption bands around 2928 and 2856 cm^{-1} and possibly minor lead carboxylate at 1525 cm^{-1} (Possenti et al. 2021).

The use of chalk for the lower ground layer of Saint Agnes might seem surprising, as it more often refers to Northern European practices (Kuckova et al. 2013a; Mercier 2019; Kollandsrud and Plahter 2019) than Italy, where gesso seems to have been systematically used (Baracchini 1995; Fachechi and Susanna 2019). An interesting example is the *Virgin from the Urnes* dated from c. 1175 in Norway (Kollandsrud and Plahter 2019), where a layer of gypsum and anhydrite was applied over a thin layer of chalk (which was smoothened), and then tin gilded, as for Saint Agnes. The use of lead white observed in the Saint Agnes samples is not uncommon for that time period but is usually observed in sculptures from France and the Low countries (Le Pogam 2014; Le Hô and Pagès-Camagna 2014; Mercier 2019), although there is also evidence of the use of lead white in other sculpture attributed to Central Italy (Castelnuovo-Tedesco, Soultanian, and Tayar 2010).

4.3.2. Gilding, brocades, glazes

The stratigraphy of the paint samples revealed the presence of complex multi-layered systems, including the use of gilding, brocades and glazes. While the NMS Madonna and Child were repainted at least five times in part, Saint Agnes only shows two levels of polychromy. On Saint Agnes it appears that the visible surface decoration is very similar to what lies beneath. The same is not true of the NMS sculpture. In the following sections, the composition of comparative samples across the sculptures is discussed, focusing on the layers that were identified as part of the original polychromy (see Table 4 and see SI-1 in supporting information for the detailed data set).

The evidence from the cross-sections suggests that Saint Agnes was robed predominantly in lead white with overlying brocade decoration in gold leaf over tin: traces of a design based on a triangular pattern is visible on the mantle beneath overpainting and x-ray radiography detected what could be the original design on the tunic (Figures 8 and 10) (A5, A6, A10, A13). A red bole with gold leaf was used to cover the entirety of the NMS Virgin's mantle (M4, M8), veil and crown, bearing similarity to an Umbrian Virgin and Child now in the Metropolitan Museum of Art (Castelnuovo-Tedesco, Soultanian, and Tayar 2010). Tin was used on the Madonna and Child for the Madonna's robe to imitate a brocade coated with a green glaze (M6) and also to realize the diamond decoration on

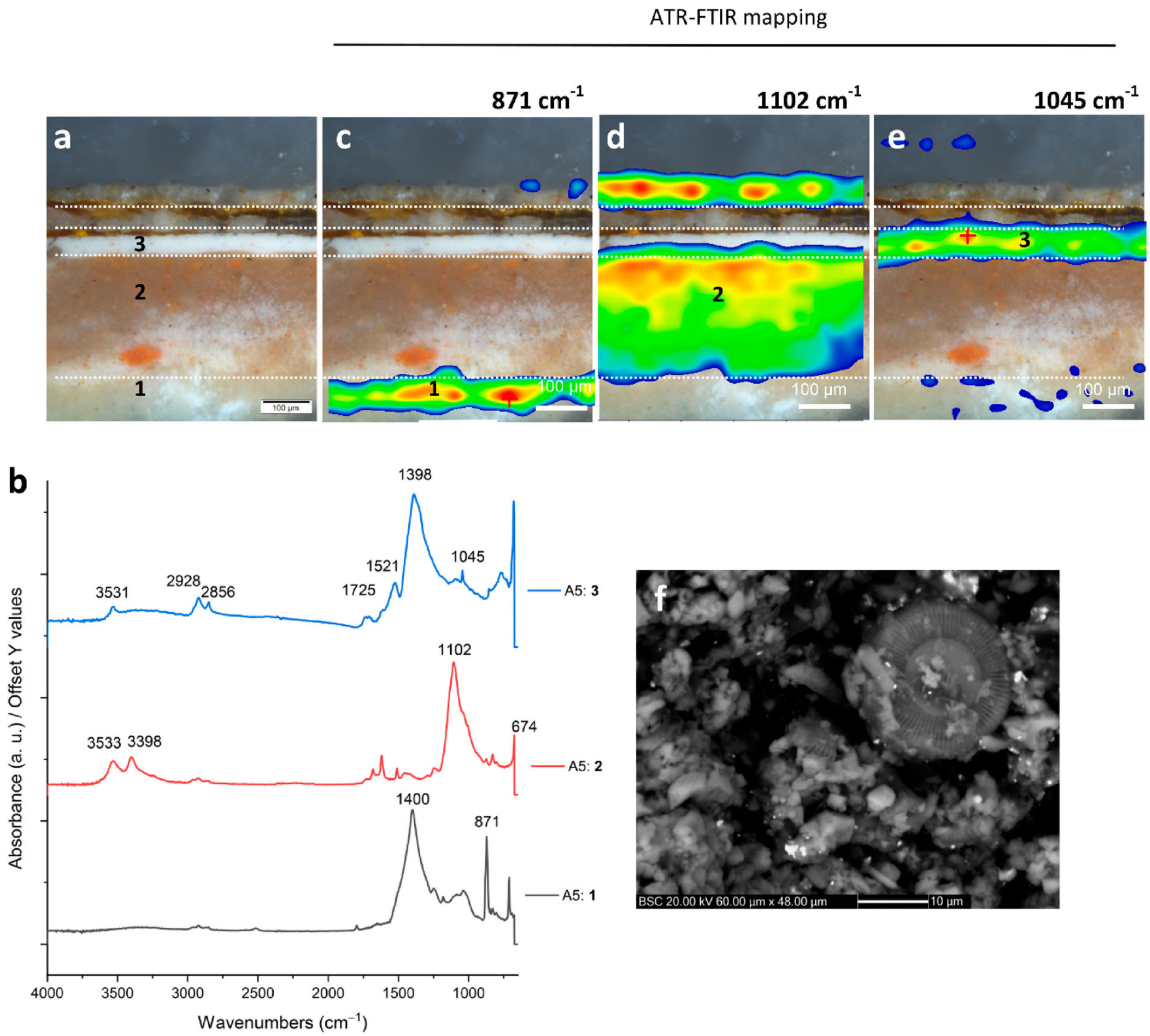

Figure 7. Investigation of paint sample A5 (Saint Agnes - mantle) - (a) cross-section observed under natural visible light; (b) ATR-FTIR spectra of the ground and paint layers with identification of key vibration bands; (c) the presence of calcium carbonate (chalk) is put forward by the ATR-FTIR mapping extracted at 871 cm^{-1}; (d) the presence of calcium sulfate (gypsum and anhydrite) is put forward by the mapping extracted at 1102 cm^{-1}; (e) the presence of lead carbonate is put forward by the mapping extracted at 1045 cm^{-1}; (f) SEM-BSE micrograph showing a coccolith fossil in the chalk ground layer. © National Museums Scotland.

the proper right of the throne (M1), but with no trace of an overlying glaze or gilding (Figures 9 and 10). A 3-D interpretive model was created to give an impression of this use of tin on the Virgin's tunic and the throne for the viewing public (https://www.nms.ac.uk/collections-research/collections-departments/global-arts-cultures-and-design/projects/revealing-the-layers/). The use of tin foil is reported to be common to sculptures of the fourteenth century period (Cennini 1960), although from scientific analysis it seems that the technique of brocade became more extensively used in Europe from the fifteenth century (Le Hô et al. 2021; Lelong et al. 2021). A parallel example of the diamond decoration from the NMS Madonna and Child is found in the Gardner collection on another piece – a terracotta sculpture of the *Virgin Adoring the Christ Child* by Mateo Civitali – though of a later date, where cut-out diamonds of gilded tin leaf over-lie a red lake layer (Chloros et al. 2010).

The detailed analysis of samples A5 and M1 is described below (Figure 10). Microscopic observations revealed that the tin foils used in the brocades are quite thick (c. 30-40 µm) and their aspect and color would probably be consistent with the presence of romarchite (SnO) and cassiterite (SnO_2), commonly reported in oxidized tin (Lelong et al. 2021; Bordet et al. 2021). While sample A5 typically displays the layering system expected to be found in a brocade (Le Hô et al. 2021), with a thin gilding of high purity gold, sample M1 is less sophisticated, with the tin layer applied directly on a pigmented organic size,

Figure 8. (a) En-face projected radiographic image of Saint Agnes highlighting cross and dot pattern invisible to the naked eye due to overpainting, potentially showing the original gilded tin design on the tunic; (b) evidence of an original triangular pattern on the mantle. © National Museums Scotland.

possibly containing carbon black and without the use of additional gilding. ATR-FTIR analysis of the organic materials present in the brocades and gilding (Figure 11) suggests the use of a similar technique: a protein-based media, possibly an animal glue. The significant C–H stretching bands (2850, 2930 cm^{-1}) and weak C=O stretching band (1720 cm^{-1}) observed in several of the samples (Figure 11a) suggest the

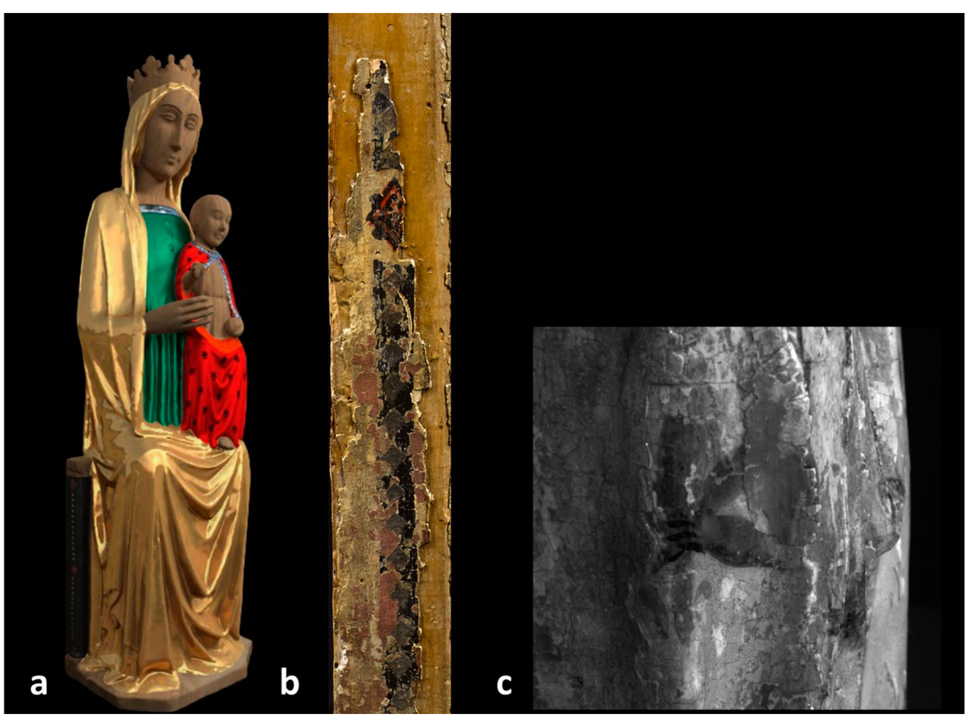

Figure 9. (a) Generalized 3D interpretive model of NMS Madonna and Child using the result of the paint analysis (created by School of Simulation & Visualization, Glasgow); (b) detail of the tin lozenges and red and black design on the throne; (c) IRR image of "leaf" design on the Christ Child's mantle. © National Museums Scotland.

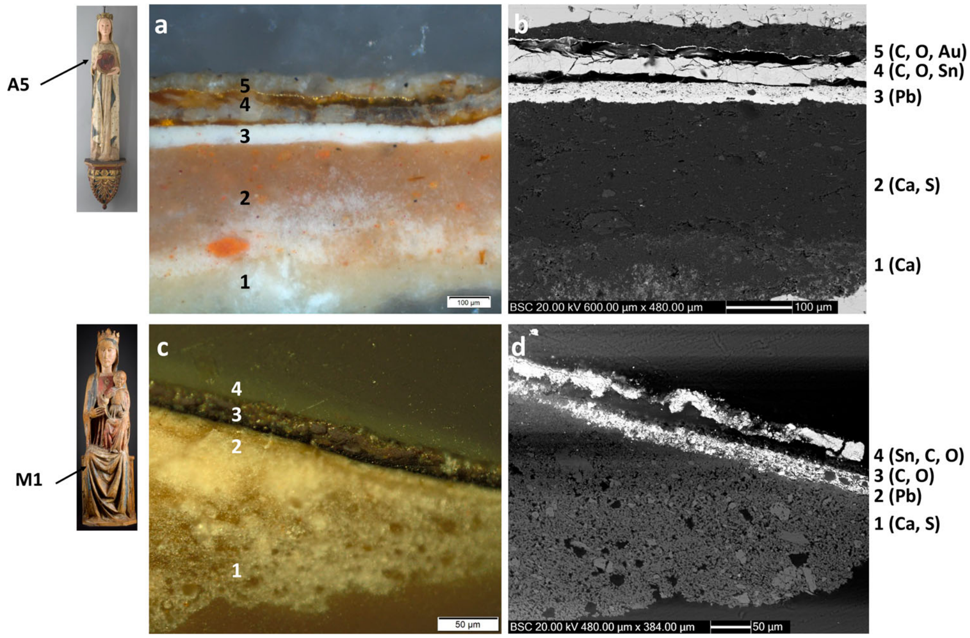

Figure 10. Investigation of tin brocades by optical microscopy and SEM-BSE: (a, b) paint sample A5 (Saint Agnes - mantle); and (c, d) paint sample M1 (Madonna and Child - throne). In both samples the tin foil is applied on an organic binder for the brocade decoration. © National Museums Scotland.

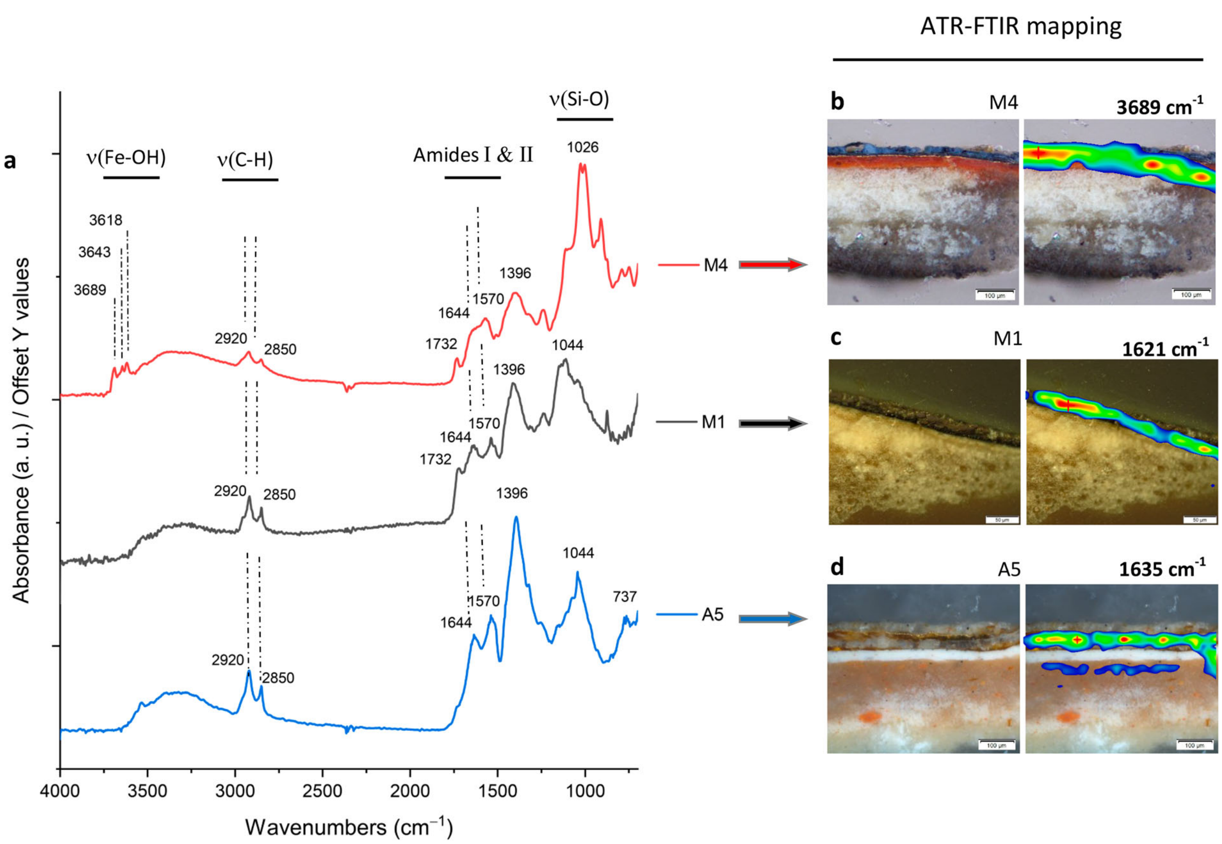

Figure 11. (a) ATR-FTIR investigation of samples M4 (Madonna and Child - Virgin's veil), M1 (Madonna and Child - throne) and A5 (Saint Agnes - mantle) with identification of key vibration bands; (b) the red bole layer in sample M4 is put forward by the ATR-FTIR mapping extracted at 3689 cm^{-1}; (c, d) the presence of a protein binder in samples M1 and A5 is put forward by the mappings extracted at c.1635 cm^{-1}. (* note that for sample M1 and M4, the small band at 1732 cm^{-1} may also relate to the acrylic resin used for embedding). ©National Museums Scotland.

additional presence of a lipidic binder and/or a wax. Whether egg yolk or a siccative oil and a wax medium is unclear, both cases having been reported in other studies (Kuckova et al. 2013a; Kuckova et al. 2013b; Rigante et al. 2021) the later was identified on French and German tin brocades from fifteenth century (Lelong et al. 2021; Le Hô et al. 2021). For the NMS Madonna and Child, the gold leaf of the crown (M4) is applied on a red bole, easily identified by ATR-FTIR analysis with the characteristic Si-O stretching band at 1027 cm^{-1} and the O-H stretching bands at 3618, 3645 and 3689 cm^{-1} (Figure 11a).

Colored glazes were additionally used on both sculptures: in the Madonna and Child, the Madonna's robe is decorated using tin foil coated by a green glaze (M6), while the Christ's mantle was richly decorated in vermilion overlaid with a red lake (M12). For Saint Agnes, the mantle and veil (A8) may have had a green glaze lining now covered with degraded smalt, while pink lakes were used for the carnation and jewel of the crown (A12, A14).

The detailed analysis of samples M12, M6, A8, and A4 displaying respectively the use of a red lake and a green glaze is described below (Figure 12a). ATR-FTIR analysis revealed a homogeneous technique across the red/pink lake samples with the use of a lipidic-protein binder with the significant C–H stretching bands (2850, 2930 cm^{-1}) (Figure 12a,b). The analysis was however not successful in identifying the dyestuff, although some weak absorption bands were observed in the area of 1735 and 1715 cm^{-1} usually associated to the C=O ester and acid C=O stretching bands of the insect red dye *Kerria Lacca* and identified in other studies (Kargère 2014). In this sample (M12), a broad band was detected at 1400 cm^{-1} possibly corresponding to the use of a carbonate as a substrate. The high protein content observed in the red lake may be explained by the use of an alkaline extraction from dyed wool or silk leading to significant proportions of proteins (Kirby, Spring, and Higgit 2005).

Three samples of green glaze were investigated: A brocade from the Madonna's robe (M6) from the

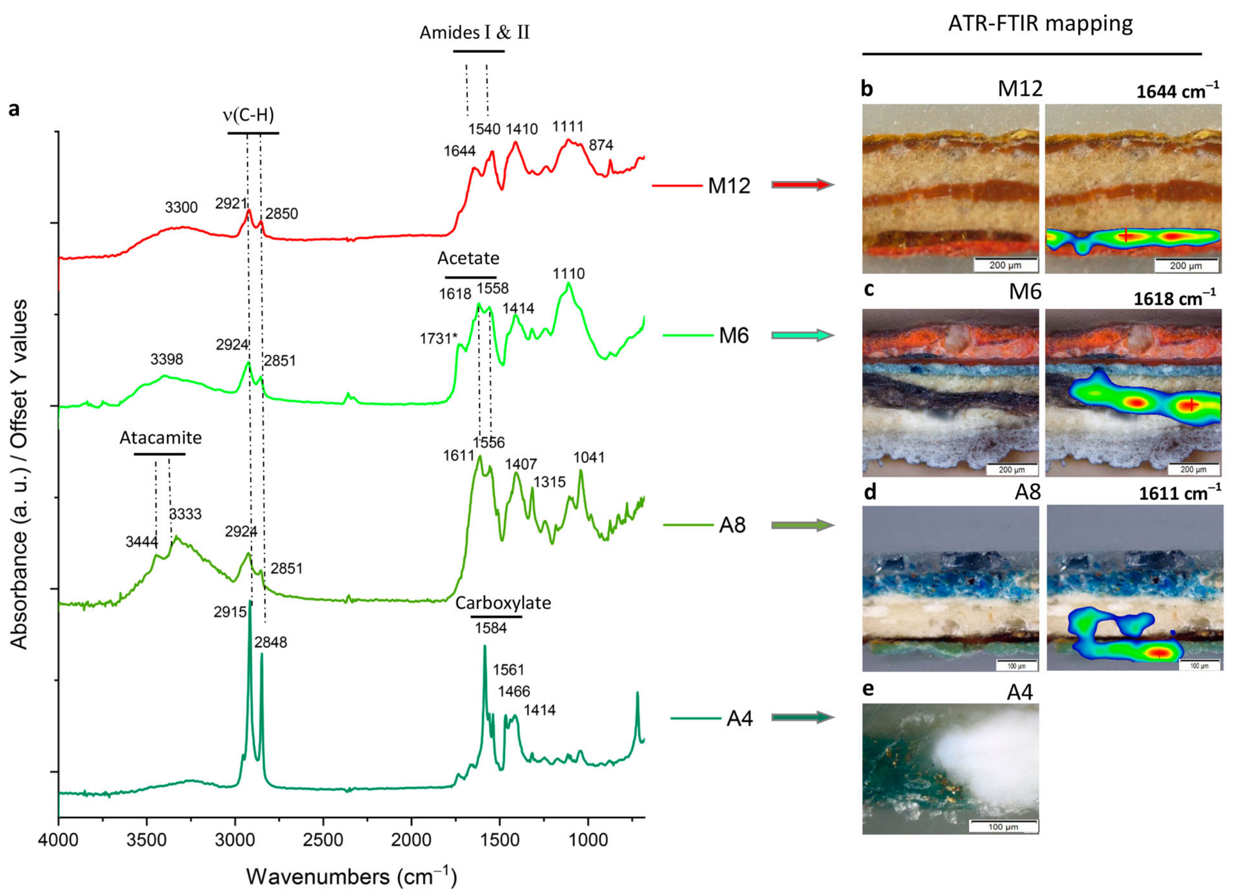

Figure 12. (a) ATR-FTIR investigation of the red and green glazes layer with identification of key vibration bands; (b) the presence of a protein binder in the red lake of M12 is put forward by the ATR-FTIR mapping extracted at 1640 cm^{-1}; (c) the presence of a copper acetate in samples M6 and A8 is put forward by the mappings extracted in the region of 1615 cm^{-1}. (* note that for sample M6, the small band at 1731 cm^{-1} may also relate to the acrylic resin used for embedding). © National Museums Scotland.

NMS Madonna and Child and two samples from Saint Agnes: Her mantle (A8), probably original and directly applied on the ground layers (chalk, gesso); the Saint's veil (A4), a modern green glaze applied on a modern zinc layer. ATR-FTIR analysis of sample M6 characterized the presence of a protein (probably from the tin brocade) and copper acetates in an oil media thanks to the intense COO^- stretching bands (1619, 1556, 1405 cm^{-1}) and C–H stretching bands (2850, 2930 cm^{-1}). The green glaze of sample A8 displays a similar composition but with the additional presence of a copper chloride phase (atacamite and/ or paratacamite) with the stretching bands at 3444 and 3333 cm^{-1}. The presence of copper and chloride in this layer was confirmed by SEM-EDS analysis and appeared to be particularly present in the opaque areas of glaze. This phase probably relates to the degradation of the verdigris pigment used in the green glaze composition, as reported in the work of Prati et al. (2015), rather than its use as a pigment (Coccato, Moens, and Vandenabeele 2017), however, its use as a pigment cannot be totally discounted. In comparison, the modern green glaze of sample A4 revealed the presence of fatty acid copper carboxylates with a sharp COO^- stretching band at 1585 cm^{-1} and strong C–H stretching bands (2850, 2930 cm^{-1}).

4.4. Radiocarbon dating

Due to the unusual ground layers found on Saint Agnes, the possibility of using two novel radiocarbon dating proxies in the pictorial layer, namely the lead white and the natural organic binder, were sought to bring additional evidence as shown in the work of Sá et al. (2021). However, as it was demonstrated in a previous study (Hendriks et al. 2018), a thorough and detailed characterization of all paint components prior to any ^{14}C measurement is crucial to identify the binder type and pigments present in the paint. On the basis of the aforementioned results, the selected paint area on Saint Agnes sleeve was deemed suitable and further sampled for ^{14}C analysis (see SI-2 in supporting information). The results of this exciting but still experimental approach were surprising in that the age estimate of the organic binder falls before that of the wood (Figure 13). While the validity of the measurement is not in doubt, it is the quality and size of the sample and respective sample preparation to be challenged (see details in supporting information). In the attempt of gaining an age estimate from the lead white pigment, the overall lead white layer was found to be much thinner than expected and the sampled 1.5 mg of material was too little to yield a ^{14}C age. The remaining paint

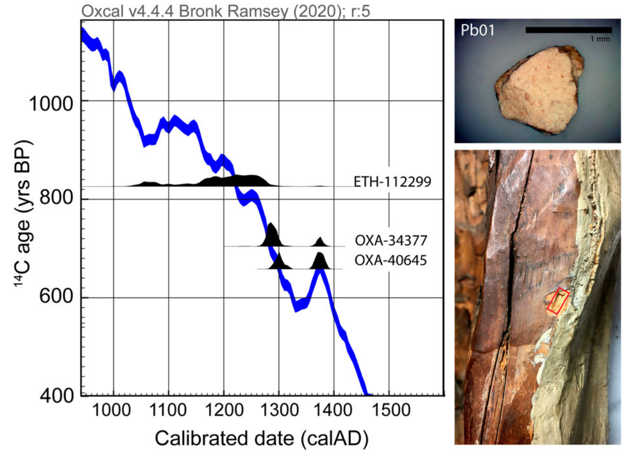

Figure 13. Calibration of radiocarbon ages obtained on the wood sampled from NMS Madonna and Child (OXA – 34377) and Saint Agnes (OXA-40645) in comparison to the binder age gained from a lead white paint sample (ETH-112299) plotted against the IntCal20 calibration curve (blue) and represented as probability density function with 95.4% confidence level. The respective sample sizes sampled from Saint Agnes are depicted on the right, one lead white bearing paint subsample (top) and wood sampling location (below).

offered as much as 37 µg C for dating of the organic binder, whereas both wood measurements conducted at the Oxford lab were performed on 1 mg C. In comparison to the wood sample, which is one of the most common materials submitted to ^{14}C laboratories (Hajdas 2009), the dating of the pictorial layer is much more complex and requires a full sample characterization to exclude possible sources of exogenous carbon. A common contamination source found in cultural heritage objects is conservation material. Although, the uppermost paint layers were removed before sampling, it is possible that conservation materials could have penetrated down through the layers. In the present case, the observed offset may be attributed to carbon contamination following a conservation treatment in 1934, when the flaking paint and gesso was consolidated with a combination of beeswax and gum elemi (Jakstas 1934). Nevertheless, despite the small offset, the additional dating of the organic binder helps increase confidence in the assertion that Saint Agnes and the residual polychromy is indeed medieval and can be placed no later than the fourteenth century.

5. Discussion

5.1. Carving and wood analysis

The aim of this article was to use "technical" analysis and what is considered the work of the conservation scientist and conservator to test stylistic links; however, the line between these two methods is not clear cut. Much of today's carving analysis was based on exactly the same method of data collection as that used by Previtali: that of close scrutiny. This technique would be considered the first step for any conservator when investigating an object. Tabulating the findings gives the reader a clear view of where similarities and differences are identified and allows the analyst to balance these against each other more systematically, giving a more quantitative rather than qualitative outcome but it remains the case that many of the attributes used for this comparison are still subjective such as "a straight nose" or "deep" carving (Table 1) and this cannot be avoided. Where then can the laboratory add meaning?

Wood analysis proved that the two sculptures were made from poplar; this alone is a fact with little significance but when added to the body of other indicators (and these indicators are stylistic) it can help place the sculptures geographically. X-ray radiography provides rich and of course hidden detail revealing the quality of the wood and nature of the carving (the location of knots, damaged areas, insect damage and even obscured designs). In this case, it shows categorically that Saint Agnes is composed entirely from one block while the NMS Madonna and Child was enlarged with several additions. This is a fact but is not a direct line to any one conclusion. For example, this difference alone does not indicate that the pieces were not made by the same hand as the difference can be explained by relative sizes and poses of the statues or the location for which they were destined.

Previtali believed his "Master" was working in the early 1300s. Radiocarbon dating placed the Madonna and Child between 1260–1306 and 1363–1385 and Saint Agnes between 1286–1318 and 1359–1389. Two variables push the likely date of the carving to later in the radiocarbon dating range: neither sample came from the outmost rings of the tree (i.e., the year the tree was cut down) and the time between when the tree was cut and when the sculpture was carved can only be estimated due to the lack of documentary proof (Marincola and Kargère 2020). With those variables in mind, an early to mid-fourteenth century date is plausible for both sculptures. Without the art historian's assessment of style however these results could equally place both sculptures much later in the fourteenth century. To be meaningful therefore the results must be interpreted again alongside these stylistic indicators.

Another comparative method at our disposal is the study of tool marking. Michael Rief (2010) notes that the same tools were used throughout Europe over centuries and while it is possible to identify a certain regional tradition[2] – short of a signature – the mark of an individual is harder to prove definitively. A certain serendipity is indeed required to be able to do so, such as the example given by Rief where a defect in a tool made its unique trace on the wood. Agnes le Gac was also able to identify the carvings of Cipiano da Cruz by determining the use of the same tool and the same handling of that tool for hollowing out the backs of the sculptures in question (2010). If the same technique identifies the same carver, do different techniques identify different carvers? On the NMS Madonna and Saint Agnes, the only exposed tool marks available for comparison were on the reverses and here more differences than similarities were noted; this could be indicative of different hands at work. However this does not necessarily refute the existence of a master carver as it can be explained away as evidence of the use of apprentices within one workshop carrying out the less significant aspects of manufacture.

This is one interpretation. But the combination of x-ray radiography and a deeper understanding of the mechanics of carving in this case broadens scope for conjecture still further: in the x-radiograph and on the back of the sculpture it is evident that Saint Agnes is carved from a far knottier wood than that of the NMS piece. This difference in quality could influence choice of tools and ease of carving thus affecting final shape and finish.

For Previtali, the similarities of form and his assessment of the painted surface were enough to suggest only one hand at work. Where the forms differed, he interpreted this as the development of the master's style over time (Previtali 1976). Palozzi posits that some differences in form could be related to the differences in those commissioning the pieces – with some going to more "provisional audiences" (Palozzi 2014). Both theories remain possible and cannot in fact be resolved through a technical analysis. Returning to the summary of results (Table 1) the information gathered can neither support nor refute these theories – one could count the number of pluses and minuses to weigh up how closely related the sculptures in fact are, but few would accept that this would be a satisfactory basis for a conclusion. While the understanding of the manufacture of the individual pieces in question has been much enriched, rather than enabling a refining of such theories it has resulted in the opposite with a broadening and multiplying of potential interpretations.

5.2. Underdrawing

The discovery with the use of IRR of an under-drawing on the Madonna and Child was seen as a potentially significant clue to authorship; unlike the ambiguity of the tool marking, here was what could be considered the equivalent of a makers mark. However, it was only due to the surface preservation of the Madonna and Child that this underdrawing was discovered and in the case of Saint Agnes, the IRR technique could not yield results due to the overlying layers of lead paint. The only published reference to an underdrawing on sculpture of the period that was found in the course of this study was that of Notre Dame de Bonnes Nouvelles and of the Apôtres de Rieux (Faunières, Pagès-Camagna, and Riou 2014). Underdrawing on later Bavarian polychrome wood sculpture has been discussed by Portsteffen (1998) and readers are encouraged to come forward if other examples are known.

Alongside the challenge of identifying underdrawings beneath layers of paint, the meaning of the underdrawing is not resolved simply by its discovery. Though indicating a very close link in manufacturing methods, the presence of other underdrawings could indeed be used to refute Previtali's suggestion that carver and painter were the same person. Unlike the underdrawing of a painting, these lines could not be used as an initial drawing to be refined with color as they would be obliterated by the preparatory gesso layers. What then was their purpose? Dectot suggests that they have been an instruction from carver to painter in different geographical locations on how to proceed – the detail of form on the eyes and decoration on the dress. Once again however the facts do not lead to just one possible interpretation; another can be elicited by a reading of the work of Christina Neilson who describes the symbolism of wood for a medieval audience, and its painting bringing it "to life" (Neilson 2014, 231). It could be argued that this drawing in of the eyes was a symbolic act prior to the final painting and need not suggest different hands at work.

These are only two interpretations of which more can certainly be found, particularly if documentary evidence regarding workshop practices is uncovered. The challenge of interpretation does not negate the value of the discovery however and therefore the detection of other underdrawings on sculptures within this grouping would be a significant link and the authors hope that analysis will yield more data in the future.

5.3. Paint analysis

One of Previtali's chief arguments when linking the sculptures in the Gualino group was similarities in the visible polychromy. Below that polychromy is a puzzle: The NMS statue has a traditional gesso, whereas the chalk ground on Saint Agnes is unusual for a sculpture of Italian provenance. Is there any cause therefore to doubt the authenticity of the Saint Agnes polychromy? Statues have, after all, been known to be completely stripped and repainted for the nineteenth century art market (Marincola and Kargère 2020) and the small number of repaints could also add credence to this line of argument.

Thanks to ongoing developments in the use of radiocarbon dating in heritage sciences, this point could be empirically addressed using new ^{14}C proxies which even a few years ago would not have been possible. Radiocarbon dating of the natural organic binder, despite a small age offset with the wood, supports a medieval attribution and rules out a nineteenth century one. This supports the likelihood that the polychromy is original. In the context of polychrome sculptures which frequently display intricate surfaces consisting of both original and repainted layers, Sá et al. (2021) demonstrated the potential of radiocarbon dating in guiding the interpretation of the paint stratigraphies. In the case of Saint Agnes this additional data was invaluable. The fact that there is a traditional gesso on the NMS statue does give us greater cause to question Saint Agnes's geographic origins. This clear disparity between the basic materials deserves therefore to be considered in detail.

One potential explanation for this is that carved by the same hand, they were sent out for painting to different workshops possibly closer to the place acquiring the sculpture. Marincola and Kargère describe evidence for this including some pieces even left without polychromy for many years in their devotional setting before eventually being painted (2020). This hypothesis is in turn supported by the presence of the underdrawing.

Another possibility is that Saint Agnes comes from France as was thought in 1935 upon the writing of the General Catalog, and is not Umbrian. The authors have been unable to find any published reference to another sculpture with such a ground from Italy. Indeed in the 65 sculptures analyzed for Clara Baracchini's catalog of the "Scultura Lignea" of Lucca of the period, the only piece where a carbonate ground was identified was found to be of Northern European origin (Baracchini 1995). Moreover, in conversation with the Opificio delle Pietre Dure, though not deemed impossible, such grounds have not been uncovered (Peter Stiberc, pers. comm). The stratigraphy and ground are however consistently found in French early fourteenth century sculpture (Le Hô and Pagès-Camagna 2014). Could this be the answer? The question however is thrown into further confusion by the fact that when the sculpture was *repainted* (as seen in the cross-sections) an "Italian" calcium sulfate gesso was used. A further hypothesis is that perhaps the carbonate ground is evidence of the extent of influence of the French papacy mentioned earlier in this paper, affecting not only style but also material substance. It is hoped that more analysis and evidence gathering of others in the group can move the question on.

The wealth of data gathered on the polychrome layers above the ground place both sculptures firmly in the medieval period and provide much information now in the public domain which can be cross referenced in future studies. The data, however, shows no particular connection between the two sculptures. As with the use of the same carving tools, the same pigments and paint techniques, broadly speaking, were used universally over many centuries and no characteristic "signature" was found in these pieces to link them.

Lastly can anything be inferred from the similarities in the visible painted surfaces? Connections such as the black lines and the jewel-like patterning are interesting (and form part of the basis on which Previtali established his thesis), but without stratigraphic cross-sections, such comparisons cannot be deemed reliable. Given the evidence and the advancements in technical understanding of the treatment of polychrome sculpture over the centuries it is improbable that the visible surface polychromy on the other sculptures discussed here is original.

6. Conclusion

Giovanni Previtali was able to date the NMS Madonna and Child and the ISGM Saint Agnes very accurately from the visual clues he amassed, but this article also demonstrates that these visual clues can no longer be seen to provide a direct line to the hand of one person. The carving tools and marks revealed no tell-tale idiosyncrasy and moreover were often hidden by paint. The similarities that were seen could be used legitimately to support the identification of a regional tradition but were certainly inconclusive as proof of individual authorship. Similarities in the carving were identified between Saint Agnes and Saint Catherine and others between the NMS piece and the MUNDA carvings. A link between the carving technique of Saint Agnes and the NMS Madonna are weaker. Whether these similarities and differences are signs of several hands in one workshop, simply several different workshops, or even one hand at different stages of life remain wide open to interpretation.

We now know there is no supporting evidence that these sculptures were painted by Previtali's "colorist." The NMS Madonna's tunic was not painted in "unforgettable flame red" but in green, her mantle was not a traditional blue but gold. Previtali did recognize that Saint Agnes had been repainted, what he did not (and could not) know was that this repainting was far closer to the original scheme than was the Madonna and Child's polychromy which he acclaimed.

At the time Previtali was writing, he had fewer tools at his disposal in order to be able to verify his hypothesis. The wealth of data elicited from today's techniques allows a far greater accuracy in highlighting similarities and differences in the sculptures under review and has provided a rich data set with which other Medieval polychrome sculpture can be compared. Particularly revelatory was the opportunity to date the paint layers as well as the wood. However, there are still limitations to the conclusions that can be drawn. This study set out to use empirical evidence to test an art historical hypothesis based on stylistic associations. Despite the use of many analytical techniques and the scrutiny of conservators, art historians, conservation scientists and curators, no incontrovertible proof was established. While the information gathered adds much to our understanding of the pieces in question it is not a complete narrative, neither proving nor refuting the existence of the Master of Saint Catherine of Gualino. The scientific data alone cannot provide definitive answers and without stylistic interpretation it is barren of meaning. But rather than giving credence to one hypothesis the new data allows for multiple additional interpretations.

What is self-evident is that the objects were made by someone, and in the absence of knowledge confirming their name, Previtali provided a convenient moniker (this is acknowledged in a recent sales catalogue where the master is described as a "name of convenience" (Pandolfini, 16 June 2022)). What Previtali (and his successors) saw was the quality of a body of work that was largely being ignored, the evidence collated here confirms the complexity and richness of materials and techniques employed and their "worthiness" for study.

What the attachment of a single name to these pieces does not do, however, is capture the chance that one, some or all of the objects discussed are the result of collaboration, and – as now shown by the analysis presented here – that they cannot be connected via a single person or even persons, but rather that common features relate to shared cultures of making, rooted in available materials, training, the transmission of knowledge from person to person and from generation to generation, and expectations of the commissioners and consumers.

Perhaps the most useful way to interpret the data and to consider how such information can help elucidate the art-historical record is by considering what the lack of conclusive evidence does show: that the individual hand was not considered of significance – neither individualistic tool marks nor actual signatures were deemed necessary. And if the flowering of an individual's talent was not on show, can one establish what was on show? What the conservator/scientist can reveal is exactly what materials were used and *how* they were used and thereby help to uncover what was significant about these materials and forms, be that in the shape of an eye, the preponderance of a certain pigment, the use of a certain part of the tree. The similarities of style that were repeated in these carvings do not identify the hand of individual, but do identify what was valued within that carving – as it was deemed worthy of repetition.

This article exemplifies the complexity of deciphering the origins of Medieval polychrome sculptures but also highlights the potential for discovery of new information serving to open up new lines of questioning and challenging perceptions. It is hoped this outcome will drive forward future study – not only through the type of compositional "dissection" undertaken here, but also through the continued search for documentary evidence – thus the pool of knowledge through which to glimpse the hands of potential masters, mistresses, carvers, apprentices, painters and workshops responsible for their creation can be deepened still further.

Notes

1. Since the visual inspection was made by the author where only the front was visible, a 3D model of the Di Carlo statue has been made available online. (https://www.europeana.eu/et/item/281/PM_ABR_3D_0009)
2. For example, Rief describes the identification of a way of hollowing out the heads of sculptures initially thought to be evidence of one workshop but later seen to be a regional technique.

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Diana de Bellaigue and Xavier Dectot conceived the research; Diana de Bellaigue, Lore Troalen and Jessica Chloros led the writing of the original manuscript; Diana de Bellaigue and Jessica Chloros collected CT, IRR data and undertook the sampling; Lore Troalen, Justine Lenglet, and Jerome Castel conducted and interpreted SEM and FTIR experiments; Laura Hendriks and Negar Haghipour conducted and interpreted Radiocarbon dating experiments. All authors contributed critically to the draft and gave final approval for publication.

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Data availability statement

All the data collected for this paper is held at National Museums Scotland, Isabella Stewart Gardner Museum and HES-SO University of Applied Sciences and Arts Western Switzerland.

References

Albano, Michela, Marta Ghirardello, Giacomo Fiocco, Cristian Manzoni, Marco Malagodi, and Daniela Comelli. 2021. "Complementary Mapping Techniques to Characterize the Wood Finish of Musical Instruments." *The European Physical Journal Plus* 136 (10): 1–18. doi:10.1140/epjp/s13360-021-02033-3.

Arbace, Lucia. 2019. "Un ricordo di Giovanni Previtali con alcune riflessioni sulla scultura medievale abruzzese e brevi note sull'attività del Maestro della Santa Caterina Gualino." *Giovanni Previtali e l'arte dell'Italia meridionale. Giornata di studi in ricordo di Giovanni Previtali (1934-1988)*. Naples, Italy. 13–30.

Alden, Harry A. 2019. "Wood I.D. Report 5501." Unpublished manuscript. Alden Identification Service, Chesapeake Beach.

Baracchini, Clara. 1995. *Scultura Lignea, Lucca, 1200-1425. Catalogo della Mostra a Lucca, Museo nazionale di Palazzo Mansi, Museo nazionale di Villa Guinigi, 16 Dicembre 1995 - 30 giugno 1996*. Florence: Studio Per Edizioni Scelte.

Beck, Lucile, Cyrielle Messager, Stéphanie Coelho, Ingrid Caffy, Emmanuelle Delqué-Količ, Marion Perron, Solène Mussard, Jean-Pascal Dumoulin, Christophe Moreau, Victor Gonzalez, Eddy Foy, Frédéric Miserque, and Céline Bonnot-Diconne. 2019. "Thermal Decomposition of Lead White for Radiocarbon Dating of Paintings." *Radiocarbon* 61 (5): 1345–1356. https://doi.org/10.1017/RDC.2019.64.

Beck, Lucile, Cyrielle Messager, Ingrid Caffy, Emmanuelle Delqué-Količ, Marion Perron, Jean-Pascal Dumoulin, Christophe Moreau, Christian Degrigny, and Vincent Serneels. 2020. "Unexpected Presence of ^{14}C in Inorganic Pigment for an Absolute Dating of Paintings." *Scientific Reports* 10 (1): 9582. https://doi.org/10.1038/s41598-020-65929-7.

Bordet, Pierre, Florian Kergourlay, Ariane Pinto, Nils Blanc, and Pauline Martinetto. 2021. "Applying Multivariate Analysis to X-Ray Diffraction Computed Tomography: The Study of Medieval Applied Brocades." *Journal of Analytical Atomic Spectrometry* 36 (8): 1724–1734. doi:10.1039/D1JA00143D.

Bronk Ramsey, Christopher. 1995. "Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program." *Radiocarbon* 37 (2): 425–430. doi:10.1017/S0033822200030903.

Bronk Ramsey, Chrisopher. 2009. "Bayesian Analysis of Radiocarbon Dates." *Radiocarbon* 51 (1): 337–360. doi:10.1017/S0033822200033865

Castelnuovo-Tedesco, Lisbeth, Jack Soultanian, and Richard Y. Tayar. 2010. *Italian Medieval Sculpture in The Metropolitan Museum of Art and The Cloisters*. London: Yale University Press: New Haven.

Cennini, Cennino d'Andrea. 1960. *The Craftsman's Handbook: The Italian "Il libro dell'arte."* Translatd by D. V. Thompson, Jr. New York: Dover Publications, Inc.

Chloros, Jessica, Valentine Talland, Holly Salmon, and Craig Uram. 2010. "Italian Renaissance Polychrome Terracotta Sculpture in the Isabella Stewart Gardner Museum." In *Glass and Ceramics Conservation 2010 preprints, ICOM-CC Interim Meeting, Working Group Glass and Ceramics, October 3-6, Corning*. edited by Hannelore Roemich, 210–218. New York: ICOM Committee for Conservation in association with the Corning Museum of Glass.

Coccato, Alessia, Jan Jehlicka, Luc Moens, and Peter Vandenabeele. 2015. "Raman Spectroscopy for the Investigation of Carbon-Based Black Pigments." *Journal of Raman Spectroscopy* 46 (10): 1003–1015. doi:10.1002/jrs.4715.

Coccato, Alessia, Luc Moens, and Peter Vandenabeele. 2017. "On the Stability of Mediaeval Inorganic Pigments: A Literature Review of the Effect of Climate, Material Selection, Biological Activity, Analysis and Conservation Treatments." *Heritage Science* 5 (12): 1–25. doi:10.1186/s40494-017-0125-6.

de Bellaigue, Diana, Lore Troalen, Mark Richter, Malinali Wong Rueda, Lucas Palozzi, Tobias Schwarz, Tom Challands, and Rachel King. 2017. "Revealing the Archetype: The Journey of a Trecento Madonna and Child at the National Museum of Scotland." In *ICOM-CC 18th Triennial Conference preprints, Copenhagen,* *September 4–8*, edited by J. Bridgland. Paris: International Council of Museums. Art. 1701, 1–8.

Debaene, Marjan. 2020. "The Problem with Leuven Sculpture Around 1500: The Creation of Anonymous Sculpture Workshops." *The Journal of Art Historiography* 22/MD1: 1–14. https://arthistoriography.files.wordpress.com/2020/06/debaene.pdf.

Fachechi, Grazia Maria, and Bracci Susanna. 2019. "Romanesque Polychrome Wood Sculptures in Italy: Towards a Corpus and a Comparative Analysis of the Data from Art-Historical and Technical Studies." *Medievalista* 26: 1–28. doi:10.4000/medievalista.2281.

Faunières, Dominique, Sandrine Pagès-Camagna, and Charlotte Riou. 2014. "La Vierge à l'Enfant, dite Notre-Dame de Bonnes-Nouvelles (Toulouse, musée des Augustins)." *Technè* 39: 90-98. Paris: Réunion des Musées Nationaux. https://doi.org/10.4000/techne.12354

Hajdas, Irka. 2009. "Applications of Radiocarbon Dating Method." *Radiocarbon* 51 (1): 79–90. doi:10.1017/S0033822200033713.

Henderson, Emma. 2021. "Radiocarbon Dating Report." Unpublished manuscript. Oxford Radiocarbon Accelerator Unit, University of Oxford, UK.

Hendriks, Laura, Irka Hajdas, Ester S. B. Ferreira, Nadim C. Scherrer, Stefan Zumbühl, Markus Küffner, Lukas Wacker, Hans-Arno Synal, and Detlef Günther. 2018. "Combined ^{14}C Analysis of Canvas and Organic Binder for Dating a Painting." *Radiocarbon* 60 (1): 207–218. https://doi.org/10.1017/RDC.2017.107.

Hendriks, Laura, Irka Hajdas, Ester S. B. Ferreira, Nadim C. Scherrer, Stefan Zumbühl; Gregory D. Smith, Caroline Welte, Lukas Wacker, Hans-Arno Synal, and Detlef Günther. 2019a. "Uncovering Modern Paint Forgeries by Radiocarbon Dating." *Proceedings of the National Academy of Sciences* 116 (27): 13210–13214. https://doi.org/10.1073/pnas.1901540116.

Hendriks, Laura, Irka Hajdas, Ester S. B. Ferreira, Nadim C. Scherrer, Stefan Zumbühl, Markus Küffner, Leslie Carlyle, Hans-Arno Synal, and Detlef Günther. 2019b. "Selective Dating of Paint Components: Radiocarbon Dating of Lead White Pigment." *Radiocarbon* 61 (2): 473–493. https://doi.org/10.1017/Rdc.2018.101.

Hendriks, Laura; Walter Caseri, Ester S. B. Ferreira, Nadim C. Scherrer, Stefan Zumbühl, Markus Küffner, Irka Hajdas, Lukas Wacker, Hans-Arno Synal, and Detlef Günther. 2020a. "The Ins and Outs of ^{14}C Dating Lead White Paint for Artworks Application." *Analytical Chemistry* 92 (11): 7674–7682. https://doi.org/10.1021/acs.analchem.0c00530.

Hendriks, Laura; Stefan Kradolfer, Tiziana Lombardo, Vera Hubert, Markus Küffner, Narayan Khandekar, Irka Hajdas, Hans-Arno Synal, Bodo Hattendorf, and Detlef Günther. 2020b. "Dual Isotope System Analysis of Lead White in Artworks." *Analyst* 145 (4): 1310–1318. https://doi.org/10.1039/c9an02346a.

Jakstas, Alfred J. 1934. *Saint Agnes Treatment Notes*. Boston: Isabella Stewart Gardner Museum.

Kargère, Lucretia. 2014. "L'expérience américaine. À propos de quelques Vierges romanes conservées aux Etats Unis." *Technè* 39: 13–21. Paris: Réunion des Musées Nationaux. https://doi.org/10.4000/techne.11805.

Kirby, Jo, Marika Spring, and Catherine Higgit. 2005. "The Technology of Red Lake Pigment Manufacture: Study of the Dyestuff Substrate." *National Gallery Technical Bulletin* 26: 71–87. Accessed June 6, 2023. http://www.jstor.org/stable/42616314.

Kollandsrud, Kaja, and Unn Plahter. 2019. "Twelfth and Early Thirteenth Century Polychromy at the Northernmost Edge of Europe: Past Analyses and Future Research." *Medievalista* 26: 1–30. doi:10.4000/medievalista.2303.

Kuckova, Stepanka, Irina Crina Anca Sandu, Michaela Crhova, Radovan Hynek, Igor Fogas, Vania Solange Muralha, and Andrei Victor Sandu. 2013a. "Complementary Cross-Section Based Protocol of Investigation of Polychrome Samples of a 16th Century Moravian Sculpture by Optical, Vibrational and Mass Spectrometric Techniques." *Microchemical Journal* 110: 538–544. doi:10.1016/j.microc.2013.07.002.

Kuckova, Stepanka, Irina Crina Anca Sandu, Michaela Crhova, Radovan Hynek, Igor Fogas, and Stephan Schafer. 2013b. "Protein Identification and Localization Using Mass Spectrometry and Staining Tests in Cross-Sections of Polychrome Samples." *Journal of Cultural Heritage* 14 (1): 31–37. doi:10.1016/j.culher.2012.03.004.

Le Hô, Anne-Solenn, Sandra Montlouis, Sandrine Pagès-Camagna, Nathalie Pingaud, and Yannick Vandenberghe. 2021. "A l'origine des couleurs et éléments matériels d'œuvres peintes des XIVe-XVIe siècles." Special issue, *CeROArt* 1–18. https://doi.org/10.4000/ceroart.7933.

Le Hô, Anne-Solenn, and Sandrine Pagès-Camagna. 2014. "La polychromie de la sculpture médiévale française, XIIe-XVe siècles. Bilan des examens et analyses entrepris au C2RMF." *Technè* 39: 34–41. Paris: Réunion des Musées Nationaux. https://doi.org/10.4000/techne.11940.

Le Pogam, Pierre-Yves. 2014. "La polychromie de la sculpture française aux XIIe-XIIIe siècles: un esquisse." *Technè* 39: 42–51. Paris: Réunion des Musées Nationaux. https://doi.org/10.4000/techne.11991.

Lelong, Florence, Emeline Pouyet, Sophie Champdavoine, Thomas Guiblain, Pauline Martinetto, Philippe Walter, Hélène Rousselière, and Marine Cotte. 2021. "Des « brocarts appliqués » dans la sculpture savoyarde." Special issue, *CeROArt*, 1–21. doi:10.4000/ceroart.7802.

Longstreet, Gilbert, and Morris Carter. 1935. *The Isabella Stewart Gardner Museum, Fenway Court: General Catalogue*. Boston: Printed for the Trustees.

Marincola, Michele D, and Lucretia Kargère. 2020. *The Conservation of Medieval Polychrome Wood Sculpture*. Los Angeles: Getty Publications.

Mazzeo, Rocco, Edith Joseph, Silvia Prati, and Aldo Millemaggi. 2007. "Attenuated Total Reflection-Fourier Transform Infrared Microspectroscopic Mapping for the Characterisation of Paint Cross-Sections." *Analytica Chimica Acta* 599 (1): 107–117. doi:10.1016/j.aca.2007.07.076

Mercier, Emmanuelle. 2019. "New Research Findings on 11th-Early 13th-Century Polychrome Wood Sculpture at the Royal Institute for Cultural Heritage, Brussels." *Medievalista* 26: 1–44. doi:10.4000/medievalista.2313.

Neilson, Christina. 2014. "Carving Life: The Meaning of Wood in Early Modern European Sculpture." In *The Matter of Art: Materials, Practices, Cultural Logics, c. 1250-1750*, edited by Christy Anderson, Anne Dunlop, and Pamela H. Smith, 223–239. Manchester: Manchester University Press.

Palozzi, Luca. 2014. "Polychrome Sculpture or Three-Dimensional Painting? The "Master of the Gualino St

Catherine:" Issues of Visual Culture and Collaboration Between Painters and Sculptors in Trecento Umbria." Unpublished paper presented at the University of Edinburgh, UK.

Paone, Stefania. 2011. "Tabernacoli dipinti e scultura lignea in Abruzzo: Il Maestro di Fossa e il Maestro del Crocifisso d'Argento." *Studi medievali e moderni* 1–2: 45–68.

Peters, Famke. 2013. "A Masterly Hand. Interdisciplinary Research on the Late-Medieval Sculptor(s) Master of Elsloo in an International Perspective." *Proceedings of the Conference Held at the Royal Institute for Cultural Heritage in Brussels, October 20-21, 2011*. Belgium: Royal Institute for Cultural Heritage.

Portsteffen, Hans. 1998. "Form and Polychromy: Two Different Concepts in One Object. Notes on Seventeenth-Century Sculpture Workshop Practices in Bavaria." In *Painted Wood: History and Conservation*, edited by Valerie Dorge and F. Carey Howlett, 157–165. Los Angeles: Getty Conservation Institute.

Possenti, Elena, Chiara Colombo, Marco Realini, Cai Li Song, and Sergei G. Kazarian. 2021. "Insight Into the Effects of Moisture and Layer Build-up on the Formation of Lead Soaps Using Micro-ATR-FTIR Spectroscopic Imaging of Complex Painted Stratigraphies." *Analytical and Bioanalytical Chemistry* 413 (2): 455–467. doi:10.1007/s00216-020-03016-6.

Prati, Silvia, Georgia Sciutto, Emilio Catelli, Shunsuke Ashashina, and Rocco Mazzeo. 2013. "Development of Innovative Embedding Procedures for the Analyses of Paint Cross Sections in ATR FITR Microscopy." *Analytical and Bioanalytical Chemistry* 405 (2–3): 895–905. https://doi.org/10.1007/s00216-012-6435-3.

Prati, Silvia, Irene Bonacini, Georgia Sciutto, Anaïs Genty-Vincent, Marine Cotte, Miriam Eveno, Michel Menu, and Rocco Mazzeo. 2015. "ATR-FTIR Microscopy in Mapping Mode for the Study of Verdigris and Its Secondary Products." *Applied Physics A* 122 (1): 10. doi:10.1007/s00339-015-9519-z.

Previtali, Giovanni. 1965. "Sulle tracce di una scultura umbra del Trecento: il "Maestro della Santa Caterina Gualino." *Paragone* 181: 16–25.

Previtali, Giovanni. 1976. *An Italian Hypothesis for the Two Saint Agnes Sculptures at Fenway Court*. Fenway Court: Isabella Stewart Gardner Museum.

Previtali, Giovanni. 1984. "Due lezioni sulla scultura umbra del Trecento." *Prospettiva* 38: 30–41.

Reimer, Paula J., William E. N. Austin, Edouard Bard, Alex Bayliss, Paul G. Blackwell, Christopher Bronk Ramsey, Martin Butzin, et al. 2020. "The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal KBP)." *Radiocarbon* 62 (4): 725–757. doi:10.1017/RDC.2020.41.

Rief, Michael. 2010. "Going forensic. Art historical research of Northern late Gothic Renaissance wooden sculptures based on the in-depth analysis of materials and traces left by the carving process. In *Polychrome Sculpture: Tool Marks and Construction Techniques, vol. 1. Proceedings of the ICOM-CC Sculpture, Polychromy, and Architectural Decoration Working Group, Maastricht, October 24-25*. Edited by Kate Seymour. Paris, France. 34–40.

Rigante, Elena C. L., Cosima D. Calvano, Rosaria A. Picca, Simona Armenise, Tommaso R. I. Cataldi, and Luigia Sabbatini. 2021. "Multi-Technique Characterization of Pictorial Organic Binders on XV Century Polychrome Sculptures by Combining Micro- and Non-Invasive Sampling Approaches." *Applied Sciences* 11 (17): 8017. doi:10.3390/app11178017.

Ruff, Matthias, Simon M. Fahrni, Heinz W. Gäggeler, Irka Hajdas, Martin Suter, Hans-Arno Synal, Sönke Szidat, and Lukas Wacker. 2010. "On-Line Radiocarbon Measurements of Small Samples Using Elemental Analyzer and MICADAS Gas Ion Source." *Radiocarbon* 52 (4): 1645–1656. doi:10.1017/S003382220005637X.

Sá, Sara, Laura Hendriks, Isabel Pombo Cardoso, and Irka Hajdas. 2021. "Radiocarbon Dating of Lead White: Novel Application in the Study of Polychrome Sculpture." *Scientific Reports* 11 (1): 1–14. doi:10.1038/s41598-021-91814-y.

Schäfer, Stephan. 2013. "A Luminescent Metal Chelate Stain and Its Application Protocol for the Identification of Proteinaceous Binding Media Within Paint Cross Sections." In *Coloured Glaze on Metal Leaf from Baroque and Rococo Period*, edited by E. Emmerling, M. Kühlenthal, and M. Richter, 1–8. Munich: Anton Siegl Fachbuchhandlung Munich.

Skinner, Theo. 2016. "Wood Identification Report on Umbrian Madonna." Unpublished manuscript, National Museums Scotland, UK.

Spring, Marika, Camilla Ricci, David A. Peggie, and Sergei G. Kazarian. 2008. "ATR-FTIR Imaging for the Analysis of Organic Materials in Paint Cross Sections: Case Studies on Paint Samples from the National Gallery, London." *Analytical and Bioanalytical Chemistry* 392 (1): 37–45. doi:10.1007/s00216-008-2092-y.

Stiberc, Peter. 2014. "Wood Crucifixes in Late 15th Century Florence – Innovations in Construction Techniques, First Results from a Research in Progress." In *Polychrome Sculpture: Tool Marks & Construction Techniques. Proceedings of the ICOM-CC Interim Meeting, Working Group Sculpture, Polychromy, and Architectural Decoration, October 2010 Maastricht*, edited by Kate Seymour, 41–48. Paris: International Council of Museums.

Synal, Hans-Arno, Martin Stocker, and Martin Suter. 2007. "MICADAS: A New Compact Radiocarbon AMS System." *Accelerator Mass Spectrometry* 259 (1): 7–13. doi:10.1016/j.nimb.2007.01.138.

Syson, Luke. 2018. "Polychrome and its Discontents: A History." In *Like Life. Sculpture Color and the Body*, edited by L. Syson, S. Wagstaff, E. Bowyer, and B. Kumar, 14–41. New Haven and London: Yale University Press.

Wacker, Lukas, Simon M. Fahrni, I. Hajdas, Mihály Molnár, Hans-Arno Synal, Sönke Szidat, and Yanlin Zhang. 2013. "A Versatile Gas Interface for Routine Radiocarbon Analysis with a Gas Ion Source." *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions With Materials and Atoms* 294: 315–319. http://dx.doi.org/10.1016/j.nimb.2015.01.075.

Wileman, Elizabeth. 2016. "Radiocarbon Dating Report." Unpublished manuscript. Oxford Radiocarbon Accelerator Unit, University of Oxford, UK.

Websites:

https://www.nms.ac.uk/collections-research/collections-departments/global-arts-cultures-and-design/projects/revealing-the-layers/

Appendix

Materials and methods

Wood identification

Wood identification was carried out for both sculptures on a thin section of wood: for Saint Agnes it was carried out by Alden Identification Service using a compound microscope (40× to 400×) with both chemical and fluorescent tests, while for Madonna and Child, it was carried out using SEM (Skinner 2016).

Radiocarbon dating

Wood. Radiocarbon dating of the wood samples was performed at the Oxford Radiocarbon Dating Accelerator Unit.

Paint. Based on a recent study reporting on a radiocarbon dating survey of polychrome sculptures to guide the interpretation of paint stratigraphies (Sá et al. 2021), an attempt was made to radiocarbon date the pictorial layer of St. Agnes. The ^{14}C signature of both the lead white (Hendriks et al. 2019; Beck et al. 2020) and organic binder (Hendricks et al. 2018; Hendricks et al. 2019) was pursued from the collected paint samples according to the most recent published workflow (Hendriks et al. 2020). The paint samples were measured as carbon dioxide on a MIni radioCArbon DAting System (MICADAS) system (Synal, Stocker, and Suter 2007), where the coupling of a gas interface allows the introduction of carbon dioxide from processed samples in Pyrex tubes directly or following direct combustion in an elemental analyzer (Ruff et al. 2010; Wacker et al. 2013). All radiocarbon ages were calibrated using the software Oxcal v.4.4 (https://c14.arch.ox.ac.uk/oxcal/OxCal.html) (Bronk Ramsey 1995; 2009) with the IntCal20 atmospheric calibration curve (Reimer et al. 2020).

X-ray radiography

Two-dimensional X-ray radiography of both sculptures was undertaken. Saint Agnes was x-radiographed using an XRS Comet System with MXR 320/26 tube and Carestream HPX-1 Digital System with HPX-1 scanner. Parameters were set at 65 kV tube energy 150 s exposure time 4 mA tube current with 10 mm Pb filter. The Madonna and Child was x-radiographed using an Apollo DS (Villa Sistemi Medici, Milano, Italy) system at similar parameters. CT scanning was additionally undertaken on the Madonna and Child sculpture using a 4-slice helical CT unit (Volume Zoom, Siemens AG, Erlangen Germany), 3 mm slice width, image interval 1.5 mm, 120 kV, 204 mAs, field of view 466 mm^2, pitch 1.66, 1.5 s tube rotation time, with reconstruction kernel high-frequency (proprietary B70s) and medium frequency (proprietary B40s).

XRF

Both sculptures were investigated using hand-held X-ray fluorescence (p-XRF) to identify possible areas for sampling. The pXRF analysis was done using a Bruker Tracer III-SD spectrometer and the data was collected and analyzed with S1PXRF & ARTAX, 7.4.0.0 software. Analyses were run at 40 kV, 8 μA, no filter, for 60 s live time irradiation.

Underdrawing (when observed) and paint sampling were then targeted on specific elements of decoration including the robe, mantle, and crown.

Paint sample preparation technique

Around 30 samples were prepared as cross-sections for analysis. The paint samples were embedded in Technovit 2000 LC and in other cases in a polyester resin from Struers, UK. Where enough material was available, a subset of samples was additionally prepared using a double embedding process in potassium bromide (KBr) and epoxy resin adapted from published studies (Prati et al. 2013). All the cross sections were dry polished on silicon carbide papers (Micro-Mesh®) from grade 1000 to grade 12,000 using a sample holder to ensure they could be analyzed by infrared spectroscopy.

Imaging and microscopy

Imaging. All photography of Saint Agnes was carried out using a converted Sony Alpha a7R II mirrorless digital camera with a 55 mm lens. A Deep BW infrared 49 mm filter, manufactured by LifePixel, was used to capture IRR photography. Ultraviolet (UV) light photography used 40-watt Spectroline BLE-7900B bulbs with a spectral output of 365 nm. IRR photography of the Madonna and Child was carried out using a MUSIS (Multi-spectral Imaging System) camera working in the spectral range of 750–1000 nm (near IR).

Microscopic imaging. The paint cross sections were examined under visible and ultraviolet light. The Saint Agnes samples were observed using a Zeiss Axio Imager. M2m microscope equipped with Zeiss EC Epiplan-NEOFLUAR microscope set-up with a Zeiss AxioCam MRc 5 camera and ZEN pro 2012 software. The Madonna and Child samples were observed with an Olympus BX41 microscope and an Olympus Stream Start 1.8 image analysis software.

Fluorescent staining for proteins was undertaken on a few samples with SYPRO® Ruby Protein Blot Stain (Schäfer 2013) followed by UV examination.

Raman spectroscopy

One sample of underdrawing from the Madonna and Child was analyzed by Raman spectroscopy using a Renishaw InVia microscope equipped with a 785 nm laser and ×50, ×100 objectives. The beam size was around 1–3 μm and the power at the surface of the object around 0.5 mW. Acquisition time was typically 10–60 s depending on the sample

Scanning electron microscopy (SEM-EDS)

The paint cross section samples were investigated at NMS using a CamScan MX2500 Scanning Electron Microscope (SEM) fitted with Backscattered Detector (BSE) and Energy Dispersive X-ray Spectroscopy (EDS). Imaging of the cross sections was undertaken after carbon coating using BSE detector in High Vac mode at the working distance of 20 mm. Punctual analysis and elemental mapping were undertaken using an 80 mm^2 $XMax^N$ detector working with AZtec software, at 20 kV accelerating voltage and the optimized working distance of 30 mm.

Fourier transform infrared microscopy (micro-ATR-FTIR)

FTIR spectroscopy was conducted at NMS following published methodology for paint cross sections analysis (Mazzeo et al. 2007; Spring et al. 2008; Prati et al. 2013; Albano et al. 2021). Analysis was undertaken with a Nicolet™ Thermofisher iN10 infrared microscope fitted with a mercury cadmium telluride (MCT) detector cooled by liquid nitrogen and a conical germanium crystal for attenuated total reflection (ATR) measurements. The micro-FTIR mapping were recorded in the range 4000–675 cm^{-1} typically working with an aperture of 80 µm, 25 µm steps and 16 scans at a resolution of 4 cm^{-1}. Data collection and post-run processing were performed using OMNIC Specta™ and OMNIC Picta™ software. FTIR univariate chemicals maps were produced considering the characteristic absorptions bands for each of the identified materials, extracting the peak area. The spatial distribution of the materials is displayed by a chromatic scale ranging from red for the highest to blue for the lowest values.