



Conservar els Murals del Trecento

El paper de la tècnica pictòrica

Preserving Trecento mural paintings

The role of pictorial technique

MUHBA Documents 9

Lídia Font, editora



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Ajuntament
de Barcelona

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PRESENTACIÓ

Lídia Font

Les jornades que el Museu d'Història de Barcelona, amb la col·laboració del Reial Monestir de Santa Maria de Pedralbes, va organitzar els dies 29 i 30 de novembre de 2012 amb el títol «Conservar els murals del Trecento» estaven dedicades a la tècnica pictòrica emprada en l'execució d'alguns conjunts murals rellevants d'aquell període. L'objectiu era contextualitzar les característiques de la capella de Sant Miquel del monestir de Pedralbes per plantejar el tractament de conservació integral des del millor coneixement, no només d'aquesta obra, sinó també de l'experiència restauradora d'altres.

En les diverses sessions, els responsables de la conservació i la restauració dels murals de la capella Peruzzi (1325?) i la capella major (1380-1390) de la basílica de la Santa Croce de Florència i el conjunt de la capella de San Blas (1390?) de la catedral primacial de Toledo van presentar els resultats de les seves recerques i actuacions. Per la nostra banda, l'equip que treballem en el projecte «Murals sota la lupa» a Barcelona vam donar a conèixer la tasca realitzada entorn dels murals de la capella de Sant Miquel (1346).

Amb aquesta iniciativa es propiciava l'intercanvi d'experiències i coneixements al voltant d'obres amb similituds estilístiques i de cronologia relativament propera, però executades en àrees geogràfiques distants i per tallers i mestres diferents, tots ells representants del nou corrent italianitzant que des de la Toscana es disseminà per altres territoris europeus. La proposta posava doncs en relació les obres fetes per Giotto, Agnolo Gaddi, Starnina i Ferrer Bassa.

Si bé les jornades se centraven en la tècnica d'execució, també s'analitzaren les similituds en les maneres de procedir, les alteracions sofertes per les obres i els tractaments possibles.

El punt central comú d'aquestes anàlisis de diversos cicles pictòrics és l'exploració de la matèria de la qual està feta l'obra, al marge dels aspectes estilístics i de qualitat de la representació. Els resultats obtinguts posen de manifest una vegada més que les característiques materials d'una obra són una font documental i una via d'anàlisi imprescindibles per a la conservació, alhora que contribueixen a una millor comprensió de les innovacions pictòriques del gòtic.

Sabem que en aquestes jornades haurien tingut cabuda molts altres conjunts. Aquesta primera trobada va ser tot just un punt de partida que en el futur caldrà ampliar i contrastar amb el nombre màxim d'obres, però esperem que esperoni cada cop més estudis sobre la tècnica artística.

Finalment, agraïm el recolzament de totes les entitats implicades i la contribució de tots els participants. Durant les jornades també es van presentar els treballs efectuats als murals de la capella de Saint Martial del Palau dels Papes d'Avinyó sobre el control científic i tècnic en la fase prèvia a la restauració, una aportació que no s'inclou en aquesta publicació perquè es tracta d'un projecte en curs.

PREFACE

Lídia Font

A conference entitled “Preservation of the Trecento murals”, organised by the Barcelona History Museum with the cooperation of the Royal Monastery of St. Mary of Pedralbes, was held on the 29th and 30th of November 2012. The conference focused on the painting technique used in the execution of several important groups of murals during that period. The aim was to contextualise the characteristics of St. Michael’s chapel in the Pedralbes Monastery so that the comprehensive conservation work could be undertaken based on a better understanding not only of this work, but also the experience of other restorations.

Those in charge of the conservation and restoration of the murals in the Peruzzi chapel (1325?) and the Maggiore chapel (1380-1390) in the Basilica of Santa Croce in Florence, and in the chapel of Saint Blaise (1390?) in the Primate Cathedral of Toledo, presented the results of their research and projects in the different sessions. For our part, the team working on the “Murals in the spotlight” project in Barcelona presented the work we have carried out on the murals in St. Michael’s chapel (1346).

This initiative facilitated the exchange of experiences and knowledge on work which is stylistically similar and relatively close chronologically, but which was carried out in far-flung geographical areas by various workshops and masters, all of whom represented the new trend of Italianisation which spread from Tuscany to other parts of Europe. As a result, the conference made a connection between works by Giotto, Agnolo Gaddi, Starnina and Ferrer Bassa. While the conference focused on the technique of implementation, the similarities in the procedures used, the deterioration suffered by the works and the possible treatments were also studied.

The common focus of these studies of several pictorial cycles is the exploration of the material with which the work is produced, in addition to the stylistic aspects and the quality of the representation. The findings show once again that the material characteristics of a work of art are an essential documentary source and method of analysis for conservation, while contributing to a better understanding of the innovations of Gothic painting.

We are aware that many other groups of murals could have featured in this conference. This first initiative is merely a starting point and needs to be extended in the future, including as many works as possible for comparison. However, we hope that it will encourage an increasing number of studies to be carried out on artistic technique.

Lastly, we would like to thank all the organisations involved for their support and all the participants for their contributions. As part of the conference, a presentation was also given on the work carried out on the murals in the Saint Martial chapel of the Palais des Papes in Avignon, on the scientific and technical management in the pre-restoration phase. As the project is still underway, the project has not been included in this publication.

LA CAPELLA PERUZZI DE LA SANTA CROCE

Els anys 2010 i 2011, l'Opificio delle Pietre Dure va realitzar una campanya global d'anàlisis tècniques i científiques de les pintures murals de Giotto a les capelles Bardi i Peruzzi de la basílica de la Santa Croce de Florència. L'objectiu era obtenir informació més detallada sobre la tècnica artística de Giotto en aquella etapa de la seva carrera.

Ens vam centrar especialment en els extraordinaris resultats aconseguits a la capella Peruzzi mitjançant la fotografia per fluorescència ultraviolada. Encara no coneixem els motius del nivell poc comú de fluorescència ultraviolada que s'hi va registrar, però se'n poden fer moltes hipòtesis. El més probable és que els resultats obtinguts mitjançant aquesta tècnica siguin conseqüència del treball *a secco* i, en concret, de la interacció entre l'aglutinant utilitzat i determinats pigments.

Altres explicacions possibles són una composició poc habitual de la capa de l'*intonaco*, que hauria provocat aquesta singular dispersió ultraviolada, o la interacció de pigments i aglutinants amb el pas del temps. Altres factors podrien estar relacionats amb l'historial de conservació dels murals, concretament amb la retirada de l'emblanquinat (que podria haver provocat un procés de saponificació), o amb els efectes de tractaments de preservació anteriors, en els quals es podrien haver aplicat solvents d'alta retenció o que reaccionessin fortament amb el material orgànic de les capes pictòriques. És possible que hi hagués més materials orgànics a causa de tractaments previs amb fixadors i consolidants. La interacció entre els materials de restauració i els originals també podria ser en part responsable de la inusual fluorescència ultraviolada constatada.

LA CAPILLA PERUZZI DE LA SANTA CROCE

El Opificio delle Pietre Dure llevó a cabo en los años 2010 y 2011 una campaña global de análisis técnicos y científicos de las pinturas murales de Giotto en las capillas Bardi y Peruzzi de la basílica de la Santa Croce de Florencia. El objetivo era recabar información más detallada sobre la técnica artística de Giotto en esa etapa de su carrera.

Nos centramos especialmente en los extraordinarios resultados conseguidos en la capilla Peruzzi mediante la fotografía por fluorescencia ultravioleta. Aún no conocemos los motivos del nivel poco común de fluorescencia ultravioleta que registramos, pero pueden plantearse muchas hipótesis. Lo más probable es que los resultados obtenidos mediante esta técnica se deban al trabajo *a secco* y, en concreto, a la interacción entre el aglutinante utilizado y determinados pigmentos. Otras explicaciones posibles son una composición poco habitual de la capa del *intonaco*, que habría provocado la singular dispersión ultravioleta, o la interacción de pigmentos y aglutinantes con el paso del tiempo. Factores adicionales podrían estar relacionados con el historial de conservación de los murales, en concreto con la retirada del encalado (que podría haber dado lugar a un proceso de saponificación), o con los efectos de tratamientos de preservación anteriores, que podrían haber aplicado solventes de alta retención o que reaccionaran fuertemente con el material orgánico de las capas pictóricas. Es posible que hubiera más materiales orgánicos debido a tratamientos previos que recurrieran a fijadores y consolidantes. La interacción entre los materiales de restauración y los originales también podría ser en parte responsable de la inusual fluorescencia ultravioleta constatada.

THE PERUZZI CHAPEL IN SANTA CROCE

An overall campaign of technical and scientific analyses was carried out by the Opificio delle Pietre Dure in 2010 and 2011 on the mural paintings by Giotto in the Bardi and Peruzzi chapels in the basilica of Santa Croce, in Florence.

The campaign was undertaken in order to obtain a more precise understanding of Giotto's artistic technique at this phase in his career. Much of our attention has been attracted by the extraordinary results that were collected in the Peruzzi chapel by means of ultraviolet fluorescence photography. The causes for the unusual UV fluorescence that we recorded are still unknown at this date, but many hypotheses are viable. It is most probable that the extraordinary results obtained by UV fluorescence are due to the use of the *a secco* technique and, in particular, the interaction between the binding medium that Giotto utilized and specific pigments.

Other possible explanations include the possibility that the *intonaco* layer may have an unusual composition, causing the unusual UV scattering; or the phenomenon may have to do with the interaction of pigments and binders over time. Other factors may be related to the murals' conservation history, such as the removal of the whitewash (which could have initiated a process of saponification) or the effects of past preservation treatments (albeit undocumented but probable). Such treatments could have employed high-retention solvents or solvents that react strongly with organic materials in the paint layers. Additional organic materials may also be present due to previous treatments that employed fixatives and consolidants. The interaction between later restoration materials and the original materials may also be partially responsible for the unusual UV fluorescence that we observed.

Cecilia Frosinini

Directora de la divisió de pintura mural de l'Opificio delle Pietre Dure

LA CAPELLA PERUZZI DE LA SANTA CROCE. GIOTTO SOTA LA FLUORESCÈNCIA ULTRAVIOLADA

THE PERUZZI CHAPEL IN SANTA CROCE. GIOTTO UNDER THE UV FLUORESCENCE

Cecilia Frosinini

Els cicles murals de les capelles Bardi i Peruzzi de la basílica de la Santa Croce de Florència ocupen una posició singular en l'evolució artística de Giotto di Bondone i representen els referents tradicionals de la seva etapa postpaduana. Tanmateix, aquest període de la trajectòria de l'artista no ha gaudit de tanta atenció com la seva obra anterior, probablement a causa de la conservació deficient de les capelles i perquè els experts no s'han posat d'acord pel que fa a la datació de les pintures. A més, els murals pateixen greus danys, precisament arran dels problemes de conservació: durant la primera meitat del segle XVIII totes dues capelles es van emblanquinar, i al començament del XIX es van instal·lar monuments funeraris a les parets de la capella Bardi, la qual cosa va provocar la pèrdua de parts importants del cicle narratiu. La retirada de la calç, que va començar el 1841, va malmetre considerablement la pel·lícula original de pintura: les marques que hi van deixar les eines emprades encara són visibles.

Gaetano Bianchi (conegut pintor i restaurador florentí del segle XIX) va repintar les pèrdues principals de les àrees figuratives de la capella Bardi amb una integració completament inventada; no solament hi va afegir noves figures, sinó que a més les va fer amb la tècnica tradicional del fresc.

En el cas de la capella Peruzzi no es van produir grans pèrdues, sinó una abrasió general de tot el cicle que els mateixos restauradors (Antonio Marini i Pietro Pezzati, el seu aprenent) probablement van entendre com un malguany del tractament. Potser per això la restitució es va completar amb un repintat general de totes les històries que va tapar les capes de pintura originals (que, però, estaven

The wall painting cycles in the Bardi and Peruzzi chapels, in the basilica of Santa Croce, occupy a unique position in the artistic evolution of Giotto di Bondone and are the traditional touchstones of his post-Paduan phase. However, this period of Giotto's career has received less attention than his earlier work, probably because of the fragmentary state of the chapels' conservation and the lack of scholarly agreement on the dating of the paintings. Moreover, the paintings are badly damaged due to their history of conservation: in the first half of the 18th century the two chapels were whitewashed and during the early nineteenth century funerary monuments were installed on the walls of the Bardi Chapel, leading to the loss of significant portions of the narrative cycle. The removal of the lime-based whitewash, which began in 1841, caused significant damage to the original film of paint and marks left by the tools used for the task are still visible.

The main losses of the figurative areas in the Bardi chapel were in-painted by Gaetano Bianchi (a well-known painter and restorer of 19th century Florence) with a totally invented integration, which not only added new figures but also painted them according to the traditional fresco technique.

In the case of the Peruzzi chapel, there were no major losses but a general abrasion of the whole cycle that was probably perceived as a failure of the treatment by the restorers themselves (Antonio Marini and Pietro Pezzati, his pupil). Probably for this reason the restitution was completed with an overall repainting of all the stories that hid the original paint layers (although they were in poor condition) under a neo-medieval appearance.



en mal estat) sota una aparença neomedieval.

Entre els anys 1958 i 1961 a totes dues capelles es va dur a terme una campanya moderna de restauració, a càrrec de Leonetto Tintori i sota la direcció d'Ugo Procacci, impulsada per criteris històrics i rigorosos, en la qual es van retirar tots els afegits i els repintats del XIX. En aquell moment existien ben poques anàlisis científiques, de manera que tenim escassa informació sobre les troballes tècniques. Tintori va escriure un llibre (juntament amb la historiadora de l'art Eve Borsook) sobre el tractament realitzat a la capella Peruzzi. Tot i que és fonamental des de molts punts de vista, l'obra recull moltes de les suposicions de l'època sobre la tècnica mural. Així doncs, una anàlisi global de les dues capelles de Giotto requereix amplis coneixements de la tècnica artística, en part també perquè, després del tractament de Procacci-Tintori, se'ls ha prestat poca atenció des del punt de vista tècnic.

Del 2009 al 2012 l'Opificio delle Pietre Dure i els seus socis científics van dur a terme una investigació amb l'ajut d'una subvenció de la Getty Foundation. L'objectiu era estudiar la informació recollida per tal de fer un estudi exhaustiu de la tècnica i els materials emprats per Giotto. La recerca analítica pretenia identificar els materials pictòrics fets servir originalment per l'artista i el seu taller, en un primer moment mitjançant investigacions no invasives que no requerien mostres, i després recopilant micromostres que es van analitzar per conèixer amb més precisió les tècniques artístiques i els problemes de conservació. A la fi del 2013 es publicarà un llibre sobre aquestes troballes. Mentrestant, ens agradaria

In 1958-1961 the two chapels were the focus of a modern restoration campaign carried out by Leonetto Tintori under the direction of Ugo Procacci, based on historical and scientific objectives, that removed all the additions and repainting dating back to the 19th century campaign. At the time very few scientific analyses were available, so there is little information regarding the technical findings. Tintori (along with the art historian Eve Borsook) wrote a book about the treatment carried out on the Peruzzi chapel. Although fundamental from many points of view, the book echoes many of the presumptions of the time about wall painting technique. Therefore, an overall analysis of the two Giotto chapels requires great expertise in artistic technique, also because, after the later treatment by Procacci-Tintori, little attention has been paid to the chapels from a technical point of view.

In 2009-2012 an investigation was carried out by the Opificio delle Pietre Dure and its scientific partners with the support of a grant from the Getty Foundation. The goal was to examine the data collected in order to make a comprehensive study of Giotto's technique and materials. The analytical research was aimed at identifying the original painting materials used by Giotto and his workshop, initially through non-invasive investigations that did not require samples, and later by collecting micro samples for analysis. Analyses have been performed on these to obtain more precise knowledge of artistic techniques and conservation issues. A book regarding the findings will be published at the end of 2013. In the interim, we would like to offer to a wide

Comparació entre la vista a ull nu d'una figura i la fotografia amb fluorescència ultraviolada

Comparison between the naked-eye vision of a figure and its photograph under the UV fluorescence

oferir a un ampli públic d'experts alguns dels aspectes més destacats del resultat, notables i inesperats, obtinguts a partir dels murals de la capella Peruzzi, especialment gràcies a la fluorescència ultraviolada.

Abans de parlar d'aquests resultats cal presentar una perspectiva general de la tècnica artística dels murals per tal d'entendre'ls millor.

Les capes d'*intonaco* o allisat de la capella Peruzzi es van fer mitjançant el mètode de les *pontate*; és a dir, aplicant grans àrees horitzontals d'*intonaco* que abasten tota l'amplada dels murs de la capella. Aquestes *pontate* divideixen les escenes en dues franges. A sota d'elles gairebé sempre són visibles els pegats d'*intonaco* col·locats per cegar els forats (anomenats *buche pontate* en italià) practicats a la paret per inserir-hi les bigues dels diferents nivells de la bastida. L'*intonaco* presenta una superfície especialment homogènia, tot i que les observacions fetes en determinades mostres estratigràfiques han tret a la llum una sèrie de partícules gruixudes o inerts de dimensions prou sorprenents (fins a 1000 \times m).

L'alçada dels nivells de la bastida sembla força baixa, al voltant d'1,4-1,5 metres, la qual cosa ens fa pensar que els forats de la construcció de la maçoneria es podrien haver reutilitzat, ja que la progressió de baix cap a dalt per a l'aixecament de l'estructura devia requerir plataformes de treball a intervals reduïts. En conseqüència, és probable que senzillament es descartés el nivell intermedi per poder pintar de manera uniforme les diferents escenes.

L'alineació dels forats de la bastida dels murs enfrontats indica, com il·lustra la representació termogràfica, que la bastida emprada per a la pintura devia tenir grans plataformes per cobrir tot el volum de la capella i treballar simultàniament a totes les parets. Si es van aprofitar els forats fets servir abans per a la construcció de la capella, la hipòtesi sobre la bastida amb plataformes podria ser versemblant o no, ja que el motiu del seu alineament es podria vincular a altres explicacions relacionades amb els treballs de maçoneria.

Generalment es considera que la tècnica pictòrica de la capella Peruzzi és *a secco*. Una anàlisi més acurada indica que hi ha notables diferències en la tècnica d'execució de les diverses parts. Sembla que la pintura de la volta es va començar en *buon fresco* i que la nervadura i les franges decoratives de les crugies es van fer amb aquesta tècnica. Les capes preparatòries grises per a la posterior aplicació d'atzurita també es van pintar en *buon fresco*, com també els frisos d'imitació de marbre i



Detall de l'escena de la resurrecció de Drusiana

Detail of the scene of the resurrection of Drusiana



audience of experts some highlights from the remarkable and unexpected results obtained from the Peruzzi Chapel murals, especially those gathered by means of Ultra-Violet Fluorescence.

Before presenting these results, a general overview of the artistic technique of the Peruzzi murals is required in order to provide a greater insight.

The *intonaco* layers of the Peruzzi Chapel were applied by the *pontate* method, i.e. By applying large horizontal portions of *intonaco* that span the width of each wall of the chapel. The *pontate* of *intonaco* divide each scene horizontally into two parts. Under each *pontata*, *intonaco* patches applied close to



El nen de l'Apocalipsi

The child of the Apocalypse

segurament tots els motius al·legòrics pintats a la paret de la finestra, dels quals es conserven fragments.

Totes les decoracions que emmarquen les escenes es van pintar *a secco* però fent servir una calç carbonatada triturada (*bianco di San Giovanni*) que es podria haver aplicat en una capa d'*intonaco* encara humida. Els altres elements de les escenes es van pintar completament *a secco*. L'anàlisi ha mostrat la presència de molts altres pigments incompatibles amb la tècnica del *buon fresco*: cinabri, mini, malaquita, verdigris i orpiment.

Les tècniques de transferència de dibuixos visibles encara a la superfície són marques d'incisions directes i de línies tirades amb cordill per a les composicions arquitectòniques i moltes parts decoratives. Podem localitzar també moltes zones de dibuix amb pinzell a mà alçada. Gairebé totes les parts acabades amb fulla metàl·lica estan definides amb incisions directes, com és habitual. Per construir pràcticament tots els elements arquitectònics de les escenes, com també les línies rectes

scaffolding putlog holes, are nearly always visible. These putlog holes (*buche pontaié* in Italian) are the cavities made in the wall in which the beams used to support each level of the scaffolding were inserted. The *intonaco* displays a particularly smooth surface even though observations made on some stratigraphic samples have shown a quantity of coarse or inert particles, with rather striking dimensions (up to 1000×m).

The height of the scaffolding levels appears rather low, around 1.4-1.5 meters. This leads us to believe that the scaffolding holes for the masonry construction may have been re-used, given that the progression from low to high for the construction of the architectural structure would require working platforms at short intervals. Therefore it is probable that the intermediate level was removed in order to permit the uniform painting of each individual scene.

The alignment of the scaffolding holes of the two facing walls, as illustrated by the thermographic imaging, suggests that the scaffolding used for the painting had large platforms, i.e. at a single level, extended over the full volume of the chapel, that allowed for simultaneous work on all the walls. If these putlog holes were the ones previously used for the architectural building of the chapel, the hypothesis regarding the platform scaffold may or may not be plausible, because the reason for their alignment could be linked to other explanations related to the masonry work.

The painting technique of the Peruzzi Chapel is generally considered to be *a secco*. A more thorough analysis shows that there are notable differences in the techniques used when executing the various parts. The painting of the vault appears to have been started in *buon fresco* and the ribs and the decorative bands of the bays were painted with this technique. The grey preparatory sections for the later application of azurite were also made in *buon fresco*, as well as the faux-marble dados and probably all the allegorical motifs painted on the window wall, fragments of which survive. All the decorations that frame the scenes were painted *a secco* but using a ground white lime (*Bianco di San Giovanni*) that could have been applied to a layer of not-completely dry *intonaco*. All the other parts of the scenes are completely painted *a secco*. The analysis has shown the presence of numerous other pigments which are incompatible with the technique of *buon fresco*: cinnabar, minium, malachite, verdigris, and orpiment.



Capitell de l'escena de l'Ascensió de Sant Joan Baptista

Capital of the scene of the Ascension of St. John the Baptist

verticals i horitzontals del marcs decoratius, es van fer servir línies tirades amb cordills impregnats amb un pigment de terra roja, i les abundants esquitxades de color que hi van quedar encara són ben visibles. Les línies no van deixar cap depressió en l'*intonaco*, la qual cosa fa pensar que ja devia ser força dur quan s'hi van batre els cordills.

Les línies tirades dins de les escenes no semblen travessar les figures, sinó que s'aturen amb bastant precisió i coincideixen amb el dibuix del seu contorn. Això podria indicar que, abans de col·locar els cordills per crear els elements arquitectònics, ja s'havien dibuixat els grups de figures, o com a mínim perfilat. Una hipòtesi més versemblant seria que s'hi va col·locar una plantilla (*patrono*) corresponent a la zona de les figures, cobrint la part de paret que hi tenien destinada, de manera que no van quedar els rastres que sí que es veuen en altres llocs.

Una de les característiques més sorprenents i singulars de l'estat de conservació de la capella Peruzzi és l'absència total de marques gràfiques que tracin els detalls de les figures (ulls, boca, nas, dits, etcètera) i altres elements pintats. Avui ens trobem, a les zones on hi hauria d'haver aquests detalls, amb una pèrdua clara i absoluta de tota la capa pictòrica. Malauradament, ni tan sols les anàlisis que hem dut a terme han pogut explicar-ne la raó amb certesa. És probable que aquestes pèrdues siguin degudes a un dibuix previ a l'execució de la pintura que, d'alguna manera, va perjudicar l'adhesió de les capes posteriors. Per provocar tal pèrdua i la del material pictòric superposat, el dibuix preliminar es devia fer amb un material singular, com ara la *terra verde* (un pig-

The design transfer techniques still visible on the surface are direct incision and snap-line marking for the architectural settings and many decorative parts. We can also locate many areas of freehand brush drawing. Almost all the parts finished with metallic leaf are defined by direct incisions, as usual. Snap lines were used to construct almost all the architectural elements in the scenes and the vertical and horizontal straight lines of the decorative frames. The cords were saturated with a red earth pigment and the generous splatters of the colour remaining after the operation are still quite evident today. The snap lines did not leave any depression in the *intonaco*, which implies that it must have been already quite hard when the cords were snapped.

The snap lines made inside the scenes do not seem to cut through the figures but stop in a rather precise way, corresponding with the drawing of the edges of the figure. This could indicate that, before snapping the cords to create the architectural elements, the groups of figures were drawn, or at least outlined. A more plausible hypothesis would be that a template (*patrono*) corresponding to the area of the figures was in place, covering the section of the wall allocated to them and sparing them from the traces otherwise left by the snapped cords.

One of the most striking and unusual characteristics of the state of conservation of the Peruzzi Chapel is the total absence of graphic marks that would delineate the details of the figures (eyes, mouth, nose, fingers, etc.) and other painted elements. Today, in the areas where this detail should



Figura del Crist
apocalíptic

Figure of Christ in
Revelation

ment de base terrosa que resulta sumament higroscòpic). També és possible que Giotto fes servir un mètode poc habitual per transferir el dibuix, amb trossos de paper o pergami tractats al revers amb una cera lleugerament pigmentada. En aquest cas, el caràcter hidròfug de la cera hauria impedit l'adhesió de les pinzellades al tremp superposades.

L'estat dels murals de la capella Peruzzi i la considerable contaminació provocada per les campanyes de restauració dificultaven un estudi científic definitiu de la tècnica d'execució. Les anàlisis químiques fetes en diverses zones de la decoració pintada durant el nostre procés de diagnosi van revelar la presència de lípids només en determinats indrets. En línies generals, però, s'hi va detectar un aglutinant proteic, probablement ou. En conseqüència, podem plantejar la hipòtesi que l'aplicació de calç en tota la superfície al segle XVIII podria haver saponificat les substàncies greixoses superficials, de manera que serien més difícils de detectar analíticament.

be, there is a complete and clear-cut loss of the entire painted layer. Unfortunately not even the analysis we carried out has been able to explain for certain the cause of this loss. It is likely that the losses are due to a drawing preceding the execution of the painting that, in some way, compromised the adhesion of the overlying pictorial layers. In order to cause this loss, and that of the overlying painted material, the preliminary drawing must have had unusual material qualities, such as *terra verde* (an earth based pigment which is highly hygroscopic). Alternatively Giotto may have used an unusual method for transferring the design using pieces of paper or parchment treated on the back with lightly pigmented wax. In this case the water repellency of the wax would have prevented the adhesion of the strokes of overlying tempera.

The current condition of the murals of the Peruzzi Chapel and the significant contamination caused by the restoration campaigns impeded a definitive scientific analysis of the technique of execution. The chemical analyses carried out on several areas of the painted decoration during our diagnostic campaign revealed the presence of lipids only on some parts. More generally, a proteinaceous binder was detected, probably egg. Therefore, we can hypothesise that the application of whitewash across the entire surface in the eighteenth century could have saponified superficial fatty substances, making them more difficult to detect analytically.

The new UV photographic campaign

After this first step in the research, much of our attention has been devoted to studying the extraordinary results that were collected in the Peruzzi chapel by means of ultraviolet fluorescence photography.

Ultraviolet (UV) induced fluorescence is a widely used technique in the analysis of polychrome art objects. Many subjects of conservation, such as easel painting, wall painting, ceramics and glass, textiles, wood, paper, and stone benefit from fluorescence analysis. This wavelength, which operates just beyond violet in the visible spectrum, brings out specific characteristics in painted surfaces that are otherwise invisible to the naked eye. In particular, fluorescence spectroscopy is a non-invasive tool that can differentiate between materials with similar optical properties but different chemical compositions. UV Fluorescence can highlight the presence of retouching, coatings, varnishes or other non-original materials on the surface of a work of art and, in some cases, identify the presence of specific



Figura de la resurrecció de Drusiana

Figure of the resurrection of Drusiana

La nova campanya fotogràfica ultraviolada

Després d'aquest primer pas en la recerca vam dedicar gran part de la nostra atenció a l'estudi dels extraordinaris resultats obtinguts a la capella Peruzzi mitjançant la fotografia fluorescent ultraviolada.

La fluorescència d'inducció ultraviolada és una tècnica molt estesa per a l'anàlisi d'objectes artístics policromats. L'estudi amb fluorescència s'aplica en el procés de conservació de molts elements, com ara pintures sobre tela, murals, ceràmica i vidre, teixits, fusta, paper i pedra. Aquesta longitud d'ona, que opera més enllà del violeta a l'espectre visible, revela uns trets específics de les superfícies pintades que no s'aprecien a simple vista. Concretament, l'espectroscòpia de fluorescència és una eina no invasiva que pot diferenciar entre materials amb propietats òptiques semblants però composicions químiques diferents. La fluorescència ultraviolada pot posar de manifest la presència de retocs, mans de pintura, vernissos o altres materials no originals a la superfície d'una obra d'art i, en alguns casos, identificar-ne els compostos específics, com ara pigments fluorescents particulars i colorants o vernissos naturals. La pel·lícula pictòrica sol estar formada per diverses mescles molt poc homogènies de compostos orgànics i inorgànics. En una primera aproximació, es pot descriure com una dispersió de partícules pigmentades en un medi.

L'emissió i la detecció de fluorescència en una capa pictòrica es pot veure afectada per diversos factors químics i físics, com, per exemple, la concentració de l'aglutinant, la formació de diferents compostos (quan es barregen pigments amb l'aglutinant) o fenò-

compounds, such as particular fluorescent pigments, natural colourants, and natural varnishes. The paint film is typically composed of different, highly inhomogeneous, mixtures of organic and inorganic compounds. In a first approximation, it can be described as a dispersion of pigmented particles in a medium.

The emission and the detection of fluorescence from a paint layer can be affected by several chemical and physical elements, such as the binder concentration, the formation of different compounds (when pigments are mixed with the binder), chemical-quenching phenomena induced by particular pigments, and so on, which cause difficulties in the interpretation of fluorescence analyses. Depending on their chemical composition, certain materials, especially organic ones, produce differently coloured fluorescence under UV light. Many inorganic and organic substances exhibit a characteristic colour. However, it should be noted that this method is highly sensitive. Even traces of active impurities can generate strong fluorescence, so that minerals that have the same chemical composition but different deposits show completely different fluorescence. On the other hand certain substances can quench the fluorescence of other materials. For example, verdigris, which was used as a green glaze in painting, quenches the fluorescence of natural resins like mastic or dammar. The same holds for certain ochres, umbers and Sienna earths. Fluorescence induced by UV radiation can also be stimulated in inorganic materials, defined as chemically pure, due to the presence of substances in infinitesimally small quantities, such as the remnants of the

mens de mitigació química provocats per pigments concrets; tot això provoca un seguit de dificultats en la interpretació de les anàlisis. En funció de la seva composició química, determinats materials, en especial els orgànics, emeten una fluorescència de diferents colors sota la llum ultraviolada. Moltes substàncies inorgàniques i orgàniques presenten un color característic. Cal dir, però, que aquest mètode és summament sensible. Fins i tot els residus d'impureses actives poden generar una fluorescència intensa, de manera que minerals amb la mateixa composició però dipòsits diferents mostren una fluorescència completament diferent. D'altra banda, hi ha determinades substàncies que poden mitigar la fluorescència d'alguns materials. Per exemple, el verdigrís, que es feia servir com a laca verda en pintura, mitiga la fluorescència de resines naturals com el màstic o el dammar. El mateix es pot dir de determinats ocre, terres d'ombra i sienes. La fluorescència provocada per la radiació ultraviolada també es pot estimular en materials inorgànics, definits com a químicament purs, degut a la presència de substàncies en quantitats infinitesimals, com ara restes del procés de fabricació o impureses presents per motius diversos (deteriorament natural, intervencions prèvies, infiltracions, etcètera). La identificació de materials només a partir d'un color de fluorescència concret és, consegüentment, molt difícil.

Alguns pigments inorgànics i orgànics presenten una fluorescència primària característica. Passa el mateix amb determinats aglutinants emprats sobretot en la pintura sobre tela (resines naturals, gomes, coles animals).

A causa de la longitud d'ona de la radiació ultraviolada, relativament curta, i per tant de la seva capacitat limitada de penetració, l'emissió fluorescent de les obres d'art depèn de la contribució de les capes externes, concretament dels vernissos (semi)transparents, de les capes pintades (és a dir, l'agent colorant, o pigment, i el mitjà aglutinant) i de les seves interaccions químiques.

Com que la radiació ultraviolada no té una capacitat de penetració significativa i gairebé sempre és absorbida en gran manera a la capa superior, la fluorescència primària dels pigments només s'observa en el cas de les aquarel·les, la pintura al tremp i els murals. En alguns casos això també passa en la policromia de les escultures.

En els murals, llevat dels frescos pròpiament dits, l'aglutinant acostuma a ser un material orgànic, mentre que les partícules pigmentades poden ser orgàniques o inorgàniques. En la majoria dels casos, el material or-

process by which the material was fabricated or from impurities present for diverse reasons (such as natural deterioration, previous interventions, infiltrations, etc). The identification of materials only on the basis of a specific fluorescence colour is, therefore, very difficult.

Some inorganic and organic pigments exhibit a characteristic primary fluorescence. Some of the binding media used mostly in easel paintings (natural resins, gums, animal glue) also exhibit a characteristic fluorescence.

Due to the relatively short wavelength of the UV radiation, and therefore the limited capacity of this radiation to penetrate, the fluorescence emission of artworks depends on the contribution of external layers, namely on the (semi)transparent varnishes, on the painted layers, i.e. the colourant agent, or pigment, and the binding medium, and on their chemical interactions.

Since UV radiation has no significant ability to penetrate and is almost always heavily absorbed in the top layer, the primary fluorescence of pigments can only be observed in the case of water-colours, tempera and wall paintings. This also applies in some cases to the polychromy of sculptures.

In wall painting, with the exception of proper *frescoes*, the binder is usually an organic material, whereas the pigmented particles can be either organic or inorganic. In most cases, the organic materials—binders and/or colourants—represent the highly fluorescent component, while the UV-induced fluorescence of inorganic pigments is often insignificant.

Examination of the paintings of the Peruzzi chapel under UV light displayed an exceptionally strong fluorescence in most of the painted areas. The intensity of the UV fluorescence and the insights obtained in enabling the appreciation of many disfigured or faint details demonstrates the well-known, typical results of this technique. The causes of the unusual UV fluorescence that we recorded are still unknown at this date, but there are many valid hypotheses. For example, the *intonaco* layer may have an unusual composition, causing the unusual UV scattering, or the artist may have employed unconventional painting materials. The unusual UV fluorescence could also be related to the interaction of pigments and binders over time.

The most likely hypothesis is that the extraordinary results obtained by UV fluorescence are due to the use of the *a secco* technique and, in particular, the interaction

gànic (aglutinant o colorant) és el component més fluorescent; en canvi, la fluorescència per llum ultraviolada dels pigments inorgànics sol ser insignificant.

L'examen de les pintures de la capella Peruzzi sota la llum ultraviolada va donar com a resultat una fluorescència d'intensitat excepcional en la majoria de les àrees pintades, la qual cosa, juntament amb la informació obtinguda en poder apreciar els molts detalls desfigurats o tènues, demostra els bons resultats habituals d'aquesta tècnica.

Encara no coneixem les causes de la inusual fluorescència ultraviolada que vam registrar, tot i que hi ha moltes hipòtesis vàlides; per exemple, que la composició de la capa d'*intonaco* sigui poc habitual, la qual cosa hauria provocat aquesta dispersió ultraviolada, o que l'artista hagués emprat material pictòric poc convencional. El motiu d'aquests resultats extraordinaris també podria estar relacionat amb la interacció dels pigments i els aglutinants al llarg del temps.

La hipòtesi més versemblant, però, és que siguin deguts a la utilització de la tècnica *a secco* i, en concret, a la interacció entre el mitjà aglutinant que va emprar Giotto i alguns pigments. Cal subratllar que les anàlisis han indicat la presència de nombrosos pigments incompatibles amb la tècnica del *buon fresco*, com ara el cinabri, el mini, la malaquita, el verdigris i l'orpiment. A més a més, la possible aplicació d'oli com a aglutinant podria haver ocasionat aquesta fluorescència ultraviolada tan alta.

Hi ha altres factors que poden tenir a veure amb l'història de conservació dels murals: per exemple, la retirada de l'emblanquinat (que podria haver iniciat un procés de saponificació) o els efectes de tractaments de preservació previs (probables, tot i que no documentats), en els quals es podrien haver emprat solvents d'alta retenció o que reaccionessin intensament amb els materials orgànics de les capes pictòriques. També hi podria haver altres materials orgànics com a conseqüència de tractaments anteriors amb fixadors i consolidants. La interacció entre els materials de restauració més recents i els originals podria ser en part responsable de la inusual fluorescència ultraviolada observada.

La revelació sota la llum ultraviolada de detalls increïbles que a penes es veien a simple vista ens va permetre apreciar moltes de les característiques compositives i artístiques perdudes dels murals de la capella Peruzzi. Són especialment visibles la construcció volumètrica dels cossos de les figures, la rellevància arquitectònica dels edificis i els escassos

between the binding medium that Giotto utilised and specific pigments. It must be emphasised that the analysis has shown the presence of numerous pigments incompatible with the technique of *buon fresco*, such as cinnabar, minium, malachite, verdigris, and orpiment. Also the possible overall use of oil as a binding medium could cause a very high UV fluorescence.

Other factors may be related to the murals' history of conservation, such as the removal of the whitewash (which could have initiated a process of saponification) or the effects of past preservation treatments (probable although undocumented). Such treatments could have employed high-retention solvents or solvents that react strongly with organic materials in the paint layers. Additional organic materials may also be present due to previous treatments that employed fixatives and consolidants. The interaction between later restoration materials and the original materials may also be partially responsible for the unusual UV fluorescence that we observed.

The revelation under the UV light of incredible details which were barely visible to the naked eye allowed us to see many of the lost compositional and artistic characteristic of the Peruzzi murals. More evident are the volumetric construction of the figures' bodies and the architectural relevance of the buildings and the few pieces of furniture in the setting of the scenes. Also many decorative elements "come back to light", such as those of metal leaves (which was indeed expected, because of the use of mordant oil in their application process), but also many painted details, most of them probably painted in lead, which is a highly fluorescent pigment. There are also cases of complete figures that "re-surface", such as the heads of the Twenty-Four Venerable Old Men of the Apocalypse in the medallions of the vault; and the group of the Apostles, Christ and St. Peter who receive St. John the Evangelist in Heaven, in the scene of the Saint's Assumption. The contrast between the naked-eye view of the scene and the photograph of it under the UV fluorescence is remarkable.

Many distinguished art historians strongly supported a comprehensive UV photographic campaign on the Peruzzi murals, being aware of the great advantages that this could bring to a new evaluation of Giotto's chronology and comprehension.

The funding requirements were met through two acts of great generosity. Firstly, the Getty Foundation agreed to extend the

mobles dels ambients de les escenes. A més, van sortir a la llum molts elements decoratius, com ara els de les fulles metàl·liques (la qual cosa s'esperava, atesa la utilització d'oli mordent en la seva aplicació), però també molts detalls pintats, la majoria probablement amb plom, un pigment molt fluorescent. D'altra banda, hi va haver casos de figures completes que van «reaparèixer», com els caps dels 24 venerables ancians de l'Apocalipsi dels medallons de la volta o el grup dels apòstols, Crist i sant Pere, que rep sant Joan Evangelista al cel, en l'escena de la seva assumpció. El contrast entre la vista a ull nu de l'escena i la fotografia amb fluorescència ultraviolada és notable.

Foren molts els historiadors de l'art de renom que van defensar amb força una àmplia campanya fotogràfica amb llum ultraviolada per als murals de la capella Peruzzi, conscients dels grans avantatges que això podia tenir de cara a una nova avaluació de la cronologia i la comprensió de Giotto.

Les necessitats de finançament es van resoldre gràcies a dos actes de gran generositat. En primer lloc, la Getty Foundation va accedir a ampliar el termini de la subvenció i el permís per fer servir el pressupost romanent per completar la campanya. Una altra donació molt generosa va procedir de Villa I Tatti: The Harvard University Center for Italian Renaissance Studies. Pel que fa a l'Opificio, va aportar finançament per a la bastida.

La campanya fotogràfica es va dur a terme íntegrament el novembre del 2012.

Les fotografies ultraviolades que vam obtenir aporten proves físiques convincents de l'enorme importància dels murals de la capella Peruzzi per als contemporanis de Giotto i per a les generacions posteriors d'artistes florentins. En aquestes imatges, les figures malmeses recuperen la tridimensionalitat. Veiem tots els efectes de clarobscur, la construcció dels cossos sota la indumentària i la representació arquitectònica dels edificis. Ressorgeixen molts detalls que ja no eren visibles, com ara els plects de la roba o les expressions facials.

Considerem que val la pena publicar íntegrament la campanya de fotografies per fluorescència ultraviolada com a monografia, de manera que estem cercant el suport econòmic necessari.

També ens servirà per desenvolupar noves hipòtesis sobre la cronologia del cicle i la seva influència en l'escola florentina de pintura contemporània i posterior. Era difícil imaginar l'aspecte dels murals acabats de fer, però ara ens costa menys.

Tot el material fotogràfic es publicarà a internet un cop publicat el llibre.

timing of the grant and gave permission to use the residual budget for the completion of the UV photographic campaign. An additional and very generous donation was also made by Villa I Tatti – The Harvard University Center for Advanced Studies in the Renaissance. The Opificio itself provided funding for the scaffolding.

The complete photographic campaign was carried out in November 2012.

The UV photos we obtained provide compelling physical evidence of the enormous importance of the Peruzzi murals for Giotto's contemporaries and the ensuing generations of Florentine artists. In these photographs the damaged figures become three-dimensional again. We can see all the chiaroscuro effects, the construction of bodies under garments, and the architectural rendering of the buildings. Many details that were no longer visible re-surface, such as the folds of the garments and facial expressions.

The UV fluorescence photographic campaign is worth publishing in full as a monograph, thus we are now seeking specific financial support for this purpose.

It will also allow us to develop new hypotheses on the chronology of the cycle and its influence on the contemporary and later Florentine school of painting. If it was difficult to imagine how the wall paintings would have looked when just completed, we now have a better insight.

All the photographic materials will be made available online after the publication of the book.

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LES PINTURES D'AGNOLO GADDI A LA CAPELLA MAJOR DE LA SANTA CROCE DE FLORÈNCIA

La capella major de la Santa Croce de Florència es va restaurar entre 2005 i 2010, i la intervenció ha portat una sèrie d'observacions sobre les superfícies pintades, en especial pel que fa a l'estat de conservació i la tècnica executiva, fonamentals per al projecte de l'actuació de conservació.

L'observació contextual feia ja evident que les pintures s'havien fet al fresc, amb nombroses parts deixades per a la segona fase executiva en l'*intonaco* ja sec, és a dir, la fase en la qual es duia a terme la pintura amb tintes obtingudes recurrent a aglutinants orgànics, juntament amb l'aplicació de làmines metàl·liques.

Arran de les nostres observacions va quedar molt clara la relació entre la presència de les parts al sec i de les llacunes en el teixit cromàtic, i a més a més els adhesius de les làmines metàl·liques semblaven haver patit els efectes del temps, haver perdut la seva funció i haver provocat nombroses pèrdues dins d'aquests acabats. Potser es podria atribuir la degradació experimentada per les matèries orgàniques a l'ambient molt humit de la capella, multiplicat pels segles de vida de les pintures, o potser es podia conjecturar una altra causa en la composició de les mesclures utilitzades en l'execució de les parts al sec i en l'aplicació de les làmines.

També les parts al fresc havien patit una degradació deguda a la seva porositat natural; és a dir, s'havia permès que el guix dipositat com a conseqüència de la contaminació atmosfèrica penetrés en l'espessor de la pel·lícula pictòrica i en fes malbé la cohesió. De la mateixa manera, algunes aplicacions al fresc, però fetes amb pigments sensibles a l'aigua, havien experimentat una degradació particularment greu.

LAS PINTURAS DE AGNOLO GADDI EN LA CAPILLA MAYOR DE LA SANTA CROCE DE FLORENCIA

La capilla mayor de la Santa Croce de Florencia fue restaurada entre 2005 y 2010, y la intervención condujo a una serie de observaciones sobre las superficies pintadas, sobre todo en lo relativo a su estado de conservación y su técnica ejecutiva, fundamentales para el planteamiento de la actuación de conservación.

Mediante la observación contextual era ya evidente que las pinturas se habían realizado al fresco con numerosas partes dejadas para la segunda fase ejecutiva en el *intonaco* ya seco; es decir, la fase en la que, con tintas obtenidas recurriendo a aglutinantes orgánicos, junto con la aplicación de láminas metálicas, se llevaba a cabo la pintura.

A raíz de nuestras observaciones quedó muy clara la relación entre la presencia de partes al seco y de lagunas en el tejido cromático, y además los adhesivos de las láminas metálicas parecían haber sufrido los efectos del tiempo, haber abandonado su función y haber provocado numerosas pérdidas dentro de esos acabados. Tal vez podría achacarse la degradación de las materias orgánicas al ambiente muy húmedo de la capilla, a lo que se sumarían los siglos de vida de las pinturas, o podría suponerse otra causa en la propia composición de las mezclas empleadas en la ejecución de las partes al seco y en la aplicación de las láminas.

Las partes al fresco habían sufrido una degradación debida a su porosidad natural; esto es, se había permitido que el yeso depositado como consecuencia de la contaminación atmosférica penetrara en el espesor de la película pictórica y echara a perder su cohesión. Del mismo modo, algunas aplicaciones al fresco, pero realizadas con pigmentos sensibles al agua, habían experimentado una degradación particularmente grave.

AGNOLO GADDI'S WALL PAINTINGS IN FLORENCE'S BASILICA OF SANTA CROCE

The main chapel in Florence's Basilica of Santa Croce was restored between 2005 and 2010. This process gave rise to a series of observations about the conditions of the painted surfaces, especially regarding their state of conservation and the painting technique that had originally been employed. These observations played a key role in designing the conservation techniques that would be utilized.

Based on context, it was clear that the chapel had been painted using the fresco technique; numerous sections were left for the second stage of painting, when they were painted on *intonaco* that had dried. The finishing touches entailed applying colour using binding agents and overlaying metal leaf on the work.

Our observations revealed the differences between the current appearance of the *a secco* parts of the work and those areas where gaps were visible. The adhesives used to apply metal leaf seem to have suffered during the ageing process; they no longer serve their original purpose, and areas where this finishing technique was utilised have deteriorated. The painting was exposed to the extremely humid climate inside the chapel over many centuries, which may explain the deterioration of these organic materials. Alternately, decay could be a reflection of the composition of the mixtures used for the *a secco* portions of the work and for applying metal leaf. The fresco portions of the painting also underwent deterioration as a result of their natural porousness; atmospheric pollution entered into the pictorial layer, leaving behind gypsum deposits which led to degradation. This was also the case of some fresco layers that were painted with water-sensitive pigments and suffered major deterioration.

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LE PITTURE MURALI DI AGNOLO GADDI NELLA CAPPELLA MAGGIORE DI SANTA CROCE: RELAZIONE TRA LA TECNICA DI ESECUZIONE E I FENOMENI DI ALTERAZIONE

THE WALL PAINTINGS OF AGNOLO GADDI IN THE MAIN CHAPEL OF SANTA CROCE: THE RELATIONSHIP BETWEEN THE TECHNIQUE OF EXECUTION AND THE ALTERATIONS

Maria Rosa Lanfranchi

Poiché l'argomento del mio intervento al presente convegno è la relazione tra la tecnica pittorica e l'alterazione della pittura murale, diremo innanzitutto che come conseguenza dell'intervento di restauro condotto tra il 2005 e il 2010 (vedi nota in appendice) possiamo oggi risalire con buona approssimazione alle tecniche utilizzate da Agnolo Gaddi e dalla sua bottega nella cappella maggiore di Santa Croce ed è particolarmente evidente come questa relazione esista. Parlo di approssimazione perché quello che vi dirò si basa principalmente sulle deduzioni di un'osservazione attenta e non su una infinita serie di prelievi diretti alla conoscenza dei leganti! Cioè è l'informazione che deduciamo dalla superficie dipinta che ci dice della tecnica d'esecuzione, al di là della conoscenza esatta del legante utilizzato che d'altronde è sempre abbastanza difficoltosa in condizioni di esiguità di materiale presente, d'inquinamento per la presenza di materiali sovrapposti nel tempo e per i limiti delle tecniche analitiche non invasive e invasive a disposizione.¹

La decorazione

Agnolo, il nostro autore, è figlio d'arte poiché il padre Taddeo era l'allievo prediletto del

1. Ad oggi infatti, nonostante gli enormi progressi della strumentazione analitica portatile, per il riconoscimento dei leganti che abbia una certa attendibilità, è ancora necessaria l'analisi del campione prelevato, e nella Cappella Maggiore ne sono stati fatti solo alcuni, per ovvie ragioni di rispetto della poca materia sopravvissuta. Anche di questi pochi abbiamo avuto risposte non chiarissime a causa delle sovrapposizioni di più sostanze che nel tempo si accumulano sulla superficie e che possono dare adito a fraintendimenti soprattutto quando il campione viene mescolato in tutti i suoi componenti, come avviene per certi tipi di analisi.

I would like to discuss the wall paintings in the main chapel of Florence's Basilica of Santa Croce. More specifically, I would like to focus on how the painting techniques used at the time laid the groundwork for the changes that the work would later undergo.

To begin, I would like to note that the restoration of this work – carried out between 2005 and 2010 (see note in appendix) – left us with a sound general understanding of the techniques utilised by Agnolo Gaddi and his disciples, knowledge that has shed light on the technique that was employed at the time and the changes that the piece would later undergo. I say that our understanding is “general” because what we learned is based primarily on deductions made through careful observation rather than on extensive scientific tests of binding agents.

In fact, our study told us more about *how* the fresco was painted than the exact binding agents that were used, and consequently, my remarks will focus on what we can infer from the surface of the painting. I would also like to note that it is difficult to make conclusive statements about this work due to several factors. These include the limited amounts of original materials that remain, years of pollution that have covered the surface of the work, and the limits of the non-invasive and invasive analytical techniques available.¹

1. As a matter of fact, despite the enormous progress in portable testing tools, to date the only reliable way to confirm what binding agents were used is to collect and analyse samples. As we aimed to respect the scant original material still remaining in the main chapel, we conducted a very limited number of such tests. Furthermore, since various substances accumulated on the surface of the work over time, the few tests we did conduct proved



grande Giotto, e la morte prematura (1383) del fratello Giovanni, pittore a sua volta, lo lascia a capo di un'importante e ben organizzata bottega in grado di portare a compimento la decorazione di una superficie vasta come quella della Cappella Maggiore. Si tratta infatti di circa 800 metri quadri di pittura murale che riveste tutte le pareti interne e quella esterna della cappella dell'altare maggiore, la più grande della chiesa francescana² e anche l'ultima in ordine di tempo ad essere dipinta tra quelle del transetto.

La vita delle nostre pitture comincia negli anni Ottanta del secolo XIV quando alcuni componenti della ricca famiglia degli Alberti patroni della cappella, grazie ad un lascito testamentario destinato alla decorazione, danno finalmente inizio all'impresa. Di fatto non abbiamo prove documentarie dell'incarico ad Agnolo Gaddi per l'esecuzione delle *Storie della Vera Croce*, ma vi sono fonti scritte temporalmente vicine al XIV secolo³ che attribu-

The Chapel

Agnolo Gaddi grew up steeped in the world of art. His father, Taddeo, was Giotto's leading pupil. When his brother Giovanni, who was also a painter, died prematurely in 1383, this left Agnolo at the helm of a major, well-organised workshop which was prepared to take on large-scale commissions such as the Basilica of Santa Croce's main chapel.

This chapel is the largest in the Franciscan church² and was the last to be painted after those in the transept. It includes approximately 800 square metres of frescoes spread over the internal and external walls of the chapel housing the main altar.

A bequest from a member of the wealthy Alberti family, the chapel's patrons, funded the project, and work on the frescoes began in the 1380s. Interestingly, there are no extant records confirming that Agnolo Gaddi actually received the commission for the *Legend of the*

Veduta generale della decorazione sulle pareti interne della cappella: le Storie della Vera Croce, Santi e Profeti

The internal walls of the chapel: The *Legend of the True Cross*, saints and prophets

2. La cappella è alta circa 30 metri e la sua base è inscrittibile in un rettangolo di mt. 10x11.

3. Ad esempio Antonio Billi e Vasari che scrivendo della vita di Agnolo dichiara la paternità del Gaddi sulla cappella maggiore di Santa Croce. cfr. *Il libro di Antonio Billi*, a cura di F. Benedettucci, Roma, 1991, p. 43; G. VASARI, *Le*

inconclusive. These other substances may prevent us from fully understanding the binding agents used, especially when samples include a mixture of several components, as is the case in some kinds of analyses.

2. The chapel is approximately 30 metres tall and rests on a 10 x 11 metre base.

iscono l'opera a lui e anche la critica moderna non mette in dubbio la sua paternità anche se si discute sulla collocazione temporale in seno all'attività di Agnolo. I soggetti sono tratti per lo più dalla *Leggenda Aurea* di Jacopo da Varagine, un testo della seconda metà del Duecento che ha ispirato molti pittori, nonché molti predicatori, per l'illustrazione delle storie sacre perlomeno fino alla Controriforma.⁴

Le pareti più grandi, orientate a Nord e Sud, sono sfruttate per organizzare il racconto in tre grandi registri rettangolari sormontati da un'ampia lunetta; nella volta i 4 Evangelisti, con San Giovanni Battista, patrono di Firenze, e San Francesco, il fondatore dell'Ordine detentore della chiesa; nei pilastri tra le bifore e all'ingresso vi sono varie figure di Santi alloggiati entro tabernacoli: Padri della Chiesa e i Santi eponimi dei committenti, Santi francescani e, sulla parete esterna, gli Apostoli che hanno avuto a che fare con la croce quale strumento di martirio; molte piccole figure di Profeti compaiono anche nelle cornici dove si aprono spazi delimitati da cornici mistilinee da cui si affacciano mostrando i cartigli.

La narrazione degli episodi prevede grandi composizioni corali, animate da molti personaggi con sfoggio di ricche vesti e con vari sfondi architettonici di città e campagne. Spesso nella singola scena sono narrati diversi momenti della vicenda semplicemente distribuendo i personaggi in aree separate del registro e talvolta utilizzando rocce, fiumi e architetture per separare momenti temporali diversi.

Quello che vediamo oggi è purtroppo solo una debole parvenza di quello che si poteva godere al momento in cui Agnolo completava le pitture per consentirne la visione ai committenti, ai Frati e a quanti altri potevano accedere alla base della cappella per vedere più da vicino la decorazione che altrimenti veniva scorta da distanza, essendo presente il recinto

Vite de' più eccellenti pittori scultori ed architettori scritte da Giorgio Vasari pittore aretino (1568), T. I, in *Le opere di Giorgio Vasari*, ed. cons. Sansoni Firenze, 1986, p. 637.

4. La *Leggenda Aurea*, composta dal beato Domenicano Jacopo da Varagine (Varazze 1228 - Genova 1297) a partire dal 1260, è una delle opere più diffuse e utilizzate in tutto il Medioevo sino alla metà del Seicento, al momento in cui prevarrà un atteggiamento di rettifica verso i racconti ritenuti troppo favolistici. Sono note molte copie manoscritte e molte stampate; l'originale latino fu presto tradotto nelle varie lingue volgari: italiano, francese, tedesco, ceco, inglese, così da fargli assumere un'importanza europea. Cfr. J. LE GOFF, *Il tempo sacro dell'uomo*, Bari 2012, pp. 3-4. B. BAERT, *A Heritage of Holy wood: the Legend of the True Cross in Text and Image*, Leiden 2004 (con bibliografia precedente). Nella *Leggenda* compaiono due capitoli distinti dedicati alla croce di Cristo: *l'Invenzione della croce* e *l'Esaltazione della croce*. cfr. J. DA VARAGINE, *Leggenda Aurea*, Firenze, 1985, vol I, pp. 306-315; vol II, pp. 609-617.



True Cross. However, sources written close to the fourteenth century³ attribute the work to Gaddi, and modern critics all accept that he carried out the work, although some do debate exactly when it was painted.

The majority of the work depicts stories from Jacobus de Voragine's *Golden Legend*, a mid-thirteenth century text containing sacred tales that inspired numerous painters (and preachers) until at least the Counter-Reformation.⁴

Veduta generale della decorazione sulle volta: san Giovanni Battista, san Francesco, i 4 Evangelisti

The vault: St. John the Baptist, St. Francis and the 4 evangelists

3. For example, Antonio Billi and Giorgio Vasari both attribute Santa Croce's main chapel to Gaddi. Cf. *Il libro di Antonio Billi*, ed. Fabio Benedettucci (Rome, 1991, p. 43); and Giorgio Vasari, "Le vite de' più eccellenti pittori scultori ed architettori" (1568), in *Le opere di Giorgio Vasari*, ed. Sansoni, (Florence, 1986, p. 637).

4. The *Golden Legend*, compiled by the Dominican Jacobus da Voragine (Varazze 1228 - Genoa 1297) starting in 1260, was one of the most popular works of the Middle Ages. It was widely available across Europe until the mid-1600s, when some of its tales were called into question for being overly "mythical". Numerous manuscripts and printed copies of the work survive. Originally written in Latin, it was soon translated into various vernaculars - including Italian, French, German, Czech and English - helping it to spread across Europe. Cf. Jacques Le Goff, *Il tempo sacro dell'uomo* (Bari, 2012, pp. 3-4); and Barbara Baert, *A Heritage of Holy Wood: The Legend of the True Cross in Text and Image* (Leiden, 2004; see also the bibliography referenced in this work). The Legend includes two different chapters about the cross: *The Invention of the Holy Cross* and *The Exaltation of the Holy Cross*. Cf.

destinato al coro dei Frati per un buon tratto della navata maggiore. Alla luce delle osservazioni svolte durante il restauro, possiamo perciò dire che proprio la ragione della tecnica esecutiva svolge un ruolo importante per l'aspetto attuale delle pitture, tra i vari fenomeni di degrado occorsi nel tempo quello del diverso comportamento dei leganti utilizzati è uno dei più eclatanti.

Quale tecnica?

La tecnica usata da Agnolo e compagni è quella molto diffusa nel Medioevo del cosiddetto *affresco*, secondo una manifattura che richiedeva abilità e velocità in una prima fase per la stesura delle tinte composte da pigmenti, calce e acqua sull'intonaco bagnato e quindi diviso in *giornate*⁵ più o meno grandi, a cui seguiva una seconda fase per la stesura di ulteriori tinte ottenute con leganti organici e per l'applicazione delle lamine metalliche. Spesso questa viene definita di rifinitura, quasi fosse solo per l'aggiunta di piccoli particolari, ma in realtà se osserviamo la quantità di superficie così dipinta ci rendiamo conto che "rifinitura" è un termine assai insufficiente.

"Lavorare in muro: bisogna bagnare, smaltare, fregiare, pulire, disegnare, colorire in fresco; trarre a fine in secco, temperare, adornare, finire in muro"⁶ questo è ciò che scriveva infatti Cennino Cennini nel suo "Libro dell'Arte", un famoso trattato medievale sulle tecniche artistiche che possiamo ben considerare il frutto in gran parte della pratica della bottega di Agnolo Gaddi di cui l'autore era stato a lungo discepolo. È presentata quindi come usuale nel trattato la fase di finitura a secco per la pittura su muro e nell'epoca di Agnolo Gaddi il desiderio di rendere più preziose le superfici faceva sì che questa fase fosse accurata e frequente.

Se osserviamo le mappe tematiche relative agli interventi a secco, certi e presunti, e quelle relative alle lamine metalliche presenti ... o meglio che erano presenti, ci appare chiaramente la quantità abbondante di queste finiture sul totale delle superfici affrescate.

Dall'esame delle pitture è chiaro che la maggior parte degli interventi a secco era stata programmata in anticipo lasciando le aree ad

The work includes three large rectangular panels and a sizeable lunette on each of the larger walls, which face north and south. The vault features images of the four evangelists, including St. John the Baptist, the patron saint of Florence, and St. Francis, who founded the Franciscan order. The columns between the mullioned windows and at the entrance portray figures of various saints in tabernacles, including the Church Fathers, the patrons' eponymous saints, Franciscan saints, and, on the external wall, the apostles martyred on the cross. The mixtilinear cornices feature numerous small images of prophets with scrolls in hand.

The story is told in a series of scenes containing numerous figures – all bedecked in lavish attire – set against backdrops of city and country landscapes. A single scene often narrates various episodes from the tale, placing the figures in separate parts of the painted space and interspersing rocks, rivers and architectural features in order to separate different moments.

Gaddi's original creation was designed to be seen from close up – from the base of the chapel – by patrons, monks and other visitors. Since the space for the choir extended over a large portion of the main nave, the images in the work could also be glimpsed from a distance.

Unfortunately, due to deterioration, the images we see today bear only a slight resemblance to Gaddi's original. As we were able to confirm during the restoration process, the current degraded appearance is closely tied to the original techniques used for the wall paintings. In fact, one of the most striking aspects of the decay relates to how different binding agents held up over time.

The Technique

Agnolo and his workshop painted frescoes, a technique which was quite widespread in the Middle Ages. The technique required both speed and skill, and entailed painting on sections of *intonaco* divided into *giornate*⁵ – sections referred to as "working days" because they represented the amount of work that could be completed in a day, before the *intonaco* dried – using a mixture of pigments, lime and water. In a later phase, additional pigments and metal leaf were overlaid on the work using organic binding agents. This later

Scansione delle giornate di intonaco nella scena dell'*Incontro tra la Regina di Saba e Salomone*. La presenza delle giornate testimonia l'intenzione di eseguire la decorazione ad affresco

Scan of the *giornate* in the *Meeting between the Queen of Sheba and King Solomon*. These *giornate* confirm that Angolo planned to paint the decorations using the fresco technique

5. Com'è noto le *giornate* in una pittura murale sono definibili come unità operative, cioè sono delle frazioni della superficie pittorica rivestite con l'intonaco in maniera che la deposizione del colore fosse sempre su una superficie umida; in questo modo si poteva ottenere che il legante del colore fosse la calce stessa dell'intonaco essudata durante la fase di essiccazione.

6. Cennino CENNINI, *Il libro dell'arte*, Fabio Frezzato (a cura di), Padova, 2003, p. 65.

Jacobus da Voragine, *Leggenda Aurea*, Florence, 1985, vol I, pp. 306-315; vol II, pp. 609-617.

5. In frescoes, *giornate* are generally defined as work units. In each of these units, colour was applied on wet *intonaco* over the course of a day; as the *giornata* dried, the lime in the *intonaco* itself acted as a binding agent.



essi destinate con le sole linee di disegno o con preparazioni sommarie del chiaroscuro o con tinte di sottofondo, in questi casi è chiaro che esisteva un'esigenza specifica dettata dalle caratteristiche dei pigmenti, incompatibilità o per la ricerca delle migliori condizioni di stesura, solo in qualche parte sembra che i pittori ricorressero al legante organico per zone in cui l'asciugatura del supporto era avvenuta a causa dei tempi molto lunghi richiesti dalla prima fase; in altre situazioni era invece probabile che fosse l'esigenza di uniformità cromatica che dettava l'uso di una tinta a secco: il caso specifico della pittura della croce nelle diverse scene.

Ampi interventi a secco interessavano anche le decorazioni dei costoloni e delle cornici perimetrali alle raffigurazioni: anche per queste parti minori della decorazione i pittori avevano dedicato vario tempo per rifinire e impreziosire, con colori e lamine, le basi a fresco ottenute con semplici terre.

L'osservazione dello stato di fatto della pittura

Il nostro intervento di restauro è iniziato come sempre dall'analisi visiva delle superfici e per-

phase is often referred to as *rifinitura*, since in theory, it involves adding minor details and finishing touches. In practice, however, a good portion of the main chapel was painted in this way, and the term *rifinitura* is therefore not particularly fitting in this case.

In his famous mediaeval treatise on artistic techniques, the *Libro dell'Arte*, Cennino Cennini wrote: "To work on a wall you have to wet down, to plaster, to true up, to smooth off, to draw, to paint in fresco. To carry to completion in secco: to temper, to embellish, to finish on the wall".⁶ According to this treatise, therefore, the *a secco* finishing stage constituted a normal phase of fresco painting. Since artists of the era aimed to paint exceptionally exquisite works, this phase was used quite frequently for intricate work.⁷

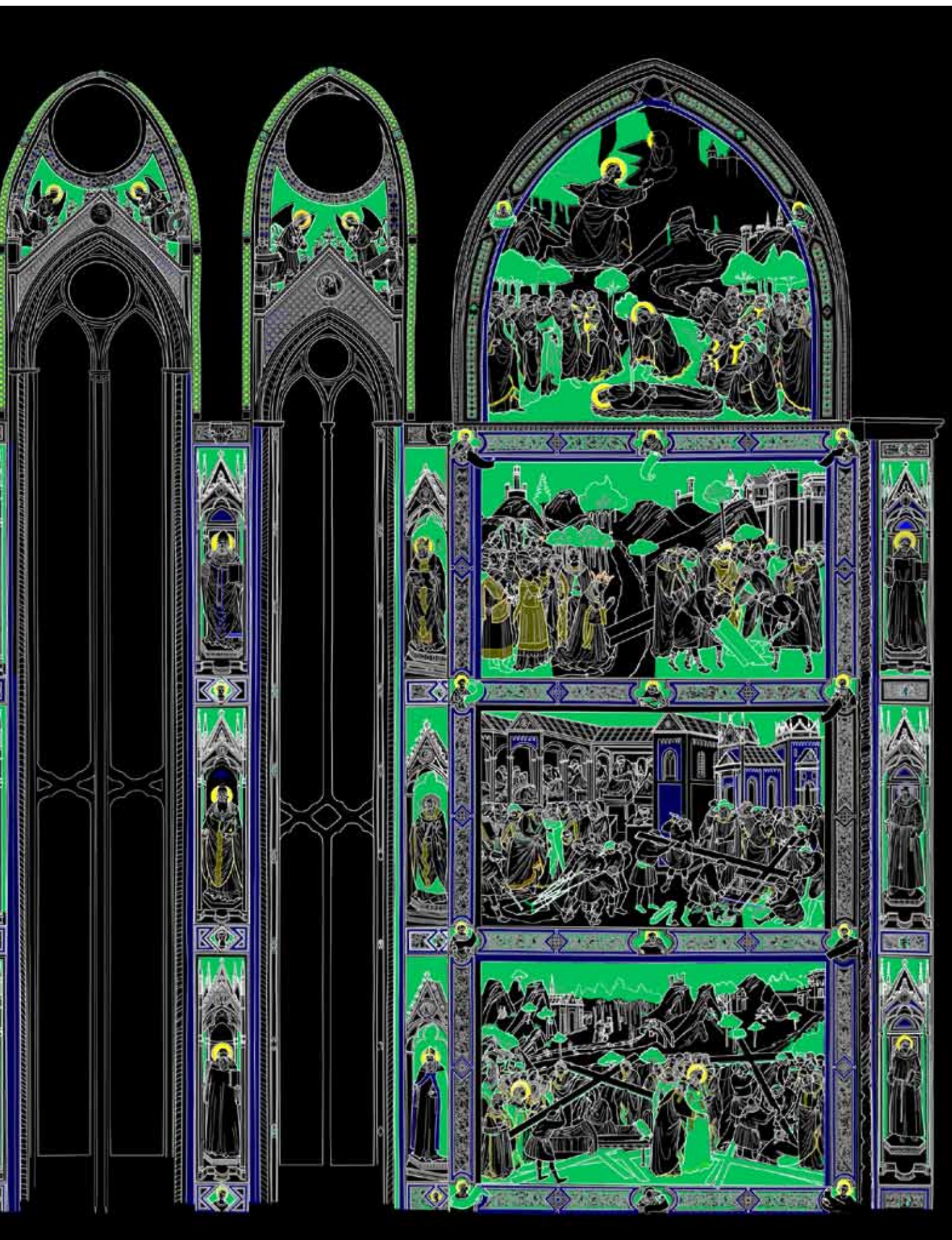
6. The *Libro dell'Arte* is based largely on the practices of Agnolo Gaddi's workshop; in fact, Cennini was a disciple of Gaddi for many years.

7. Cennino Cennini, *Il libro dell'arte*, ed. Fabio Frezzato (Padua, 2003: p. 65). English translation: *The Craftsman's Handbook. The Italian "Il Libro dell'Arte."* Translated by Daniel V. Thompson, Jr. New York: Dover Publications, Inc. 1933. All English translations of Cennino included in this paper are from Thompson's translation, available online at <http://www.noteaccess.com/Texts/Cennini/>.

Mappatura delle
presenza nelle pareti
interne della cappella
di materiali organici:
stesure pittoriche (la-
yer verde) e adesivi per
le lamine metalliche
(layer blu)

Organic materials on
the chapel's internal
walls. The pictorial
layer is shown in green
and the adhesives used
to apply metal leaf in
blue





tanto ha individuato innanzitutto i segni della tecnica esecutiva e i diversi fenomeni di degrado a carico delle pareti dipinte; la mappatura puntuale delle osservazioni ha poi permesso l'elaborazione di alcune ipotesi sul comportamento delle superfici rispetto ai fattori intervenuti nel tempo.

Tra gli aspetti del degrado ne abbiamo individuato uno piuttosto moderno e molto diffuso, dovuto all'inquinamento atmosferico degli ultimi cinquant'anni che ha interagito con il clima della cappella, ed altri più antichi, dovuti a vecchi dissesti statici (seguiti da impercettibili e continui movimenti delle masse murarie in seguito ai cicli termici stagionali); molti altri dovuti al comportamento delle stesure pittoriche rispetto al microclima della cappella e a tutto quello che poteva derivare da azioni prodottesi durante la storia secolare delle pitture: infiltrazioni d'acqua dall'esterno, interventi di manutenzione e restauro in particolare.

Il danno moderno era dovuto alla formazione di gesso sopra e all'interno dello spessore della pellicola pittorica, in questo caso il meccanismo che conduce alla formazione di piccoli sollevamenti sino alla polverulenza della pittura, parte dal deposito del solfato di calcio biidrato formatosi nell'atmosfera in seguito al prolungato utilizzo per le attività umane di combustibili fossili⁷; questo gesso poi, con gli alti tenori e con le fluttuazioni dell'umidità atmosferica nella cappella, subisce fasi alterne di dissoluzione e cristallizzazione che gli permettono di spostarsi all'interno dell'intonaco attraverso la sua porosità. La genesi di questo fenomeno è stata ampiamente chiarita a partire dagli anni Sessanta del secolo scorso,

7. L'utilizzo sistematico dei combustibili fossili risale alla fine del XVIII secolo con l'inizio della rivoluzione industriale in Europa e America del Nord, con il forte incremento di richiesta energetica da parte delle industrie; fino agli anni cinquanta il fabbisogno energetico era principalmente soddisfatto dall'utilizzo del carbone. La nascita stessa della rivoluzione industriale inglese venne favorita dalla presenza di numerosi giacimenti carboniferi, minerariamente sfruttabili, nel territorio nazionale e l'uso del carbone per il trattamento dei minerali ferrosi iniziò all'inizio del XVIII secolo.

L'utilizzo dei combustibili fossili come principale risorsa di energia è incrementato notevolmente nel XX secolo, nella seconda metà del quale si è osservata l'affermazione del petrolio come principale fonte energetica, rispetto al carbone troppo inquinante e in molti casi economicamente più gravoso nell'insieme dei costi di estrazione e trasporto all'utilizzatore finale; si stima che nel 1955 i combustibili fossili contribuissero al 52% del fabbisogno energetico mondiale, ed il loro apporto crebbe al 64% nel 1970.

Oggi i combustibili fossili provvedono a poco più dell'85% del fabbisogno energetico mondiale: di questo il petrolio contribuisce per il 40%, il carbone per il 26% e il gas naturale (in forte crescita di consumo) per il 23%.

http://it.wikipedia.org/wiki/Combustibili_fossili

The thematic map of *a secco* portions of Angolo's work (both those we are certain about and those we presume were painted using this technique), as well as the map of the metal leaf used in the piece (or, to put it more precisely, a map of where metal leaf was originally used in the piece), clearly demonstrate that this finishing stage was employed quite extensively throughout the entire fresco.

In fact, our observation revealed that the majority of *a secco* work was planned in advance. The areas which would be completed using the *a secco* technique included only sketched guidelines, basic shading or background colours, and the artists clearly adopted this approach due to the nature of the pigments they used or because they were seeking better layering techniques. Only in some sections – where the *intonaco* had dried due to the long periods of time the first phase entailed – does it seem that the painters used organic binding agents. At other times, *a secco* painting was probably used to guarantee a uniform colour, as in the case of the crosses painted in several scenes, which I shall discuss in more detail later.

The *a secco* technique was also used extensively on the outer ribs and cornices, and even in these minor parts of the work, the artists spent a great deal of time applying colour and metal leaf to embellish the first layer, which had been painted using simple pigments.

Observation

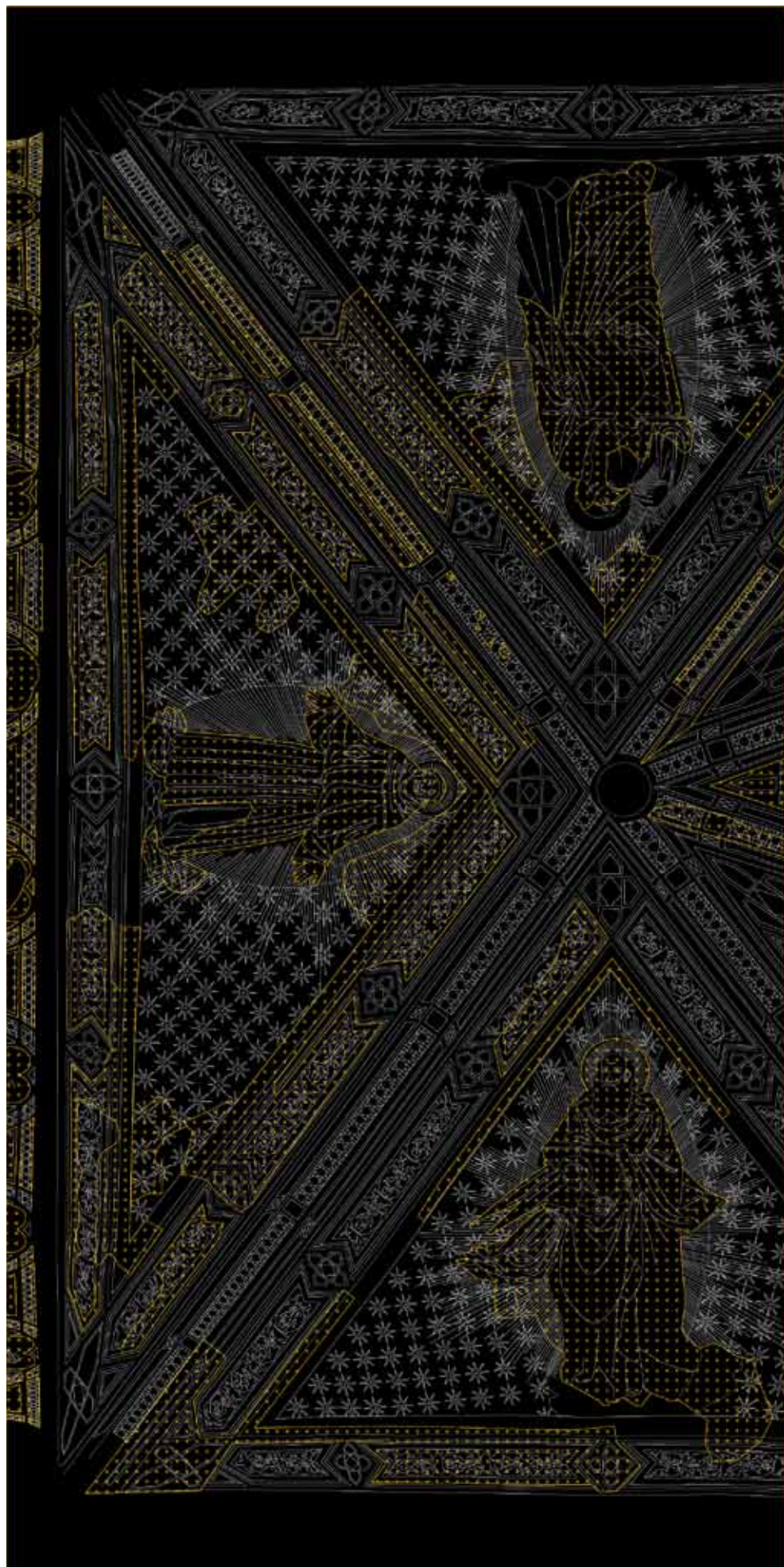
As always, we began the restoration process by visually analysing the work's surface. This allowed us to identify signs of the technique that had been used as well as the various types of visible deterioration. By creating a detailed list of our observations, we were able to craft hypotheses about the historical factors that had affected the work over time.

Our analysis revealed several different types of decay. Modern degradation was due to air pollution, which has affected the chapel's climate over the last fifty years. Earlier deterioration was the result of structural instability, which was compounded by continuous, imperceptible movements of the building as a response to seasonal changes in weather conditions. Other types of decay were related both to how the painted surfaces reacted to the chapel's microclimate and to numerous events in the fresco's centuries-old history, from water leaks to maintenance and restorations.

Modern damage came about as gypsum formed on and inside the pictorial surface, causing minor buckling and flaking. Prolonged

Mappatura della
presenza del gesso
nella pellicola pittorica
della volta

The presence of
gypsum in the vault's
pictorial layer



poiché storicamente consideriamo l'alluvione di Firenze del 1966 quale data significativa per l'analisi scientifica di questi meccanismi e per la messa a punto di un metodo di risanamento, quando perciò il degrado da gesso aveva raggiunto livelli allarmanti e manifestazioni diffuse. La penetrazione del gesso è collegata, sia alle fluttuazioni dei tenori di umidità e sia al tipo di porosità dell'intonaco, perciò la pittura murale a fresco si presta a questo attacco salino e col tempo il gesso, tendendo ad accumularsi nei pori, ne rompe le pareti rovinando lo strato pittorico.

L'intonaco di supporto delle pitture oggetto delle nostre considerazioni, era stato assai ben lavorato con la spatola ed era ricco di calce, perciò la penetrazione del solfato di calcio era arrivata, secondo il risultato dei prelievi, al massimo fino a 2 millimetri di profondità, ma vicino alla superficie aveva prodotto un danno vistoso.

La presenza di gesso in particolare era assai abbondante sulle scene più in alto e sulla volta per ragioni collegate con i meccanismi di accumulo del particolato atmosferico, ma si trovava un po' ovunque, interessando sia le parti dipinte a fresco che le aree un tempo dipinte a secco ma cadute. Potevamo però notare alcune particolarità rispetto a questa diffusione: era abbastanza evidente ad esempio nella volta la riduzione del fenomeno in occasione delle campiture gialle che definiscono le mandorle circostanti ciascun Santo, come se lì il gesso non fosse riuscito a penetrare! Il pigmento risultava essere all'analisi XRF e FORS: giallo di piombo e stagno mescolato ad ocra gialla o terra di Siena; il legante non è stato analizzato, ma certamente si trattava di una stesura realizzata con un materiale organico quindi a secco, e non per ragioni di pigmento⁸, ma perché giaceva in parte sullo strato di azzurrite del fondo ed entrambe quindi facevano parte della pittura compiuta sull'intonaco quasi asciutto. L'osservazione del fenomeno conduceva alla deduzione che proprio la minore idrofilia e la minore porosità della stesura di giallo avevano inibito la penetrazione del solfato di calcio in soluzione che invece nelle aree attigue, e ugualmente esposte, appariva in tutta la sua manifestazione rovinosa, quindi il legante in questo caso aveva creato una difesa per la stesura pittorica così come si era dimostrato anche efficace per la sua conservazione nel

8. Nella Cappella lo troviamo infatti varie volte steso a fresco

human use of fossil fuels⁸ – which caused calcium sulphate dihydrate to form in the atmosphere – and fluctuating, high levels of humidity inside the chapel led the gypsum to go through a series of phases in which it dissolved and crystallised; this allowed it to seep into the porous *intonaco*.

The discovery of this phenomenon dates back to the 1970s, and in fact, Florence's famous flood of 1966 is generally seen as a major turning point for research. At that time, gypsum-caused degradation had reached alarming levels and was quite widespread, leading researchers to begin to analyse these processes from a scientific perspective and develop restoration techniques. Fluctuating humidity levels and the porousness of the *intonaco* both favoured the influx of gypsum; the fresco's pictorial surface and porous support materials lent themselves to this attack. Over time, the gypsum had tended to accumulate within these pores, cracking the walls and destroying the fresco.

The plaster in our frescoes contained a significant amount of lime and was pressed using a trowel. According to our test results, calcium sulphate had penetrated up to 2 millimetres into the fresco, producing considerable damage close to the surface.

Our tests also revealed that gypsum was especially prevalent in the upper scenes and the vault; this was a result of the way in which atmospheric particles had accumulated. However, we detected gypsum throughout the pictorial surface, in both frescoed areas and sections which were painted using the *a secco* technique and were later lost.

Interestingly, gypsum was clearly present in the vault but was less prevalent in the yellow aureoles around each saint. It seems that the

8. Widespread use of fossil fuels dates back to the end of the eighteenth century and the beginning of the Industrial Revolution in Europe and North America, at which time industry started to demand more and more energy. Until the fifties, these energy demands were met primarily by burning coal. In fact, the large number of coalfields in the United Kingdom would support the British Industrial Revolution; coal was first used to process ferrous minerals in the early eighteenth century.

The use of fossil fuels as our primary source of energy increased significantly in the twentieth century; during the second half of the twentieth century, oil replaced coal as the main energy source. (Coal produced too much pollution, and mining and transport costs often made it more expensive than oil.) It is estimated that fossil fuels accounted for 52% of global energy requirements in 1955 and 64% in 1970.

Today, fossil fuels meet slightly more than 85% of global energy consumption; oil, coal and natural gas account for 40%, 26%, and 23% of this consumption, respectively. Meanwhile, natural gas consumption is firmly on the rise. Source: http://it.wikipedia.org/wiki/Combustibili_fossili

tempo. Le mandorle gialle nella volta erano in genere ben conservate, a differenza di altre zone a secco della cappella, eccezione fatta per la rovina in qualche zona dovuta a infiltrazioni d'acqua dal tetto verso cui nemmeno il legante era riuscito a resistere!

Sorte diversa era infatti toccata alle tante altre stesure a secco che in generale risultavano aver sofferto il trascorrere dei secoli molto più dell'affresco e per motivi non strettamente connessi alla solfatazione, ma piuttosto per la situazione climatica della cappella. La presenza delle aree dipinte a secco tracciata sulla mappa generale delle pitture della cappella, si poteva sovrapporre a quella della perdita della pellicola pittorica, eccezioni a parte: le mandorle come abbiamo già visto e alcune altre situazioni particolari della Cappella.

Negli anni di nostra permanenza notavamo estati calde e umide e inverni molto freddi, il clima dell'esterno si ripercuoteva subito all'interno data la scarsa inerzia termica delle pareti e per la presenza delle molte aperture vetrate⁹. Tutta la zona della città dove sorge la basilica era rinomata nel passato perché malsana¹⁰, cioè molto umida e spesso sommersa dalle esondazioni del vicino fiume. In condizioni di prolungate e continue sollecitazioni di temperatura e contenuto di umidità nell'aria e sulla superficie, il legante organico può subire un'alterazione, perdendo parte della sua capacità adesiva e quindi provocando la decoesione e la perdita della stesura corrispondente; in altri casi può invece verificarsi uno scolori-

9. Le murature della cappella maggiore della Basilica, sono soggette ad una deformazione termica naturale come tutti i corpi immersi nel clima terrestre. Il fenomeno della deformazione e della trasmissione del calore, così come lo abbiamo rilevato nel nostro edificio, è la conseguenza della particolare esposizione dell'abside della chiesa (forte insolazione soltanto sul versante sud est, cioè sulla parete destra vista dall'interno) e la veloce trasmissione e invece tipico di un paramento murario compatto nel suo spessore e realizzato con materiale fortemente conduttivi – nel nostro caso, la pietra di cui sono fatte le murature verticali. Il passaggio di calore e di agenti atmosferici generici è poi, nel caso specifico, dovuto alla grande quantità di aperture esposte a Est ed alla presenza di discontinuità nelle strutture murarie dovute ai movimenti di subsidenza (= lento movimento di sprofondamento di parte della crosta terrestre) delle fondazioni e dei fenomeni termici stessi. Cfr. Comunicazione dell'ing Leonardo Paolini, consulente dell'OPA di Santa Croce.

10. Questa zona anticamente era una vera e propria isola formata da due bracci dell'Arno che si separavano vicino all'attuale Piazza Beccaria, per ricongiungersi davanti alle mura che passavano all'altezza di via Verdi/via de' Benci. Non a caso il toponimo del fossato restava nel nome dell'antica chiesa di San Jacopo tra i Fossi. I Francescani, giunti a Firenze nel 1226-1228, scelsero questa zona isolata per il loro insediamento. In seguito l'area verrà bonificata e si creerà la piazza antistante la chiesa. Cfr. http://it.wikipedia.org/wiki/Piazza_Santa_Croce

gypsum was unable to penetrate these surfaces! X-ray fluorescence (XRF) and fibre-optic reflectance spectroscopy (FORS) tests revealed that the pigment used here was lead tin oxide mixed with yellow ochre and sienna. We did not test the binding agent, but it was undoubtedly made with an organic material (and therefore, it was painted *a secco*). This was not due to the pigment,⁹ but rather because it partially overlapped a background coat of azurite; both layers were therefore painted on the nearly dry *intonaco*. Our observations led us to conclude that the limited hydrophilia and porousness of the yellow coat prevented the calcium sulphate from penetrating the fresco. However, in adjacent, equally exposed areas, calcium sulphate caused widespread damage. Therefore, in this case the binding agent ended up protecting the pictorial surface and proved to be effective for long-term conservation. Unlike other *a secco* areas in the chapel, the yellow aureoles in the vault were generally well preserved, with the exception of some areas which were ruined by a leaking roof: there, even the binding agent was unable to hold out!

However, many other *a secco* layers suffered a different fate: in general, they were much more affected by the passing of time than the fresco layer. This was not, however, directly related to sulphatisation; in fact, it was primarily due to the climatic conditions inside the chapel. On the map of the painted areas of the chapel, *a secco* areas generally overlap with those where the pictorial layer was lost, except for the aureoles – as we have seen – and a few other special areas.

During the years we spent restoring the work, we observed that summers were warm and winters were extremely cold. Temperatures in the Basilica quickly mirrored those outside due to the limited insulation in the walls and the numerous windows.¹⁰ In fact, the Basilica and its surroundings have long been famous for particularly poor weather:¹¹

9. In fact, the pigment was used numerous times for fresco painting in the chapel.

10. The walls of the Basilica's main chapel are subject to natural, temperature-induced warping like all buildings on the planet. The warping and heat transfer we observed in the Basilica are due to the orientation of the apse (which is strongly insulated on only its southeast-facing side – the right wall, as seen from inside the church). On the other hand, this rapid transfer is typical of compact, thick walls built of highly conductive materials – in our case, stone. In the Basilica, heat in particular and atmospheric agents in general are transferred due to the large number of eastward-facing openings, cracks that appear in the walls as the foundations subside (as parts of the Earth's surface shift downwards), and thermal phenomena themselves. Source: Leonardo Paolini, Santa Croce OPA consultant.

11. Historically, this area was actually an island in the middle of two branches of the Arno which forked near

mento, ad esempio delle lacche rosse che sono fotosensibili, per cui la luce e l'umidità portano spesso al degrado del principio colorante.¹¹

In ogni caso il legante è una sostanza organica che circonda i granuli dei pigmenti ed è dotata di proprietà filmogene grazie alle quali garantisce la coesione e l'adesione del film pittorico al supporto; è necessario innanzitutto un giusto bilanciamento tra le proprietà adesive e coesive del legante per ottenere uno strato pittorico stabile nel tempo e l'esperienza portava perciò i pittori a regolare il rapporto tra la quantità di ogni pigmento rispetto al legante per avere stesure più o meno coprenti e non troppo né poco viscosi (dipende dalla concentrazione del pigmento rispetto al medium), così come conoscevano anche quali erano le combinazioni più efficienti per stendere i singoli pigmenti e ciò dipendeva dalla natura del pigmento come dalla dimensione dei granuli.¹²

Una caratteristica sostanziale tra i leganti per la pittura murale, nell'immediato e per le conseguenze nel tempo, è l'idrofilia che determina un comportamento favorevole ai passaggi d'acqua, frequenti nelle murature, e quindi insieme degli inquinanti, così come può favorire o meno la possibile reazione tra due pigmenti incompatibili e mescolati nella medesima stesura. Nell'ambito dei leganti storici sappiamo che le sostanze proteiche¹³ sono piuttosto idrofile, quelle oleose idrofobe.

Le proprietà ottiche e meccaniche delle stesure a secco erano quindi dipendenti da una serie di fattori che nel tempo si traducevano anche in una diversa resistenza all'invecchiamento e in diverse trasformazioni; il sistema pigmento/legante, trasformato in un film pittorico, possiede una reattività elevata che in relazione alle condizioni ambientali (luce, umidità, agenti biologici, interazione con altre specie chimiche) può subire nel tempo profonde alterazioni. Le proteine ad esempio ten-



the area is exceptionally humid and often flooded when the nearby river spilled over its banks.

Fluctuating temperatures, high humidity and damp walls may create long-standing adverse conditions and cause the organic binding agent to undergo a change. As it becomes less adhesive, the paint sticks to the walls less and layers of paint flake off. In other cases, such as those painted with red lake, the surface can become discoloured: since the coating is sensitive to light, light and humidity often cause the main pigment to deteriorate.¹²

In any case, the binding agent is an organic substance that surrounds the particles of pigments and forms a film, allowing the paint to cling to and bond with the *intonaco* support. The binding agent needed to strike a good balance between adhesiveness and cohesiveness to guarantee that the pictorial layer would remain stable over time. Experience therefore led painters to monitor the proportions of pigments and binding agents in order to determine the extent to which they coated the wall and to guarantee that they were neither too viscous nor too runny. (This depended on the percentage of the pigment in the medium). They also knew which combinations were most effective for spreading a single pigment;

the current location of Piazza Beccaria and came back together in front of the walls at Via Verdi/Via de' Benci. Indeed, this is why the word *fossato* (moat) is still part of the name of the old Church of *San Jacopo tra i Fossi*. When the Franciscans arrived in Florence between 1226 and 1228, they decided to settle in this isolated area. Later, the land was reclaimed and the piazza in front of the church was built. See http://it.wikipedia.org/wiki/Piazza_Santa_Croce
12. Cf. A. Casoli, M. P. Colombini, M. Matteini, *I pigmenti*, in L. Campanella, A. Casoli, M. P. Colombini, R. Marini Bettolo, M. Matteini, L. M. Migneco, A. Montenero, L. Nodari, C. Piccioli, M. Plossi Zappalà, G. Portalone, U. Russo, M. P. Sammartino, *Chimica per l'arte*, Bologna, 2007, p. 129-135.

Foto in luce radente di un particolare della volta: si veda come i piccoli sollevamenti della pellicola pittorica si interrompano sulla stesura gialla della mandorla del Santo

Close-up image of the vault in oblique light. Small buckling in the pictorial layer is not present in the yellow aureole surrounding the saint

11. Cfr. A. CASOLI, M. P. COLOMBINI, M. MATTEINI, *I pigmenti*, in L. CAMPANELLA, A. CASOLI, M. P. COLOMBINI, R. MARINI BETTOLO, M. MATTEINI, L. M. MIGNECO, A. MONTENERO, L. NODARI, C. PICCIOLI, M. PLOSSI ZAPPALÀ, G. PORTALONE, U. RUSSO, M. P. SAMMARTINO, *Chimica per l'arte*, Bologna, 2007, p. 129-135.

12. Naturalmente questo non vietava sperimentazioni nuove rispetto alla regola dell'arte appresa nella bottega e questo portava spesso al progresso della tecnica come a risultati rovinosi.

13. Le proteine, ad esempio quelle dell'uovo, posseggono molti gruppi capaci di formare legami a idrogeno (gruppo peptidico, carbossilico, amminico, ecc.) per cui risultano sostanze tipicamente idrofile, ossia affini all'acqua. Esse sono in grado di formare soluzioni acquose di natura colloidale, non costituite da singole molecole ma da aggregati molecolari chiamati micelle che si trovano disperse stabilmente in acqua grazie ad uno strato elettrico di ioni che circonda ognuna di esse.

dono a denaturarsi (perdita dell'iniziale struttura tridimensionale) sotto l'azione di agenti chimici e fisici, diventando più insolubili. La tempera ad uovo, a detta del Cennini molto utilizzata, è conosciuta in particolare per essere molto resistente e il fatto che nella cappella maggiore le parti a secco siano in queste condizioni può farci pensare o ad un grande stress climatico, oppure all'uso di un legante diverso, magari l'uovo mescolato a qualche altro materiale organico più debole. Dal Libro di Cennino Cennini sappiamo che veniva usato il solo tuorlo o l'intero uovo di gallina¹⁴ in emulsione acquosa e con l'aggiunta di lattice di fico come fluidificante e per ritardarne l'essiccazione¹⁵ e probabilmente anche l'aceto come antifermantativo, ma nel nostro caso non siamo riusciti ad avere riscontri analitici precisi, data l'esiguità del materiale da prelevare e la presenza di materiali di restauro sovrapposti. L'utilizzo invece di una sostanza oleosa è invece ipotizzabile per la stesura delle lacche, forse mescolata alla tempera all'uovo (formando quindi la cosiddetta *tempera grassa*) per rendere la stesura più lucida e trasparente.¹⁶

La presenza di queste stesure, abbiamo detto prima, si nota oggi di fatto proprio per la loro assenza che ritaglia vuoti all'interno delle scene, o per la presenza di povere tracce, che però si possono mettere molto più in luce e documentare mediante l'analisi visiva e la ripresa fotografica con luce ultravioletta, cioè mediante un'indagine ottica, molto poco invasiva, che sfrutta le reazioni provocate in alcune molecole dall'irraggiamento con radiazioni ultraviolette, ovvero per il fenomeno della luminescenza.¹⁷ Come è noto, questa tecnica è

14. C. CENNINI, cap. LXXII, p. 120-122, 2003

15. Il lattice di fico è il liquido lattiginoso che sgocciola spezzando i ramoscelli del fico e consiste in una emulsione di una resina, una cera e una gomma; serve a ritardare l'essiccazione delle tinte a cui viene mescolato: la ficina in particolare è un enzima che idrolizza le proteine rendendole più fluide. Cfr. C. Cennini, a c Frezzato, 1971, nota 5, p. 86

16. In questo caso anche il colore molto più intenso della fluorescenza potrebbe far pensare ad un legante oleoso. Un fattore considerato importante era il colore proprio del legante al momento dell'uso e come conseguenza dell'invecchiamento, perché non avesse un'influenza eccessiva sul colore delle tinte prodotte. In questo senso l'uovo era migliore dell'olio perché quest'ultimo tendeva ad ingiallire, ma comunque si pensa che all'epoca di Agnolo l'uso dell'olio era forse ancora abbastanza raro, perlomeno per la pittura su muro in Italia.

17. Alcuni materiali presentano la proprietà conosciuta come luminescenza. Questo fenomeno consiste nell'assorbimento dell'energia corrispondente ad una forma di radiazione e nella riemissione di questa sotto forma di luce visibile. L'emissione di luce avviene dopo un tempo caratteristico *tc* dall'assorbimento della radiazione; In particolare se il processo cessa al cessare della causa eccitatrice, cioè tra assorbimento e riemissione c'è solo l'intervallo di tempo necessario per la transizione atomica

this depended on both the nature of the pigment and the size of the granules.¹³

The degree to which binding agents are hydrophilic plays a major role both at the moment the fresco is painted and over time. Hydrophilia determines whether water – which frequently seeps into the walls – will pass through a bonding agent easily and therefore whether pollutants will do the same. It can also make it easier – or harder – for a reaction to occur between two incompatible pigments mixed together in the same coat. As regards what are often referred to as “binding agents”, which were frequently used, we know that protein substances¹⁴ tend to be absorbant and oily substances, hydrophobic.

As such, the optical and mechanical properties of a *secco* paint depended on a series of factors that over time affected their respective resistance to age, as well as other transformations; the pigment/binding system, once transformed into a pictorial film, possesses a raised level of reactivity, as a result of which it can progressively suffer profound alterations from exposure to environmental conditions (light, humidity, biological agents, interaction with other chemical substances). Proteins, for example, tend to become denatured (i.e. they lose their original tridimensional structure) under the action of chemical and physical agents, consequently becoming more insoluble. Egg tempera, which according to Cennini was frequently used, is particularly renowned for being very resistant.

The current conditions of a *secco* portions of the main chapel can lead us to conclude that the wall paintings either faced significant climatic stresses or were painted using a different binding agent – perhaps egg mixed with another, weaker organic material.

Cennino Cennini's book describes how the yolk from a chicken egg, or the entire egg itself,¹⁵ was diluted with water. Fig-tree latex was added to make it more fluid and slow down the drying process,¹⁶ and vinegar was

13. Of course, this did not keep the painters from experimenting, pushing the limits of the technique they had learned in the workshop. This led to both technical advances and disastrous results.

14. Proteins, such as egg-based ones, have many formations capable of binding with hydrogen (e.g. peptide, carboxyl and amino groups). As a result they produce typically absorbant substances that are not dissimilar from water. These have the capacity to form watery, colloidal solutions that are not made up of single molecules but molecular groups known as micelles, which are found dispersed in stable form in water thanks to their outer coating of electrical ions.

15. C. Cennini, ch. LXXII, p. 120-122, 2003.

16. Fig-tree latex is a milky liquid obtained by breaking fig twigs. It is an emulsion of resin, wax and rubber, and

molto efficace per poter fare una serie di osservazioni sulla superficie dipinta, nel nostro caso potevamo distinguere e documentare la presenza di sostanze organiche (leganti e coloranti), soprattutto se invecchiate, e forniva un'informazione importante per noi della loro distribuzione spaziale, cioè una mappa della loro presenza, ma purtroppo non poteva dare informazioni dettagliate sui materiali stessi. Oggi si cerca di affinare quest'indagine migliorando la qualità delle fotografie grazie alle nuove tecnologie digitali e la qualità della sorgente d'irraggiamento, cercando di trarre informazioni delle materie organiche tramite colore di fluorescenza e, soprattutto correlando la fluorescenza con altre indagini di tipo fisico (UV/FC; UV Rifi; IR/FC), si cerca di trarre anche informazioni sulla natura dei pigmenti, ma non sempre è infallibile per l'identificazione del materiale organico perché esiste un forte condizionamento dei materiali aggregati al legante (pigmenti e coloranti).¹⁸

Comunque nella cappella maggiore le tracce di materiali organici documentabili grazie alla fluorescenza indotta erano tante e molte sono state documentate. Spesso si trattava solo di impronte sull'intonaco di quella che era stata una stesura pittorica, cioè era l'effetto del legante che aveva impregnato l'intonaco.

Con la tecnica a secco sono state realizzate numerose parti dell'abbigliamento dei personaggi: copricapi, vesti, calzari ecc... campite dai pittori con lacche e pigmenti che esulavano dalla tavolozza dell'affresco, quali: biacca, cinabro, minio, azzurrite (azzurrite + biacca spesso!), malachite, lapislazzuli¹⁹; materiali

probably also added to prevent fermentation. In the case of the work in question, given the scarcity of the original materials and the fact that these materials had been covered with other substances during a subsequent restoration, we were unable to test the composition of the binding agent precisely.

Oily solutions might theoretically have been used for lake coats, perhaps mixed with egg tempera (thus forming *tempera grassa*) to make the coat shinier and more transparent.¹⁷

As I have already mentioned, today we know that this layer existed because parts of the work have been lost – leaving empty spaces in the middle of scenes – or because of the scant traces of this layer which still remain. However, observation and ultraviolet light technology – both visual, almost completely non-invasive techniques – can flesh out this conclusion and furnish proof thereof by taking advantage of how some molecules react to radiation or luminescence.¹⁸

These techniques are quite effective for observing the pictorial surface. In the case of the work in question, we were able to distinguish and prove the presence of organic substances (binding agents and pigments) – especially those which had aged – and acquire valuable information about how these were distributed, leaving us with a veritable map of where these substances had been applied. Unfortunately, however, the technique failed to provide detailed information about the materials themselves.

keeps the paints it is mixed with from drying. The ficain enzyme in particular hydrolyses proteins, making them more fluid. Cf. C. Cennini, ed. Frezzato, 1971, note 5, p. 86.

17. Here too, the much more intense colour of the fluorescence could lead one to conclude that an oily binding agent was used. The original colour of the binding agent and colour as it aged were also important: artists preferred binding agents that changed colours to the least extent possible. Given this, eggs were better than oil, since oil tended to yellow. In any case, it is believed that oil was used only rarely in Agnolo's times, at least in Italian wall painting.

18. Some of the materials exhibited the property known as luminescence, whereby the energy corresponding to a form of radiation is absorbed and re-emitted as a form of visible light. Light is emitted a characteristic time (CT) after radiation is absorbed. If the process ends after the source that excites the pigments is cut off (in other words, between absorption and re-emission) and the characteristic time is the amount of time necessary for atomic transition (CT < 10-8 s), the process is referred to as fluorescence; when the excited elements are metastable and luminescence persists, re-emission is delayed and the process is called phosphorescence. Luminescence stems from the fact that some materials can absorb discrete amounts of energy, which is later released as photons (with a lower amount of energy). Fluorescence is the ability some substances have to re-emit the electromagnetic energy they have received, usually with higher wavelengths and therefore lower energy. In particular, fluorescence entails absorbing ultraviolet radiation and emitting it on the visible spectrum.

($t_c < 10^{-8}s$) il processo viene chiamato fluorescenza; se invece lo stato di eccitazione è metastabile, la luminescenza persiste, cioè la riemissione è ritardata e in tal caso il processo è detto fosforescenza. La luminescenza nasce dalla proprietà di alcuni materiali di assorbire quantità discrete di energia, successivamente restituita sotto forma di fotoni di energia inferiore. La fluorescenza è la proprietà di alcune sostanze di riemettere, nella maggior parte dei casi a lunghezza d'onda maggiore e quindi a energia minore, le radiazioni elettromagnetiche ricevute, in particolare di assorbire radiazioni nell'ultravioletto ed emetterla nel visibile.

18. A volte ad esempio il pigmento mescolato può assorbire in parte o tutta l'emissione di fluorescenza, per cui ci può anche sfuggire la presenza del legante in una stesura, ad es. i pigmenti di rame inibiscono la fluorescenza del legante ad es l'azzurrite e la malachite. Anche per questo problema si studiano delle funzioni matematiche per cercare di sottrarre, mediante interpolazione, l'alterazione prodotta dai pigmenti sulla fluorescenza. Quindi questo tipo di indagine non sempre fornisce una lettura chiara della situazione dei materiali, ma è così promettente e utile che sono in corso numerosi studi per migliorarla.

19. L'indagine sui pigmenti è stata condotta principalmente mediante strumentazione XRF (fluorescenza X), correlata per una serie di punti con FORS (spettroscopia in riflettanza UV/Vis/IR) e sezioni lucide da prelievi.

quindi che per varie ragioni non dovevano avere contatto diretto con la calce idrata che trasudava dall'intonaco durante l'asciugatura, pena l'alterazione più o meno veloce nel tempo,²⁰ oppure perché la calce come legante non offriva sufficiente isolamento dal contatto con l'aria (ad esempio per il vermiglione) come era risaputo dai pittori antichi.²¹

I fondi azzurri erano stati pressoché tutti realizzati con azzurrine mescolata ad un legante, per motivi di macinazione grossolana e di incompatibilità con la calce idrata, ma per gran parte i cieli delle scene e dei tabernacoli appaiono oggi di colore rosso scuro, ovvero ciò che si vede è lo strato preparatorio, chiamato in gergo "morellone" (sinopia + nero), e questo significa che l'ultimo strato ha risentito degli effetti del clima interno e forse anche degli interventi di manutenzione. Unica eccezione a questa rovina quasi totale dei fondi blu è qualche zona nelle vele della volta dove appare ancora in buono stato di conservazione: soprattutto nella vela di san Francesco ad esempio e parzialmente anche quelle di san Matteo e di san Giovanni Ev. Ciò però solleva qualche interrogativo essendo di solito la volta una sede prediletta dal degrado a causa delle frequenti infiltrazioni dal tetto e dell'eventuale assorbimento e/o condensa dell'umidità dell'aria sulle superfici. Vero è che su questi cieli abbiamo trovato un consistente strato di ossalato di calcio frutto dell'alterazione di un materiale organico steso in passato probabilmente a scopo protettivo e forse ciò significava un'attenzione particolare a queste zone che non ha interessato il resto delle altre campiture azzurre, oppure potremmo ipotizzare una differenza di legante tra queste stesure e quelle azzurre in parete... Il Cennini consiglia

20. La biacca ad esempio può trasformarsi da carbonato basico di piombo di colore bianco, in PbO_2 di colore bruno, per effetto dell'ambiente alcalino e agenti esterni (luce $T^\circ C$; RH) o può reagire con lo ione S^- dall'aria o da pigmenti limitrofi, diventando solfuro di piombo PbS di colore nero.

21. C. CENNINI, cap. XL, 2003, p. 92: *ma ttieni a mente che lla natura sua nonn-è di vedere aria, ma più sostiene in tavola che in muro, però che per lungheza di tempo, stando all'aria, vien nero quando è lavorato e messo in muro*. Il fenomeno dell'annerimento del cinabro è da attribuirsi alla trasformazione della sua struttura cristallina = metacinnabarite nera; oppure per degrado fotochimico favorito dal Cl dell'aria per cui il solfuro di mercurio (HgS) si scinde in S e Hg metallico che depositandosi sulla superficie crea l'annerimento. A causa dell'umidità, o ancora alla formazione di una miscela di composti (il calomelano: cloruro di Hg, la metacinnabarite e/o solfuro di mercurio amorfo), circostanza che giustifica appieno il viraggio in grigio piuttosto che in nero delle alterazioni effettivamente riscontrate sui dipinti. Sembra che un elemento importante per il verificarsi dell'alterazione sia il metodo di produzione,

We are now working to hone these techniques by increasing the quality of photographs (using new digital technologies) as well as the quality of the X-ray source. We hope to use the colour of the fluorescence to learn more about the organic materials that were used. By correlating fluorescence with other, physical tests (UV/FC, UV Refl, IR/FC), we aim to reveal additional information about the pigments. However, these techniques are not always infallible when it comes to identifying organic material since other elements added to the binding agents (pigments and colourants) generate significant bias.¹⁹

Using fluorescence, we determined that numerous traces of organic materials were left in the main chapel. These were often merely hints of the original work – namely, of the binding agent that had impregnated the *intonaco*.

The *a secco* technique was often used for painting attire, including headgear, clothing, and footwear. The painters used lakes and pigments – including white lead, cinnabar, minium, azurite (often azurite + white lead!), malachite and lapis lazuli²⁰ – to show off the full palette of colours at their disposal. However, for a variety of reasons these materials could not come into contact with the slaked lime that seeped out of the *intonaco* as it dried. Some quickly changed colour,²¹ while the slaked lime did not sufficiently prevent others, like vermilion, from touching the air. This was common knowledge among painters of the day.²²

19. Sometimes mixtures of pigments can absorb part or all of the fluorescence emission, preventing us from detecting some binding agents in a layer. For example, copper pigments inhibit fluorescence of pigments such as azurite and malachite in the binding agent. Given this, researchers are currently studying the mathematics of fluorescence in order to interpolate values and subtract the changes produced by given pigments under fluorescence. Although this type of research does not always produce a clear picture of the materials utilised, its potential remains highly promising and numerous studies to improve it are currently underway.

20. We primarily tested pigments using XRF (X-ray fluorescence), and correlated results using FORS (UV, Vis and IR Fibre Optics Reflectance Spectroscopy) for a series of points and on sections where samples were extracted.

21. For example, alkalines or external agents (light, temperature, relative humidity) could decompose white lead into dark brown lead dioxide (PbO_2); white lead could also react to S^- ions in the air or in adjacent pigments, becoming the black-coloured lead sulphide (PbS).

22. C. CENNINI, ch. XL, 2003, p. 92: *ma ttieni a mente che lla natura sua nonn-è di vedere aria, ma più sostiene in tavola che in muro, però che per lungheza di tempo, stando all'aria, vien nero quando è lavorato e messo in muro* ("But bear in mind that it is not its nature to be exposed to the air, but it stands up better on panel than on the wall; because, in the course of time, from exposure to the



Immagine delle fluorescenze indotta dagli ultravioletti: nel berretto del personaggio è evidente la presenza di un legante per la stesura pittorica rossa

Image from an ultraviolet fluorescent test. A binding agent is clearly visible in the red layer

appunto due leganti per gli azzurri: la colla di pergamena più trasparente e il rosso d'uovo, e tra questi certamente il più resistente nel tempo è il secondo, ma il pittore sceglieva, secondo il Libro, in base alla qualità cromatica del pigmento: se chiaro si doveva preferire l'uovo che dava una maggiore pregnanza alla tinta. Forse nella nostra cappella i pittori avevano anche avuto a disposizione due quantità e qualità diverse di azzurrite.²²

Come è risaputo oggi l'azzurrite è soggetta ad alterazione se a contatto con pH basici,²³ il Cennini lo consiglia su muro in secco con rosso d'uovo²⁴ o colla, ma non avverte di alcuna alterazione per l'uso a fresco (come fa ad esempio per la biacca ...) e forse perché la sua attenzione era rivolta piuttosto alla granulazione che all'alterazione, essendo un pigmento poco macinato che non poteva quindi essere

22. L'indagine FORS segnala un'ottima qualità per l'azzurrite esaminata sulla volta. Cfr. *Relazione Scientifica*, IFAC, Firenze.

23. A contatto con pH > 9 può alterarsi in idrossido di rame e quindi in ossido scuro CuO, tenorite; per l'alterazione in verde un tempo l'interpretazione prevalente era che per effetto della pressione e dell'umidità si tramutasse in malachite liberando CO₂

24. L'analisi FT-IR di un campione della volta ha riscontrato effettivamente tracce di rosso d'uovo, cfr. S. 1469.18, scheda di indagini diagnostiche/Analisi spettrofotometria FT-IR; Analista: Moles, C. 13 (vela di san Marco).

Almost all of the blue backgrounds were painted using azurite mixed with a binding agent, since azurite was ground into large granules and was incompatible with slaked lime. However, most of the skies in the scenes and tabernacles currently appear to be dark red. In fact, what we are seeing is the preparatory layer, commonly referred to as *morellone* (sinopia + black). This means that the uppermost layer was affected by the internal climate and perhaps also by maintenance work. The only exception to this near total destruction of the blue background can be seen in a few parts of the rib vaults, where the blue is still well conserved. This is especially the case in the depiction of St. Francis; the blue background is also partially visible in the images of St. Matthew and St. John the Evangelist. This is a bit surprising, since the vault usually tends to deteriorate due to frequent roof leaks, humidity absorption and/or air vapour condensation.

In these depictions of the sky, we consistently found a layer of calcium oxalate, a by-product of an organic material that had been applied in the past, probably to protect the work. This may suggest that special attention was paid to this particular blue section. Alternatively, the vault may have been painted using a different binding agent than the walls. Indeed, Cennini recommends two different binding agents for blues: a more transparent version made from parchment and one made from egg yolk. The latter certainly holds up better over time, but according to Cennini's book, the painter selected the binding agent he would use based on the colour of the pigment; egg was the agent of choice for lighter pigments, since it impregnated them better. It is also possible that the painters worked with two different sources of azurite, which may have had different qualities.²³

As we now know, contact with alkaline pHs tends to cause azurite to undergo alterations.²⁴

air, it turns black when it is used and laid on the wall"). Cinnabarite darkens in several cases: when its crystalline structure becomes black metacinnabarite; when chlorine in the air favours photochemical degradation, leading mercury sulphide (HgS) to split into S and metallic Hg, which are deposited on the surface and lead to blackening; in the presence of humidity; or when a mixture of compounds (calomel – Mercury(I) chloride – metacinnabarite and/or amorphous mercury sulphide) is formed. This fully explains the grey rather than black tones that can be observed in the work. It seems that the way in which the pigments were produced played an important role in determining what changes would occur.

23. The FORS test revealed that the azurite sample we took from the vault was of optimal quality. See *Relazione Scientifica*, IFAC, Florence.

24. When azurite comes into contact with pHs > 9, it can

steso con la sola acqua, ma con una giusta dose di legante più viscoso.

Nel suo libro è presente un'interessante considerazione che ci fa capire quanto non fosse facile ottenere una efficiente mescolanza tra pigmenti e legante e di come i pittori a volte si accorgessero che il legante non era stato sufficiente per la coesione della stesura: in un capitolo infatti consiglia di dare in questo caso una mano di colla chiara di pergamena sopra la stesura di colore come fissativo!²⁵

L'alterazione dell'azzurrite è presente nella nostra cappella, nella vela di san Francesco, dove lo strato di azzurrite originale è più continuo, e dopo la pulitura delle ridipinture di restauro, anche nelle vele adiacenti il fenomeno è tornato visibile sebbene in misura minore: si notano alcune aree verdi che le analisi hanno chiarito trattarsi di cloruri di rame (Atacamite e Paratacamite).²⁶

Altra alterazione, peraltro moderata, si notava a carico di qualche stesura di cinabro, un altro pigmento difficilmente stendibile ad affresco senza provocare variazioni di tono²⁷: sui costoloni della volta, sulle calze di un personaggio nella lunetta e forse sulla veste di un personaggio al primo piano, tra i personaggi che assistono alla decapitazione di Cosroe II.

Potevano comunque esserci vari altri motivi per legare un pigmento con un legante, ad esempio per addensare la tinta, cioè per migliorare la resa cromatica della stesura e per consentirne più agevolmente l'applicazione in parete. Il Cennini ad esempio nel suo libro scrive che per dipingere gli alberi o i prati²⁸ era meglio mettere prima una campitura di *nero puro temperato, ché in fresco mal si possono fare*²⁹, cioè suggerisce di fare un fondo con nero a tempera e il nero di vite³⁰ è la qualità di pigmento che più spesso si trova nelle pitture murali e che anche Cennini descrive. Il motivo non è quindi per evitare un'alterazione, essendo il nero vite difficilmente alterabile, bensì perché il legante organico forniva una stesura più efficiente rispetto alla sola acqua.

Osservando lo stato di conservazione degli alberi dipinti nelle varie scene, nonché del bel prato fiorito nel secondo registro della parete

Cennini recommended using azurite for a *secco* wall painting with egg yolk²⁵ or glue, but did not mention any alterations that might arise for fresco work (as he did, for example, when referring to white lead). This may be because he focused more on the pigment's granularity than on potential alterations, since it is a relatively coarse pigment that required a solid dose of viscous binding agents rather than water.

In his book, Cennini also noted that painters sometimes realised that binding agents were not strong enough to cause a layer to cohere. When this was the case, Cennini recommended a surprising solution: spreading a layer of clear parchment glue over the layer of colour to reinforce it! This provides interesting food for thought and helps us understand how difficult it was to effectively mix pigments and binding agents.²⁶

We detected azurite alterations in the rib vault depicting St. Francis, where the original layer of azurite is more continuous. After cleaning areas which had been repainted during previous restoration processes, we also detected this phenomenon – albeit to a lesser extent – in the neighbouring rib vault, which includes some green areas that tests confirmed to be copper chloride (atacamite and paratacamite).²⁷

Moderate alteration can be seen in some cinnabar layers – on the ribs in the vault, on the hosiery of a figure in the lunette, and perhaps in the clothing of one of the figures gathered to see Khosrau II decapitated (in the foreground). It should also be noted that this pigment is difficult to apply to frescoes, often leading to tone variations.²⁸

A given binding agent could also be used with a pigment for other reasons, including thickening the paint, improving the colour of the layer and making it easier to apply to the wall. For example, in his book Cennini wrote that the best way to paint trees or meadows²⁹

degrade into copper hydroxide and the dark-coloured tenorite (CuO). For a long time it was also believed that pressure and humidity changed azurite into malachite by freeing CO₂, causing the pigment to green.

25. A FTIR test of a sample from the vault found traces of egg yolk. See S. 1469.18, diagnostic reports/FTIR spectrophotometer analysis; Analyst: Moles, C. 13 (rib depicting St. Mark).

26. C. Cennini, ch. CXI, 2003, p. 141. *e dove avessi campeggiati cholori che non fussero stati ben temperati, dà una man di questa colla* (“And apply a coat of this size in any place where you have happened to lay in colours which were not tempered sufficiently”).

27. In general, humid air and/or walls and the presence of Cl ions are necessary for this transformation to take place.

28. See footnote 22.

29. ... *albori e erbe e verdure* (“trees and plants and fo-

25. C. CENNINI, cap. CXI, 2003, p. 141. *e dove avessi campeggiati cholori che non fussero stati ben temperati, dà una man di questa colla*

26. In genere perché avvenga questa trasformazione è necessaria l'umidità dell'aria e/o della parete e la presenza di ioni Cl.

27. Vedi nota 21.

28. ... *albori e erbe e verdure*; C. CENNINI, cap. LXXXVI, 2003, p. 127

29. C. CENNINI, c s.

30. Cioè un pigmento ottenuto dalla combustione lenta dei tralci della vite e quindi dalla macinazione dei residui.

nord (*La fuga dei Persiani*), possiamo dedurre che la conservazione di questo strato sia dipesa piuttosto spesso dalle condizioni del fondo su cui giaceva il nero. In qualche caso lungo la giunzione di giornate d'intonaco si nota una netta differenza di conservazione che fa pensare a come queste stesure sfruttassero anche la carbonatazione dell'intonaco diventando più stabili, mentre di per se avevano un legante assai debole, si tratta perciò nel primo caso della cosiddetta "tempera ausiliaria".³¹ Le foglie dipinte sopra il nero sono ancora a secco con un pigmento di rame e giallo di stagno e piombo, in perfetta linea con quanto scrive il Cennini che consiglia di usare un *verde azzurro*, un pigmento artificiale comprato dai pittori con questo nome, fatto con blu di azzurrite e piuttosto grossolano nella macinazione per poter ottenere un buon tono e come schiarente in questo caso suggerisce il *giallorino*, ovvero il giallo di stagno e piombo.³² Le indagini scientifiche prontamente mostrano una simile composizione e in parete si nota per le foglie uno spessore consistente in seguito alla grossezza dei grani dei pigmenti. Se osserviamo poi il prato fiorito, l'unico terreno così dipinto in tutta la cappella, vediamo che la sua tecnica è simile nella stratigrafia a quella degli alberi, e che la sua conservazione è in genere pessima. Delle tracce dello strato verde delle foglie si conservano meglio quando sono dipinte direttamente sulle vesti dei personaggi e ciò può significare una intrinseca debolezza coesiva dello strato nero che ha causato la caduta di foglie e fiori di per sé realizzate invece con un legante efficiente.

Nella Cappella Maggiore per il ricorso ad un legante, esistono anche altre ulteriori ragioni pratiche, dettate dallo svolgimento del cantiere pittorico. È questo il caso ad esempio della pittura delle croci che sono quasi sempre dipinte a secco, utilizzando la biacca come bianco, benché il colore del legno non implicasse per forza l'utilizzo di pigmenti partico-

31. Il termine è stato coniato da Leonetto Tintori (1908-2000), un famoso restauratore fiorentino appassionato ricercatore delle antiche tecniche, secondo il quale i pittori sapevano sfruttare le ultime conseguenze della carbonatazione (pittura sull'intonaco "stanco", cioè quasi asciutto) stendendo le tinte con legante, evitando contemporaneamente la possibile alterazione del legante stesso per il pH e del pigmento. Tintori è autore di varie pubblicazioni in merito alle tecniche antiche, grazie alle sperimentazioni condotte presso la sua casa di Vaianella (Prato) divenuta una scuola dell'affresco e donata nel 1988 al Comune di Prato.

32. Stannato di piombo Pb_3SnO_4 la cui produzione era legata probabilmente all'industria vetraria e infatti Cennini lo definisce *artifiziato* e lo consiglia per ogni tecnica come molto durevole, ma difficile da macinare. C. CENNINI, cap. XLVI, 2003, p. 95; *ibid* p. 250-52.

was to apply a layer of *nero puro temperato, ché in fresco mal si possono fare*³⁰ (pure black, tempered, for they can hardly be done in fresco). In other words, he suggests that the background contain tempered black and vine black³¹, and indeed, this is the type of pigment most frequently found in wall paintings, as Cennini also described. This approach was not adopted to avoid alterations, as vine black rarely undergoes such processes. Rather, it was employed because the organic binding agent provided a more efficient layer than water.

The state of the trees painted in various scenes as well as the beautiful blooming meadow in the second panel on the northern wall (*The Flight of the Persians*) leads us to conclude that this layer's conservation depended primarily on the conditions of the background upon which the black was painted. A clear difference can be observed at the junctions of some *giornate*, indicating that these layers also underwent carbonatation as the *intonaco* became more stable – despite having quite a weak binding agent. This therefore constitutes the first case of *tempera ausiliaria*.³²

The leaves were painted *a secco* on the black using copper and lead-tin yellow. This meshes perfectly with Cennini's advice to use *verde azzurro* (malachite), an artificial pigment purchased ready-made that contained azurite blue and relatively large-ground granules, thereby providing a good tone. For lightening, Cennini recommended *giallorino* (his name for lead-tin yellow).³³ Scientific tests immediately reveal that their composition was similar.

This is also visible in the fresco, where the consistency of the leaves is in keeping with the aforementioned granule size. If we look at the blossoming meadow – the only stretch painted in this style in the entire chapel – we

liage"); C. Cennini, ch. LXXXVI, 2003, p. 127

30. *ibid*.

31. This pigment is obtained by slowly charring vine shoots and then grinding the ashes.

32. The term was coined by Leonetto Tintori (1908-2000), a famous Florentine restorer and passionate researcher of ancient techniques, who argued that in earlier ages, painters knew how to take advantage of carbonatation, painting on *intonaco* that was *stanco* (tired) – i.e almost completely dry – and applying colour with a binding agent, thus avoiding possible alterations of the binding agent itself which might be related to the pH and the pigment. As a result of the experiments he carried out in his home in Vaianella (Prato), Tintori authored various works on ancient techniques. His studio later became a school of fresco painting and was donated to the Town of Prato in 1988.

33. Lead-tin yellow, Pb_3SnO_4 , was probably produced by the glass-making industry. In fact, Cennini called it *artifiziato* (artificial) and recommended it for very durable uses but noted that it is difficult to grind. C. Cennini, ch. XLVI, 2003, p. 95; *ibid* pp. 250-52.



Probabile alterazione della biacca contenuta nella tinta dei calzari del cavaliere al seguito della Regina Elena (lunetta parete nord)

Possible alteration of white lead contained in the color of the boots of the rider in the entourage of Queen Elena (lunette north wall)

lari, ma probabilmente per il desiderio di mostrare una pittura dall'aspetto omogeneo. In molti casi si riscontra che la pittura della croce interessa più *giornate*, ed era ben noto ai pittori la possibilità che la stessa mescolanza di pigmenti potesse risultare diversa con l'asciugatura della singola giornata³³, perciò a fresco veniva realizzato solo il disegno preparatorio, mentre a secco si dipingeva tutta la croce sulle giornate. Buona parte delle croci infatti sono oggi quasi scomparse e le vediamo solo grazie al suggerimento del nostro ritocco pittorico o per il mantenimento della vecchia ridipintura.

La croce, protagonista della storia narrata, compare in tutte le scene delle parete nord e in due della parete sud e un'unica eccezione conservativa riguarda proprio questa parete, quella presente nella scena della sua fabbricazione, al secondo registro dal basso. Qui la croce è relativamente ben conservata e forse in virtù di un diverso legante. Altra eccezione tecnica è invece nel registro sottostante, quello in cui si racconta appunto del ritrovamento delle croci del Golgota e del riconoscimento di quella di Cristo: qui ne vengono dipinte ben sei, ma quelle a terra sono frutto di ridipinture di un restauro precedente al nostro, mentre quelle maneggiate dagli operai sono stranamente dipinte in affresco su più *giornate* con risultati cromaticamente assai disomogenei. Se mai era esistita una finitura a secco oggi è scomparsa, e comunque questa procedura rappresenta una rarità nella cappella³⁴.

Altre ragioni pratiche e contingenti riguardavano semplicemente il non avere più a disposizione un intonaco sufficientemente

can see that the layering approach was similar to that used for the trees and that the quality of conservation in this section was generally abysmal. Traces of green leaves were conserved better when they were painted directly on clothing. This may indicate that the black layer was intrinsically weak, causing the leaves and flowers – which had been painted using an efficient binding agent – to fall off.

In the main chapel, there were also other practical reasons for using binding agents. These depended on when a given section was painted. For example, the crosses were almost always painted *a secco*, using white lead for white hues. Although the colour of the wood did not require this particular pigment to be used, the painters probably wished to maintain a homogeneous appearance. The painters were well aware that the same mixture of pigments could turn out differently as a single *giornata* dried. Consequently, only the preparatory designs for the crosses were done in fresco, while the crosses themselves were painted *a secco*, often over several adjacent *giornate*.³⁴ In fact, today a good portion of the crosses have disappeared; what we can see is visible as a result of an earlier restoration as well as our retouches.

The cross – the object for which this cycle is named – appears in every scene on the northern wall and in two of the scenes on the southern wall. It is only well conserved in the scene that depicts it being erected, in the second panel up from the bottom. Perhaps the cross was relatively well conserved here because a different binding agent was used. It is also relatively visible in the bottom-most panel, which depicts the finding of the crosses in Golgotha and the discovery of Christ's cross. This particular scene actually contains at least six painted crosses, although the crosses resting on the ground were repainted during a previous restoration. Even more strangely, those in the hands of the labourers were painted using the fresco technique over several *giornate*; the colours in them thus turned out to be rather inhomogeneous. If *a secco* elements were added, they have been lost. In any case, this procedure was quite exceptional in our chapel.³⁵

33. L'alternativa a questa soluzione a secco sarebbe stata quella di impiegare una giornata unica per tutta la croce, oppure usare una tinta a calce che attutisse gli effetti della carbonatazione, ma in questo caso con l'incognita ancora della possibile disomogeneità.

34. Il motivo forse è da ricercare con un cambio nell'equipe degli esecutori. Altra croce dipinta totalmente a fresco è presente nella scena di fronte, ma si tratta di un elemento che occupa una sola giornata.

34. Alternatives to the *a secco* technique would have entailed painting the entire cross over a single *giornata* or using a lime-based layer that diminished the effects of carbonation. However, in this case the painters would have had to deal with the fact that the crosses might not have been homogeneous.

35. Could this be because the team of painters changed? Another cross was also painted using only the fresco technique in the scene facing this one, but it was painted over a single *giornata*.

bagnato, com'è quando viene dipinto il terreno a secco, o le corde, o il manico di una pala, tutti elementi che non richiedevano pigmenti particolari e che potevano quindi essere dipinti anche a fresco e se Agnolo usa qui un legante lo fa perché appunto le condizioni del supporto non erano più tali da consentire una buona carbonatazione e con ciò la stabilità delle tinte.

Oppure a secco si dipingono alcuni elementi per motivi oggi difficilmente identificabili: la colonna della città di Gerusalemme nella *Fuga dei Persiani* o gli animali disseminati nel *Ritrovamento della Croce*; è difficile spiegarsi il perché se non pensando alla volontà di riprodurre magari un disegno dal vero per l'elemento architettonico, o, per gli animali, ad un ripensamento in corso d'opera per poter aggiungere dei particolari, infatti il loro disegno è graffiato direttamente sull'intonaco già dipinto e poi vengono campiti a secco.

Moltissima pittura a secco era anche presente sulle cornici che oggi appaiono con le sole stesure di fondo a fresco e anche qui è assai degradata. Anche queste parti secondarie erano state molto curate, soprattutto per la volta rispetto alle pareti dove sembra un po' affievolirsi la raffinatezza della decorazioni.

I motivi geometrici dei costoloni si mostrano oggi come una sequenza di figure geometriche rosse su fondo bianco, ma un tempo erano blu con forme definite da lamine metalliche; le cornici che chiudono da ogni lato le scene si configurano come dei segmenti contornati alternativamente da bande rosse e verdi, due nello sviluppo verticale e quattro per quello orizzontale, interrotte da rombi e formelle da cui si affacciano delle figure di Profeti; all'interno si sviluppa una serie di racemi vegetali con grossi fiori un tempo decorati in rilievo con bottoni in cera, e in parte campiti in blu, mentre i segmenti esterni erano decorati con sottili e fitti segmenti di lamina metallica.

Tra le vittime degli effetti del microclima della Cappella dobbiamo annoverare anche alcune campiture dipinte a fresco, le campiture verdi ad esempio erano per la maggior parte sollevate dal supporto per effetto degli alti tenori di umidità relativa. La terra verde è un pigmento costituito da un miscuglio di silicati tra cui principalmente la Celadonite³⁵ e la Glauconite (silico-alluminati ferrosi e ferrici di potassio e magnesio + altri minerali: ossidi

At other times, the *a secco* technique was used simply because the *intonaco* was no longer wet enough – notably, for items like the ground, ropes, or the handle of a shovel. Since these items did not require a specific pigment, they could also be painted using the fresco technique; when Agnolo used a binding agent for them, he did so because the support was no longer in a good enough condition to carbonate well and thereby stabilise the pigments.

Some other items – such as the column in Jerusalem in the *Flight of the Persians* or the animals dotted throughout the *Finding of the Cross* – were painted using the *a secco* technique for reasons that are difficult to identify. Perhaps the artists wanted to reproduce an actual column in the first case, or decided to add or modify the animals over the course of the commission in the second case. These elements were painted directly onto the *intonaco*, which had already been painted and dried; highlights were added using the *a secco* technique.

Significant *a secco* work was also used on the cornices. Today, these parts of the pictorial surface are rather degraded and only the fresco background layer remains. Here, too, painstaking care was paid to detail, especially for the vault. It seems, however, that when it came to the walls, the decorations were somewhat less refined.

Today, the ribs appear to display a series of red geometrical figures on a white background. However, in the past, these geometrical motifs were blue and the figures were formed of metal leaf. The cornices around each scene now appear as a series of decorative stripes framed by red or green bands – two of each on the vertical parts of the frame, and four of each on the horizontal parts – with rhombuses and other shapes housing images of prophets interspersed among them. Inside these decorative motifs, we see a series of vines with large flowers. These were once decorated with wax reliefs of sprouts, some parts of which were painted blue; the external segments were embellished with a mixture of thin and thick strips of metal leaf.

Some layers painted using the fresco technique also fell victim to the chapel's microclimate. For example, the green layers generally buckled due to the high relative humidity. Green earth is a pigment comprised of a mixture of silicates, including celadonite³⁶ and

Esecuzione delle fronde degli alberi a cavallo di due giornate d'intonaco: si evidenzia come sia chiara la differenza di conservazione tra le due parti forse a ragione del contributo della carbonatazione in aggiunta al legante nella giornata più fresca

Foliage of a tree painted on two different *giornate*. The two parts were conserved differently, perhaps due to carbonation in addition to the binding agent in the fresher *giornata*

35. Celadonite = minerale terroso costituito da squame minute di color verde cupo. È essenzialmente un silicato idrato di ferro, alluminio, magnesio e potassio, trovato come riempimento secondario di cavità entro un basalto amigdaloide di Monte Baldo (Verona). Cfr. www.EnciclopediaTreccani.online.

36. Celadonite is an earthy mineral composed of small, dark green sheets. It is a ferromagnesian silicate hydrate containing aluminium and potassium, and was found in amygdaloidal basalt in Mt. Baldo (Verona). See the online EnciclopediaTreccani.



e idrossidi), di consistenza appunto terrosa, cioè costituiscono un pigmento fine e compatto che ha la struttura cristallografica propria delle miche, cioè a strati sovrapposti. In quanto ricco di silicati è capace di assorbire forti quantità d'acqua dilatandosi. In questo modo potremmo spiegarci uno stato così disastroso di conservazione. Possiamo chiederci ad esempio da dove provenisse la terra verde comprata da Agnolo e i suoi: dal nord Italia, da sempre famoso per i suoi giacimenti, o dalla Toscana, dato che Cennini stesso racconta di aver trovato nella campagna senese la terra verde?³⁶

A proposito dei materiali organici sulle pareti, sottolineiamo come nella cappella degli Alberti ne troviamo anche in seguito alle tante e diverse applicazioni delle lamine metalliche, sia all'interno delle scene che in tutte le zone limitrofe: fasce decorative e costoloni, secondo il chiaro intento di impreziosire le superfici

36. C. CENNINI, cap. LI, 2003, p. 98. Anche Vitruvio chiamava la terra verde: *creta viridis* ed è uno dei pigmenti più utilizzati in ogni epoca in pittura murale per la sua resistenza alla calce e la sua compatibilità con gli altri pigmenti; è dotato un discreto potere coprente. Il Cennini consiglia di macinarlo molto per avere un buon colore e lo dice grassissimo, volendo segnalare la consistenza untuosa quando mescolato con l'acqua. Le proprietà fisiche sono variabili in relazione alla qualità originaria del pigmento raccolto e della sua lavorazione successiva (macinazione e lavaggio); il tono del pigmento è variabile in relazione alla zona di provenienza, con diverse sfumature di verde, in qualche caso riesce ad essere molto intensa e fredda quasi come la malachite (celadonite). In Italia era molto famosa la terra di Verona, nel nord, a base di celadonite; i maggiori giacimenti erano infatti nell'Italia del nord: Trentino e Veneto. Altra provenienza famosa nella storia è l'isola di Cipro.

glauconite (aluminium silicate, potassium, magnesium and iron oxide in combination with other minerals – namely oxides and hydroxides). It has an earthy consistency and produces a fine, compact pigment whose crystallographic structure resembles that of mica (i.e. it has a series of layers). As this pigment contains numerous silicates, it can absorb large quantities of water; when it does so, it expands. This helps to explain the disastrous state of the section of the work painted using green earth.

It is also worth considering where Agnolo and his disciples bought their green earth. Did it come from northern Italy, which has always been famous for its deposits, or from Tuscany, since Cennini himself described finding green earth in the countryside of Siena?³⁷

Just as in the Alberti Chapel, a large amount of organic material was detected on

37. C. Cennini, ch. LI, 2003, p. 98. Vitruvius also described the same green earth pigment, which he called *creta viridis*. This pigment has been among the most frequently used in wall painting over the years due to its resistance to lime and compatibility with other pigments, as well as the fact that a small amount thereof goes a long way. Cennini recommended grinding it finely to obtain a good colour and referred to the pigment as *grassissimo* – exceptionally thick – to underscore that it is oily when mixed with water. The physical properties of *terra verde* vary depending on the original quality of the pigment and the way it is processed (ground and washed). The tone of the pigment depends on where it came from, giving rise to various shades of green; at times, it can be nearly as intense and cold as malachite. In Italy, the famous *terra di Verona*, a celadonite-based mineral, was very common in the north. In fact, the largest deposits were found in northern Italy – in the Trentino and Veneto regions. Historically, Cyprus was also well known for this mineral.

creando una molteplicità di riflessi metallici di cui oggi purtroppo non possiamo più godere, dato lo stato di grave degrado.

L'utilizzo dei diversi metalli in foglia era naturalmente in relazione al colore proprio, quindi alle esigenze rappresentative, ma all'interno di questa suddivisione di tipo estetico c'erano poi altre specificità di carattere più operativo che rispondevano cioè alla logica di utilizzo delle lamine, o foglie che dir si voglia. Sono presenti infatti sia foglie metalliche semplici che doppie, esse vanno a riempire aree di una certa vastità, oppure rivestono minuti e più o meno frastagliati motivi decorativi e per ciascuna situazione la sapienza del fare posseduta dalla grande bottega di Agnolo Gaddi ricorreva a variazioni significative.

Cennino Cennini, a cui spesso abbiamo fatto riferimento, dedica vari passi alle modalità di applicazione delle lamine metalliche in muro, in coda alla sezione dedicata alla pittura murale e in altri brani disseminati per il trattato, ma possiamo dire che le modalità osservate in cantiere sono più articolate di quelle descritte.

Lo stagno³⁷ era un materiale molto utilizzato per creare in parete superfici riflettenti, sicuramente perché lo si poteva facilmente ridurre in foglia e nella Cappella lo troviamo in tutte le zone dove era necessario imitare metalli di aspetto argenteo come l'acciaio delle armature, o comunque per avere degli elementi rilucenti come nelle fasce decorative, o piuttosto come appoggio e rinforzo della lamina d'oro, in quest'ultimo caso l'aumento dello spessore della lamina rendeva più facile le delicate procedure di applicazione. La lamina così preparata doveva essere tagliata su un asse di legno con un coltellino molto affilato e quindi veniva applicata, per gli elementi più piccoli invece si doveva probabilmente già mettere il collante sul retro. Le analisi indicano l'uso generale di materiale lipidico mescolato a resina, quella che per il Cennini è la cosiddetta "vernicio", con l'aggiunta talvolta di biacca e di ocre rossa; in particolare per la lamina di stagno, notoriamente più spessa³⁸, il collante era invece addensato grazie all'introduzione di cera d'api.

Per realizzare però le forme più frastagliate e minute, decorazioni delle stoffe di alcune vesti e alcuni bordi decorati con finte lettere

the walls. This material was the by-product of the metal leaf used both within the scenes and in adjacent areas like the decorative bands and ribs, and confirms a clear desire to adorn these surfaces with copious amounts of glimmering metal leaf. Unfortunately, due to the poor state of conservation, today these metallic adornments are no longer visible.

The choice of metal leaf depended on the metal's colour and the colour the artist aimed to produce. In addition to these aesthetic factors, however, other, more technical characteristics determined which sheets or leaves were used. Metal leaf could be used to fill relatively large spaces or to embellish minute, somewhat uneven decorative motifs, and both single and double metal leaf were used in the chapel. In each situation, Agnolo Gaddi's skilled workshop employed its extensive knowledge base to determine which variety was most appropriate.

Cennino Cennini, whom I have already mentioned several times, described several approaches for applying metal leaf to the wall in both the closing lines of the section on wall painting and other fragments peppered throughout his treatise. However, the approach used in our chapel was more advanced than the techniques Cennini described.

Tin³⁸ was often used to create reflective surfaces on walls. It was almost certainly employed because it could be easily pressed into sheets. In the chapel, we detected it in all of the areas where the painters aimed to imitate silvery metals, such as in the steel of armour. It was also used to create a reflective effect in the decorative bands and to support and strengthen gold leaf, where the increased thickness of the sheet made the delicate application process easier. Sheets prepared in this manner were cut on a wooden board using a very sharp penknife and were then applied directly to the walls; a binding agent was probably used on the back of smaller pieces. Our tests indicate that a lipid mixed with resin – what Cennini called *vernicio* (varnish) – was widely used; it was sometimes combined with white lead or red ochre. For tin leaf in particular – which is notoriously thicker³⁹ – the glue was thickened with beeswax.

Double leaf had to be avoided for more minute, uneven forms such as the fabric

Il tracciato disegnativo della croce interessa tre giornate d'intonaco ed è realizzato in parte mediante battitura di corda mentre la pittura è realizzata a secco sul fondo bianco o campito di rosso per il fondo dell'azzurro

The cross was painted over three *giornate* using the *battitura di corda* technique (where the frayed end of a rope was used to spread paint on the wet *intonaco*) and then painted *a secco* on a white background or highlighted with red over a blue background

37. Lo stagno è un metallo malleabile e duttile bianco argenteo

38. La statistica tratta dalle analisi in sezione deduce uno spessore circa 10 volte superiore; cfr. M. MATTEINI, A. MOLES, *Le tecniche di doratura nella pittura murale*, in C. DANTI, M. MATTEINI, A. MOLES (a cura di), *Le pitture murali, tecniche, problemi, conservazione*, Centro Di, Firenze, 1990, p.122.

38. Tin is a malleable, ductile metal with a whitish, silvery colour.

39. Our analysis revealed that tin leaf was about 10 times thicker than other kinds of metal leaf; cf. M. Matteini, A. Moles, *Le tecniche di doratura nella pittura murale*, in C. Danti, M. Matteini, A. Moles (eds.), *Le pitture murali, tecniche, problemi, conservazione*, Centro Di, Florence, 1990, p.122.



cufiche, l'espedito della foglia doppia si doveva evitare perché era necessario disporre di una lamina molto sottile. In questa situazione la lamina veniva incollata e semplicemente spolverata con una piuma di gallina per rimuovere quella che non appoggiava sul collante e il residuo veniva così recuperato per altri usi. In queste tipologie decorative la lamina d'oro era applicata grazie ad un collante di colore rosso ben visibile e dallo spessore evidente, grazie all'aggiunta di terre e ocre.³⁹

Nel caso di queste decorazioni si capiva la praticità del procedere decorativo, ma vi sono altre situazioni in cui si utilizza la foglia d'oro semplice per rivestire aree più grandi dove ci

39. CENNINI C., 2003, p. 175. Il Cennini descriveva più distesamente questa procedura in capitoli lontani dall'argomento della pittura murale, quando illustrava il caso dell'esecuzione di ornamenti sottili tratteggiati con la punta del pennello intinta nel mordente in maniera parsimoniosa per non fallire la precisione della scrittura decorativa. In questa tecnica l'oro utilizzato era "il più battuto oro e'l più fiebole che possi trovare", del tipo quindi più sottile e dopo l'essiccamento del mordente le parti eccedenti dal suo tracciato e non trattenute dal collante venivano rimosse con una penna; l'avanzo, scriveva il Cennini, poteva essere recuperato perché i frammenti erano utili al pittore stesso o agli orefici. È evidente che in questo caso non era necessario l'uso del coltellino per la maggiore fragilità della lamina.

of some clothing and some of the borders decorated with faux Kufic letters; here, a very thin sheet was necessary. In these cases, the leaf was affixed to glue spread on the wall and a chicken feather was later used to brush away the parts of the metal that did not touch this glue. These leftover bits were saved and could be used for other purposes in the future. In this kind of decorative work, gold leaf was applied using a highly visible variety of red glue; due to the earth and ochre added to it, this glue was also quite thick.⁴⁰

This approach was practical for these types of decorations, but there were other situations

40. Cennini C., 2003, p. 175. Cennini described this procedure in more detail in chapters that did not focus on wall painting when he discussed tracing detailed ornamentation work with a brush tip dipped into a small quantity of mordant, which was exceptionally precise for decorative writing. In this technique, the gold used was to be "il più battuto oro e'l più fiebole che possi trovare" ("the most thoroughly beaten gold, and the most fragile, that you can secure") – in other words, the thinnest gold leaf available. After the mordant dried, the parts that were not held by the binding agent were removed with a brush. According to Cennini, the remnants could be collected, since they could be used not only by the painters themselves but also by goldsmiths. Obviously, in this case, a penknife was not needed since the metal leaf was much more fragile.

si poteva aspettare la foglia doppia: nelle aureole dei Santi della volta, nei pilastri e nelle piccole figure di Profeti delle fasce decorative e negli oggetti rubati dai Persiani che fuggono da Gerusalemme. Qui appunto la foglia è sottile e stesa su un collante trasparente.

Un'ultima variante per l'applicazione dell'oro consisteva nel rivestimento dei rilievi in cera che sottolineavano taluni elementi decorativi: alcune perle e decori per le corone; il bottone tondo al centro delle stelle; le piccole borchie delle bardature dei cavalli; parti dei libri in mano ai Santi nei tabernacoli o nella volta; alcuni piccoli elementi tondi delle fioriture vegetali nelle fasce delle cornici delle scene. In questi casi il rilievo era prodotto con un impasto di cera mescolata a pece,⁴⁰ modellato con le mani per i bottoni, ritagliato probabilmente da mattonelle di un certo spessore, ottenute forse tramite fusione e colatura entro stampi, per ottenere le parti della corona, ad esempio della Regina di Saba.

Il degrado di queste lamine è presto detto, generalmente possiamo dire che sono in pessimo stato di conservazione, la maggior parte è infatti persa e non possiamo nemmeno stabilire precisamente una correlazione tra tecnica e stato di conservazione, ad eccezione forse delle decorazioni più minute incollate tramite l'adesivo colorato in rosso, perché in molti casi se osserviamo le varie situazioni ci appaiono alcune incongruenze. Ad esempio le aureole della volta, decorate in lamina semplice, sono relativamente ben conservate mentre quelle sulle pareti, apparentemente della stessa tipologia tecnica, sono pressoché scomparse; così ad esempio tutti gli oggetti d'oro rappresentati nella *Fuga da Gerusalemme*.

I raggi in lamina doppia sono più conservati nella volta che non in parete.

Le lamine in stagno sono generalmente degradate, ma si può dire in misura minore di quando lo stagno sostenga la lamina d'oro: forse per un'eccessiva contrazione dell'adesivo dell'oro?

L'unica situazione da sottolineare è il buono stato delle decorazioni minute su collante rosso che spiccano per essere ancora ben visibili. Quindi in generale si può dire che, anche se non possiamo esattamente risalire ai miscugli utilizzati a quel tempo, alcuni adesivi si sono dimostrati più resistenti di altri.

when single leaf gold was used on larger areas where double leaf gold might have been expected. These include the saints' aureoles in the vault, the columns, the small figures of the prophets in the decorative bands, and the objects stolen by the Persians fleeing from Jerusalem. In fact, in these cases a thin layer of leaf was applied using transparent glue.

A final technique for applying gold consisted of gilding the wax reliefs under some decorative elements, including some pearls and decorations on the crowns, the round button in the centre of the stars, the small studs on the horses' harnesses, parts of the books the saints are holding in the tabernacles or the vault, and some small, round flowery elements in the bands surrounding the scenes. In these cases, the relief was made using a mixture of wax and pitch,⁴¹ which was hand-moulded in the case of the buttons and was probably cut into tiles of a given thickness. It may have been made by melting and casting plates to make the parts of the crown, such as the one worn by the Queen of Sheba.

This metal leaf is generally in a terrible state, and the degradation process is easy to observe. Indeed, the majority has been lost, but it is impossible to establish a definitive correlation between the technique and the state of conservation. A possible exception may be seen in the minute decorations affixed using a red-coloured adhesive, where we can observe some inconsistencies. The aureoles in the vault, which were decorated using single leaf, are relatively well conserved whilst those on the walls, which were apparently applied using the same technique, have almost completely disappeared. This is also the case for all of the golden objects depicted in the *Flight from Jerusalem*.

The sunbeams illustrated with double leaf are better conserved in the vault than on the walls.

Tin leaves generally degraded, although to a lesser extent than when the tin was used to support gold leaf. Perhaps this owes to the fact that the adhesive used for the gold was quite prone to shrinking.

It should be noted that the small decorations affixed using red glue are in good condition and are still quite visible. Therefore, although we cannot be completely sure of the mixtures used when the work was painted, we can be certain that some adhesives held up better over time than others.

40. Pece greca cioè resina colofonia

41. Greek pitch, i.e. rosin

Nota relativa al cantiere

L'Opificio è stato il responsabile della metodologia e delle scelte dell'intervento, così ha anche coinvolto diversi istituti di ricerca per lo studio della Cappella. Varie sono le persone che si sono succedute nella Direzione dell'Istituto durante i 5 anni del cantiere: C. Acidini (2005/07); B. Santi (2008), I Lapi Ballerini (2008/10); per la Direzione del Settore Pitture Murali: C. Danti (2005/07) e C. Frosinini (2007/10).

Per il Settore P Murali dell'OPD i restauratori: M. R. Lanfranchi (responsabile del cantiere); F. Bandini, A. Felici; P. I. Mariotti; i collaboratori: A. Bargellini, S. Begliardi, S. Careccia, L. Ciceri, A. Cinotti, G. Cocciolini, S. Franceschini, I. Gambina, V. Ghiso, A. Martinelli, D. Murphy, C. Napolitano, E. Onnis, L. Poli, K. Stura.

Responsabile per la sicurezza dell'OPD: P. Capone.

Per il Laboratorio Scientifico dell'OPD: A. Aldrovandi, A. Cagnini, M. Galeotti, C. Lalli, G. Lanterna, D. Pinna, S. Porcinai, M. Rizzi, I. Tosini, con la collaborazione di A. Moles.

Per il Laboratorio Fotografico dell'OPD: A. Aldrovandi (direttore); fotografi: S. Cipriani; fotografi esterni: Luca Lupi, Annette Keller, A. Latronico, A. Quattrone.

Misure spettroscopiche e colorimetriche per i pigmenti: M. Picollo, B. Radicati (IFAC-CNR Firenze); D. Magrini.

Misure di spettrometria di fluorescenza x: A. Migliori.

Termovisione: G. Roche.

Collaborazioni esterne: Progetto OMWP per lo studio e l'individuazione delle sostanze organiche sulle pitture murali: Getty Conservation Institute di Los Angeles e Opificio delle Pietre Dure; coordinamento F. Pique (GCI). P. Colombini, A. Andreotti (Analisi GC-MS; Dip Chimica, Univ. Pisa); A. Romani, C. Clementi, G. Favaro (FOFS; Dip Chimica, Università di Perugia), C. Miliani, F. Rosi (FT-IR; CNR-ISTM Pg).

Consulenza per l'uso delle nano calci: L. Dei; B. Salvadori, A. Macherelli (Dip Chimica, CSGI, Univ Firenze)

Analisi XRD portatile: A. Duran and J. Castaing, C2RMF – CNRS UMR 171, Palais du Louvre, Paris.

Raccolta e gestione dati: Culturanuova® sas, Arezzo Massimo Chimenti, Sandra Damianelli, Elena Iacopozzi, Sara Rutigliano, Giacomo Tenti.

Riprese video: Iain Antony MacLeod.

A note about the restoration

The Opificio was in charge of methodology and decision-making during the restoration process, whilst numerous other research institutes participated in studying the chapel. Several individuals helmed the Institution over the 5 years during which the restoration process was underway: C. Acidini (2005-07), B. Santi (2008) and Lapi Ballerini (2008-10). C. Danti (2005-07) and C. Frosinini (2007-10) served as successive directors of the Settore Pitture Murali (Wall Paintings Department).

Restorers working in the OPD's Settore Pitture Murali included M. R. Lanfranchi (project manager), F. Bandini, A. Felici and P. I. Mariotti. Others who worked on the project included A. Bargellini, S. Begliardi, S. Careccia, L. Ciceri, A. Cinotti, G. Cocciolini, S. Franceschini, I. Gambina, V. Ghiso, A. Martinelli, D. Murphy, C. Napolitano, E. Onnis, L. Poli and K. Stura.

OPD Safety Manager: P. Capone.

OPD Science Laboratory Staff: A. Aldrovandi, A. Cagnini, M. Galeotti, C. Lalli, G. Lanterna, D. Pinna, S. Porcinai, M. Rizzi and I. Tosini, with assistance from A. Moles.

OPD Photography Laboratory Staff: A. Aldrovandi (director), S. Cipriani (photographer), and Luca Lupi, Annette Keller, A. Latronico and A. Quattrone (external photographers).

Spectroscopic and colorimetric measurements of pigments: M. Picollo, B. Radicati (IFAC-CNR Firenze), D. Magrini.

X-ray fluorescence spectrometry: A. Migliori.

Thermovision: G. Roche.

External partnerships: The OMWP Project helped study and identify organic substances in the wall paintings; it included the Getty Conservation Institute of Los Angeles and the Opificio delle Pietre Dure, and was coordinated by F. Pique (GCI). P. Colombini, A. Andreotti (GC-MS Analyses; Faculty of Chemistry, University of Pisa); A. Romani, C. Clementi, G. Favaro (FOFS; Faculty of Chemistry, University of Perugia), C. Miliani, F. Rosi (FTIR; CNR-ISTM Perugia).

Nanolime consultants: L. Dei; B. Salvadori, A. Macherelli (Faculty of Chemistry, CSGI, University of Florence)

Portable XRD analysis: A. Duran and J. Castaing, C2RMF – CNRS UMR 171, Palais du Louvre, Paris.

Data collection and management: Culturanuova® sas, Arezzo Massimo Chimenti, Sandra Damianelli, Elena Iacopozzi, Sara Rutigliano, Giacomo Tenti.

Video: Iain Antony MacLeod

RESTAURACIÓ DEL CONJUNT ARTÍSTIC DE LA CAPELLA DE SANT BLAS DE LA CATEDRAL DE TOLEDO

La capella de San Blas, construïda per l'arquebisbe Pedro Tenorio el 1398 i situada en un dels laterals del claustre de la catedral primacial de Toledo, està considerada un exemple excel·lent de l'art florentí a Espanya. La controvèrsia provocada fins ara pels diferents historiadors i les intervencions *restauratives* indegudes n'havien fet qüestionar l'autoria i fins i tot la iconografia representada als seus murs. A la destrucció progressiva de les pintures, causada per les humitats derivades de les filtracions d'aigua, s'afegien els intents infructuosos de solucionar el problema amb nombroses restauracions. Les diferents expurgacions de documents en els arxius de Toledo van donar els seus fruits i van posar en ordre les intervencions produïdes al llarg de la història. La darrera, realitzada a partir de l'any 2000, va evidenciar les alteracions que afectaven la capella i les seves causes. Per això, el Capítol i els tècnics conservadors de la catedral van decidir encarregar un estudi exhaustiu amb tecnologia no destructiva a diverses empreses italianes de la regió de la Toscana. Les conclusions finals es van exposar en un informe preventiu que va servir de base per elaborar el projecte definitiu. En aquests primers estudis es va utilitzar un georadar dirigit per les empreses IDS, Irma i Editech per efectuar la termografia i l'anàlisi de les pintures. Igualment, es van estudiar amb endoscopi les mesures de temperatura i humitat durant un any, i l'empresa Geocisa va efectuar una anàlisi exhaustiva del terreny i dels murs mitjançant sondatges geotècnics. Després d'aquests exàmens i amb el projecte acabat es va aconseguir el finançament i el patrocini del World Monuments Fund, Iberdrola i la Fundación Cultura y Deporte de la Comunitat de Castella-la Manxa.

RESTAURACIÓN DEL CONJUNTO ARTÍSTICO DE LA CAPILLA DE SAN BLAS DE LA CATEDRAL DE TOLEDO

La capilla de San Blas, construida por el arzobispo Pedro Tenorio en 1398 y situada en uno de los laterales del claustro de la catedral primada de Toledo, está considerada un excelente ejemplo del arte florentino en España. La controversia provocada hasta ahora por los diferentes historiadores y las indebidas intervenciones *restaurativas* habían suscitado dudas sobre su autoría e incluso sobre la iconografía que se representa en sus muros. A la destrucción paulatina de las pinturas, debida a las humedades provocadas por las escorrentías, se sumaban los intentos infructuosos de solucionar el problema con numerosas restauraciones. Las diferentes expurgaciones de documentos en los archivos de Toledo dieron sus frutos y pusieron en orden las intervenciones a lo largo de la historia. La última, a partir del año 2000, dejó claras las causas y las alteraciones que afectaban a la capilla. Por ello, el cabildo y los técnicos conservadores de la catedral decidieron encargar un estudio exhaustivo con tecnología no destructiva a diversas empresas italianas de la región de la Toscana. Las conclusiones finales se expusieron en un informe preventivo que sirvió de base para realizar el proyecto definitivo. En estos estudios iniciales se utilizó un georadar dirigido por las empresas IDS, Irma y Editech para efectuar la termografía y el análisis de las pinturas. Asimismo, se estudiaron mediante endoscopia las medidas de temperatura y humedad durante un año y la empresa española Geocisa llevó a cabo un análisis exhaustivo del terreno y los muros mediante sondeos geotécnicos. Después de estos exámenes y con el proyecto terminado se lograron la financiación y el patrocinio del World Monuments Fund, Iberdrola y la Fundación Cultura y Deporte de la Comunidad de Castilla-La Mancha.

RESTORATION OF THE ARTWORK OF THE SAINT BLAISE CHAPEL IN THE CATHEDRAL OF TOLEDO

The Saint Blaise Chapel, built by Archbishop Pedro Tenorio in 1398 and located on one side of the cloister of the Primate Cathedral of Toledo, is considered to be an excellent example of Florentine art in Spain. The controversy generated to this day by the various historians and the misguided attempts at restoration had raised doubts about the identity of the artists and even with regard to the iconography displayed on its walls. On top of the gradual destruction of the paintings due to the dampness caused by surface runoff, unsuccessful attempts were made to solve the problem through numerous restorations. The various moves to clean up the documents in the archives of Toledo paid off and gave a clear picture of the restoration work over the whole period. The most recent, starting in 2000, clarified the causes and the alterations which affected the chapel. The chapter and the cathedral's conservation technicians decided to commission several Italian companies from Tuscany to undertake a comprehensive study using non-destructive technology. The final conclusions were presented in a preventative report, which formed the basis for the final project. In these initial studies the companies, IDS, Irma and Editech, used ground-penetrating radar to carry out the thermography and the analysis of the paintings. Similarly, temperature and humidity measurements were taken over the course of a year using an endoscope and a comprehensive analysis of the terrain and walls was carried out by the Spanish company Geocisa using geotechnical sounding. After these studies and the completion of the project, an agreement was reached for the funding and sponsorship by the World Monuments Fund, Iberdrola and the Culture and Sports Foundation of the Castille-La Mancha Government.

Antonio Sánchez-Barriga

Conservador de béns mobles de la Catedral de Toledo

RESTAURACIÓN DEL CONJUNTO ARTÍSTICO DE LA CAPILLA DE SAN BLAS DE LA CATEDRAL DE TOLEDO

RESTORATION OF THE ARTWORK OF THE SAINT BLAISE CHAPEL IN THE CATHEDRAL OF TOLEDO

Antonio Sánchez-Barriga

Al poco tiempo de la terminación de la capilla comenzaron los primeros problemas de humedades en el interior, debido a los diversos desniveles del terreno exterior con respecto a la capilla, que se encuentra a siete metros por debajo del nivel de la calle Hombre de Palo. Esta situación ha propiciado con el paso del tiempo, y hasta nuestros días, la filtración por capilaridad de las aguas pluviales, que han traspasado los muros y el suelo.

Los intentos infructuosos de solucionar el problema tienen ya una larga historia. Existen en los archivos de la catedral numerosos datos que lo confirman, y se tiene noticia de las humedades ya en el año 1402; como dice ese primer documento, el agua provenía de las «pluvias» que se acumulaban entre la capilla y las casas particulares de un pintor y de un tal maestro Yllana, por lo que la reparación debía ser pagada por ambas partes.

También se citan las «descostraduras» reparadas por un albañil (1456), los «remiendos» realizados por un pedrero (1480), el pintado de lo «despintado» (1489) y los continuos «aderezos» de las pinturas murales llevados a cabo por diferentes artífices en varios años: 1556, 1566, 1571, 1583, 1590, etcétera. El problema afectó incluso al mobiliario de la sacristía adosado al muro, que hubo de ser protegido con un entablado en 1609. Todas esas intervenciones no solucionaron la caída del agua sobre el muro exterior norte. Por el contrario, el intento de que no continuase la desaparición de las pinturas originó numerosos repintes e incluso su ocultación con enlucidos indebidos, ya en el siglo XVIII.

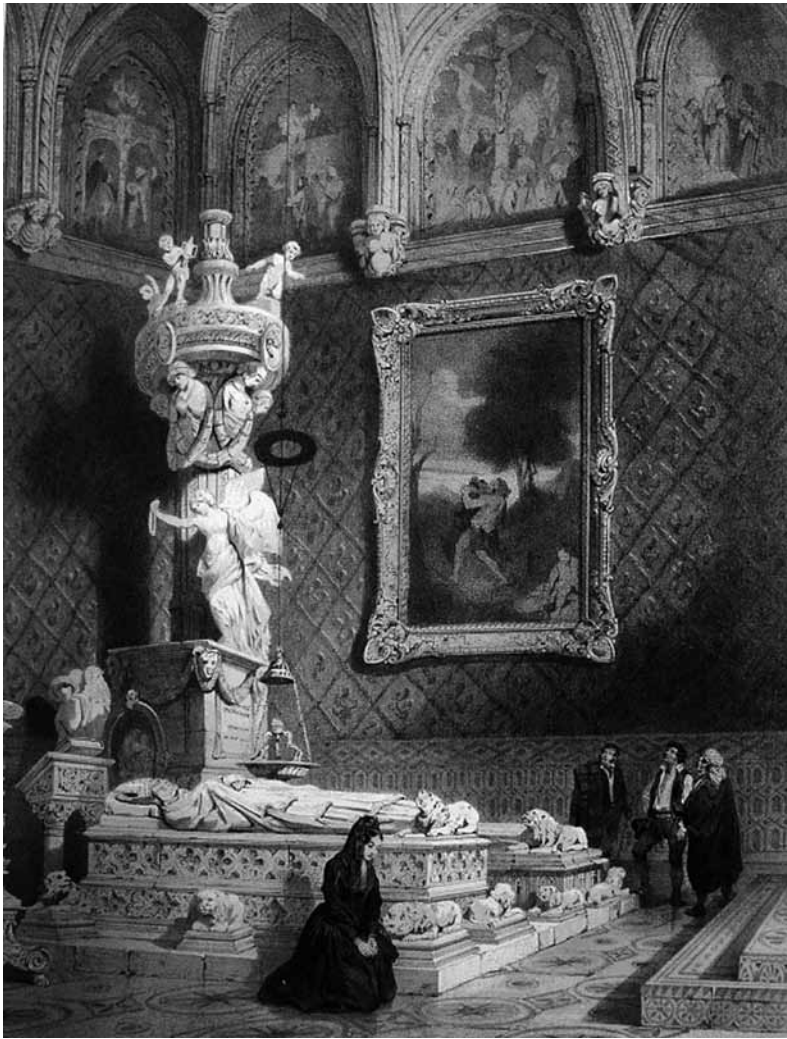
Entre los años 1685 y 1692 se cerró la capilla y se suspendieron sus actividades por débitos, hasta que, gracias a las iniciativas del

Shortly after its completion, the chapel experienced its first problems with internal dampness. These were due to numerous variations in the relief of the terrain surrounding the chapel and the location of the chapel itself, which stands seven metres below the level of the street, Hombre de Palo. Over time, and up to the present day, this location has resulted in the filtration through capillary action of rainwater, which has soaked through the walls and floor.

There has been a long history of failed attempts to solve the problem. The cathedral's archives include copious information to corroborate this, noting the damp for the first time in 1402. As this initial document states, the water came from the "pluvias" (rainwater) that collected between the chapel and the private homes of a painter and of a master, Yllana, therefore the cost of the repair had to be shared between the two parties.

There is also mention of "crumbling" repaired by a mason (1456), "patching up" carried out by a stone cutter (1480), the repainting of "missing paint" (1489) and the continuous "enhancement" of the wall paintings undertaken by various craftspeople over a number of years: 1556, 1566, 1571, 1583, 1590, etc. The problem even affected the furniture attached to the wall in the sacristy, which in 1609 had to be protected by a wood board panel. None of these efforts solved the problems caused by rain falling on the northern outer wall. On the contrary, attempts to prevent the further disappearance of the paintings resulted in frequent repainting and even, in the 18th century, the inappropriate concealment of the paintings behind plaster.

Finally, in the period 1685-1692 the chapel



Grabado del pintor Genaro Pérez Villamil del interior de la capilla en 1841

The Chapel in 1841. Etching by the painter Genaro Pérez Villamil

arzobispo don Luis Manuel Fernández Portocarrero, se reabrieron sus puertas en el otoño de 1692.

Más adelante, entre 1719 y 1720, se decidió realizar la actuación más agresiva, esto es, la aplicación de un enlucido total desde la cornisa hasta el suelo de la capilla, cuyo frente norte presentaba importantes pérdidas. Fue entonces cuando se picaron los paramentos para que la preparación se trabase mejor y se destruyó así buena parte de las pinturas murales.

En el invierno de 1778-1779 se intentó cortar con el problema realizando una importante obra en la calle Hombre de Palo que fue pagada a medias entre el Ayuntamiento y la catedral. Las obras consistieron en nivelar y corregir un conducto y unas alcantarillas que recorrían la vía arrimados a los muros del claustro, pero tampoco solucionaron los problemas. Llegó entonces la Guerra de la Independencia contra los franceses y se cerró la capilla desde 1810 hasta 1815.

En 1855, el historiador Sixto Parro escribía en su guía de Toledo: «Hace algunos años que se cubrieron con el blanqueo estas pinturas, con otros letreros que allí había condenando la

was closed, and its activity was completely suspended due to debts, until, on the initiative of Archbishop Luis Manuel Fernández Portocarrero, it was re-opened in the autumn of 1692.

Some time after, between the years 1719 and 1720, the decision was taken to carry out the most aggressive work. This involved plastering the whole area from the cornice to the floor of the chapel, whose northern front showed significant losses. It was at this time that the walls were chipped at in order to allow for better re-plastering, therefore damaging much of the wall painting.

In the winter of 1778-1779 an attempt was made to put an end to the problem by carrying out significant construction work in Hombre de Palo Street, the cost of which was shared between the Toledo city council and the cathedral. The work consisted of levelling, and mending a pipe and the sewers that ran along the street next to the walls of the cloister, but this was also unsuccessful in solving the problems. The War of Independence against the French broke out, and the chapel was closed from 1810-1815.

In 1855, the historian Sixto Parro describes in his guide to Toledo: “Only a few years ago these paintings were covered by whitewash and signs condemning simony in an ancient and extravagant language, unfitting to the site”. He continues: “Today only the vault and the top third of the walls still have fresco painting.”

Later, in 1924, as a result of the involvement of Dean Julio Polo Benito, the plaster was cleaned off the lower register and the badly damaged remains of wall paintings and the signature of the enigmatic painter Rodríguez de Toledo appeared underneath.

Subsequently, in 1925, the Dean himself in his description of the Saint Blaise wall paintings criticised their condition, stating, “The door opens and the visitor, eager to take in the view, is unpleasantly surprised to find a darkened enclosure and an uncomfortable damp mist. This is because only a secondary light comes through the single existing window. Invasive barbarism appropriated cathedral land, built a domestic laundry and the water poured out for many years and is still pouring out to some extent, onto the wall painting, with considerable damage to the art of Toledo [...] causing decomposition of its walls due to the formation of salt, which remains on the surface of the wall in the form of a white powder.”

The chapel remained closed, although other misguided intervention continued to be

San Pedro entronizado
martilleado, como se
encontró antes de la
intervención

St. Peter on his Chair.
Hammered scene as it
was before the restora-
tion



San Pedro entronizado
martilleado, tras reinte-
grarse las faltantes con
tinta neutra (aspecto
final)

St. Peter on his Chair.
Hammered scene with
the areas reintegrated
using neutral ink



simonía en un lenguaje antiguo y extravagante e impropio del sitio». Y añadía: «Hoy sólo permanece pintada al fresco la bóveda y el tercio más alto de los muros».

Más tarde, en 1924, gracias al interés del deán Julio Polo Benito, se limpiaron los enlucidos de la zona inferior y bajo ellos aparecieron los restos muy deteriorados de las pinturas murales y la firma del enigmático pintor Rodríguez de Toledo.

carried out during the years that followed. It was in 1965 that, to the best of our knowledge, the last repair to date was carried out. This involved the usual repainting and fixing with animal glue and the removal of some of the paintings, which, sadly, have now disappeared.

In 1975, the cathedral chapter put in an application for the state to undertake the restoration. Subsequent problems of a technical nature meant that this work was not

Posteriormente, en 1925, el mismo deán criticaba su estado, en la descripción de las pinturas murales de San Blas, con estas palabras: «La puerta se abre y el visitante, ansioso de espaciar la vista dá con la ingrata sorpresa de una cerrazón que entebrece, de un vaho de humedad que molesta. Es que por el único ventanal existente penetra sólo una segunda luz, es que la barbarie invasora, que se apropió del terreno catedralicio, construyó un lavadero doméstico y las aguas vertieron por muchos años y aún siguen vertiendo en parte, sobre las pinturas murales con notorio perjuicio del arte toledanista, [...] provocando en sus muros una descomposición por haberse formado salitre, quedando en forma de polvillo blanco en la superficie de la pared».

La capilla permaneció cerrada, aunque siguieron efectuándose otras intervenciones desafortunadas durante los años posteriores. Hubo que llegar a 1965 para que se realizara la última reparación que hasta ahora conocemos, en la que continuaron aplicándose los consabidos repintes y fijaciones con cola orgánica y se arrancaron algunas de las pinturas, que desgraciadamente ahora están desaparecidas.

En 1975 el cabildo catedralicio cursó una petición para que se iniciara una restauración por parte del Estado, pero problemas posteriores de orden técnico provocaron que se desistiera de la intervención hasta que en el año 2000 empezaron los primeros estudios.

Se trataba de un análisis previo de las causas del problema y de las alteraciones que afectaban a la capilla. El cabildo y los técnicos conservadores de la catedral decidieron comenzar un estudio exhaustivo con tecnología no destructiva con diversas empresas italianas de la región de la Toscana. Las conclusiones finales se expusieron en un informe preventivo que sirvió de base para el proyecto definitivo. En esos exámenes iniciales se utilizó un georradar, dirigido por las empresas IDS, Irma y Editech, para efectuar la termografía y el análisis de pinturas. Asimismo, mediante endoscopio se tomaron las medidas de temperatura y humedad durante un año, y la empresa española Geocisa llevó a cabo un examen exhaustivo del terreno y los muros con sondeos geotécnicos.

Después de estos estudios, y con el proyecto terminado, se logró un acuerdo gracias a la financiación y el patrocinio del World Monuments Fund, Iberdrola y la Fundación Cultura y Deporte de la Comunidad de Castilla-La Mancha, y al poco tiempo se firmó el convenio con el cabildo catedralicio y el arzobispo de Toledo. La obras empezaron el 10 de diciembre de 2003.



undertaken until 2000, when the first study commenced.

This consisted of a prior analysis of the underlying causes of the problems and the alterations affecting the chapel. It was decided by the chapter and the cathedral's conservation technicians to begin a comprehensive study using non-destructive technology. This was carried out by several Italian companies from Tuscany, and the final conclusions were presented in a preventative report, which was the basis for the final project. In these initial studies the companies IDS, Irma and Editech used ground-penetrating radar and carried out the thermography and analysis of the paintings. Likewise, the temperature and humidity measurements were taken over a year using an endoscope, and a comprehensive analysis of the terrain and walls was carried out by the Spanish company Geocisa using geotechnical sounding.

With these studies and the project completed, an agreement was reached for the funding and sponsorship of the project by the World Monuments Fund, Iberdrola and the Culture and Sports Foundation of the Castilla-La Mancha Government. Shortly after all the sponsors signed an agreement with the cathedral chapter and the Archbishop of Toledo, and the work began on 10 December 2003.

La cabeza de la Virgen antes de la intervención

The head of the Virgin before the restoration process



Escena de la
anunciación de
la Virgen con luz
ultravioleta

The Annunciation
of the Virgin under
ultraviolet fluorescent

La cabeza de la
Virgen después de la
restauración

The head of the Virgin
after the restoration
process



Don Pedro Tenorio (1328-1399), promotor de la capilla

La primera piedra del nuevo claustro se colocó el 14 de agosto de 1389. Su traza general debió de salir de la mano del maestro Rodrigo Alfonso, quien dirigiría la obra hasta principios del cuatrocientos. La planta del claustro tuvo que adaptarse al relieve del terreno y se asentó seis pies (1,68 metros) por encima del nivel de la catedral con un alzado —de proporción dupla— potente y sólido, preparado para soportar un segundo nivel que no se construiría hasta el pontificado del cardenal Cisneros.

Como ha sucedido con otras catedrales españolas, a falta de una regla monástica que ordenara la vida comunitaria de los canónigos toledanos el claustro nació con una finalidad estrictamente civil. Lejos de las necesidades conventuales, fue un lugar —a decir de Eugenio Narbona, en 1624— «donde pudiese la gente retirarse a la comunicación civil, quedando el templo sólo para los fines suyos, oración y sacrificios». La carencia de un edificio propio donde reunirse hizo que los ayuntamientos de la ciudad de Toledo celebraran sus sesiones en el claustro. Con el tiempo las diferentes cámaras comunicadas con sus galerías se destinaron a finalidades variadas: unos almacenes donde se guardaban la cera,

Pedro Tenorio (1328-1399), promoter of the chapel

The first stone of the new cloister was laid on 14 August 1389. The general design must have been the work of the master builder, Rodrigo Alfonso, who directed the works until the early 15th century. The floor of the cloister had to be adjusted to the relief of the terrain. It was laid 6 feet (1.68 metres) above the level of the cathedral with a solid and powerful, double-height elevation, designed to support a second level that would not be built until the time of the pontificate of Cardinal Cisneros.

As was the case with other Spanish cathedrals, in the absence of a monastic rule that structured the Toledo canons' community life, the cloister originated with a purely civilian purpose and not to meet the needs of the convent. It was a place, according to Eugenio Narbona in 1624, "where people could retreat from civil communication, the temple being only for its own uses, prayer and sacrifice". The lack of a separate building in which to meet meant that the councils of the city of Toledo held their meetings in the cloister. Over time the various rooms connected by galleries were used for varied purposes: store-rooms for keeping wax, oil,



el aceite, las tapicerías y el monumento de la Semana Santa; la capilla mozárabe, antes de trasladarse a su ubicación actual; el cabildo de verano, o sala donde se leía la gramática, etcétera.

En el ángulo nordeste del claustro se erigió la capilla de San Blas. La dirección de esta obra corrió a cargo del citado Rodrigo Alfonso, quien contó con la valiosa colaboración del maestro Alvar Martínez y su taller. Aunque en planta nació dissociada del claustro, formando una especie de apéndice, resulta evidente la relación física y hasta formal que desde su origen tuvo con el entorno arquitectónico que la rodea. En concreto, su entrada principal se abre directamente a la galería o panda oriental del claustro, manteniendo una unidad de estilo con la portada de enfrente, la puerta de Santa Catalina. Carece, pues, de cualquier conexión directa con el exterior. Además, comparte con el claustro uno de sus muros, el sur, sobre el que se asientan la bóveda de esquina de éste y la que cierra la capilla.

La construcción

Los libros de cuentas de la capilla nada dicen del inicio de las obras. Tampoco aportan referencia alguna sobre la fecha en que se cerró la bóveda octopartita que cubre este espacio. Las primeras noticias documentadas sobre su construcción —que no las más antiguas— da-

tapestries and the Holy Week monument; the Mozarabic chapel, before being moved to its current location; the summer council; the reading room for studying Latin, etc.

The chapel of Saint Blaise was erected in the north-east corner of the cloister. The work was directed by the above-mentioned Rodrigo Alfonso, who had the valuable assistance of the master builder Alvar Martínez and his workshop. Although on the ground plan it was separate from the cloister, forming a kind of annex, the physical and even formal relationship that it had with the surrounding architectural setting was evident from its inception. In particular, its main entrance opens directly onto the gallery or eastern ambulatory of the cloister, maintaining a stylistic unity with the facade of St. Catherine which is opposite. It does not, therefore, have any direct connection to the outside. Furthermore it shares its southern wall with the cloister, which supports the corner vault and encloses the chapel.

Its construction

The chapel's accounts books make no mention of when construction began. Neither do they make any reference to the date when the octagonal dome that covers the chapel was completed. The earliest documented news of its construction - not the oldest -

La crucifixión antes de la intervención; son evidentes los repintes

The Crucifixion before the intervention, with visible repainting

La crucifixión con luz rasante; se aprecian las extrañas *giornate* efectuadas por el pintor

The Crucifixion under raking light. The *giornate* are visible



tan del otoño de 1398, apenas unos meses antes de que falleciera el arzobispo Tenorio. Por aquel entonces los trabajos se desarrollaban sobre la bóveda de la capilla, en la cubierta. Se levantaban los cuatro pilares de ladrillo que le darían más altura y servirían para sostener la armadura, fabricada poco tiempo después por el equipo del maestro Aly, quien no tardaría en entablar sus vertientes y cubrirlas de teja. Finalmente, una vez protegida la estructura de las inclemencias del tiempo, se procedió a cerrar los muros, de pilar a pilar, con piedra de mampostería. Es decir, se configuró el espacio situado sobre la bóveda de la capilla que hoy se halla ocupado por una vivienda a la que se accede desde el claustro alto.

Lo expuesto hasta ahora serviría para afirmar que la arquitectura de la capilla, en lo que respecta a su espacio principal, era una realidad manifiesta en noviembre de 1398, y tal vez muchos meses antes. La escritura de fundación y el propio testamento del arzobispo Tenorio aportan indicios en esta dirección. Así, en la primera, cuando se alude a la manera en que debía celebrarse la fiesta anual de San Blas, se remite a los detalles de la oficiada en febrero de 1397, lo que podría significar que la bóveda estrellada estaba terminada por entonces. Se trata de una fecha temprana que adelantaría aún más el comienzo de las obras de la capilla y que daría pie a plantear la hipótesis

dates from the autumn of 1398, only a few months before the death of Archbishop Tenorio. At that time work was being carried out on the roof of the chapel dome. Four brick pillars were built to give it greater height and to support the roof frame, which was constructed shortly afterwards by the master builder, Aly, who rapidly boarded up the sides and covered them with tiles. Finally, once the structure was protected from the weather, the walls between the pillars were enclosed with stone masonry. In this way, the space above the vault of the chapel was formed. This is now occupied by a house, which is accessed from the upper cloister.

On the basis of the above, we can affirm that the architecture of the chapel, with regard to its main area, was clearly in place by November 1398, and perhaps many months before. The deed of foundation and the will of Archbishop Tenorio provide evidence in this regard. In the former, when referring to the form of the celebrations for the annual feast of Saint Blaise, the details of those officiating in February 1397 are mentioned, suggesting that the starry vault was completed by then. This early date would place the start of construction of the chapel much earlier and would lead to the hypothesis that this had begun at the same time as the cloister, as of August 1389.



La escena de la crucifixión tras la intervención

The Crucifixion scene restored

de que se hubieran iniciado al mismo tiempo que el claustro, siempre a partir del mes de agosto de 1389.

El ciclo iconográfico

El mayor tesoro artístico que guarda esta capilla son las pinturas que decoran sus muros. Según se entra por la puerta principal el visitante que levanta la vista queda impresionado por una magnífica crucifixión de indudable proge- nie florentina. Fue pintada por dos maestros que tuvieron muy presentes las lecciones de Antonio Veneziano; en concreto, la tabla del mismo tema que se expone en el Museo Nazionale di San Matteo de Pisa. Sin embargo, en este caso se complicó la composición con un remolino de figuras de diferentes tamaños — entre las que no faltan los niños en un primer plano— que envuelve las cruces, en un intento de trasladar al espectador a una escena con una perspectiva muy profunda y oblicua. Por su posición frente a la puerta de entrada y por la significación simbólica de su tema, es una referencia principal de este ciclo iconográfico dedicado al credo. Se desarrolla en 14 escenas distribuidas por los muros de la capilla desde

Iconographic cycle

The greatest artistic treasures contained in this chapel are the paintings that decorate its walls. Coming in through the main doorway, on looking up, the visitor is struck by a magnificent Crucifixion of undoubted Florentine origin. It was painted by two masters who echo the style of Antonio Veneziano, in particular, the panel painting that is displayed in the National Museum of San Matteo in Pisa. However, the composition of the painting in the Saint Blaise chapel is more complex, featuring a swirl of figures of different sizes, including a profusion of children in the foreground, which envelops the crosses, in an attempt to draw the viewer into the very deep and oblique perspective of this scene. Due to its position in front of the main entrance and the symbolic significance of its subject, it is a primary reference for this iconographic cycle dedicated to the Creed. This is developed in fourteen scenes spread across the walls of the chapel from the cornice upwards. They begin on the west side, with the portrayal of the apostles St. John and St. Luke, who are reading and writing

la cornisa hacia arriba. El inicio está en el lado oeste, con la representación de los evangelistas san Juan y san Lucas en actitud de leer y escribir, respectivamente, una alusión al símbolo que, según una tradición legendaria muy extendida en la Edad Media, habían compuesto los apóstoles bajo la inspiración del espíritu santo. En el libro abierto de san Juan se lee la frase «In principio erat Verbum».

Desde esa primera escena se inicia el ciclo iconográfico siguiendo el movimiento de las manecillas del reloj. La anunciación (muro oeste), con la presencia imponente del Dios creador en la parte superior, es una de las más bellas. Pintada con gran detalle y primor decorativo, manifiesta el interés de su autor por experimentar con la perspectiva. Tras las figuras de la Virgen y del ángel se abre una sucesión de estancias que dotan de profundidad al interior. Es tal vez el mejor anuncio del estilo internacional que comenzaba a abrirse paso en las cortes europeas, con buenas manifestaciones en tierras catalanas y levantinas. Estamos, pues, ante un intento de actualizar el lenguaje trecentista todavía presente en las arquitecturas sesgadas que tanto recuerdan los modelos desarrollados por los pintores florentinos del círculo de Agnolo Gaddi, con el que tuvo contacto Gerardo Starnina (capilla de los Castellanos de la basílica de la Santa Cruz de Florencia). No hay que descartar que detrás de esta manera de pintar estuviera la mano de un artífice familiarizado con el trabajo precioso de la miniatura. Fue también el autor de una bellísima santa Elena y de un san Antón, pintados en recuadros cuatrilobulados sobre fondo de oro bajo la cornisa de la crucifixión.

En el muro norte, además de la citada crucifixión, se pintaron a los lados la adoración de los pastores y Jesús ante Caifás (izquierda), así como el santo entierro y el descenso al limbo (derecha). De estos últimos sólo quedan algunos restos pintados y las viejas fotografías que delatan su ascendencia florentina, quizá más convencional y menos novedosa con respecto a la crucifixión y la anunciación. El artista de estas composiciones representó el espacio exterior con cierta impericia, más preocupado por destacar el volumen de las figuras.

En el lado este se distribuían la resurrección, san Marcos y san Mateo en actitud de escribir los evangelios —desaparecidos para siempre— y la ascensión de Cristo. Hoy sólo es visible con algunas pérdidas esta última escena, en la que se vislumbra el interés por la simetría de la composición, por los amplios ropajes que marcan los volúmenes de los personajes y por el escorzo de los rostros que miran al cielo.

respectively, an allusion to the idea that, according to a widespread legendary belief in the Middle Ages, the apostles had composed under the inspiration of the Holy Spirit. In St. John's open book you can read the phrase "in principio erat Verbum".

Starting out with this first scene, the iconographic cycle follows the movement of the hands of a clock. The Annunciation (west wall), with the imposing presence of God the creator at the top, is one of the chapel's most beautiful scenes. Painted with great detail and decorative delicacy, it reflects the artist's interest in experimenting with perspective. The figures of the Virgin and the angel give way to a succession of rooms that create an illusion of depth. It is perhaps the best instance of the international style that began to be adopted by European courts, with good examples in Catalonia and Levante. This was an attempt to update the 13th century language still present in the distorted architecture, so reminiscent of the models developed by the Florentine painters of the Agnolo Gaddi group, with whom Gherardo Starnina had contact (the Castellani Chapel in Santa Croce in Florence). The exquisite craftsmanship in this method of highly detailed painting suggests a master in miniature artwork. The same artist also painted a beautiful St. Helen and St. Anthony on four-lobed boxes on a gold background, under the cornice of the Crucifixion.

The northern wall, apart from the Crucifixion mentioned above, was adorned with paintings of the Adoration of the Shepherds; Christ before Caiaphas (left), the Entombment and the Descent into Limbo (right), although only fragments remain of the latter two scenes. Old photographs reveal their Florentine origin, possibly more conventional and less innovative than the Crucifixion and the Annunciation. The artist who designed these compositions represented the surrounding space with a certain lack of expertise and was more concerned with emphasising the size of the figures.

The eastern side featured the Resurrection and St. Mark and St. Matthew in the act of writing the Gospels - which are permanently lost - and the Ascension of Christ. Today only this last scene is visible and it has partial losses. You can discern the interest in the symmetry of composition, the flowing robes that accentuate the size of the characters and the foreshortening of the faces raised towards heaven.

Jesus sitting on the right hand of God, the Last Judgment, Pentecost and the Resurrection of the Flesh decorate, in that order, the



Firma del enigmático pintor Rodríguez de Toledo, en la actualidad desaparecida

Signature of the enigmatic painter Rodríguez de Toledo, which has disappeared

El hijo sentado a la derecha del padre, el juicio final, el Pentecostés y la resurrección de la carne decoran, en este orden, el muro sur. La llegada del espíritu santo a los apóstoles se distribuye en una equilibrada composición, sólo rota por el grupo de judíos que contempla la escena desde el exterior. Entre ellos, un personaje ataviado con una túnica roja y con rasgos personales mira al espectador presentando con las manos el acontecimiento sagrado. Pudiera tratarse del autorretrato de uno de los tres pintores que, como mínimo, participaron en la decoración de la capilla de San Blas. Más a la derecha, la resurrección de la carne nos ilustra dos aspectos de la representación muy queridos por la pintura toscana del *trecento*: por un lado, la figura humana desnuda, a una escala destacada que recuerda mucho a los torturados personajes arrastrados por los demonios de las pinturas murales del camposanto de Pisa, y por otro, el diseño simbólico de la ciudad —en este caso de la Jerusalén celeste—, tan próximo a las arquitecturas pintadas por Ambrogio Lorenzetti.

Cierra este desarrollo descriptivo del credo —de nuevo en el muro oeste— la transfiguración en el monte Tabor, una imagen que resume mejor que ninguna la fórmula trinitaria que constituye su esencia divina.

La decoración pictórica se completaba en la parte baja de la capilla, desde la cornisa hasta el suelo. Por desgracia, las humedades presentes en este espacio desde los tiempos de su fundador y una intervención calamitosa, que picó y ocultó estas escenas bajo un enlucido, dejaron este conjunto con muchas pérdidas y en un estado ruinoso que se ha paliado en la presente restauración. Del juicio final, que abarcaba todo el frente bajo del lado occidental, sólo nos han llegado la parte central y el

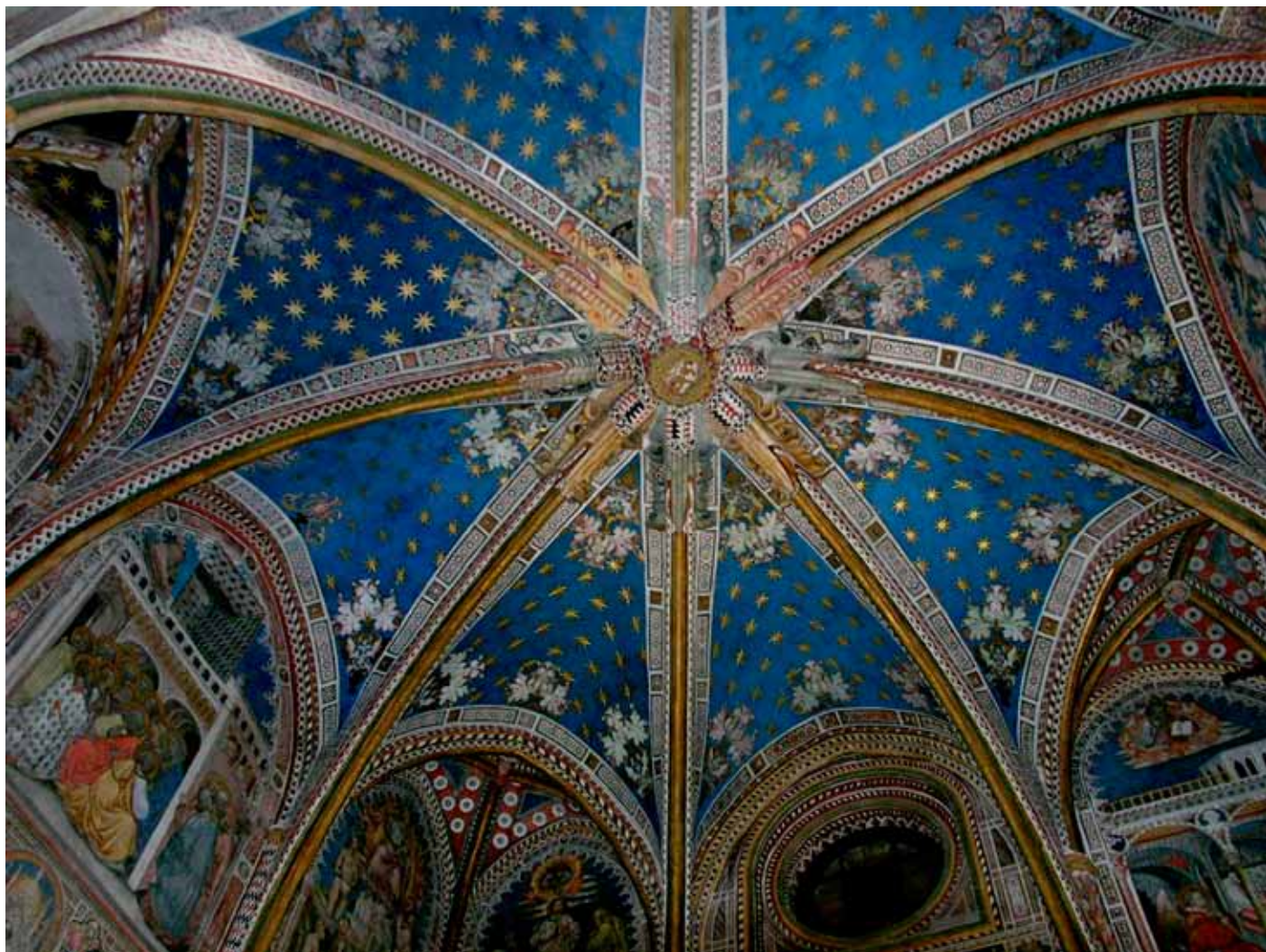
southern wall. The appearance of the Holy Spirit before the apostles is set out in a balanced composition, broken up only by the group of Jews who are watching the scene from outside. Among them, a character wearing a red tunic and with discernible features looks at the viewer and presents the holy event with his hands. It may be the self-portrait of one of the at least three painters who participated in the decoration of the Saint Blaise chapel. Further to the right the resurrection of the flesh illustrates two aspects of representation that were very popular in Tuscan *trecento* painting. Firstly, the naked human form, on an exaggerated scale reminiscent of the tortured characters dragged by demons in the murals of the cemetery of Pisa, and secondly, the symbolic design of the city, in this case heavenly Jerusalem, so close to the architecture painted by Ambrogio Lorenzetti.

Returning to the western wall, this descriptive account of the Creed is completed by the Transfiguration on Mount Tabor, a painting that encapsulates better than any other the Trinitarian formula that constitutes its divine essence.

The illustrated decoration was completed in the lower register of the chapel, from the cornice down to the floor. Unfortunately the dampness in this area from the time it was built and disastrous intervention, in which the scenes were chipped at and hid under plaster, left this section with many losses and in a dilapidated state that has been improved in the current restoration. Of the Last Judgment that covered the whole lower front on the western side, only the central section and a depiction of a group of the blessed marching towards salvation have survived. Canon Blas Ortiz, in his *Summi templi toletani* (1549), described on the opposite side “souls of ethnic infidels burning in sulphuric eternal flames”. Indeed, not unlike how the Muslims dragged by demons are swallowed up by the jaws of hell, as represented in the Last Judgment in the Pisa cemetery.

On the northern side only one of the stories remains, of St. Anthony, which is also in an incomplete form. Of the patron saint of the chapel, St. Blaise, only three scenes are still in place on the eastern wall: St. Blaise, as Bishop of Sebaste, led by soldiers to the governor; the saint in prison, visited by the woman whose pig he had saved in the miracle of the wolf; and the burial of the saint, who was beheaded after being tortured with an iron comb.

Above the arch at the entrance to the chapel, several scenes were painted about the life and miracles of St. Peter and St.



Vista de la bóveda
terminada

View of the restored
vault

cortejo de los bienaventurados dirigiéndose hacia la salvación. El canónigo Blas Ortiz, en su *Summi templi toletani* (1549), describió en el lado contrario las «almas de étnicos infieles ardiendo en las tartáreas eternas llamas». Seguro que no eran muy diferentes de los musulmanes que, arrastrados por los demonios, son engullidos por las fauces del infierno representado en el juicio final del camposanto de Pisa.

En el lado Norte tan sólo se conserva una de las historias, también incompleta, de san Antonio Abad. Del titular de la capilla, san Blas, apenas nos han llegado tres escenas en el muro este: el santo, como obispo de Sebaste, es conducido por los soldados ante el gobernador; a continuación lo vemos preso en la cárcel, a la que acude la mujer con el cerdo protagonista del milagro del lobo, y por último, después de que fuera torturado con un rastrillo y decapitado, asistimos a su entierro.

Sobre el arco de entrada a la capilla se pintaron varios pasajes de la vida y milagros de san Pedro y san Pablo. Empezando por la izquierda, pugnan ante Nerón contra el mago Simón, que se lanza a volar con la ayuda de los

Paul. Starting from the left, before Nero, the saints confront the sorcerer Simon, who levitates into the air with the help of demons. Higher up, next to the old organ case, only the cripple healed by St. Peter and part of his boat can be seen. In the centre there is a magnificent representation of St. Peter on his Chair, flanked by deacons. Further to the right on that wall the conversion of St. Paul is illustrated, in this case without a horse, and St. Peter with the angel. Their respective martyrdoms are depicted below, showing Paul beheaded and Peter crucified upside down.

This rich set of pictures markedly emphasises the reformist nature of the Toledo pontificate of Tenorio. This was a return to the core values of the formulations of faith as expressed in the Creed, faith firmly held in the face of idolatry (St. Blaise) and sin (St. Anthony), and the exaltation of the authority of Peter as the father of the only Christian Church, at a time when the Papal Schism seemed to have become established as a sad reality in European chancelleries.

After many vicissitudes and problems, this is the pictorial legacy of the chapel of Saint



demonios; más arriba, junto a la vieja caja del órgano, sólo se puede contemplar al tullido curado por san Pedro y parte de su barca; en el centro tenemos una magnífica representación de san Pedro en cátedra flanqueado por los diáconos; más a la derecha del citado muro se distribuyen la conversión de san Pablo, en este caso sin caballo, y san Pedro con el ángel; y más abajo tenemos sus respectivos martirios: Pablo decapitado y Pedro crucificado boca abajo.

Se trata de un rico conjunto de imágenes que incidía de manera notoria en el carácter reformista del pontificado toledano de Tenorio: vuelta a los valores esenciales de las fórmulas de fe expresadas en el credo, al mantenimiento firme de la fe ante la idolatría (san Blas) y el pecado (san Antonio Abad) y a

Blaise that has survived to the present day. Over the 600 years of its history, many of the polychrome paintings decorating the lower register have been lost due to dampness.

In search of the artists

Since Eugenio Narbona wrote in 1624 that the artist of the paintings was “Ioto Greek, the most excellent painter [...] apprenticed with Zimabue”, all the writers who have studied these paintings have concurred on their marked Italian influence and the fact that they inherit the best Giotto tradition. The composition of the scenes, the building of only apparently three-dimensional space, the volume of the figures, the use of colour shading, cosmati decoration and various iconographic details, place this whole art

La pared norte terminada de integrar, con las lagunas entonadas con tinta neutra

The North Wall restored with the missing areas reinstated in a slightly more subdued shade

la exaltación de la autoridad de Pedro como padre de la única Iglesia cristiana, en un momento en que el cisma parecía consolidarse como una triste realidad en las cancillerías europeas.

Después de muchas vicisitudes y problemas, éste ha sido el legado pictórico de la capilla de San Blas que ha llegado a nuestros días. En el camino de sus más de 600 años de historia se ha perdido, por la acción de las humedades, buena parte de las policromías que decoraban los muros inferiores.

En busca de una autoría

Desde que Eugenio Narbona escribiera en 1624 que el artífice de las pinturas había sido «Ioto Griego excelentísimo pintor [...] discípulo de Zimabua», todos los autores que se han acercado a estas imágenes han coincidido en resaltar su influjo italiano, la herencia de la mejor tradición giottesca. La composición de las escenas, la construcción del espacio sólo aparentemente tridimensional, el volumen de las figuras, el uso matizado del color y de la decoración cosmatesca y algunos detalles iconográficos alejan este conjunto del ambiente castellano en que fue pintado y lo acercan al arte de alguno de los maestros florentinos que trabajaron en la península a finales del siglo XIV. Es el caso de Gerardo Starnina y Nicolás de Antonio, documentados en Valencia y Toledo entre 1395 y 1401.

En lo que respecta a la catedral toledana, la presencia de estos pintores florentinos se detecta en 1395, cuando en el mes de diciembre cobraron el último plazo por un *panno* de la pasión de Cristo pintado para la antigua capilla del Salvador. Los estudios posteriores han coincidido en señalar que algunas tablas de este supuesto retablo hoy se hallarían dispersas —y retocadas por otros pintores— en las capillas de San Eugenio, del Bautismo y de la cripta. Esa estancia en la catedral, documentada, abriría la puerta a considerar que los mismos pintores —quizá ayudados por un tercero también florentino, el enigmático Simón de Francisco— pudieran haber participado en la decoración mural de la capilla de San Blas.

Sea como fuere, la interpretación del proceso constructivo de la capilla —bien documentado desde 1398— aleja esa posibilidad, pues indica que no se terminó hasta 1400 y, por ende, hasta entonces no se habrían iniciado los trabajos decorativos. Es una visión restrictiva, en lo cronológico, que debe revisarse, pues todo indica que este espacio funerario fue diseñado al mismo tiempo que el claustro, cuya primera piedra se colocó en agosto de 1389; es decir, que entraría dentro de lo pro-

collection a long way from the Castilian surroundings in which it was painted, bringing it closer to the art of some of the Florentine masters who worked in the Iberian peninsula in the late 14th century. They include Gherardo Starnina and Nicolao d'Antonio, who were recorded as being in Valencia and Toledo between 1395 and 1401.

The presence of these Florentine painters at the Cathedral of Toledo was recorded in 1395, when in December they received the final payment for an altarpiece depicting the Passion of Christ, painted for the former chapel of the Saviour. Subsequent studies have noted that some of the panels from this retablo have been retouched by other artists and are today scattered in the chapels of St. Eugene, the Baptism and the Crypt. The documentation of this time spent at the cathedral opens the door to considering that these same painters, perhaps assisted by a third Florentine painter, the enigmatic Simone di Francesco, may have participated in the wall decoration of the chapel of Saint Blaise.

Be that as it may, the interpretation of the process of construction of the chapel - which has been well documented since 1398 - makes that seem improbable, because it indicates that the architecture was not completed until 1400, and consequently the decorative work would not yet have been started. This view is restrictive, chronologically, and must be revised, given that everything points to the tomb being designed at the same time as the cloister, of which the foundation stone was laid in August 1389. In other words, it is likely that the vault of Saint Blaise was already covered over and ready for painting in 1395, when Gherardo Starnina and Nicolao d'Antonio were recorded as being at the cathedral. Their almost continuous presence in Valencia (1395-1401) and Florence (from 1404), in addition to there being no record of a payment for their work in the chapel accounts for the period 1397-1404, reinforce this hypothesis.

The period spent in Toledo by Starnina, the same painter who, since the research of Jeanne van Waadenonjen, is identified with the master of the Bambino Vispo, must be considered as a new stage in his career. Its most immediate precedent would be the scenes from the life of St. Anthony depicted in the Castellani chapel of the Santa Croce church. The paintings of Saint Blaise still reveal traces of this Giotto tradition, based on the teaching gained from his master Agnolo Gaddi. On the other hand, if one accepts the

bable que la bóveda de San Blas estuviera ya cerrada y dispuesta para ser pintada en 1395, cuando se documenta a Gerardo Starnina y Nicolás de Antonio en la catedral. Su presencia casi continua en Valencia (1395-1401) y Florencia (a partir de 1404) y el hecho de que no aparezca ningún pago por su trabajo en las cuentas de la capilla en el periodo 1397-1404 aconsejan plantear esa hipótesis.

La estancia toledana de Starnina —el mismo pintor que desde los estudios de Jeanne van Waadenonjen se identifica con el Maestro del Bambino Vispo— debe considerarse un eslabón más de su evolución profesional. Su precedente más inmediato serían las escenas de la vida de san Antonio Abad pintadas en la capilla de los Castellanos de la Santa Cruz. En las pinturas de san Blas son visibles todavía las huellas de esa tradición giottesca procedente de las enseñanzas de su maestro, Agnolo Gaddi, pero al mismo tiempo son reconocibles —dando por cierta la información proporcionada por Vasari— las influencias de la pintura colorista de Antonio Veneziano.

La reciente restauración de la capilla de San Blas ha puesto de manifiesto que este eslabón toledano puede ponerse en relación con las obras realizadas por el florentino en su etapa valenciana. En concreto, algunas figuras de su crucifixión se repiten en el retablo de Bonifacio Ferrer que se conserva en el Museo de Bellas Artes de Valencia, una obra que la crítica atribuye casi por unanimidad a Starnina. Su evolución, pues, hacia los presupuestos más decorativos del gótico internacional —conocido en Valencia gracias a la obra de pintores como Marcial de Sax— tendría un escalón previo en las pinturas toledanas.

LA INTERVENCIÓN

Estudio previo del laboratorio de química

De los análisis efectuados se ha podido constatar que el *arriccio* presente en la capilla de San Blas tiene un espesor de cerca de un centímetro y está compuesto principalmente de yeso, arcilla, negro carbón y algo más de calcita, de tal manera que las proporciones yeso / calcita / cuarzo son, aproximadamente 10 / 1 / 0'5. Las dimensiones de los gránulos de yeso y de otros materiales inertes están entorno a 5-150 \times . Todas las muestras tienen una preparación similar, un mortero en dos capas que denominaremos *enfoscado* (inferior) y *enlucido* (superior). No son las proporciones que generalmente nos encontramos en los morteros de cal con árido de yeso y arena, ya que entonces la proporción de cal y yeso debería ser del orden de 1:1 a

information provided by Vasari, the influences of the colourist painting of Antonio Veneziano are also discernible.

The recent restoration of the Saint Blaise chapel has revealed that this Toledo stage can be linked to the work carried out by the Florentine artist during his time in Valencia. Specifically, some of his Crucifixion figures are repeated in the retablo of Bonifacio Ferrer which is preserved in the Museum of Fine Arts in Valencia, which critics almost unanimously attribute to Starnina. The Toledo paintings would be a preliminary step in his evolution towards the more decorative elements of international gothic, which were well-known in Valencia through the work of painters such as Marcial de Sax.

INTERVENTION

Prior study by the chemistry laboratory

The analyses that were carried out showed that the *arriccio* in the chapel of Saint Blaise is approximately 1 cm thick. It is mainly composed of plaster, clay, carbon black and some calcite, and the resulting proportions of plaster/calcite/quartz are approximately 10/1/0.5. The dimensions of the granules of gypsum and other inert materials are around 5-150 \times . The preparation of all the samples is similar, comprising a mortar in two layers that we will call *render* (lower) and *plaster* (upper). The proportions are not those generally found in lime mortars with gypsum aggregate and sand, where the proportion of lime and gypsum would be in the order of 1:1 to 1:3 and not 1:10. This upper layer, visible in almost all the samples, is a more highly-sifted mortar, with a maximum particle size of 30-35 \times . The layer of animal glue that is found as a primer on the finished mortar is particularly interesting. We suspect that one of the masters working in the chapel used a painting technique very similar to that used in panel painting, which is typical of the late Middle Ages.

The colour application technique could generally be described as mixed, as some colours are painted with tempera and others with oil. For example, the Creed scene is produced using pigments that are based on an oily organic binder, in which the red is done in oil paint, while the blue, greys and flesh tones are in an organic medium. In other instances the technique mixes both media.

On the other hand, the Crucifixion scene is produced with three *pontate*, and on top of this lime *giornate*, which would be the oldest found in Spain to date. The colour used in these three *pontate*, such as the sky,

1:3 y no 1:10. Esta capa superior, visible en casi todas las muestras, es un mortero más tamizado, con tamaño de partícula máximo de 30-35 μ . Es de especial interés el estrato de cola animal que se encuentra como imprimación en el mortero final, por lo que sospechamos que alguno de los maestros de la capilla utilizó una técnica pictórica muy parecida a la pintura sobre tabla, típica de la Baja Edad Media.

La técnica de aplicación de colores podría describirse en general como mixta, esto es, unos colores se aplicaban al temple y otros al óleo; por ejemplo, la escena del credo está realizada con pigmentos a base de un aglutinante orgánico de naturaleza oleosa (el rojo es con óleo, mientras que el azul, los grises y las carnaciones son con un medio orgánico, y en otros casos se utilizan ambos medios).

Por su parte, la escena de la crucifixión está realizada con tres *pontate*, y sobre ella hay *giornate* a la cal, que serían las más antiguas encontradas en España hasta ahora. Los colores aplicados sobre esas tres *pontate*, en el cielo, en el manto azul de la Virgen y en alguno de los mantos rojos y amarillos de María Magdalena, están realizados a seco con medios orgánicos y de naturaleza grasa. Mientras, los de las *giornate*, que comprenden casi todas las figuras de la crucifixión, están aplicados al fresco. En los análisis efectuados antes de la intervención se constató que la escena entera se había repintado con ténpera de naturaleza orgánica.

Existen otros repintes antiguos, como el encontrado en una muestra analizada (número 1), de pintura al barniz (óleo rico en resina de conífera). Una mezcla de esos dos materiales aparece en muchas de las muestras, incluso de temple y de «fresco», por lo que se concluye que junto al repinte hay una impregnación casi generalizada de aceite y resina, muy diluida en gran parte de la superficie pictórica de una de las restauraciones precedentes y aplicada sobre toda la superficie pictórica.

En cuanto a las pinturas de la parte inferior del muro, se utilizó el temple, más magro que en las pinturas superiores, por ejemplo en la escena del credo, por lo que se comprueba que existe una intervención de restauración antigua. Tienen también en su superficie una capa de suciedad formada por yeso recristalizado con polvo (negro carbón y arcillas), del material aplicado en el siglo XVIII.

Metodología utilizada en la restauración conservativa

Los análisis nos han dado una gran diversidad de tipos de degradación de los materiales, des-



the blue robe of the Virgin, and a few of the red and yellow robes of Mary Magdalene, are produced *a secco* using organic and oily materials. The colours applied in the *giornate*, including almost all the figures of the Crucifixion, are applied *al fresco*. The analyses carried out before the intervention discovered that the whole scene had been repainted with organic tempera.

There is other old repainting in varnish paint, using an oil rich in conifer resin, such as the one in an analysed sample (number 1). This mixture of the two materials appears in many of the tempera and *al fresco* samples. Therefore, we may conclude that as well as the repainting, in one of the earlier restorations there was an almost universal impregnation across much of the painted surface of this oil and resin material in a diluted form.

The paintings on the lower register of the chapel wall were produced in tempera. However, the paint is leaner than in the upper paintings, such as the scene of the Creed, which confirms that an earlier restoration was

Detalle de la crucifixión; se aprecian las *giornate* sobre fondo de un solo tono

Detail of the Crucifixion with the *giornate* on a single tone background

de la técnica de ejecución en las escenas hasta la del cielo estrellado de la bóveda, pasando por las anteriores intervenciones de restauración o la superficie martilleada.

Estado de conservación y técnica de ejecución

La bóveda

En la superficie de las divisiones del cielo estrellado, así como en las nervaduras, se utilizó temple con medio orgánico sobre un mortero compuesto de hidrato de cal, yeso y negro carbón que le confería una tonalidad gris oscura, servía de imprimación y pretendía ahorrar pigmento azul.

Los lunetos

Las escenas de los lunetos, que se hicieron con témpera y aglutinantes de diversa naturaleza, presentan variadas e interesantes características técnicas, como, por ejemplo, el diseño preparatorio sobre la capa pictórica o una incisión directa con punzón de alguna de las arquitecturas y pequeñas *giornate* y *pontate*. Los dorados de las diversas aureolas y de otras zonas se realizaron siempre al mixtión, mientras que los incrustados en los vestidos y mantos se efectuaron con oro fino al pincel. La degradación de algunos de los lunetos es consecuencia de las filtraciones de agua y del goteo de la tubería de un baño del piso superior, hoy solucionado, lo que provocó la pérdida definitiva de parte de la arquitectura y de las pinturas, con eflorescencias salinas, levantamientos del color y pérdidas de mortero.

La superficie martilleada

En tres de las paredes inferiores, desde la cornisa que divide los lunetos de estas escenas, se empleó casi en exclusiva el temple, que presenta una tipología de degradación con dos variantes. Una es consecuencia de una intervención realizada entre los años 1719-1720 que supuso el martilleado de todas estas paredes para poder adherir un enlucido de yeso y cal que favoreciese una nueva decoración de incisiones y dibujos repetitivos. Este estrato se eliminó ya en una intervención del año 1924 que causó la pérdida de parte de la superficie pictórica original y dejó a su vez una pátina blanquecina de los restos de los yesos del secientos. La otra causa de degradación fue la filtración de agua de lluvia que descargaba en el reverso del muro y provocó la caída del mortero y, por lo tanto, de la capa pictórica. Acentuó mucho más la degradación y la caída de muchas de estas zonas la formación de sales por el empleo de un mortero de cemento donde faltaba el original.

carried out. There is also a layer of surface dirt, formed by gypsum re-crystallised with powder (carbon black and clay) left by the plastering over of the paintings in the 18th century.

Methodology applied in the conservation-restoration

The analyses have shown that the materials have a wide variety of types of deterioration, from the technique used to produce the scenes to that used for the vault's starry sky, including the previous restoration attempts and the hammered surface of the painting.

State of conservation and execution technique

The vault

The surface of each of the divisions of the starry sky, as well as the ribs, was rendered with organic tempera on a mortar composed of hydrated lime, gypsum and carbon black. This gave it a dark grey hue, which served as a primer and saved on blue pigment.

The lunettes

The scenes in the lunettes were produced using tempera and various kinds of binders. The lunettes display a variety of interesting technical features, such as the preparatory design on the pictorial layer or the direct scoring with a punch of some of the architecture, and small *giornate* and *pontate*. The golds of the various halos and other areas were all applied with mixtion, whereas the golds encrusted on the dresses and shawls were painted in fine gold with a brush. The deterioration of some of the lunettes was caused by water seepage and leakage from a bathroom on the upper floor, which has now been mended. This led to the permanent loss of part of the architecture and of the paintings, causing salt efflorescence, lifting colour and loss of mortar.

The hammered surface

On three of the lower walls, starting from the cornice that divides the lunettes from these scenes, almost all of the painting is done using the tempera technique. Their deterioration relates to two factors. Firstly, the damage from the intervention carried out in 1719-1720, which involved the hammering of all these walls in order to attach a gypsum-lime plaster that would facilitate a new decoration of scoring and repetitive patterns. This stratum was removed in work carried out in 1924 which caused part of the original surface of the painting to be lost, while leaving a whitish

La restauración en la bóveda y la consolidación de las pinturas

Para la preconsolidación del color a punto de caer se utilizaron caseinato de amonio y una solución de hidróxido de bario filtrada, aplicada mediante pinceles y jeringas especiales bicomponentes sobre papel japonés, a veces sintético, sucesivamente tamponado con esponja natural ligeramente humedecida, para favorecer la adherencia del color y la eliminación del exceso de consolidante.

La eliminación del negro de humo y de los restos indebidos se consiguió mediante la aplicación de papel japonés con pincel cargado de agua desionizada con tiempo de contacto breve y el sucesivo tamponado de la esponja humedecida.

La limpieza se efectuó con una solución de bicarbonato de amonio al 3-10 por ciento aplicada con pincel sobre el papel japonés de gramaje idóneo con un tiempo de contacto de 6-15 minutos. Después se eliminaron los depósitos con un algodón impregnado de agua desionizada. En ciertas zonas muy localizadas se repitió la aplicación. En cuanto a los repintes y a la protección aplicada en las sucesivas restauraciones anteriores, se retiraron con hisopos de algodón o con pinceles pequeños empapados en carbonato de amonio y después se utilizó agua desionizada para taponar.

El estucado de las zonas faltantes se hizo a nivel con hidrato de cal y arena lavada de una granulometría idónea. La consolidación de los morteros se efectuó con una mezcla específica desalinizada (sales solubles con un contenido de 1,1 por ciento).

La restitución pictórica se realizó a veladuras o con selección cromática, según los casos, con pigmentos minerales disueltos en caseinato de amonio al 1,5 por ciento. Las zonas faltantes de decoración repetitiva de las nervaduras se reconstruyeron con un tono ligeramente más bajo, traspasando el dibujo con estarcido y con la aplicación de los colores al pigmento mezclado con goma arábiga al 3-4 por ciento.

La restauración de los lunetos

Para la preconsolidación del color desprendido y microdesprendido se aplicó caseinato de amonio en solución saturada de hidróxido de amonio filtrado con la misma metodología que en la bóveda, si bien con alguna variante en zonas muy concretas. En las áreas en que había exfoliaciones de la capa pictórica se empleó una resina acrílica E330, al 3-5 por ciento en alcohol etílico, inyectada con jeringa y protegiendo a su vez con papel japonés las zonas afectadas, y siempre tamponando con la

patina de los restos de la 18th century plaster. Secondly, the deterioration from the infiltration of rainwater falling on the back of the wall, as a result of which the mortar, and consequently, the pictorial layer, fell away. The formation of salt, due to the use of a cement mortar to fill in gaps in the original mortar, greatly accentuated the deterioration and collapse of many of these areas.

Restoration of the vault and consolidation of the paintings

The pre-consolidation of the colour near to flaking off was carried out using ammonium caseinate and a filtered barium hydroxide solution. It was applied using brushes and special bicomponent syringes on Japanese paper, sometimes synthetic, buffering with a slightly moistened natural sponge in succession to facilitate adhesion of the colour and the removal of the surplus consolidant.

The removal of smoke blackening and unwanted debris was carried out by applying Japanese paper with a brush soaked with deionised water, left in contact with the paint surface for short periods of time, and then a moistened sponge was applied.

The cleaning was carried out with a 3-10 percent ammonium bicarbonate solution applied with a brush to Japanese paper of a suitable weight, and left in contact for 6-15 minutes. The deposits were then removed with cotton swabs soaked in deionised water. In certain, very specific areas the solution was reapplied. The repainting and protection that had been applied in successive previous restoration work was removed with cotton swabs or small brushes soaked in ammonium carbonate. The painting was then buffered with deionised water.

The missing areas were plastered over and levelled off with hydrated lime and washed sand of a suitable grain size. The consolidation of the mortar was achieved with a specific desalinated mix (containing 1.1 percent soluble salts).

The restoration of the painting was carried out using glazes or chromatic selection, as appropriate, using mineral pigments dissolved in 1.5 percent ammonium caseinate. The missing areas of repetitive decoration on the ribs were reinstated in a slightly more subdued shade. The drawing was transferred using a stencil and colour was applied in pigment mixed with 3-4 percent gum arabic.

Restoration of the lunettes

The pre-consolidation of the areas where the colour was coming away was carried out using

Escena de Pentecostés
una vez terminada la
intervención

The Pentecost scene
after the restoration



esponja natural ligeramente humedecida en una solución de agua desionizada y alcohol etílico para adherir la zona desprendida y eliminar el exceso de consolidante. Al terminar la operación se dejaron pasar de dos a cuatro horas y luego se eliminó el papel japonés mediante un pincel con alcohol etílico.

La retirada del negro de humo y del polvo superficial incrustado se logró con la misma metodología ya descrita en la intervención de la bóveda, excepto los depósitos de los materiales incoherentes de las cornisas, que se eliminaron con aspiradores y pinceles pequeños.

ammonium caseinate in a saturated solution of filtered ammonium hydroxide, following the same method as used on the vault, although with a few variations in very specific areas. In areas where the pictorial layer was peeling, E330 acrylic resin was used, in 3-5 percent ethyl alcohol, injected with a syringe while protecting the affected areas with Japanese paper, followed by buffering with a natural sponge slightly moistened in a solution of deionised water and ethyl alcohol to attach the area that was coming away and remove surplus consolidant. On finishing this process, the painting was left for 2-4 hours before

La consolidación previa

Se llevó a cabo la consolidación previa de las zonas levantadas (escamas y médium pulverulento) mediante caseinato de amonio, de la siguiente manera:

Caseína.....	8 g
Agua.....	100 g
Amoniaco.....	5 cc

Se añadió agua de cal filtrada en el momento de su empleo 50:50.

Se aplicó con jeringa a través del papel japonés, tamponando y dejando secar. Después se humedeció el papel con un nebulizador. A las 24 horas se controló el resultado con la esponja humedecida.

El arranque de las pinturas a punto de caer

En los muros norte y oeste existían dos segmentos de pintura de tres metros por uno a punto de caer, separados del muro que los sustentaba por unos 20 centímetros, por lo que se decidió su arranque inmediato y su transporte posterior a un nuevo soporte.

Para realizar esta intervención, una vez retiradas las pinturas y protegidas con una tela doble de algodón adherida con Paraloid B72 al 20 por ciento, se preparó un lugar de trabajo cercano a la capilla, en concreto un habitáculo cerrado con plásticos, para reducir el reverso en unos dos milímetros con la máquina de molar. Posteriormente se colocó una tela adherida con caseinato cálcico y, al mismo tiempo, se preparó sobre un plástico una mezcla de agua desionizada con una parte de Arbocel BC1000 y otra de Arbocel BC200 hasta obtener una densidad idónea. Sobre ese lecho se apoyó el arranque en su reverso, para impedir el paso del adhesivo Paraloid B72 a los sustratos interiores al eliminar la tela protectora.

Para la supresión de esa tela se utilizó un papel secante especial absorbente de 80 por 80 centímetros empapado en disolvente nitro y con un tiempo de contacto de entre seis y ocho horas. Sucesivamente se tamponó en lugares más reacios con algodón y pincel con una mezcla de dos partes de acetona y una parte de disolvente nitro.

La pintura se adhirió a un nuevo soporte de vidrio-resina de poliéster, reforzado con una red metálica antioxidante, y con un tamaño total de cuatro milímetros. El adhesivo empleado fue Acril 33 puro con polvo de piedra pómez, carbonato cálcico micronizado y arena de granulometría idónea para obtener una buena densidad de aplicación. El estrato donde había que intervenir estaba constituido por un cartón de venta en exclusiva en Italia, denominado *carta a frattura predeterminata*, que se colocó en un formato de 50 por 70 centímetros.

removing the Japanese paper using a brush moistened with ethyl alcohol.

The removal of smoke blackening and superficial, encrusted dust was carried out following the same methodology as described for the work in the vault, apart from the deposits of debris on the cornices, which were removed with vacuums and small brushes.

Pre-consolidation

The areas where the colour was lifting (flakes and powdery material) were pre-consolidated using ammonium caseinate, in the following manner:

Casein.....	8 g
Water.....	100 g
Ammonia.....	5 cc

Filtered lime water was added 50:50 at the time of use.

This solution was applied using a syringe through Japanese paper, buffered and left to dry. The paper was then moistened with a humidifier. After 24 hours the result was checked with a moistened sponge.

Removal of paintings at the point of falling off

On the north and west walls, there were two segments of painting measuring three metres by one, which had detached around 20cm from the supporting wall, i.e. were on the verge of falling off. The decision was therefore taken for them to be immediately removed and subsequently transferred onto a new backing.

For this procedure, the paintings were previously protected with a double cotton fabric bonded with 20 percent Paraloid B72, and removed to a place of work set up near the chapel. Within the work area enclosed by plastic sheeting, the underside was reduced by around 2 mm with a grinder. Subsequently, a fabric bonded with calcium caseinate was laid out while, simultaneously, a mix of deionised water and one part Arbocel BC1000 and another part Arbocel BC200 were prepared on plastic sheeting until the right density was achieved. The painting was then placed upside down on this base to prevent the Paraloid B72 adhesive seeping through to the interior substrates when the protective fabric was removed.

For the removal of this fabric, a special 80x80 cm absorbent blotter soaked in nitro solvent was applied and left in contact for 6-8 hours. Any areas which resisted removal were then successively buffered with cotton swabs and a brush using a mixture of two parts acetone and one part nitro solvent.

The painting was attached to a new glass-

El procedimiento de aplicación del adhesivo en el reverso se realizó con brocha sobre el soporte. Se humedeció el cartón con agua desionizada, se aplicó el adhesivo sobre el reverso y se colocó sobre toda la superficie del soporte de vidrio-resina, y para que se adhiriera bien se le pasó un rodillo, presionando correctamente.

Después de 24-36 horas se colocó el soporte al reverso de la pintura aplicando un adhesivo más débil (60 partes de Acril 33 y 40 de agua desionizada), con los mismos inertes antes descritos. Se extendió de modo homogéneo sobre la *carta a frattura predeterminata* con un pincel y se colocó la pintura sobre el soporte, de modo correcto, antes de lavar ligeramente la superficie pictórica con agua desionizada nebulizada y continuar la adhesión con el método de vacío, con una aspiración de dos o tres horas. Posteriormente se recolocó en la pared, en su lugar correspondiente, fijado con pernos de plástico y tornillos de acero inoxidable colocados en los agujeros de golpes antiguos. Se realizó el estucado de unión con la zona no arrancada, una vez comprobado que el método es reversible en el tiempo.

La consolidación definitiva

Estructural

Los nervios de la bóveda o arcos formeros se encontraban en general en buen estado, excepto en una esquina, la noreste, donde se había perdido de media un 60 por ciento de la sección. Asimismo, se había producido pérdida del volumen de piedra en el mismo plemento noreste.

El procedimiento de consolidación se hizo en primer lugar con una limpieza mediante cepillo de cerdas naturales, hasta conseguir una superficie en la piedra sana y dura para después aplicarle papetas de celulosa (Arbocel 1000 y 200) para la completa eliminación de las sales en sucesivas etapas. Posteriormente, se aplicó un consolidante a la piedra por pintado de la superficie con EOS.

En los plementos de la bóveda, no dañados por la humedad, se consolidó mediante perforaciones el soporte del fresco, que estaba separado de la base de piedra o abombado, y con jeringa se inyectó una cal aditiva de PLM en pequeñas cantidades que se dejó secar para volver a actuar posteriormente y así, mediante sucesivas inyecciones, conseguir una adherencia total.

La consolidación y la limpieza definitiva de los morteros y la capa pictórica

El procedimiento seguido consistió en el empleo de bario, que en solución acuosa al cuatro

polyester resin backing strengthened with an antioxidant metallic mesh, with a total thickness of 4 mm. The adhesive used was pure Acril 33 with pumice powder, micronised calcium carbonate and sand of a grain size suitable for obtaining a good density of application. The stratum for the intervention consisted of a cardboard sold exclusively in Italy, called *carta a frattura predeterminata*, which was applied in 50 by 70 cm sections.

The cardboard was moistened with deionised water, the adhesive was brushed onto the back and it was placed onto the entire surface of the glass-resin base. A roller was passed across it with the correct pressure to ensure good adhesion.

After 24-36 hours, the backing was fixed to the underside of the painting, applying a weaker adhesive (60 parts Acril 33 and 40 parts deionised water) with the same inert materials as described above. This was brushed evenly onto the *carta a frattura predeterminata* cardboard and the painting was correctly positioned on the backing. The surface of the painting was then gently cleaned with nebulised, deionised water and the adhesion process was continued, using the vacuum method for about two to three hours. The painting was subsequently re-attached to the wall in the correct place, and secured with plastic bolts and stainless steel screws, which were placed in the original holes. Plastering was carried out to align it with the area which had not been removed, having first verified that this could be subsequently reversed.

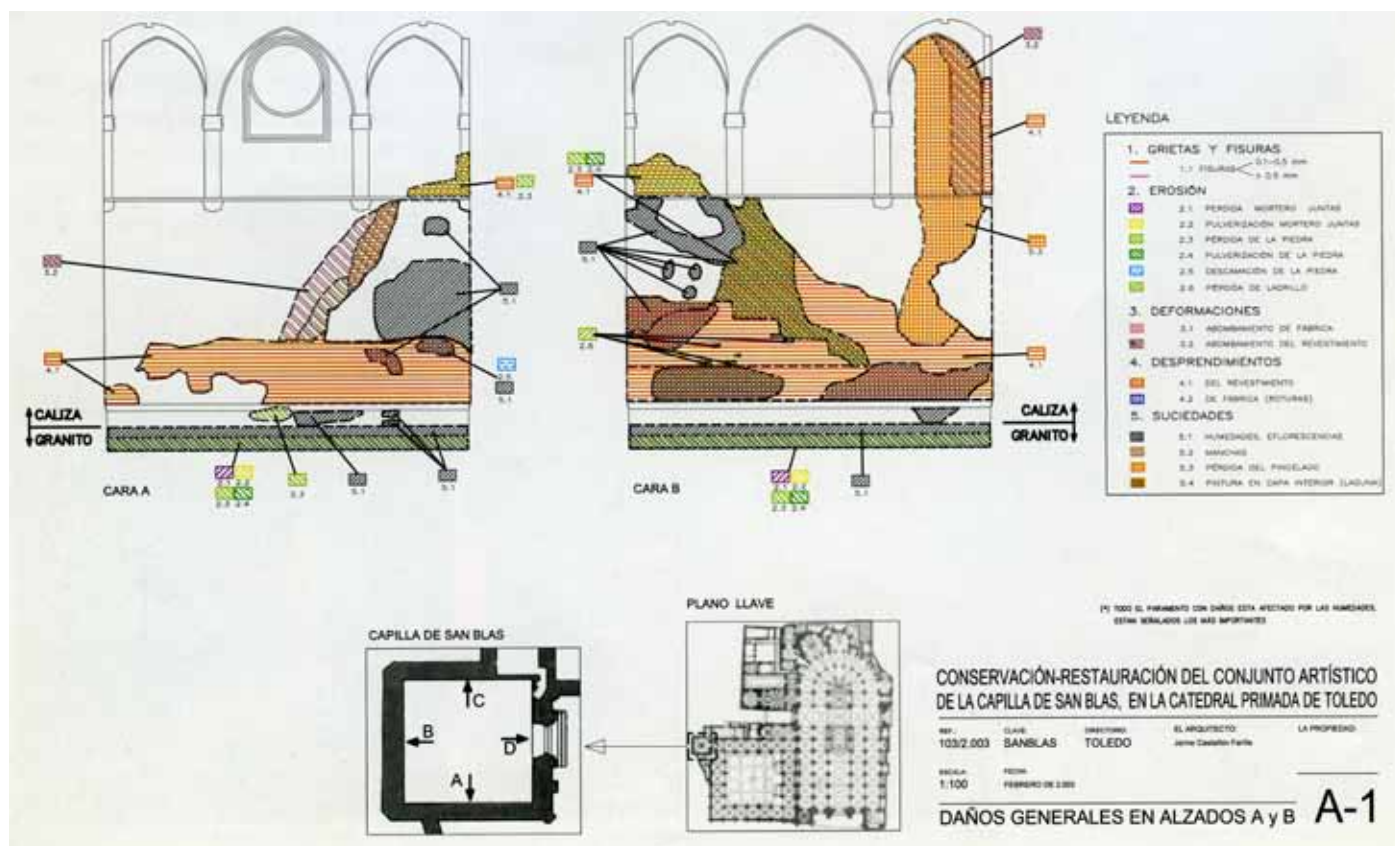
Final consolidation

Structural

The ribs of the vault or side arches were generally in good condition except for one corner, the north-eastern, which had lost 60 percent of its mid-section. Also, the stone in the same north-eastern cell had experienced a loss of volume.

The consolidation process was carried out first, using a cleaning brush with natural bristles, to produce a sound, hard stone surface. Cellulose poultices (Arbocel 1000 and Arbocel 200) were then used to extract the salts in successive stages, until they were completely removed. Subsequently, a consolidator was applied to the stone for painting of the surface with EOS.

In those cells of the vault that were not damaged by moisture, fresco backing that was detached or curving out from the stone base was consolidated. For this purpose, perforations were made and small amounts of a PLM lime additive were injected using



Mapa del deterioro

Map of deterioration

por ciento se aplicó a la capa final del fresco base, que fija el *intonaco*, además de ablandar la capa superficial de cola animal para su posterior eliminación. Con un lento secado se fijó la capa y se eliminaron las sales nocivas con óxido de bario, que reacciona con la cal y le da la dureza necesaria.

Esta metodología de trabajo se desarrolló adecuadamente con consolidación previa del color, con caseína al 0,5 por ciento con solución saturada de hidróxido de bario, filtrado y aplicado ya fuera con jeringa o con pincel sobre un folio de papel japonés con la sucesiva *tamponadura*. En las zonas de levantamiento de escamas de color de tamaño medio y grande se utilizó, de forma localizada y limitada, primer al 10 por ciento, se *tamponó* sucesivamente con agua y se eliminó el exceso con acetona.

La consolidación previa con compresa de hidróxido de bario

Efectuada la limpieza y transcurridos de cinco a 10 días se comprobó que era necesario realizar alguna prueba con compresa de hidróxido de bario, para prevenir problemas futuros que se vincularían especialmente a zonas con levantamientos muy débiles o microlevantamientos pulverulentos de capa pictórica y mortero (por ejemplo, el sepulcro por debajo del limbo, el Cristo, el juicio o la coronación de la Virgen). Se hizo una primera prueba con hi-

a syringe, left to dry then subsequently re-injected, until, through successive injections, the backing was completely secured.

Consolidation and final cleaning of the mortar and the pictorial layer

The procedure followed involved the use of barium, in a 4 percent aqueous solution, which was applied to the final layer of the fresco backing, which fixed the *intonaco*, in addition to softening the surface layer of animal glue to be subsequently removed. It was slowly dried to fix the layer, and harmful salts were eliminated by applying the barium oxide that reacts with lime and gives it the necessary hardness.

This work procedure was successfully carried out with pre-consolidation of the colour, using 0.5 percent casein and a saturated solution of barium hydroxide, filtered and applied either in a syringe or using a brush on a piece of Japanese paper and successively buffered. In areas where medium and large flakes of colour were coming away, 10 percent primer was used in a limited and localised way, thereafter buffering with water and removing the surplus with acetone.

Pre-consolidation using barium hydroxide compress

Five to 10 days after the cleaning, it was found

dróxido de bario al cuatro, seis y ocho por ciento, aplicado con compresas de Arbocel 1000 y 200, sepiolita o papel japonés, según los casos.

Estas pruebas demostraron, después de la eliminación de la compresa, una buena cohesión y resistencia superficial de las escamas y el retorno a su origen de la capa pictórica, lo que permitió hacer una primera limpieza aceptable con la mezcla de agua y carbonato de bicarbonato de amonio.

El porcentaje de bario idóneo casi no se aprecia, pero se optó por una variación que iba de cuatro al seis por ciento, para mayor seguridad de la basicidad de la pintura a seco de debajo.

En definitiva, el hidróxido de bario, aplicado con una compresa de pasta poco humedecida con un tiempo de contacto de entre dos y tres horas, ablandó la zona al temple, unió el médium y lo compactó, con lo que se formó una unión químico-mineral entre la capa superficial y el mortero. Después de una primera limpieza y de la eliminación de la compresa se pudo intervenir y tras unos días de espera se logró un acabado más perfecto. Sin embargo, existían dos inconvenientes. El primero ocurría en algunas zonas con blanqueamiento, pero pudo eliminarse con la resina catiónica o una solución ligera de EDTA, aunque en esos casos sólo se aplicó en zonas muy puntuales. El segundo inconveniente era tener que volver a fijar el color, pero se remedió haciendo una consolidación posterior con caseína e hidróxido de bario o de cal, según las necesidades.

Además, pudo comprobarse, aplicando una pequeña compresa de pasta neutra mezclada con bario al seis por ciento, que el poder disolvente y humectante del agua pura no consolidaba lo suficiente la pintura. En ese sentido, se observó que existía una diferencia en la aplicación de una compresa del cuatro al ocho por ciento. Esto último dio resultados muy convincentes en algunas zonas, como debajo de la escena del limbo, donde se hizo al 10 por ciento con resultados incluso mejores, dejando intactas las incisiones en la preparación de la pintura. Se explica probablemente porque, cuanto menor sea la concentración de bario, mayor es la acción soluble del agua sobre la parte de yeso que lleva el mortero. Así, se aplicó un estrato de papel japonés sobre la totalidad de la escena, humedecida con agua desmineralizada, para aminorar el proceso de secado del mortero y la capa pictórica, y garantizar la buena salida de la carbonatación del hidróxido de bario.

La limpieza después de la consolidación, tanto con caseína inyectada como con solución saturada de bario en contacto con la superficie, se efectuó con muy buenos resultados con una

that some tests needed to be carried out using a barium hydroxide compress, aimed at preventing future problems that would particularly affect areas where there was very slight lifting, or powdery micro-lifting of the pictorial layer and mortar (for example, the tomb below the Limbo, Christ, the Judgement and the Coronation of the Virgin). An initial test was carried out using barium hydroxide at 4, 6 and 8 percent, applied using compresses of Arbocel 1000 and Arbocel 200, sepiolite or Japanese paper, as appropriate.

After removal of the compress, the tests showed good cohesion and surface resistance of the flakes and the restitution of the pictorial layer to its original state. This enabled an acceptable initial cleaning process to be undertaken using a mixture of water, carbonate and ammonium bicarbonate.

The most suitable barium percentage is close to zero, but a variation was selected ranging from four to six percent, as an increased safeguard for the basicity of the *a secco* painting underneath.

In short, the barium hydroxide, which was applied with a lightly-moistened pulp compress and left in contact for two to three hours, softened the tempera area, bonded the medium and compacted it, creating a chemical-mineral bond between the surface layer and the mortar. After initial cleaning and removal of the compress, work could be carried out, and after waiting for a few days a more perfect finish was achieved. However, there were two drawbacks. The first involved some areas with whitening. It was, however, possible to remove this using cation resin or a light EDTA solution, although in this case, this was only done in very specific areas. The second drawback was the need to carry out a second colour fixation; however this was remedied by a subsequent consolidation using casein and barium or lime hydroxide, as required.

In addition, by applying a small compress of neutral pulp mixed with 6 percent barium, it was verified that the dissolving and moistening power of pure water did not sufficiently consolidate the painting. Differences were noted when applying a compress with a four to eight percent solution. The latter produced very convincing results in some areas, such as under the Limbo scene. When a 10 percent solution was used, it gave even better results, leaving the preparatory scoring for painting intact. This can probably be explained because the lower the concentration of barium, the greater the soluble action of the water on the gypsum

solución de bicarbonato de amonio al 10 por ciento con carbonato de amonio al cinco por ciento, y para su empleo en zonas de mayor resistencia de la suciedad se aumentó la dosis de bicarbonato de amonio al 20 y al 10 por ciento.

En las zonas preconsolidadas con hidróxido de bario al cuatro y seis por ciento se empleó una ligera compresa de dos estratos de papel japonés de nueve gramos o con sepiolita con la anterior solución. Se hizo así, en esos casos, para limitar la emisión excesiva de soluciones de bicarbonato y carbonato. El tiempo de contacto no excedió los 30 segundos en pequeñas zonas, según el pigmento y la decoración.

Durante la limpieza se consiguió, como objetivo principal, el empleo muy limitado en el tiempo de concentraciones máximas de soluciones alcalinas de bicarbonato y carbonato de amonio, vista la naturaleza técnica de la pintura. En ese sentido, intentamos debilitar la sustancia de cola orgánica (puede ser que estuviese mineralizada en forma de oxalatos) de repintes y fijativos que permanecían en superficie con una compresa de solución de EDTA tetrasódico al dos-tres por ciento en zonas muy puntuales. Se consiguió eliminando, transportando y secando la zona con algodón y posteriormente interviniendo con el bicarbonato y el carbonato de amonio.

La reintegración

Estructural

Los nervios formeros de la bóveda estaban en buen estado, excepto en la esquina noreste, donde, como se ha dicho, se había perdido un 50 por ciento de su sección de media. Para su reintegración se aplicaron varillas de fibra de vidrio, cosidas a la piedra en perforaciones a rotación rellenas con resina epoxi, que se conectaron a una malla de fibra de vidrio mediante resina de dos componentes. Por último se colocó un mortero pétreo que, una vez seco, se talló hasta darle la apariencia del conjunto.

El plemento de esta esquina tenía también pérdida de volumen de piedra y había que recuperarlo. Se procedió después de su consolidación a la colocación de las varillas de fibra de vidrio como en el caso anterior, mediante perforaciones a rotación. Fueron fijadas a la base con resina epoxi y también se dispuso una malla de fibra de vidrio que, junto al mortero pétreo aplicado, permitió obtener la planimetría original, aunque se dejaron tres milímetros de diferencia con el resto del plemento para que se diferenciase las zonas nuevas al observarlas con detenimiento.

La reintegración se realizó sobre la capa fina de mortero en las zonas arquitectónicas, con la posibilidad de repetir con tonos tres

contained in the mortar. Therefore, a layer of Japanese paper was applied to the whole scene, moistened with demineralised water to reduce the drying out of the mortar and pictorial layer, and ensure the successful removal of the barium hydroxide carbonation.

The cleaning after the consolidation was carried out with both injected casein and saturated barium solution in contact with the surface. This produced very good results with a solution of 10 percent ammonium bicarbonate and 5 percent ammonium carbonate. For its use in areas of higher dirt resistance, the dose of ammonium bicarbonate was increased to 20 and 10 percent.

In areas that had been pre-consolidated with four and six percent barium hydroxide, a light pad of two layers of nine-gram Japanese paper or sepiolite was used with the above solution. This was done to limit the excess seepage of bicarbonate and carbonate solutions. It was used in small areas, and depending on the pigment and decoration, was left for no longer than 30 seconds.

The cleaning process achieved its main objective, which was, due to the technical characteristics of the painting, to apply maximum concentrations of bicarbonate and ammonium carbonate alkaline solutions for a very brief period. In very specific areas, we used a pad of two to three percent tetrasodium EDTA solution to attempt to weaken the animal glue material that remained on the surface from previous retouching and fixatives (which may have been mineralised in the form of oxalates). This was done by lifting off, transporting and drying the area with cotton swabs, and subsequently treating it with bicarbonate and ammonium carbonate.

Re-integration

Structural

The ribs in the vault were in good condition, except in the north-east corner which, as mentioned above, had lost about 50 percent of its mid-section. In order to reinstate it, fibreglass reinforcements were used, which were bonded to the stone using rotary perforations filled with epoxy resin and connected to fibreglass netting using two-part resin. Lastly, a stone mortar was applied. It was left to dry, then sculpted to give a unified appearance to the whole area.

The cell in this corner had also experienced a loss in volume of the stone which needed to be restored. Fibreglass reinforcements were again put in place using rotary perforations, and attached to the base with epoxy resin. Fibreglass netting was also used in

puntos más claros, para conseguir una armonía más lógica en la intervención. La reintegración se realizó con caseinato cálcico (40 por ciento de leche y 60 de agua de cal) con agua mezclado con pigmentos. La tonalidad del color es acuosa, más o menos fría según la zona de la laguna y el original.

La superficie donde existían grandes eflorescencias salinas, en especial donde se había aplicado cemento, se trató con empaques absorbentes de Arbocel 1000 con tiempos de contacto muy largos, según la necesidad.

La capa pictórica

La reintegración de lagunas se realizó con caseinato cálcico (40 por ciento de leche y 60 de agua de cal) con agua mezclado con pigmentos. La tonalidad del color es acuosa, más fría y de menos tono, según la zona de la laguna y los daños en el original. La reintegración de las grandes lagunas se realizó con mortero de cal y arena en bicapa, finalizado con veladura de pigmento en agua de cal.

conjunction with stone mortar. This appears to achieve the original flatness; however there is a 3-millimetre difference, so that if you look closely the new areas can be distinguished.

Re-integration was carried out on the fine layer of mortar in the architectural areas, with the option of reinstating it in tones three points lighter, thereby achieving more logical harmony in the restoration. Re-integration was carried out using calcium caseinate (40 percent milk and 60 percent lime water) and water mixed with pigments. The colour tone is watery, and its warmth varies according to the area of the lacunae and the original colour.

The surfaces that had considerable salt efflorescence, especially where cement had been applied, were treated with Arbocel 1000 absorbent poultices, which were left in contact for long periods of time as needed.

Pictorial layer

The re-integration of lacunae was carried out using calcium caseinate (40 percent milk and 60 percent lime water) and water mixed with pigments. The colour tone is watery, and cooler and lighter according to the area of the lacuna and the damage to the original. The re-integration of the large lacunae was carried out with two-layer lime-sand mortar, finished with a glaze of pigment in lime water.

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LA CONSERVACIÓ DELS MURALS DE LA CAPELLA DE SANT MIQUEL DEL REIAL MONESTIR DE PEDRALBES

Quan l'abadessa del monestir de Pedralbes estableix en el contracte de Ferrer Bassa que els murals de la capella de Sant Miquel es facin a l'oli segurament fa referència a una tècnica pictòrica consistent a aglutinar els pigments amb oli d'una capa prèvia feta a base de blanc de plom. Però la tècnica que ens trobem no és aquesta: si bé s'utilitza l'oli, s'empren altres aglutinants proteics i resines terpèniques, essent la fase prèvia una pintura al fresc.

Els murals estan pintats al fresc i al sec gairebé en la mateixa proporció, i la distribució dels dos procediments està perfectament planificada abans de començar a pintar. També està previst fer la profusa decoració amb daurats i platejats.

Els principals problemes de conservació són els inherents a la utilització d'aglutinants orgànics. El film pictòric i l'aplicació de làmines metàl·liques alteren el procés d'adsorció i desorció de vapor d'aigua del substrat. La capa pictòrica, en aquestes circumstàncies, està sotmesa a tensions i pressions i sovint acaba per desprendre's. Altres alteracions estan relacionades amb canvis cromàtics o la pulverulència localitzada dels pigments.

La tècnica executiva és l'element que més ha condicionat la conservació dels murals, mentre que l'ambient estable de la capella i la seva ubicació han permès que aquest cicle pictòric hagi superat prop de set-cents anys d'història en un estat molt intacte i complet.

LA CONSERVACIÓN DE LOS MURALES DE LA CAPILLA DE SAN MIGUEL DEL REAL MONASTERIO DE PEDRALBES

Cuando la abadesa del monasterio de Pedralbes dispuso en el contrato de Ferrer Bassa que los murales de la capilla de San Miguel se pintaran al óleo probablemente hacía referencia a una técnica consistente en mezclar los pigmentos con aceite y pintar encima de una capa de albayalde. Sin embargo, la utilizada finalmente es muy distinta: el óleo se empleó junto con otros aglutinantes proteicos y resinas terpénicas, siendo la fase previa una pintura al fresco.

Los murales están pintados al fresco y al seco casi en la misma proporción. La distribución de las dos técnicas se planificó perfectamente antes de empezar a trabajar. También estaba previsto hacer la riquísima decoración con dorados y plateados.

Los problemas de conservación son los inherentes a la utilización de aglutinantes orgánicos. La película pictórica y la aplicación de láminas metálicas alteran el proceso de adsorción y desorción de vapor de agua del sustrato. La capa pictórica está sometida a tensiones y presiones y acaba por desprenderse. Otras alteraciones están relacionadas con cambios cromáticos o la pulverulencia localizada de los pigmentos.

La técnica pictórica es el elemento que más ha condicionado la conservación de los murales, mientras que el ambiente estable y la situación de la capilla han permitido que este ciclo pictórico haya superado cerca de setecientos años de historia casi intacta y completa.

THE CONSERVATION OF THE PAINTING IN SAINT MICHAEL'S CHAPEL IN THE MONASTERY OF ST MARY OF PEDRALBES

When the abbess of the Pedralbes Monastery commissioned Ferrer Bassa to paint the murals in Saint Michael's Chapel using oil, she indubitably imagined he would use a technique that entailed mixing pigments with oil and painting onto a layer of white lead. Yet the technique that Bassa ended up using would prove to be significantly different: in addition to oil, the work incorporated protein-based binding agents and terpene resin. The former phase was a fresco painting.

The fresco and a secco techniques were used in almost identical proportions, and the areas where each technique would be used were planned out to the last millimetre before painting began. The painters also planned to apply gold and silver leaf to the surface to create exquisite finishing touches.

The conservation-related problems this work faces are a consequence of the organic binding agents that were used when it was painted. The pictorial layer and the use of metal leaf altered the permeability of the wall and affected the adsorption and desorption processes in the underlying layer. This pressure and tension led parts of the pictorial layer to be lost. Other alterations were related to chromatic changes and powdery in the pigments. The painting technique proved to be the factor which had the greatest impact on conservation, whereas the chapel location provided a sufficiently stable environment so as to allow this work to weather the challenges of nearly seven hundred years of history and, for the most part, remain intact and complete.

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LA CONSERVACIÓ DELS MURALS DE LA CAPELLA DE SANT MIQUEL DEL REIAL MONESTIR DE SANTA MARIA DE PEDRALBES

THE CONSERVATION OF THE PAINTINGS IN SAINT MICHAEL'S CHAPEL IN THE MONASTERY OF ST MARY OF PEDRALBES

Lídia Font i Rosa Senserrich

La capella de Sant Miquel del Reial Monestir de Pedralbes de Barcelona és una petita estança de només vint metres quadrats de superfície, la decoració de la qual fou encarregada al taller de Ferrer Bassa l'any 1346. Malgrat les seves dimensions reduïdes, en conjunt suma prop de cent metres quadrats de superfície pictòrica, uns setanta-cinc dels quals corresponen als murals que omplen els paraments amb escenes de la Passió de Crist, els Goigs de la Verge, el Judici Final i la Salvació de les Ànimes, com també amb diverses figures de sants. La superfície restant és la decoració de l'embigat que representa la volta celeste.

La pintura mural s'estructura en registres delimitats per sanefes amb motius geomètrics. Als registres central i superior es desenvolupen les diverses escenes emmarcades a dalt i a baix per una arquitectura simulada de plafons de marbre fingits.¹ Tots aquests elements accentuen el marcat italianisme del cicle pictòric que vincula Barcelona i la Corona d'Aragó amb les innovacions que neixen a les ciutats toscanes pels volts de l'any 1300. Aquestes innovacions, com veurem més endavant, no estan només relacionades amb un nou llenguatge figuratiu, sinó també amb les noves maneres d'executar la pintura que són, en bona part, coincidents amb les italianes.

El conjunt està ben conservat i complet i és accessible i de dimensions abastables, la qual cosa en facilita la preservació i estudi. També

Saint Michael's Chapel in Barcelona's Pedralbes Monastery is a small room just 20 square metres in size. Ferrer Bassa's workshop was commissioned to decorate the space in 1346. Despite its small size, the chapel contains nearly 100 square metres of painted surfaces, including 75 metres of murals decorating the walls with scenes from the Passion of Christ, the Joys of the Virgin, the Last Judgment and the Weighing of the Souls, as well as various images of saints. The beams and ceiling are also decorated to represent the heavens.

The paintings are surrounded by friezes decorated with geometric motifs. The central and upper registers portray various scenes that are framed above and below by a faux marble background.¹ All of these elements accentuate the marked Italianism of the ensemble of works, which links Barcelona and the Crown of Aragon to the innovations that arose in Tuscany around the year 1300. As we shall see later, these innovations are related not only to a new figurative language but also to new painting techniques that to a large extent mirrored Italian techniques.

The work as a whole is well conserved, complete, and accessible in size, making it easy to conserve and study. In terms of location, the monastery is far from the city centre and the chapel is well protected from external environmental factors, guaranteeing a highly stable environment with regard to climate-related issues. To a large extent, this is a result of the chapel's location on the ground

1. L'arrimador i el parament d'entrada a la capella estan decorats amb aquests marbres fingits, però aquesta policromia original resta actualment oculta sota repintades fetes amb posterioritat. L'estudi dels murals en curs ha permès confirmar la presència d'aquesta decoració, els testimonis de la qual es poden veure en diverses cates efectuades.

1.. The wainscot and entrance wall of the chapel are decorated with this faux marble, although their original polychromy was covered up when they were repainted at a later point. Based on several test cuts, we were able to detect these original decorations.



és favorable el seu emplaçament, ja que el monestir està allunyat del centre de la ciutat i la capella ocupa un espai protegit de l'ambient extern, que resulta molt estable a nivell climàtic. En bona mesura això és gràcies al fet que l'estança se situa a nivell de planta baixa, ocupant l'espai entre dos contraforts de l'església, de tal manera que queda aïllada de l'exterior per murs molt sòlids i pels espais que l'envolten: la galeria del claustre, l'església a la qual està adossada i el pis superior. Malgrat tot, les alteracions hi són presents, i els prop de set-cents anys d'història han deixat empremtes significatives.

Les formes d'alteració estan relacionades d'una manera o altra amb la naturalesa dels materials utilitzats i, més concretament, amb la tècnica pictòrica i la incidència que sobre aquesta exerceixen les condicions ambientals de l'entorn més immediat. Es pot considerar que aquesta tècnica pictòrica és el factor que més ha condicionat l'evolució de l'obra, sobretot si és té en compte que, com molts altres murals d'època medieval, es comença al fresc i es continua al sec i que, per tant, hi ha una presència abundant d'aglutinants orgànics que resulten vulnerables.

En el marc del projecte endegat pel Museu d'Història de Barcelona «La conservació dels murals de la capella de Sant Miquel del Reial

floor between two buttresses supporting the church; consequently, it was isolated from the outside by highly solid walls and by the spaces surrounding it, which included the gallery of the cloister, the church to which it is attached, and the upper floor. Despite these factors, nearly seven hundred years of history left their mark, and numerous alterations can be seen in the chapel.

These alterations are all to some degree related to the materials used and, more specifically, to the painting technique and the impact of the nearby environmental conditions. In fact, the factor that most influenced subsequent alterations was the painting technique itself. This is especially relevant when we bear in mind the fact that – like many other mediaeval mural paintings – the work started with a fresco layer and was finished *a secco*. Consequently, the paintings frequently utilised organic binding agents that turned out to be susceptible to change.

Supervised by the Museu d'Història de Barcelona, the project entitled “The Conservation of the Paintings in Saint Michael's Chapel in the Royal Monastery of Saint Mary of Pedralbes” aims to take a scientific approach to determining the best conservation and treatment options available for this work. In recent years, significant

Vista general de l'interior de la capella amb la pintura mural que representa la Passió de Crist, els Goigs de la Verge i diverses figures de sants, així com el sostre decorat amb la volta celeste

The interior of the chapel. The wall paintings depict the Passion of Christ, the Joys of the Virgin, and various images of saints; the ceiling is decorated to resemble the heavens

Monestir de Santa Maria de Pedralbes», que té com a objectiu decidir sobre una base científica quin és el millor sistema de conservació i de tractament, en els darrers anys s'ha fet un esforç important per conèixer l'obra, el clima i les característiques de l'entorn, com també les relacions existents entre uns i altres.²

El projecte es basa en l'exploració visual exhaustiva feta pel restaurador amb vista a conèixer amb detall l'estat de la superfície de tot el conjunt, és a dir, els materials de què està feta l'obra, la tècnica d'execució emprada i les alteracions. Aquesta tasca s'ha realitzat amb el suport de la lupa binocular i de tècniques no destructives com la fotografia ultraviolada (UV) i infraroja (IR). El conjunt de dades obtingut s'ha contrastat amb les fonts escrites, sobretot els tractats sobre la tecnologia pictòrica i molt en particular *Il libro dell'arte* de Cennino Cennini, però també amb altres documents contemporanis de l'obra, com el contracte establert entre l'abadessa i el pintor Ferrer Bassa. Només en segona instància s'ha fet l'anàlisi d'unes quantes micromostres amb tècniques instrumentals diverses³ i, en aquest moment, s'està aprofundint en l'avaluació de dades i la diagnosi amb el suport d'un equip d'especialistes en diverses disciplines amb el qual es treballa la relació entre tècnica i deteriorament.

La tècnica i els procediments d'execució

La tècnica dels murals de la capella de Sant Miquel s'insereix en l'arquitectura que els sosté, que en aquest cas són els sòlids paraments de l'església del monestir, d'uns seixanta centímetres de gruix, i dos dels seus contraforts, de 120 centímetres, un dels quals té un petit podi o basament amb un lleuger cornisament. Són murs de doble fulla amb reblert, i a la cara externa tenen un encintat que segella perfectament les juntes i evita l'entrada d'aigua a l'interior.⁴ En canvi, el pany d'entrada, a di-

energy has been invested in learning more about the piece, the climatic conditions and characteristics of the environment in which it is located, and the link between these factors.²

Currently, the restorer is in the midst of carrying out an exhaustive visual examination of the work in order to derive a detailed understanding of its entire surface, including the materials and technique used and the subsequent alterations that have taken place. This research was carried out using a binocular loupe and non-destructive techniques including ultraviolet (UV) and infrared (IR) photography. We compared the data we compiled with written sources, looking at treatises on painting technology, especially Cennino Cennini's *Il libro dell'arte*. We also examined other contemporaneous documents, including the contract entered into by the abbess and the painter, Ferrer Bassa. Later, we analysed several microsamples using a variety of techniques.³ At the current moment, we are delving deeper into the data we have collected and assessing the work with the assistance of a multidisciplinary team of experts in order to examine the relationship between the technique employed and deterioration that has occurred.

The painting technique

The technique utilised in Saint Michael's Chapel was based on the architecture of the space, namely the church's solid, 60-cm-thick walls and the two 120-cm-thick buttresses, one of which has a small pedestal base with a minor entablature. The perfectly sealed joints in the filled cavity walls' external face prevented water from getting into the building.⁴ The entry wall differs from the others, and is constructed of 8-cm-thick solid brick.

2. En aquest sentit es pot consultar el web del projecte «Murals sota la lupa. La conservació de les pintures de la capella de Sant Miquel del Reial Monestir de Pedralbes», on hi ha el resum de la tasca realitzada i els articles publicats fins al moment: <<http://www.bcn.cat/monestirpedralbes/Murals-sota-la-lupa-Monestir-Pedralbes/ca/>>.

3. Les tècniques d'estudi utilitzades són: microscòpia òptica amb llum polaritzada, incident i transmesa; llum halògena i llum UV (tincions selectives i assajos microquímics); espectroscòpia infraroja per transformada de Fourier (FTIR per transmissió i FTIR-ATR); cromatografia de gasos - espectrometria de masses (GC-MS); cromatografia en capa fina d'alta resolució HPTLC; microscòpia electrònica d'escombratge - microanàlisi mitjançant espectrometria per dispersió d'energies de raigs X (SEM-EDXS).

4. Les especificitats constructives de l'església de Pedralbes, com també les d'altres basíliques barcelonines, es recullen en l'article: Màrius VENDRELL, Pilar GIRÁLDEZ,

2. For more information, please see the website "Murals in the spotlight: Conservation of the paintings in Saint Michael's Chapel. Monastery of Pedralbes," which summarises the work done and articles published to date. <http://www.bcn.cat/monestirpedralbes/Murals-sota-la-lupa-Monestir-Pedralbes/en/>.

3. We used the following techniques: transmitted and incident polarised light microscopy; halogen and UV light (selective staining and microchemical tests); Fourier transform infrared spectroscopy (FTIR transmission and ATR-FTIR); Gas chromatography-mass spectrometry (GC-MS); high performance thin layer chromatography (HPTLC); and Scanning Electron Microscope - Energy-dispersive X-ray spectroscopy (SEM - EDXS).

4. For details about the techniques used to build the Pedralbes church - as well as the other basilicas in Barcelona - see Màrius VENDRELL, Pilar GIRÁLDEZ, Reinald GONZÁLEZ, Francesc CABALLÉ, Pere ROCA, «Les basíliques gòtiques barcelonines: trets comuns i diferencials», *El gòtic meridional català: cases, esglésies i palaus*. Barcelona, Clavell Cultura, 2009, p. 85.



ferència dels anteriors, és un envà fet de maó massís d'uns vuit centímetres de gruix.

Tot l'interior de la capella està revestit, com la resta de paraments del monestir, amb un enlluït blanc, molt ben lliscat, fet de calç i àrid. Aquest arrebossat primigeni sembla tenir la mateixa composició que el morter de l'espai adjacent, la tomba de la reina Elisenda, un morter de calç que conté pols de marbre de granulometria fina i algun gra de quars i jaspí.⁵ A la capella està format per dues capes de composició molt similar: la interna té un gruix d'uns quatre mil·límetres i l'externa, un enlluït d'un mil·límetre escàs i la superfície perfectament lliscada, fet que confirma la seva funció de revestiment final.

El dibuix preparatori o sinòpia es va fer aprofitant aquesta superfície blanca impecablement lliscada, emprant pigments de color ocre groc i vermell, aplicats a pinzell i utilitzant la llinyola per traçar, prèviament, les línies mestres. A continuació es va repicar a martell per facilitar l'adhesió del nou morter estès a *giornate* per fer la pintura al fresc.

Reinald GONZÁLEZ, Francesc CABALLÉ, Pere ROCA, «Les basíliques gòtiques barcelonines: trets comuns i diferencials», *El gòtic meridional català: cases, esglésies i palaus*. Barcelona, Clavell Cultura, 2009, pàg. 85.

5. A manca de confirmar la composició precisa del morter de la capella, disposem de les anàlisis de micromostres realitzades per CETEC Patrimoni en relació amb la tomba de la reina i que han estat observades *de visu* a la capella: CETEC PATRIMONI, «Estudi analític per a la determinació dels materials i de la tècnica pictòrica del monument funerari de la Reina Elisenda de Montcada. Monestir de Pedralbes» (inèdit, dipositat al Reial Monestir de Santa Maria de Pedralbes).

Like the other walls of the monastery, the entire chapel interior is covered with a coat of extremely smooth white plaster made of lime and aggregate. The composition of this underlying mortar seems to be the same as that of the mortar used in the tomb of Queen Elisenda, a space which lies alongside the chapel, namely lime with finely granulated marble powder and a bit of quartz and jasper.⁵ The chapel contains two very similar layers of mortar. The inner layer is four millimetres thick and the outer layer is barely one millimetre thick and perfectly smooth, confirming that it served as an outer coating.

The *sinopia* (preparatory design) was done on top of this impeccably smooth surface. A snap line was used to trace the designs and yellow ochre, and red pigments were subsequently applied using a paintbrush. Next, the plaster was roughened to make it easier to apply the mortar for the new *giornate*, which would be painted using the fresco technique. This plaster coat is approximately four millimetres thick and is comprised of lime; the silicon aggregate contains a more varied assortment of minerals than the underlying layer, and also has small

5. Although we did not test the exact composition of the mortar in the chapel, a visual observation corroborated the results CETEC Patrimoni found in analysing microsamples from the tomb of the queen. See CETEC PATRIMONI, «Estudi analític per a la determinació dels materials i de la tècnica pictòrica del monument funerari de la Reina Elisenda de Montcada. Monestir de Pedralbes» (unpublished, available at the Monastery of Saint Mary of Pedralbes).



Desplegament de la capella amb la reconstrucció de la decoració de marbres fingits de l'arrimador, obtinguda a partir de les dades de l'estudi

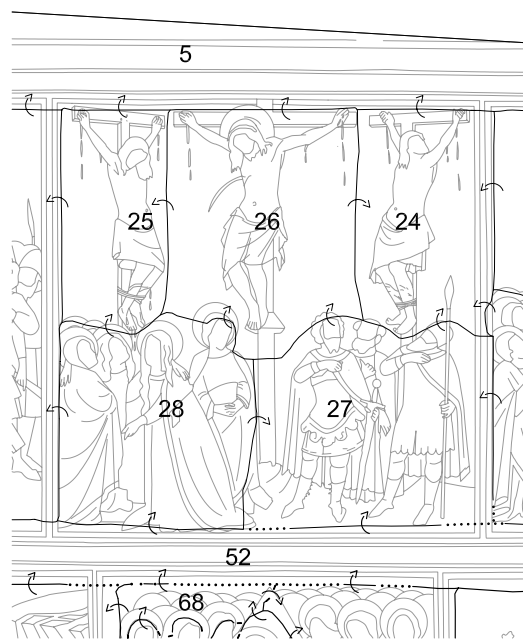
Reconstructed view of the chapel with faux marble wainscot. Data from the study were used to create this image

L'enlluït que rep la pintura té un gruix d'uns quatre mil·límetres i és de calç, i conté àrids, de tipus silici, amb un assortiment més variat de minerals que l'estrat preexistent. A més, s'hi observen petits percentatges d'impureses procedents del terreny d'on prové l'àrid, en forma de mica.

Segons l'estudi realitzat, els murals es van executar en 113 *giornate*⁶ i després es van prosseguir al sec emprant diversos procediments (trepmp, oli assecant i altres tècniques o combinacions encara per identificar) i nombroses aplicacions de làmines metàl·liques (daurades i platejades). Tot el programa decoratiu respon a una planificació prèvia perfecta, en la qual s'estableix fer unes parts al fresc i reservar-ne d'altres per fer-les al sec en funció, sobretot, de la compatibilitat dels pigments que es volen utilitzar amb la calç. El sec, de vegades, s'estén sobre una base prèviament pintada al fresc (blaus d'atzurita, veladures) i també algunes làmines metàl·liques.⁷

6. Rosa SENSERRICH, Lídia FONT, «La planificació del treball al fresc en les pintures que decoren la cel·la de Sant Miquel del Monestir de Pedralbes», *Quaderns tècnics del MHCB*, 2, 2007, pàg. 24-43.

7. Els blaus d'atzurita s'estenen sobre dos tipus de fons o bases diferents (de color gris per als cels i de vermellós per als motius geomètrics de la sanefa). Alguns motius dels vestits estan pintats al fresc amb un roig òxid de ferro i completats al sec amb to vermelló, o els colors verds clars dels mantells, que estan acabats amb una laca de tonalitat més càlida. Així mateix, les làmines metàl·liques d'alguns nimbes s'apliquen sobre una base ocre pintada al fresc, com també les transparències d'alguns motius de la indumentària dels personatges més destacats. Aquestes veladures es treballen, indistintament, sobre bases fetes al



Delimitació de les cinc *giornate* amb què es va executar l'escena de la Crucifixió, amb la numeració que indica l'ordre amb què es concatenen

The five *giornate* depicting the Crucifixion; numbers reflect the order in which the sections were connected

percentages of impurities (mica) as a result of the source of the aggregate.

Our study revealed that the paintings were spread out over 113 *giornate*.⁶ Afterwards, a second *a secco* layer was added using a variety of techniques (tempera, drying oils, and other techniques and combinations we have yet to identify) and gold and silver metal leaf was applied. The decoration reflects a perfectly planned design whereby some portions of the paintings would be painted using the fresco

6. Rosa SENSERRICH, Lídia FONT, "Fresco Work Plan in the Paintings of the Saint Michael's Cell at Pedralbes Monastery", *Quaderns tècnics del MHCB*, 2, 2007, p. 24-43.

Tant al fresc com al sec, la pintura es realitza majoritàriament per capes i seguint la premissa tècnica d'aplicació de gras sobre magre, que garanteix una bona adhesió.

En l'aplicació al fresc se segueixen també pautes per aconseguir els efectes desitjats, com ara pintar els rostres amb *verdaccio* de les dues maneres que recull Cennino Cennini en el seu tractat.⁸

Les capes de pigment diluït en aigua o mesclades amb una mica de *bianco di San Giovanni*⁹ (blanc de calç) se succeeixen damunt el morter humit i en conjunt donen un fresc amb una certa pastositat, tal com es pot observar precisament als rostres, que es conserven en unes condicions òptimes. Pel que fa a la pintura al sec, en aquestes pintures murals es treballa amb una gran riquesa de procediments que impliquen la presència de diversos materials orgànics que, en alguns llocs, arriben a adquirir un gruix i una densitat considerables. Els materials orgànics que ha estat possible determinar són:¹⁰ l'oli de llinosa, elements proteics d'origen animal i resines terpèniques entre les quals s'ha identificat la colofònia.

No es poden descartar les mescles de l'oli amb altres substàncies per formar tremps

fresc o al sec, i en capes molt primes.

8.«Poi abbi un pennello aghuzo di vaio, e va' rifermando bene ogni contorno, naso, occhi, labri e orecchie, di questo verdaccio. Alchuni maestri sono che adesso, staendo il viso in questa forma, tolghono un poco di bianco sangiovanni stemperato con acqua e vanno cerchando le sommità e rilievi del detto volto, bene per ordine; poi danno una rossetta ne'labri, e nelle ghote chotali meluzine; poi vanno sopra con un poco d'acquerello, cioè incharnazion ben liquida, e rimane colorito, tochandolo poi sopra i rilievi d'un pocho di bianco. È un buon modo. Alchun campeggia il volto d'incharnazione prima, poi vanno ritrovando con un poco di vedaccio e incarnazione, tochandolo con alchuno bianchetto; e riman fatto. Questo è un modo di quelli che sanno pocho dell'arte; ma ttieni questo modo di ciò che tti dimosterrò del colorire, però che Giotto, el gran maestro, tenea chosi». Cennino CENNINI, *Il libro dell'arte*, a cura di Fabio Frezzato, Vicenza, Neri Pozza Editori, 2003, LXVII, pàg. 114.

9. El *bianco di San Giovanni* és un pigment blanc, imprescindible per a la pintura al fresc del Trecento, emprat sol o barrejat amb altres pigments per fer gradacions cromàtiques. Es fabricava a partir de la calç amarada, amassant-la en forma de petits panets i deixant-la assecar a la intempèrie. La seva composició, bàsicament carbonat de calç, contenia també diferents percentatges d'hidròxid de calç, el qual conservava el seu caràcter lligant i afavoria una mínima carbonatació dels pigments amb què es mesclava.

10. En aquest sentit, són prou conegudes les dificultats per a la determinació precisa dels lligants orgànics a causa de l'envelliment dels materials, la presència de mescles de més d'un aglutinant o les aplicacions posteriors d'altres productes que emmascaren els materials originals. Per anar obrint camí s'han analitzat les imatges obtingudes de la fluorescència induïda per UV (amb làmpades UV Osram i càmera Linhof Technika amb filtre Kodak Wratten 2E, groc) i s'han realitzat anàlisis d'algunes micromostres amb diverses tècniques instrumentals.

technique and others would later be painted *a secco*; this approach was based especially on whether or not the pigments to be used were compatible with lime. Sometimes both the *a secco* layer and metal leaf were applied on top of a fresco layer (azurite blue, glazes).⁷

For both fresco and *a secco* painting, the majority of paint was applied in layers. The "fat over lean" approach was used to ensure good paint stability. The fresco sections were also based on technical guidelines; for example, faces were painted with *verdaccio* in the two ways Cennino Cennini describes in his treatise.⁸

These layers of pigments were diluted in water or mixed with a bit of *bianco di San Giovanni*⁹ (lime white) and applied on the wet plaster. In general, they provided a fresh, somewhat thicker appearance, as we can see in the faces, which have been excellently preserved. The *a secco* portions of these murals were painted using a rich variety of processes which utilised various

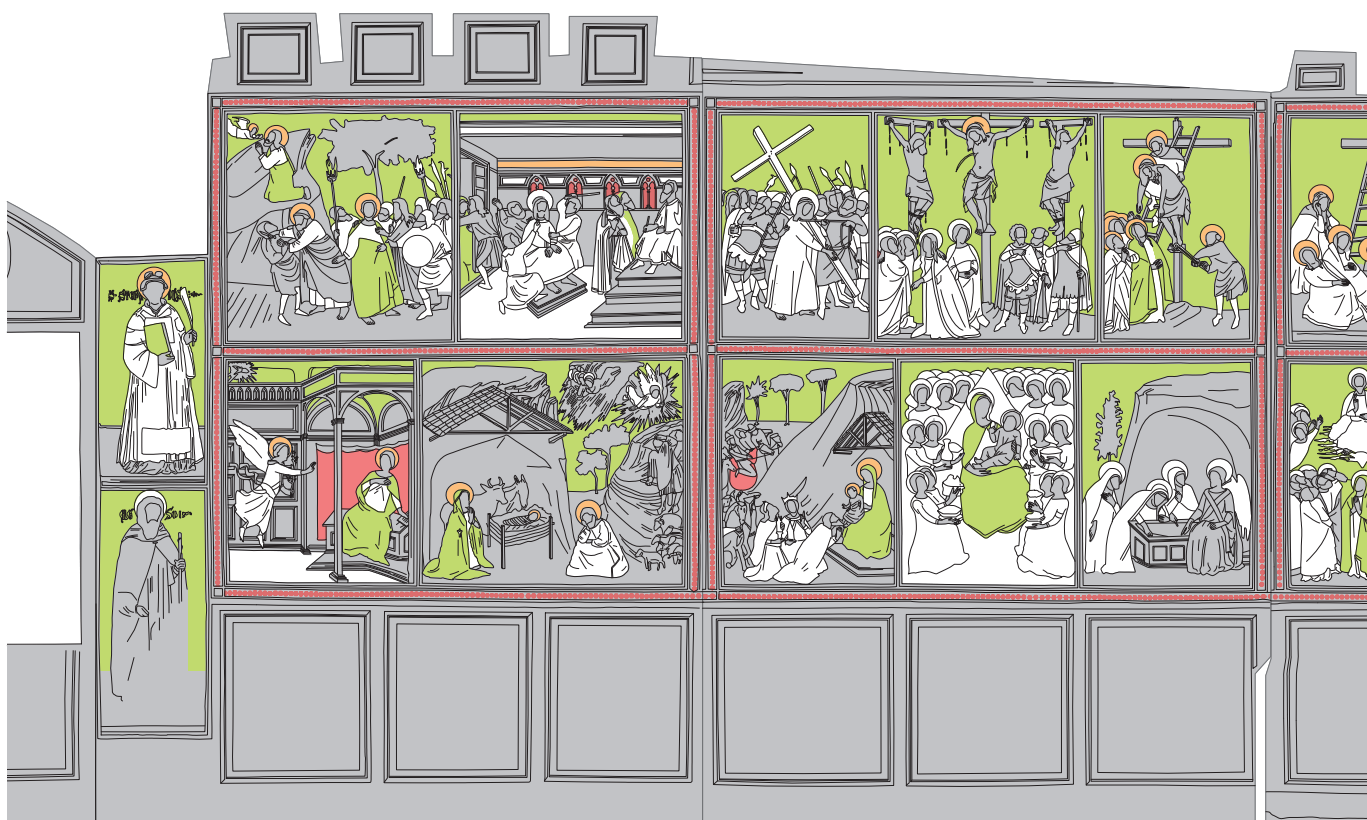
7. Azurite blues were applied over two different undercoats or background layers (a grey layer in the case of the ceilings and a yellowish layer for the geometric motifs of the friezes). Some clothing motifs were painted in fresco using a red iron oxide and finished *a secco* with vermilion. The light green of the cloaks was embellished with a warmer-coloured lake. The metal leaf in some aureoles was also applied to an ochre undercoat that had been painted in fresco; this was also the case with the transparent glaze in some motifs in the most important figures' apparel. All of these glazes were applied very thinly over layers painted using both the fresco and *a secco* techniques.

8.«Poi abbi un pennello aghuzo di vaio, e va' rifermando bene ogni contorno, naso, occhi, labri e orecchie, di questo verdaccio. Alchuni maestri sono che adesso, staendo il viso in questa forma, tolghono un poco di bianco sangiovanni stemperato con acqua e vanno cerchando le sommità e rilievi del detto volto, bene per ordine; poi danno una rossetta ne'labri, e nelle ghote chotali meluzine; poi vanno sopra con un poco d'acquerello, cioè incharnazion ben liquida, e rimane colorito, tochandolo poi sopra i rilievi d'un pocho di bianco. È un buon modo. Alchun campeggia il volto d'incharnazione prima, poi vanno ritrovando con un poco di vedaccio e incarnazione, tochandolo con alchuno bianchetto; e riman fatto. Questo è un modo di quelli che sanno pocho dell'arte; ma ttieni questo modo di ciò che tti dimosterrò del colorire, però che Giotto, el gran maestro, tenea chosi». Cennino CENNINI, *Il libro dell'arte*, a cura di Fabio Frezzato, Vicenza, Neri Pozza Editori, 2003, LXVII, p. 114. (Cennino CENNINI, *The Craftsman's Handbook. The Italian "Il Libro dell'Arte"*. Translated by Daniel V. Thompson, Jr. New York: Dover Publications, Inc. 1933).

9. *Bianco di San Giovanni* is a white pigment. It was a crucial part of 14th-century fresco paintings, where it was used on its own or mixed with other pigments to produce shades of colours. It was produced from slaked lime, which was formed into small cakes and left to dry in the open. Comprised predominantly of calcium carbonate, it contained varying percentages of calcium hydroxide, which helped it to serve as a binding agent and minimised carbonatation of the pigments with which it was mixed.

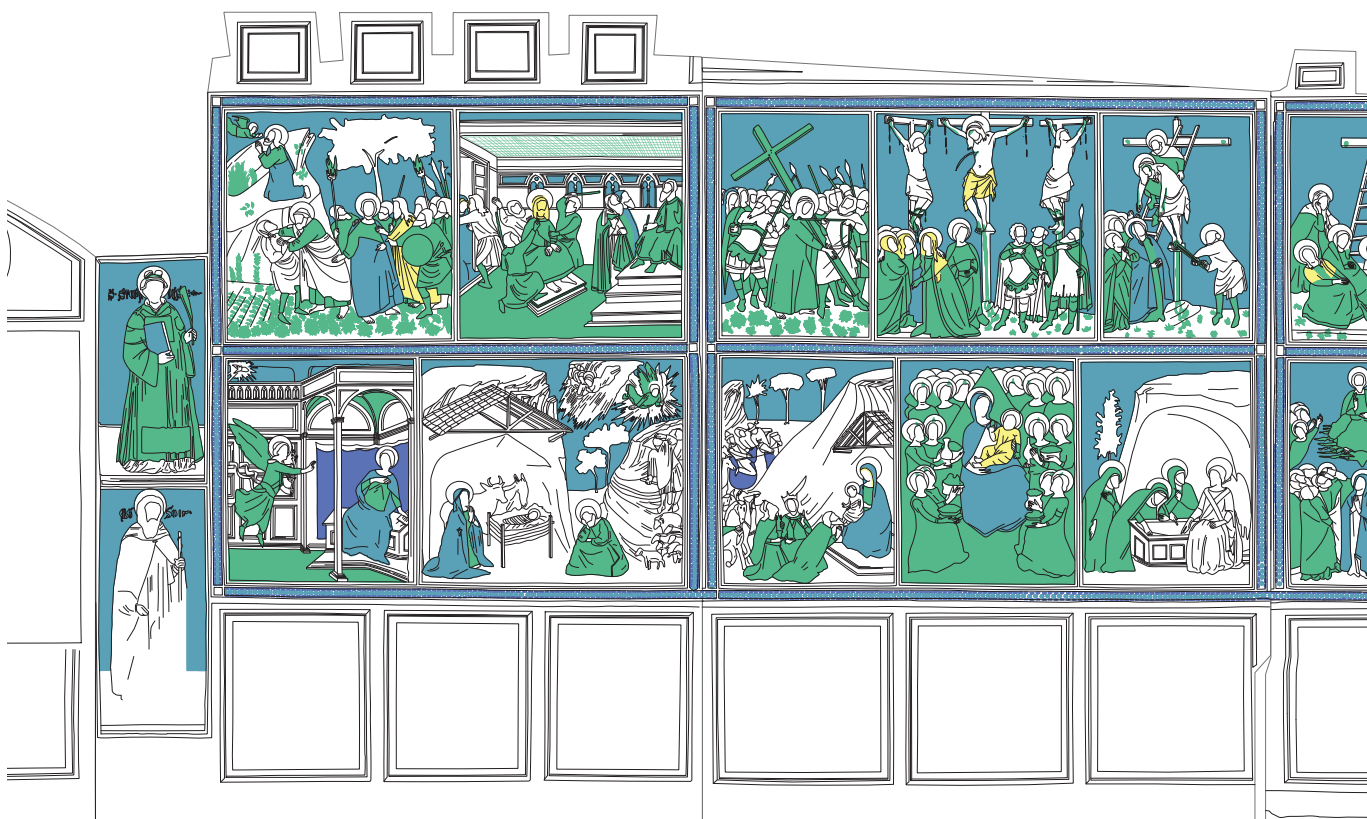
Mapa de les àrees pintades al fresc i al sec, respectivament. Les zones pintades amb tècnica mixta apareixen tan en una fase com en l'altra

Map of the fresco and *a secco* sections. Areas painted with both techniques appear in both phases



MAPA FASE FRESC (PINTURA CARBONATADA)

- PINTURA CARBONATADA (FRESC I RETOCS DE CALÇ)
- BASE GRIS (PER A LATZURITA AL SEC)
- BASE ROIG-OXID-DE-FERRO FOSC (PER A LATZURITA AL SEC)
- BASE OCRE (PER A LA LÁMINA METÀL·LICA)
- BASE ROIG-OXID-DE-FERRO PER AL CINABRI AL SEC



MAPA FASE SEC (AGLUTINANTS ORGÀNICS)

- PINTURA AL SEC
- PINTURA AL SEC: ATZURITA (PIGMENT BLAU)
- PINTURA AL SEC: TRANSPARÈNCIES
- PINTURA AL SEC: CINABRI SOBRE BASE FRESC

PRODUCTES ORGÀNICS / ORGANIC MATERIALS

<p>OLI DE LLINOSA</p> <ul style="list-style-type: none"> • Usat com a aglutinant de pigments i laques, i puntualment, com a estrat aïllant entre colradures i capes pictòriques als esgrafiats sobre làmines metàl·liques. • Adhesiu entre les làmines metàl·liques dobles (estany-plata). • Component principal de l'adhesiu oleoresinós que fixa les gruixudes làmines metàl·liques d'estany a la superfície mural. 	<p>LINSEED OIL</p> <ul style="list-style-type: none"> • It was used as a binder for pigments and lakes, and from time to time, as an insulant between gold-tinted varnish (yellow glazing) applied over metal leaf and the pictorial layer for the sgraffiti on metal leaf. • It was also used to bind sheets of tin and silver leaf. • It was the primary component in the oleoresinous adhesive used to attach the thick tin leaf to the painted surface.
<p>ELEMENTS PROTEICS D'ORIGEN ANIMAL</p> <ul style="list-style-type: none"> • Usats com a aglutinants de pigments i com a adhesius de les làmines metàl·liques simples i fetes amb metalls nobles (plata i or). 	<p>ANIMAL PROTEINS</p> <ul style="list-style-type: none"> • They were used to bind pigments and attach noble metal leafs (silver and gold).
<p>RESINES TERPÈNIQUES SENSE ESPECIFICAR</p> <ul style="list-style-type: none"> • Component de les colradures aplicades sobre algunes làmines metàl·liques. 	<p>UNIDENTIFIED TERPENE RESINS</p> <ul style="list-style-type: none"> • They were used as part of the gold-tinted varnish (yellow glazing) applied to some metal leaf.
<p>RESINES TERPÈNIQUES: COLOFÒNIA</p> <ul style="list-style-type: none"> • Identificada com a segon component de l'adhesiu oleoresinós que adhereix les làmines metàl·liques d'estany –més gruixudes– a la superfície mural. • Identificada, puntualment, com a capa aïllant entre estrats pictòrics i les laques verdes aplicades al damunt. 	<p>TERPENE RESIN: GREEK PITCH</p> <ul style="list-style-type: none"> • It was the second ingredient in the oleoresinous adhesive used to affix the thicker tin leaf sheets to the painted surface. • It was occasionally used as an insulating layer between pictorial layers and the green lakes applied to them.

Imatge de la fluorescència visible induïda per radiació ultraviolada de l'escena del Triomf de la Verge. Les diferències de color i intensitat orienten sobre la presència de productes orgànics corresponents a la pintura original i als retocs posteriors

Ultraviolet-induced visible fluorescence image of the Triumph of the Virgin. Colour and intensity differences reflect organic products in the original painting and in subsequent touch-ups

grassos,¹¹ ni la presència d'algun altre aglutinant orgànic encara per determinar, com podria ser el que lliga el colorant blau d'indi amb el qual es pinten plantes i delicats motius vegetals.

S'ha de fer esment de la identificació de l'oli de llinosa en alguns estrats superiors dels vestits i mantells d'alguns personatges pintats amb la tècnica de superposició de capes: l'emprimació acolorida inferior s'acaba d'ajustar amb l'aplicació d'una veladura a sobre, que li aporta un cromatisme més ric i sofisticat. Aquests estrats semitransparents o laques estan fets amb colorants vermells o pigments verds de diferents tonalitats, probablement molts en oli de llinosa,¹² i aplicats sobre unes

organic materials; these tend to be rather thick and dense in some places. We identified the following organic materials in the work:¹⁰ linseed oil, animal proteins, and terpene resins including Greek pitch.

Oil was also mixed with other substances to make thick tempera.¹¹ Furthermore, the paintings contain other organic binding agents we have yet to identify, such as the one mixed with indigo blue to paint plants and delicate plant motifs.

It should be noted that linseed oil was used in some of the upper layers of the clothing and cloaks worn by figures painted using various superimposed layers; the coloured

10. The challenges entailed in determining the exact composition of organic binding agents are well known; they are related to the ageing process of different materials, the use of mixtures including more than one thickener, and later applications of products which covered up the original materials used. To help unravel some of these challenges, we analysed the images collected using UV fluorescence (with Osram UV lamps, a Linhof Technika camera and a pale yellow Kodak Wratten 2E filter) and tested microsamples using several instrumental techniques.

11. In fact, our analysis of the joint cover strips in the chapel's beams reveal evidence of such a mixture of materials. The rafters and walls were painted at the same time and so a highly similar painting technique was used. For example, lime white was applied to the edges of the beams. Consequently, we can assume that the substances identified on the beams could also have been used on some parts of the walls.

11. De fet, les anàlisis de la tècnica emprada als tapajunts de l'embigat de la capella donen aquesta mescla de materials. L'embigat i els murals es fan al mateix temps, de manera que la pintura sobre fusta té moltes connexions amb allò que es fa al mur. A les arestes de les bigues, per exemple, s'hi aplica el blanc de calç. Per tant, es pot suposar que, a la inversa, el que es detecta a les bigues podria haver estat aplicat, en part, als murs.

12. El tractat de Cennini recull, en diferents capítols, l'ús de l'oli de llinosa com a medi per moldre qualsevol pigment que serà aplicat amb el procediment a l'oli. També s'utilitza l'oli de llinosa per moldre el verd de coure i poder executar veladures sobre làmines d'estany o per moldre pigments assecants i preparar, afegint-hi una mica de vernís, els mordents adequats per adherir làmines fines d'or o plata. CENNINI, *Il libro...*, LXXXXIII, pàg. 131, LXXXXVIII, pàg. 134, CLI, pàg. 173-175.



bases opaques de tonalitats diverses (blanques, vermelles, verd-blavoses).

En el cas de les laques verdes, s'ha constatat que el pigment verd de coure¹³ amb el qual estan confeccionades no està, *a priori*, mesclat amb cap resina, com ocorre amb el color conegut tradicionalment com a «resinat de coure», utilitzat profusament per fer veladures en la pintura de cavallet als segles XV i XVI. Actualment, però, se sap que aquest color es podia obtenir barrejant el *verdigris* amb diferents medis, no solament resinosos, sinó també amb barreges d'olis i resines o solament amb olis, com podria ser aquest cas. Alguns autors¹⁴ han identificat un verd d'aspecte transparent i de caràcter resinós en manuscrits il·luminats dels segles VIII al XV. La recepta del capítol CLI del tractat de Cennini per a l'elaboració d'un mordent en calent sembla seguir el mateix procés que el d'obtenció del resinat de coure, la qual cosa fa pensar que possiblement ja es coneixia abans del segle XV.

Hi ha indicis que algunes terres vermelles van ser aplicades al sec amb un aglutinant proteic, la qual cosa demostraria el coneixe-

primer underneath was finished off with a layer of glaze, imbuing it with a richer, more sophisticated colour palette. These semi-transparent layers and lakes were made using a variety of shades of red colourants and green pigments, which were probably ground up and mixed into linseed oil.¹² These were applied over opaque bases in a variety of hues (including whites, reds and blue-greens).

We found that the *verdigris*¹³ pigment used to make green lakes was not *a priori* mixed with resins, as is the case with the colour traditionally known as copper resinate, which was used extensively as a glaze in 15th and 16th century easel painting. We now know that this colour could be obtained by mixing *verdigris* with a variety of different media, including not only resins but also oil and resin mixtures and oil itself, which may have been the case in this work. Some authors¹⁴ have

13. El verd de coure o *verdigris* és un pigment que no té una única composició química, sinó que pertany a la família dels acetats de coure, amb lleugeres variacions i canvis de tonalitat —verds més freds o més càlids— segons els components que intervenen en el seu procés d'obtenció.

14. Arthur P. LAURIE, *The Pigments and Mediums of the Old Masters*. Londres, Macmillan and Co., Ltd., 1914, pàg. 35-39; François FRIEDLER, «Mise au point des techniques d'identification des pigments et des liants inclus dans la couche picturale des enluminures des manuscrits», *Studies in Conservation*, XIII, 2, 1968.

12. In several chapters, Cennini discusses how nearly every pigment to be applied using linseed oil can be ground with this oil. Linseed oil could also be used to grind copper green, glaze sheets of tin or grind drying pigments. A bit of varnish was added to prepare the mordant needed to affix thin gold or silver leaf. CENNINI, *Il libro*, LXXXIII, p. 131, LXXXVIII, p. 134, CLI, p. 173-175.

13. *Verdigris* (copper green) belongs to the family of copper acetates and can have a varying chemical composition. The elements used to make each copper acetate give rise to small variations in colours and hues, producing cooler or warmer greens.

14. Arthur P. LAURIE, *The Pigments and Mediums of the Old Masters*, London, Macmillan and Co. Ltd., 1914, p. 35-39; François FRIEDLER, "Mise au point des tech-

LES LÀMINES METÀL·LIQUES / METAL LEAVES

Tipus de làmines / Type of leaves

DAURAT Gold gilding	PLATEJAT Silver gilding
Doble làmina Sn /Ag - colrada <i>Double leaf Sn /Ag - varnished</i>	Doble làmina Sn/Ag <i>Double leaf Sn /Ag</i>
Làmina simple Ag - colrada <i>Single leaf Ag - varnished</i>	Làmina simple Ag <i>Single leaf Ag</i>
Làmina simple Au <i>Single leaf Au</i>	Làmina simple Sn <i>Single leaf Sn</i>

Maneres de treballar les làmines / Different techniques for working on metal leaf



a, b, c, d) Làmina metàl·lica llisa: amb o sense colra

e) Treball amb punta dura que multiplica els reflexos de la llum

f) Marques gravades amb un punxó de punta circular

g) Rajos d'un nimbe fets a motlle i aplicats després sobre el mur amb un adhesiu

h) Relleu –molt poc pronunciat– fet a base d'unes pinzellades fetes amb calç fluida per simular uns rajos del nimbe. Després s'adhereix una fina làmina de plata colrada

i) Superfície en relleu en negatiu obtingut mitjançant la pressió amb un bastonet

j) Cas únic de nimbe fet en relleu amb morter de calç i sorra (Sant Esteve) que sobresurt uns 6 mm. de la superfície mural

k) Sanefa que s'adhereix: làmina d'estany colrat que ha estat prèviament decorada amb uns motius quadrilobats pintats vermells i negres

l) Motius quadrilobats pintats en negre sobre làmina d'estany

m, n) Esgrafiat: la policromia aplicada a l'oli sobre l'estany ha estat raspada amb una punta fina: les ales dels àngels a l'escena del Triomf de la Verge, gerres que porten els àngels de l'escena del Triomf de la Verge

a, b, c, d) Smooth metal leaf: varnished or not

e) Incised lines which multiply reflections created using a stylus

f) Marks made with a circular punch on metal

g) Moulded relief applied to the wall using an adhesive to simulate rays around the aureole

h) Very minimal relief made with weak lime brushstrokes and applied using a paintbrush to simulate rays around the aureole. Later, thin silver leaf was varnished to these.

i) Area with negative relief created by pressing with cotton wool and following a radial design

j) A single aureole relief made with lime and sand mortar (Saint Stephen); the relief protrudes 6 mm from the wall

k) Decorative frieze of the architecture. Tin leaf was decorated with red and black quadrilobate motifs and affixed to the frieze

l) Red and black quadrilobate motifs on tin leaf

m, n) Sgraffito where the polychromy applied to oil on tin was scratched using a thin point. This is visible in the wings of the angels in the scenes depicting the Triumph of the Virgin and in the enamel on metal in the jars carried by the angels in the Triumph of the Virgin

Taula amb les diferents maneres de treballar les làmines metàl·liques dobles i simples

Table: Different techniques for working on single and double metal leaf

ment de la incompatibilitat d'aquest pigment amb els olis assecants, perquè els components metàl·lics del ferro no es mesclen bé en l'oli i són assecants pobres o dèbils que s'hidrolitzen al marge de quines siguin les condicions ambientals. També hi ha indicis d'un material proteic per treballar al tremp als estrats fets amb atzurita, i molt probablement en molts detalls acabats al sec.

Els daurats i platejats són un compendi de tota mena de recursos decoratius que donen idea de la gran riquesa d'aquests murals a l'hora de destacar les decoracions dels teixits i les architectures o per simular objectes de metall. S'obtenen, majoritàriament, amb làmines d'estany soles o com a suport d'una làmina més prima de plata, essent l'adhesiu que les uneix entre si l'oli de llinosa.¹⁵ La doble làmina d'estany-plata de vegades està envernissada, probablement amb una colradura, per simular l'or, com a la major part dels nimbes i alguns filets decoratius que perfilen les vores dels mantells. No obstant, en el cas dels nimbes el tractament de relleu de la capa subjacent amplia la varietat d'efectes òptics que s'aconsegueixen amb l'aplicació del metall.

Algunes d'aquestes maneres de treballar el relleu —utilitzant el pinzell, la punta metàl·lica o el punxó— ens remetent al procés d'execució de les decoracions rellevades dels retauls, com també a l'ús poc habitual d'adhesius aquosos per a l'aplicació de les làmines metàl·liques més primes: ho veiem a les lletres daurades dels noms dels sants o els cascs de plata dels soldats, en diverses escenes del cicle de la Passió. En canvi, sota les puntes de les llances —elaborades amb làmina d'estany simple, retallada, adherida al mur i treballada després amb punta metàl·lica— s'entreveu la gruixuda capa de l'adhesiu oleoresinós que es va emprar per fixar el metall a la superfície.

No totes les làmines metàl·liques primes (or i plata), però, semblen haver estat aplicades utilitzant adhesius aquosos. En ocasions especials, com en l'escena del Triomf de la Verge, l'aspecte d'algunes decoracions molt delicades (per exemple, el fil que subjecta l'ocellet del nen Jesús) semblen estar fetes seguint les indicacions del capítol CLI del llibre de Cen-

15. Cennini parla d'un líquid que denomina *doratura* per adherir el full d'or fi sobre la làmina d'estany. Per la seva descripció, sembla que es tracta d'un mordent que s'ha de deixar assecar bastant abans de superposar-hi la segona làmina metàl·lica. No descriu en cap moment la seva composició. En canvi, uns quants capítols enrere, fa referència a un mordent fet amb una lliura d'oli de llinosa a la qual s'hi afegeix una onça de vernís líquid. El resultat és un bon oli per fer mordents. CENNINI, *Il libro...*, LXXXXVIII, pàg. 134-135, LXXXXI, pàg. 130.

identified a transparent, resinous green in 8th to 15th century illuminated manuscripts. In chapter 151 of his treatise, Cennini sets out a recipe for making mordant using warm oil that appears to follow the same approach used for copper resinate, leading us to believe that the technique for obtaining it may have been known before the 15th century.

It appears that some green earth pigments were applied *a secco* using a protein-based binding agent, demonstrating that this pigment was not compatible with drying oils, since the metallic components in iron do not mix well in oil and are poor, weak drying agents that hydrolyse in some environmental conditions. Moreover, it seems that a protein-based material was utilised for tempera work on layers painted with azurite; it is also likely that these were used in much of the *a secco* detail work.

A wide variety of decorative approaches were employed for the gold and silver accents, underscoring Bassa's wealth of techniques for enhancing fabrics and architectural features and creating the appearance of metal. In general, these effects were created using tin leaf on its own or a thin layer of silver leaf attached to tin leaf using linseed oil.¹⁵ The tin-silver double layer was sometimes varnished, probably with gold-tinted varnish, to simulate gold; this is the case in most of the aureoles and in some gilded decorations on the edges of cloaks. In the aureoles, the range of possibilities for treating the underlying layer increased the number of visual effects that could be created using metal leaf.

Some of these techniques for working on reliefs — using a paintbrush, stylus or punch — bring to mind the process used for decorative reliefs on altarpieces. For example, in both cases, watery adhesives were used to apply thinner metal leaf, a practice which was not particularly common. We can see this in the golden letters in the saints' names or the soldiers' silver helmets in various scenes from the Passion series. On the other hand, we can see the thick layer of oleoresinous adhesive

niques d'identificació des pigments et des liants inclus dans la couche picturale des enluminures de manuscrits", *Studies in Conservation* (London), XIII, 2, 1968.

15. Cennini discusses using a liquid he refers to as *doratura* ("gold size") to affix gold leaf to a sheet of tin. Based on his description, it seems that this mordant needed to be left to dry for a long time before affixing the second sheet of metal leaf. Cennini never explains how this is made. However, a few chapters earlier, he discusses a mordant made with one ounce of liquid varnish for every pound of linseed oil, which produces a good oil for making mordants. CENNINI, *Il libro*, LXXXXVIII, p. 134-135, LXXXXI, p. 130.

nini, on l'elaboració en calent d'un mordent oliós serveix per realitzar treballs molt subtils, pinzellades molt fines que, un cop assolit el grau just d'assecatge, són recobertes amb fulles impalpables d'un metall noble i adaptades posteriorment a la superfície pressionant amb una mica de cotó.

Els teixits llavorats per imitar les teles brocades utilitzant fils metàl·lics també estan decorats amb làmines de metall. En són alguns exemples la túnica de la Verge a l'escena del Coronament; els cortinatges de l'Anunciació i la tela del fons; les decoracions de l'escot, mànigues i cisa dels vestits dels àngels de l'escena més ricament ornada, el Triomf de la Verge. Les tècniques d'aplicació de les làmines metàl·liques emprades pels brocats són dues:¹⁶ en una, l'adhesiu s'aplica sobre la superfície mural amb un pinzell fi, perfilant acuradament els motius que aniran recoberts pel full d'or (com s'ha descrit abans) i en l'altra, la làmina d'estany, retallada apart amb la forma corresponent, porta incorporat al darrere l'adhesiu oleoresinós que serveix per fixar-la directament al mur.

A les pintures de la capella, la làmina d'or apareix més esporàdicament i sempre a base d'un aliatge de molt baixa qualitat,¹⁷ per fer els noms que acompanyen les figures dels sants i, molt probablement (segons apreciacions visuals), en les decoracions tèxtils dels àngels de les escenes més destacades: el Coronament i el Triomf de la Verge. Referent als noms dels sants, la capa que es troba sota la làmina d'or i que dibuixa, amb cal·ligrafia gòtica, els traços de les lletres sobre el fons blau, està composta bàsicament de blanc de plom, sense que s'hi hagi pogut detectar l'aglutinant que acompanya el pigment. La majoria d'aplicacions metàl·liques corresponents als nimbes dels personatges sagrats estan fetes sobre una base pictòrica subjacent de color ocre; a la resta, el metall està en contacte amb el morter blanc.

16. CENNINI, *Il libro...*, LXXXXVI a C, pàg. 133-135.

Cennini, en diversos capítols del seu tractat, explica abastament aquest dos sistemes. Pensem que l'adhesiu incorporat al revers de la làmina d'estany, prèviament retallada sobre una fusta preparada amb el que ell denomina *vernís líquid* (possiblement una barreja d'oli de llinosa i una resina terpènica, amb l'adició o no de gomes, ja que en l'època medieval n'hi havia nombroses fórmules), ha de diferir bastant de l'adhesiu-mordent que s'aplica directament sobre el mur amb un pinzell, el qual ha de ser molt més fluid, per poder dibuixar amb ell les fines línies i filigranes de les decoracions tèxtils.

17. L'aliatge d'aquesta fina làmina daurada és el següent: 39% Au - 40% Ag - 21% Cu. No es tracta, doncs, d'una làmina d'or fi ni compleix les proporcions habituals en què es troben els seus aliatges, sempre amb una quantitat d'or superior a la dels altres metalls.

that was used to attach the metal to the surface underneath the tips of their spears, which were made of simple tin leaf that was cut and affixed to the wall and then shaped using a stylus.

However, not all of the thin metal leaf (gold and silver) seems to have been applied using watery adhesives. In a few special cases, such as the scene depicting the Triumph of the Virgin, some exceptionally delicate decorations (e.g. the thread by which baby Jesus is holding the bird) seem to have been painted following the instructions in chapter 151 of Cennini's book. Here, he describes making a warm oil-based mordant for highly detailed work – fine brushstrokes that dry to just the right degree and are then covered with thin sheets of noble metal and pressed on with a bit of cotton so that they fit the surface.

Fabrics that used metal thread to imitate brocade were also decorated with metal leaf. Examples can be found in the Virgin's tunic in the Coronation scene, in the drapery in the Annunciation scene, and in background fabric, the decorative work on the neckline, sleeves and armhole in the most richly decorated scene, the Triumph of the Virgin. Two different techniques were used to apply metal leaf to the brocade.¹⁶ In the first technique (described earlier in this chapter), the adhesive was applied to the painted surface using a thin paintbrush, carefully tracing the motifs that would be covered in gold leaf. In the second, tin leaf was cut into the appropriate shape, the oleoresinous adhesive was spread on its back, and the leaf was affixed directly to the wall.

Gold leaf was utilised much more sparsely than other kinds of metal leaf in the chapel, and the gold that was used was of a very low quality alloy.¹⁷ Gold leaf was employed for the names accompanying the figures of the saints, and was probably also used in the decorations on the angels' clothing in the most important scenes, the Coronation and

16. CENNINI, *Il libro*, LXXXXVI - C, p. 133-135. In several chapters of his treatise, Cennini explains these two systems in great detail. In the latter case, the tin sheet was cut on a specially prepared piece of wood coated with what Cennini referred to as "liquid varnish". This was possibly a mixture of linseed oil and terpene resin, which may or may not have contained gum; various formulae were used in the mediaeval era. We believe that this adhesive must have been significantly different from the mordant painted directly on the wall with a paintbrush; a much more watery mordant was needed to paint the fine lines and filigree work used to decorate the fabrics.

17. This thin gold-coloured sheet had the following composition: 39% Au - 40% Ag - 21% Cu. Therefore, it was not a sheet of fine gold, as it did not observe the normal proportions for gold alloys, where the quantity of gold is always greater than that of the other metals.

Detall del despreniment del pigment vermell d'una franja que emmarca les escenes, a causa d'una deficient carbonatació

Detail of the red pigment in a border framing the scenes; this was caused by poor carbonatation



Finalment, les làmines metàl·liques poden ser policromades, com és el cas de la sanefa decorativa de l'escena dels Improperis o de les ales de l'arcàngel Gabriel en l'Anunciació i algunes de les ales dels àngels a l'escena del Triomf de la Verge, decorades *in situ* amb la tècnica de l'esgrafiàt.

Els tractaments posteriors

Els quasi set segles que ens separen de l'execució dels murals han propiciat diverses intervencions, realitzades de manera parcial o més generalitzada, per pal·liar els danys que han sofert les pintures al llarg del temps, sia per filtracions d'aigua o per cops o pèrdues, per l'obertura de finestres, pel despreniment de capes pictòriques o per la falta de cohesió d'alguns pigments. Les intervencions més antigues no estan documentades, tot i que es poden observar algunes reintegracions fetes amb pigments molt costosos, com l'atzurita, sobre morters de reposició aplicats en el passat per reomplir alguna pèrdua puntual (escena de l'Ascensió de Crist). Per la informació que ens aporten les fotografies entorn l'any 1906,¹⁸ es dedueix que ja hi havia una part de la pintura original de l'arrimador coberta amb una capa uniforme i de color clar, molt probablement un emblanquinat de calç.

El llibre de Manel Trens¹⁹ és el testimoni més fidedigne, fins a l'actualitat, d'una de les

18. Sèrie de fotografies fetes el 1906 a l'arxiu Mas amb còpies sobre paper conservades a les fitxes d'inventari del Catàleg General del Reial Monestir de Santa Maria de Pedralbes.

19. Manuel TRENDS, *Ferrer Bassa i les pintures de Pedralbes*. Barcelona, Institut d'Estudis Catalans, 1936.

the Triumph of the Virgin. The layer under the gold leaf used to write the names of the saints was comprised basically of white lead, with which the letters were traced out in Gothic calligraphy against a blue background. We were unable to determine which binding agent had been used with the pigment. Most of the gold used to create the aureoles for holy figures — predominantly those located in the upper register — was placed over an underlying ochre-coloured base; in the case of the other figures, the metal was affixed to the white mortar.

Finally, the metal leaf was at times polychromed. This was the case in the decorative frieze in the scene of the Passion of the Christ, in the wings of the Archangel Gabriel in the Annunciation, and in the wings of some of the angels in the Triumph of the Virgin, which were decorated *in situ* using the *sgraffito* technique.

Later conservation treatments

Over the nearly seven centuries that have passed since they were first created, the paintings have been touched up several times. These efforts — which ranged from small-scale to more extensive actions — aimed to address the damage caused over time due to water leaks, buffeting, open windows, loss of the pictorial layers and pigments that did not stay affixed. The earliest renovations were not documented, but some touch-ups are visible. These were done using expensive pigments like azurite, which were applied over replacement mortar to fill in gaps (such as in the scene of the Ascension of Christ).

intervencions de restauració més importants realitzades a les pintures de la capella. Va ser encarregada per Trens al restaurador italià Arturo Cividini, que cap a finals de la dècada de 1920 estava actiu a Catalunya. La seva intervenció, de caràcter general, va ser bastant respectuosa per l'època. Segons Trens, es realitzà una neteja i es feren reviure els colors, i també es va procedir a l'anivellament dels morters dels nombrosos esvorancs practicats al mur i s'efectuà la reintegració cromàtica corresponent. També es va eliminar el presatge continu situat entre els dos registres i es realitzà una repintada generalitzada de l'arrimador i de la part central del pany d'entrada, més malmès, emprant un color gris de tonalitat freda.

L'actuació més recent a la capella ha estat la que efectuà, cap als anys 1951 i 1952, el Servicio de Conservación de Monumentos Históricos de la Diputación de Barcelona, per acabar d'adequar l'espai i fer-lo visitable. Durant aquesta intervenció se cegà una gran obertura no original que hi havia en una de les parets d'un racó de la capella²⁰ i es repintà, una vegada més, la part corresponent a l'arrimador i al pany d'entrada malmès.²¹ Desconeixem si també es va actuar sobre les pintures.

Fruit de tots aquests tractaments fets en el passat, avui en dia es localitza sobre la superfície pintada una cola d'origen animal, aplicada de forma generalitzada. En algunes de les mostres analitzades aquesta capa té un gruix significatiu (fins a 20 micres en algun cas) i, observada amb UV, té fluorescència. També s'ha detectat la presència d'un fixatiu soluble a l'aigua, igualment aplicat per quasi la totalitat de la superfície. Sembla tractar-se d'una goma vegetal, molt probablement una goma aràbiga. Aquests materials filmògens juguen un paper molt important en la conservació perquè agreugen les alteracions vinculades a la tècnica pictòrica que analitzarem tot seguit.

20. A les fotografies de 1906 es veu que aquesta obertura, practicada al mur sud-oest en èpoques passades i que destruï part de la pintura original, s'utilitzava com a armari per penjar les claus del monestir i dipositar altres objectes sobre les lleixes. En els últims temps, la capella havia fet de cel·la abacial fins a l'any 1936, quan es va autoritzar la visita al públic.

21. Aquesta redecoració intenta acostar-se al color verdós i a les formes que tenia l'arrimador al segle XIV i que havien estat coberts per diferents estrats al llarg del temps. La nova capa que s'hi superposa reconstrueix, amb força exactitud, el traçat dels plafons motllurats originals, però no la imitació dels marbrejats de vius colors existents a l'interior dels plafons, deixant-los del color verdós que hi ha, com a base, per tot l'arrimador.

Photographs dating to circa 1906¹⁸ lead us to conclude that some of the original paint on the wainscot was covered with a clear, uniform coat, probably lime whitewashing.

To date, Manel Trens' book¹⁹ has provided the most faithful record of one of the most significant restorations undertaken on the paintings in the chapel. The Italian restorer Arturo Cividini, who was active in Catalonia in the late 1920s, was commissioned to carry out this work by Trens. Cividini's restoration was rather respectful for the era. According to Trens, the painting was cleaned, the colours were brought back to life, the mortar in several gaps was levelled out, and colours in these areas were touched up. The shelf between the two registers was also removed, and the wainscot and central part of the entry wall, which had been more badly damaged, were repainted using a cold, grey colour.

The most recent restoration of the chapel was carried out in 1951 and 1952 by the *Servicio de Conservación de Monumentos Históricos de la Diputación de Barcelona* (Provincial Council of Barcelona's Historical Monument Conservation Service) in order to make the space accessible and open it to visitors. During this restoration, a large opening in one of the walls in the corner of the chapel – an opening which had been added after the piece was first painted – was blocked in²⁰ and the damaged wainscot on the entry wall was again repainted.²¹ We do not know if the paintings were restored in any way.

As a result of these earlier actions, today we find an animal-based glue spread across much of the painted surface. In some of the samples we analysed, this layer is quite thick (up to 20 micrometres); it fluoresces under UV light. We also discovered a water-soluble fixative

18. A wide number of photographs shot in 1906 are available in the Mas Archive; paper copies are preserved in the inventory records in the General Catalogue of the Monastery of Saint Mary of Pedralbes.

19. Manuel TRENS, *Ferrer Bassa i les Pintures de Pedralbes*. Barcelona, Institut d'Estudis Catalans, 1936.

20. This opening was cut into the southwest-facing wall at an earlier time and destroyed part of the original painting. In the 1906 photographs, we can see that it was used as an armoire for hanging the keys to the monastery; other objects were placed on the shelves. In recent years, the chapel had served as a cell for the abbey until 1936, when it was first opened up to the public.

21. This redecoration aimed to reproduce the greenish colour and forms of the wainscot from the 14th century, which had been covered by various layers over the course of time. The new layer painted on top of previous layers was a nearly perfect copy of the original panel mouldings. However, it did not imitate the vibrantly coloured marbling inside the panels, instead leaving them the greenish hue which serves as the base colour for the entire wainscot.

Detall de la manca de cohesió entre pinzellades fetes al fresc de les fulles d'un arbre a l'escena del Prendiment

Detail of leaves painted using the fresco technique that did not bind well. Scene depicting the Arrest of Jesus



Relació entre la tècnica d'execució i les alteracions

Un cop coneixem en profunditat la tècnica i els materials de la pintura mural es poden entendre millor les alteracions que presenta. Els murs de l'església i la bona factura dels morters han estat una garantia de bona conservació. Tot i així, la darrera capa de morter o *intonaco*, aplicada sobre els murs de la capella per pintar directament al fresc, es troba força bufada i separada de l'enlluït preexistent que feia de primer revestiment i que va ser conservat per la seva funció com a pla anivellat. Amb tot, després de passar per diverses vicissituds, relacionades amb obres i remodelacions, la pintura no presenta grans pèrdues per despreniment i els bufats més greus es limiten a les àrees intervingudes, que representen uns deu metres quadrats de la superfície total.

A les capes pictòriques hi ha freqüents alteracions resultants directament de la tècnica d'execució i que es posen de manifest o s'agreuen amb el pas del temps. El temps, per contra, també fa palesa la resistència d'alguns materials a l'envelliment.

En el cas de les pintures murals de la capella, la millor conservació sol coincidir —tret d'algunes excepcions— amb els pigments lligats amb hidròxid càlcic, l'aglomerant inorgànic necessari per a la formació de l'estrat carbonatat en la pintura al fresc. Però fins i tot en aquestes parts més ben conservades s'hi poden llegir alguns senyals, molt localitzats, que revelen l'aplicació de la tècnica d'una manera menys precisa, i que solament després d'estar exposats a nombrosos cicles naturals

that had been applied over virtually the whole surface. It appears to be a natural gum, most likely gum arabic. These two materials have a main role in conservation because they aggravate the alterations related to the painting technique.

The relationships between painting technique and subsequent alterations

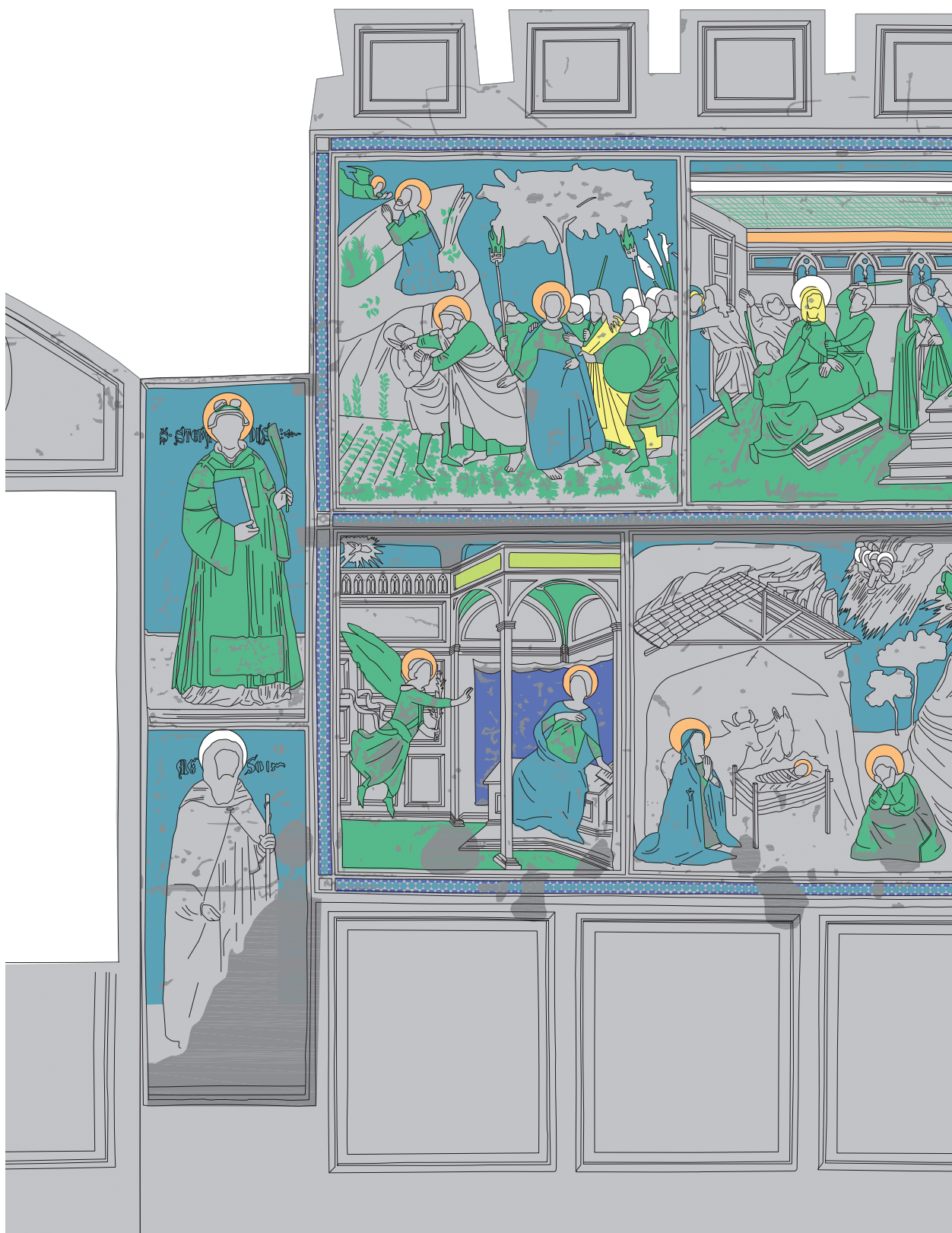
Our in-depth description of the painting technique and materials utilised allows us to better understand the alterations present in the work. The church's walls and well-made mortar helped to guarantee that the piece would be well preserved. However, much of the upper layer of *intonaco*, which was applied onto the chapel walls to paint the fresco, has become detached from the first coat of plaster painted on the chapel walls. Nevertheless, despite the numerous challenges posed by construction and renovations, little of the painted surface has been lost. Rather, the most significant detachment was limited to the areas where previous work was conducted, which account for ten square metres of the total surface area.

The pictorial layers reflect frequent alterations that were a direct result of the painting technique used; these appeared or worsened over the years. Conversely, time has also underscored the fact that some materials were resistant to ageing.

Except for a few isolated cases, the best-conserved parts of the chapel tended to be those areas where pigments were affixed with calcium hydroxide, the inorganic

Mapa de pèrdues de policromia en relació el procediment al fresc i al sec (no s'inclouen les làmines metàl·liques)

Lost polychromy in fresco and *a secco* sections (metal leaf was not included)

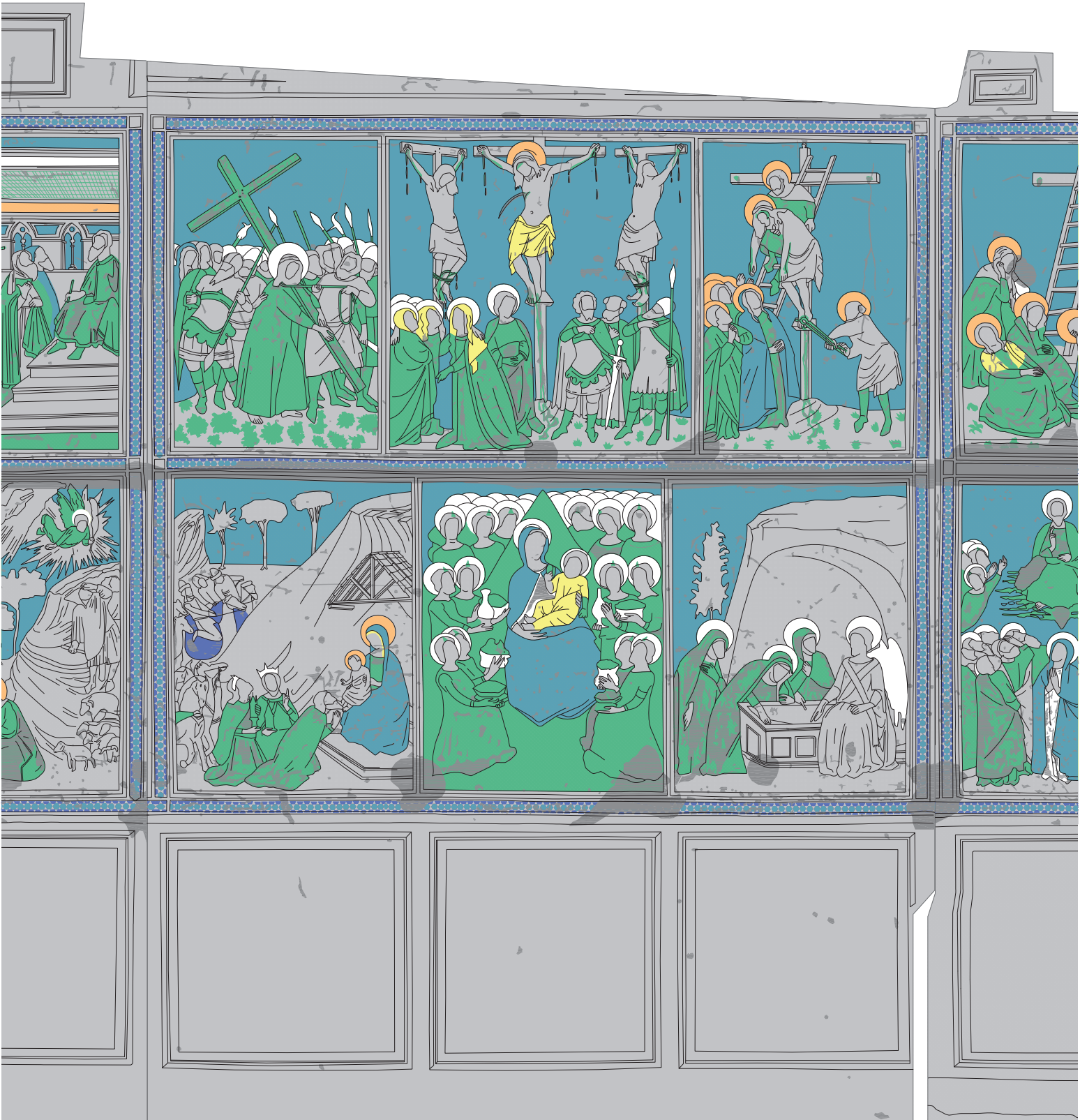


MAPA FASE FRESC (PINTURA CARBONATADA)

- PINTURA CARBONATADA (FRESC I RETOCS DE CALÇ)
- BASE GRIS (PER A L'ATZURITA AL SEC)
- BASE ROIG-ÒXID-DE-FERRO FOSC (PER A L'ATZURITA AL SEC)
- BASE OCRE (PER A LA LÀMINA METÀL·LICA)
- BASE ROIG-ÒXID-DE-FERRO (PER AL CINABRI AL SEC)

MAPA FASE SEC (AGLUTINANTS ORGÀNICS)

- PINTURA AL SEC
- PINTURA AL SEC: ATZURITA (PIGMENT BLAU)
- PINTURA AL SEC: TRANSPARÈNCIES
- PINTURA AL SEC: CINABRI SOBRE BASE FRESC



ALTERACIONS CAPA PICTÒRICA

■ PÈRDUES CAPA PICTÒRICA



Dos exemples del procés de desprendiment de la pintura presumiblement feta a l'oli. Escena dels Impropis i de la pietat

Two examples of painting loss, presumably done in oil. Scene depicting the Passion of Christ and Piety

d'envelliment, han sortit a la llum. Ens referim a les zones amb pigments pulverulents, coincidint pràcticament amb el color vermell òxid de ferro que s'aplica com a fons a l'intradós i en alguns punts de les bandes vermelles que emmarquen les escenes. Aquests traços finals de color intens i saturat, exempt d'hidròxid càlcic, es degueren aplicar, sobre un *intonaco* ja força sec que no va permetre la correcta carbonatació dels pigments al morter, de manera que aquests, dipositats sobre la superfície més que no pas englobats en la matriu de calç, s'han anat desprenent.

Un altre cas de mala adhesió entre capes fetes al fresc és el que té lloc al verd dels arbres (escena del Prendiment), on la superposició de pinzellades denses per simular fulles de diferent tonalitat no està suficientment cohesionada. Segons quin fos el temps transcorregut entre les pinzellades, és possible que es formés un vel fi de carbonat de calci en la superfície de cadascuna que dificultés el procés de carbonatació del conjunt. En aquest cas no s'observa pulverulència, perquè les pinzellades són riques en *bianco di San Giovanni*, però si que es manifesta certa falta d'adhesió entre elles, sobretot en les més superficials. Aquesta descohesió, però, solament es posa en relleu amb l'aplicació, durant alguna intervenció de restauració antiga, d'una substància filmògena de caràcter fixatiu, que propicia l'exfoliació dels estrats.

Com s'ha comentat unes ratlles més amunt, les obres fetes amb tècnica mixta posen en evidència la seva vulnerabilitat perquè el sec utilitza materials orgànics, en contrast amb la millor conservació de les parts fetes al fresc, completament inorgàniques. Una mirada ràpida als murals de la capella de Sant Miquel detecta com un conjunt que ha estat sotmès a les mateixes condicions de conservació ha evolucionat de manera diferenciada. No obstant

binding agent needed for frescoes to carbonate. Yet even in these best-preserved parts of the work, we can pinpoint small signs which demonstrate that the technique may have been followed less strictly; these only came to light after years of the natural ageing process. Concretely, this was the case in areas with powdery pigments, generally those where the iron oxide red colour was applied as a background on the soffit and in some parts of the red borders framing the scenes. These lines of intense, saturated colour, which did not contain calcium hydroxide, must have been applied at the final stage of the process onto relatively dry *intonaco*. As this mortar was too dry for the pigments to carbonate properly, they ended up deposited on the surface rather than embedded into the lime, and therefore were lost over the years.

The green trees in the scene of the Arrest of Jesus are another case where fresco layers failed to bind well to the underlying mortar; here, the overlapping, dense brushstrokes which create an impression of different coloured leaves did not bind fully to the surface. Depending on the time that passed between brushstrokes, a thin layer of calcium carbonate may have formed on the surface of each stroke, preventing the area as a whole from carbonating properly. In this particular case, we did not see any signs of powderiness, since the brushstrokes contain ample amounts of *bianco di San Giovanni*. However, we did see signs of a lack of cohesion between them, especially among the layers closest to the surface. Nonetheless, it should be noted that this lack of cohesion only became an issue when a fixative film was applied to the work's surface during an early restoration, an action that actually caused layers to flake off.



Figura de sant Domninus alterada per una filtració antiga d'aigua

Image of Saint Domninus disfigured by past water leaks

això, la pintura feta amb aglutinants orgànics no sempre està abocada al màxim deteriorament. La seva resistència està supeditada a la força i durabilitat de l'aglutinant mateix, als efectes que aquest introdueix en la porositat de l'*intonaco* i a les condicions d'humitat i temperatura a les quals ha estat exposat i que poden desencadenar processos físics i químics o propiciar l'atac microbiològic.

La cohesió entre els aglutinats grassos o magres i l'*intonaco* depèn de cada tipus de material, essent l'oli, per la seva baixa porositat, el que crea una superfície més impermeable que altera l'intercanvi de vapor d'aigua entre el mur i l'ambient i en propicia el despreniment, sobretot quan es produeixen canvis sobtats i acusats de la humitat relativa.²²

Ara bé, com han afectat les condicions climàtiques el cicle pictòric? Tenint en compte l'abundància de materials orgànics i la tècnica emprada, l'estat de conservació dels murals és més bo del que es podria esperar. En aquest sentit, les característiques físiques de la ca-

22. Això es produeix perquè els murs tendeixen a reequilibrar la quantitat d'aigua amb l'entorn, expulsant l'aigua que contenen quan la humitat ambient és baixa i absorbint-la dins el mur quan és elevada.

As noted above, works made with a mixed technique are vulnerable because organic materials are used to paint on dry surfaces, whereas fresco painting is done with completely inorganic substances, which stood up better to the test of time. A quick glance at the murals in Saint Michael's Chapel shows how different parts of the work evolved differently despite facing identical environmental conditions. However, it should be noted that the parts of the painting done with organic binding agents did not necessarily face serious deterioration. The conservation of these sections depended on the strength and durability of the binding agent, how it affected the porousness of the *intonaco*, and the humidity and temperature to which the section was subjected, which could have a bearing on the physical or chemical processes at play or create a favourable environment for microbiological attacks.

Cohesion between fat and lean binding agents and the *intonaco* depends on the type of material. Since oil is not highly porous, it created a less permeable surface. This affected how water vapour was exchanged between the wall and the environment and favoured



Pigment de coure + oli de llinosa
Copper pigment + Linseed oil

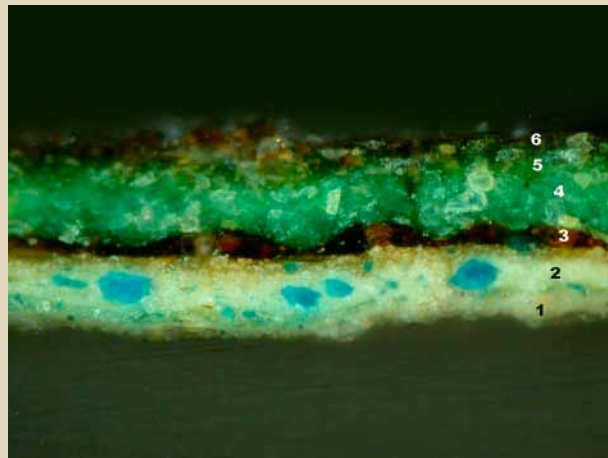
Verdigris, blanc plom, groc de Pb i Sn (m.b.p.), carbonat càlcic (b.p.)
Verdigris, white lead, copper and lead-tin yellow, calcium carbonate

Capa aïllant resina colofònia
Insulating layer of Greek pitch

Blanc de plom, atzurita, groc de Pb i Sn, carbonat càlcic (b.p.)
White lead, azurite, copper and lead-tin yellow, calcium carbonate

(Terra groga, carbonat càlcic)
(Yellow earth, calcium carbonate)

INTONACO / *Intonaco*



ella hi han tingut un paper decisiu. Malgrat tot, l'ús de l'espai al llarg dels anys (obertura i tancament de la porta d'accés i les finestres, engrandiment de finestres i obertura de noves al pany d'entrada, presència de persones a l'interior) ha hagut d'incidir forçosament en les condicions ambientals. A més a més, a l'embigat es detecten rastres d'alguns incidents, com ara regalims i taques d'humitat antigues que podrien haver estat produïdes en el curt període que la capella va estar sota teulada, o pocs anys després, quan aquesta teulada s'elimina i es dota el primer pis d'un forjat pla. També hi

paint loss, especially in cases of sudden, significant changes in relative humidity.²²

How did climatic conditions affect the paintings? Given the abundance of organic materials and the technique employed, the paintings have held up better than we would have expected. The chapel's physical characteristics played a key role in this.

22. This occurs because the walls tend to exist in a state of equilibrium with the environment; they exude water when the humidity levels are low and absorb it when levels are higher.

ha notícia d'un fort temporal que es va produir a finals del segle XVII i va provocar destrosses considerables.²³ Els efectes de l'acció directa de l'aigua als murals es fan palesos als murs situats al sud-est, just en el sentit de desguàs de l'aigua de la coberta: des de l'embigat l'aigua es va escolar i va rentar la policromia, no se sap si durant el temporal.

Més enllà d'aquests episodis excepcionals, l'ús de l'espai generava necessàriament canvis bruscs de la humitat. El clima mediterrani de Barcelona és temperat, però la humitat absoluta pot augmentar les tardes d'estiu amb la brisa marina, i els dies de fort vent del nord l'ambient s'asseca amb rapidesa. En un espai tan reduït només el fet d'obrir i tancar la porta havia d'afectar les condicions climàtiques.²⁴ Així ho confirmen els registres acumulats.

En relació amb la situació dels darrers deu anys, s'han adoptat algunes mesures de protecció, basades en els estudis ambientals realitzats. La porta d'entrada connecta directament amb una petita cabina de metacrilat que permet contemplar les pintures sense incidir en l'ambient, alhora que possibilita una certa ventilació natural controlada. Les finestres estan habitualment tancades i l'entrada d'aire es redueix al seu pas a través de les juntes. L'evolució climàtica a l'interior de la capella és adequada per a la conservació donada l'estabilitat: les oscil·lacions diàries de la temperatura són d'1 °C o com a màxim 2 °C i les de la humitat són d'entre 5 i 7 %.²⁵ Això s'aconsegueix a causa de la inèrcia tèrmica de la capella, i més quan es controla l'obertura de la porta.

No obstant això, les humitats elevades i els cicles adsorció-desorció han trobat

Nevertheless, the way the space was used over the centuries (people opening and closing the door and windows, enlarging the windows and adding new ones to the entry wall, and spending time inside the space) must have had a significant impact. We also found traces of past water seepage and humidity stains on the beams. These may have come to pass during the short period in which the chapel had a gambrel roof, or a few years later, when it was removed and a flat roof was installed in its place. A strong storm in the late 17th century also caused serious damage.²³ We can see the effect of water on the paintings on the southeast-facing wall, right where water drained off the roof. The water ran down from the beams and over the polychrome; we do not know when this took place, but it may well have been during the storm.

Quite aside from these isolated events, abrupt changes in humidity levels would almost definitely have resulted merely from using the space. Barcelona enjoys a temperate, Mediterranean climate, but the sea breeze can cause absolute humidity to increase on summer afternoons, and when the wind blows strongly from the north, the environment can dry out quickly. In such a small space, simply opening and closing the door must have affected climatic conditions.²⁴ Cumulative logs confirmed that this was the case.

Over the last decade, environmental studies have led us to adopt several protective measures. A small Perspex booth at the entrance to the chapel allows visitors to view the paintings without affecting the environment and also provides for a kind of natural, controlled ventilation. The windows are usually closed, and joints reduce

23. *AHCB* (Arxiu Històric de la Ciutat de Barcelona), CONSELL DE CENT, *Deliberacions* II-200, 1691, 12 novembre, f. 298-299, «Donació de les cent lliures acostumades per reparar especialment les destrosses causades per la tempesta del dia 30 d'octubre, l'aigua va arribar fins a l'arxiu i causant desperfectes a l'església, el claustre, el confessionari i moltes parets».

24. En un estudi recent per estimar quins serien els efectes de la presència de tres persones en jornades de vuit hores a l'estiu (emprant focus que incrementen la temperatura de l'interior) s'ha demostrat de manera predictiva el risc d'augment dels nivells d'humitat relativa. En aquestes condicions adverses es comprova que es podrien assolir valors propers a la condensació i fins i tot la condensació mateixa (dies més calorosos de juliol i agost). Santi FERRER, Gema CAMPO, «Estudio sobre las posibles alteraciones en las condiciones de temperatura y humedad en la Capilla de Sant Miquel del Monasterio de Pedralbes durante los trabajos de restauración a realizar en el verano de 2013» (estudi inèdit), 2013.

25. L'any 2011 les mitjanes trimestrals a l'interior de la capella eren: 17,42 °C i 71,37 % d'HR a la primavera; 24,62 °C i 67,69 % d'HR a l'estiu; 17,63 °C i 61,8 % d'HR a la tardor i 12,72 °C i 64,89 % d'HR a l'hivern. Aquestes dades corresponen a l'estudi que el Museu d'Història de Barcelona duu a terme des de l'any 2003.

23. *AHCB* (Historical Archives of the City of Barcelona), CONSELL DE CENT, *Deliberacions* II-200, 1691, 12 November, p. 298-299, «Donació de les cent lliures acostumades per reparar especialment les destrosses causades per la tempesta del dia 30 d'octubre, l'aigua va arribar fins a l'arxiu i causant desperfectes a l'església, el claustre, el confessionari i moltes parets». (Donation of one hundred pounds to repair the damage caused by the storm on 30 October, when the water entered the archive and caused damage inside the church, the cloister, the confessional, and on many walls.)

24. A recent study to determine the effects caused by three people spending time in the space for eight hours during the summer (using lights that increased the inside temperature) predicted that there was a risk that relative humidity levels would increase. These adverse conditions could create a setting ripe for condensation or, on the hottest July and August days, lead to condensation itself. Santi FERRER, Gema CAMPO, «Estudio sobre las posibles alteraciones en las condiciones de temperatura y humedad en la Capilla de Sant Miquel del Monasterio de Pedralbes durante los trabajos de restauración a realizar en el verano de 2013», 2013 (unpublished).

una barrera en el film pictòric al sec o en les làmines aplicades, causant-ne el despreniment, i que els despreniments més severs coincideixen amb estratigrafies pictòriques que estan formades per moltes capes. Tot i així, hi ha excepcions importants, com ara els blaus d'atzurita, que es mantenen sòlidament adherits, probablement per l'ús d'un lligant orgànic resistent a l'oxidació i a la solubilitat en aigua i, molt possiblement també, per certa compatibilitat física amb la part inorgànica de la capa pictòrica o del morter.

Quant als contaminants, els nivells de partícules en suspensió són correctes i no es detecten contaminants gasosos ni concentració de compostos àcids. Pel que fa a l'estat microbiològic, les mostres ambientals donen uns nivells de bacteris i fongs moderats i una bona qualitat de l'aire; al seu torn, les mostres superficials indiquen una contaminació bacteriana escassa i una contaminació fúngica en la qual s'han aïllat majoritàriament espècies que pertanyen als gèneres *Stemphylium* i *Penicillium*.²⁶ Amb tot, no hi ha cap indicatiu que apunti a un procés actiu que suposi cap risc.

A continuació s'exposen amb més deteniment alguns casos que il·lustren la relació entre l'estat de conservació i les alteracions.

Acetat de coure i laca verda a base d'un pigment de coure (oleat?)

La indumentària d'alguns personatges de tonalitat verd fosc, feta a base de *verdigris* (acetat de coure) ha experimentat un procés molt greu de deteriorament. La superfície pictòrica està completament clivellada i les partícules en forma d'escates s'han després progressivament i han provocat grans llacunes. L'alteració afecta el gruix sencer de la pel·lícula pictòrica, de tal manera que la manca de policromia deixa a la vista l'*intonaco*. Una de les àrees més deteriorades correspon al mantell d'una de les figures de l'escena de l'Ascensió de Crist, però això es detecta també a altres punts de la pintura on presumiblement s'ha emprat el mateix pigment i la mateixa tècnica.

Però, quina és aquesta tècnica i quin és el procediment emprat? L'anàlisi estratigràfica revela, sobre el morter, una terra groga corresponent al dibuix preparatori, damunt la qual s'ha estès una capa de to verd clar, seguida d'un gruix de color ambre i, tot seguit, un altre estrat de to verd fosc que gradualment esdevé

the amount of air that enters the chapel. Climatic changes inside the chapel are sufficiently stable for preserving the work: the temperature fluctuates by 1°C per day (or a maximum of 2°C) and humidity is between 5-7%.²⁵ The thermal inertia of the chapel helps to guarantee these conditions, which are even more stable when the frequency with which the door is opened is limited. Nonetheless, it should be noted that the *a secco* pictorial film and metal leaf shielded the work from the effects of high humidity and the absorption-desorption cycle, but were therefore lost as a result. The most severe damage occurred in pictorial strata comprised of multiple layers. Nevertheless, there were several major exceptions, including azurite blues; these remained solidly affixed to the surface, probably due to an oxidation-resistant organic binding agent and their water solubility and possibly also due to a degree of physical compatibility with the inorganic part of the pictorial layer or the mortar.

With regard to pollution, the levels of suspended particulate matter were appropriate, and we did not detect gaseous pollutants or a concentration of acidic compounds. In terms of microbiology, environmental samples revealed moderate bacterial and fungal levels and good air quality. Surface samples indicated very limited bacterial and fungal contamination; the most frequently detected species were *Stemphylium* and *Penicillium*.²⁶ Overall, there were no indications of active processes that might threaten the work.

The following sections examine a series of cases to paint a more detailed picture of the relationship between the state of conservation and alterations.

A copper (oleate?) pigment in copper acetate and green lake

The dark green hues found in the clothing of some figures were painted using verdigris (copper acetate) and suffered serious deterioration. The pictorial surface is marred by major cracking and the particles flaked off progressively, causing major gaps. Indeed, so severe is the alteration that the polychromy

25. According to a study conducted by the Museu d'Història de Barcelona since 2003, in 2011, the quarterly averages inside the chapel were: 17.42°C and 71.37% RH in spring; 24.62°C and 67.69% RH in summer; 17.63°C and 61.8% RH in fall and 12.72°C and 64.89% RH in winter.

26. Four samples of microorganisms suspended in a buffer solution were studied by Arte-Lab in January 2012. See "Calidad ambiental interior, capella sant Miquel Monestir de Pedralbes", carried out by Sik-Lab in December 2011.

26. Estudi de quatre mostres de microorganismes suspeses en solució *buffer*, realitzat per Arte-Lab el gener del 2012. Informe: «Calidad ambiental interior, capella Sant Miquel Monestir de Pedralbes», estudi realitzat per Sik-Lab el desembre de 2011.



L'atzurita es manté ben adherida al mur tot i que amb algunes alteracions. Imatge de Sant Honorat

Azurite remains well affixed to the wall despite some changes. Scene depicting Saint Honoratus

transparent. Pel que fa a la capa transparent superficial, es tracta d'una laca, possiblement un oleat de coure, perquè s'ha detectat presència d'oli de llinosa. L'oli de llinosa és l'aglutinant de totes les capes pictòriques.

La seqüència estratigràfica ens remet doncs a una tècnica elaborada que treballa amb la superposició de tons per aconseguir els efectes cromàtics desitjats, amb algunes precaucions a l'hora de barrejar o superposar diferents materials. Així, la capa de colofònia podria haver actuat com un aïllant aplicat per protegir el pigment de coure de l'alcalinitat de l'*intonaco*, però la presència de carbonat càlcic, lleugerament alcalí, en la mescla de pigments posa en qüestió aquest supòsit. Una altra raó per a l'existència d'aquesta capa de resina es podria buscar en la incompatibilitat d'algun component de les dues capes pictòriques que queden separades per la colofònia, però en aquest cas, les dues tenen el mateix lligant i pigments secundaris idèntics (encara que en diferents proporcions), la qual cosa, *a priori*, ens faria descartar aquesta hipòtesi. L'única diferència està en els pigments que donen la tonalitat principal a ambdós estrats. Els dos són pigments derivats del coure: blau d'at-

has worn off completely, leaving the *intonaco* visible. The cloak worn by one of the figures in the scene depicting the Ascension of Christ is one of the most deteriorated areas. This same situation was also visible in other parts of the painting where we believe the same pigment or technique was used.

Exactly what technique and process were employed? Our stratigraphic analysis found that yellow earth was used for the preparatory design on the mortar. This was coated with several different layers: first, a light green layer, then, an amber one, and finally, a dark green layer which gradually gave way to a transparent hue. The transparent layer on the surface of the work was a lake; here we detected linseed oil, leading us to believe that this layer might have been a copper oleate. Linseed oil was used as the binding agent in all of the pictorial layers.

Stratigraphic sequencing therefore revealed that the painters used an elaborate technique which entailed layering several shades on top of one another in order to produce the desired chromatic effect. The painters were fully aware that some precautions needed to be taken when mixing or layering given

zurita en la capa de sota i *verdigris* en la capa de sobre. Una hipòtesi és que el pintor hauria cercat de protegir l'atzurita del contacte amb el *verdigris* que li superposaria al damunt. No hem trobat en el tractat de Cennini cap indicació en aquesta direcció, únicament ens prevé d'acostar el pigment *verdigris* al blanc de plom.²⁷ Tampoc sabem la composició exacta del *verdigris* de la capella, encara que veient que generalment està barrejat amb pigments de color groc, podríem pensar que es tractava de la varietat més freda, que es volia modificar cap a una tonalitat més càlida. Si fos així, potser estaríem, prenent totes les precaucions, davant d'un acetat bàsic de coure, un verd de tonalitat més blavosa. Cennini, quan parla d'aquest pigment —que ell denomina *verderame*— aconsella moldre'l amb vinagre²⁸ i aplicar-lo sobre taula amb tremp de cola o bé amb tremp de rovell d'ou, sobre paper o pergamí. Però en aquest cas, el *verdigris* que s'aplica a les pintures de la capella utilitza un medi oliós, i és més que probable que es molgués utilitzant l'oli de llinosa,²⁹ sense cap conseqüència negativa, per tant, en l'estrat subjacent que es pretenia aïllar. Alguns autors coetanis a Cennini ja advertien dels inconvenients d'emprar *verdigris* sobre làmines d'or, cosa que Cennini s'encarrega de contrarestar.³⁰ Leonardo da Vinci, més tard, també comenta el ràpid deteriorament cromàtic que sofreix aquest pigment quan no està envernissat i la seva descohesió en contacte amb l'aigua, encara que estigui aplicat a l'oli.³¹

27. «Guar' ti di none avvicinarlo mai con biacca, perché in tutto sono inimici mortali». CENNINI, *Il libro...*, LVI, pàg. 100-101. De totes maneres, a la capa situada sobre l'estrat aïllant de resina, on trobem *verdigris* i blanc de plom, no observem cap tipus de reacció adversa entre aquests, potser perquè estan barrejats en un vehicle oliós que aïlla, d'alguna manera, els grans dels pigments i els impedeix reaccionar. De fet, el *verdigris* apareix amb freqüència en la pintura medieval mesclat amb blanc de plom i groc d'estany i plom sense que s'hi detectin signes de deteriorament (vegeu Hellen HOWARD, *Pigments of English Medieval Wall Painting*. Londres, Archetype Publications, 2003, pàg. 86). El mateix Cennini es refereix a la mescla d'oli, una mica de *biacca* i de *verdigris* amb un percentatge de vernís que després s'ha de bullir per preparar mordents per aplicar les làmines metàl·liques. CENNINI, *Il libro...*, CLI, pàg. 156.

28. Fabio Frezzato, en una nota a peu de pàgina, troba una explicació molt plausible en el fet exposat per Cennini sobre la utilització de vinagre com a medi per moldre el *verderame*. Diu que d'aquesta manera s'afavoreix la transformació de l'acetat bàsic de coure a la seva forma neutra, que conserva el seu color durant més temps. (Vegeu nota anterior).

29. Vegeu nota 12.

30. CENNINI, *Il libro...*, CLII, pàg. 175

31. Leonardo DA VINCI, *Tratado de pintura*, Madrid, Akal, 1986, CXIX.

materials. Indeed, the layer of Greek pitch may have been applied to insulate and protect the copper pigment from the alkalinity of the *intonaco*, although the presence of calcium carbonate in the mixture of pigments casts some doubt on this hypothesis. This layer of resin might also have been applied to separate incompatible components into two pictorial layers. However, since the two layers both used the same binding agent and identical secondary pigments (albeit in different proportions), we have discarded this hypothesis *a priori*.

The only difference we found was related to the pigments which provided the main colour in each of the layers. Both pigments are copper derivatives: azurite blue was used in the underlying layer and verdigris in the upper layer. One hypothesis is that the painter may have tried to keep the azurite from coming into contact with the verdigris which would be painted on top of it. In his treatise, Cennini makes no mention of this or any other related techniques, simply advising readers not to put verdigris near white lead.²⁷ We also do not know the exact composition of the verdigris used in the chapel. However, seeing as it was generally mixed with yellow pigments, we believe that the coldest type of verdigris was used, and that the painters aimed to give it a warmer tone. Though we cannot be overly confident about this hypothesis, if this were the case, perhaps we are looking at a basic copper acetate, a green with a lot of blue in it.

When Cennini discusses this pigment — which he refers to as *verderame* — he recommends grinding it with vinegar,²⁸ applying it on panels tempered with glue

27. «Guar' ti di none avvicinarlo mai con biacca, perché in tutto sono inimici mortali» (“Be careful never to put it near white lead, because these two colours are mortal enemies in everything.”) CENNINI, *Il libro*, LVI, p. 100-101. Despite this admonition, we found verdigris and white lead in the layer underneath the resin insulant and did not detect adverse reactions of any type between them, perhaps because they were mixed in an oily vehicle which somehow isolated the grains of the pigments and prevented them from reacting. In fact, in mediaeval painting verdigris was frequently mixed with white lead and lead-tin yellow, and no signs of deterioration have been detected in these cases (see Hellen HOWARD, *Pigments of English Medieval Wall Painting*, London, Archetype Publications, 2003, p. 86). Cennini himself refers to mixing oil, a bit of *biacca* (white lead), verdigris and varnish and boiling the substance to prepare mordants which could be used to apply metal leaf. CENNINI, *Il libro*, CLI, p. 156.

28. In a footnote, Fabio Frezzato presents a highly plausible explanation: Cennini suggested grinding *verderame* with vinegar, and Frezzato notes that this would transform basic copper acetate into its neutral form, which keeps its colour for longer. (See previous footnote).



El blau d'indi descolorit

Discoloured indigo

No trobant, doncs, una justificació prou clara en la incompatibilitat química entre els components dels estrats que es pretenen aïllar, ens ha semblat que l'explicació més versemblant per entendre l'existència de l'estrat a base de resina de colofònia està relacionada amb l'aïllament de la humitat. Segurament el que es volia era evitar una futura migració de la humitat, a través del mur, cap a la capa de *verdigris*, que disgregués la delicada sal de coure i la fes deliqüescent. Afortunadament, això no ha passat i el verd de coure està molt ben aïllat. Es tractaria, en certa manera, d'un doble «aïllament» del *verdigris*: primer, a tocar el morter, amb un estrat que funciona com una base de color i que, en estar aplicat a l'oli, proporciona una certa impermeabilitat, i després, amb el veritable estrat translúcid aïllant, la resina de colofònia. Precisament, l'alteració està molt relacionada amb la presència d'aquestes capes impermeables que han suposat una barrera important al pas al vapor d'aigua i han causat, finalment, el despreniment de tot el film pictòric. La gruixuda i rígida pel·lícula pictòrica es va esquerdar probablement per efecte de la pressió del vapor emergit del mur. Les fissures arriben a la superfície de l'*intonaco* i, per tant, el despreniment no es produeix a l'alçada de la colofònia, sinó a la zona de contacte entre la primera capa feta a l'oli i l'*intonaco*.

Un altre factor que hi ha contribuït, sens dubte, és el gruix de la pintura, el qual, sumant totes les capes, és d'entre 120 i 155 micres. Un gruix més que considerable si es té en compte que les zones pintades al fresc només fan entre 15 i 40 micres. Per tant, el pes d'aquestes capes, si no estan ben subjectes, en facilita el despreniment. Quant a l'enfosquiment superficial de la laca verda i la variació del cromatisme (adquirint una tonalitat marró) a nivell superficial (internament manté el color),

and tempering it with glue or egg yolk on parchment or paper. In the chapel, however, the verdigris applied to the paintings used an oily medium, and it is more likely that the painter ground it using linseed oil²⁹ without any negative consequences on the underlying layer it was supposed to be separated from. While some of Cennini's contemporaries published works noting the downsides of using verdigris on gold leaf, Cennini took pains to counter this argument.³⁰ Later, Leonardo da Vinci also pointed out that the colour of this pigment deteriorated swiftly when it was not varnished and that it lost cohesion when it came into contact with water, even if it had been applied using oil.³¹

As the argument for chemical incompatibilities between the components in the layers proved hard to justify, we concluded that this layer of resin was most likely used to provide insulation from humidity. Undoubtedly, the painters attempted to keep humidity from moving through the wall to the verdigris layer, disintegrating the delicate copper salt and causing it to become deliquescent. Luckily, this did not occur, and the copper green remained well insulated. To a certain extent, this served as a double "insulation" of the verdigris: first, when it touched the mortar, with a coloured undercoat which was somewhat impermeable, given that it was applied using oil, and later, with a truly translucent insulating layer of Greek pitch. Indeed, the fact that the work suffered few alterations is closely tied to the presence of these impervious layers which served as a strong protection against water vapour and ended up leading to the loss of the entire pictorial layer. The thick, rigid pictorial layer cracked probably due to the pressure of the vapour coming from the walls. The fissures reached the surface of the *intonaco*, and consequently, losses occurred at the first layer where the oil touched the *intonaco* rather than at the resin layer.

Undoubtedly, the thickness of the painting – between 120 and 155 micrometres – also contributed to this situation. This is especially significant when we bear in mind the fact that the frescoed portions of the work measure between 15 and 40 micrometres. Therefore, if these layers were not firmly affixed, they were likely to be lost due to their weight. We are not entirely certain why the green lake on

29. See footnote 12.

30. CENNINI, *Il libro*, CLII, p. 175

31. LEONARDO DA VINCI, *A Treatise on Painting*, Mineola, New York, Dover Publications, 2005. 119.

l'alteració encara no està del tot clara, però es pot comprovar en nombroses obres, on la part més superficial exposada a la llum pateix, reiteradament, aquest canvi cromàtic. Molt probablement hi tenen a veure les radiacions ultraviolades o potser el contacte amb algun component de l'atmosfera, com per exemple l'oxigen.

Atzurita

L'atzurita (carbonat bàsic de coure) s'ha aplicat sobre una capa prèvia de tonalitat grisa pintada al fresc.³² Com és ben sabut, aquesta base fosca compleix una doble funció: fa que la llum que es transmet als cristalls d'atzurita reflecteixi un blau més profund i permet estalviar pigment. Pel que fa al procediment pictòric, el pigment blau ha estat mesclat amb una baixa proporció de carbonat càlcic i aglutinat amb un producte de naturalesa proteica que encara no s'ha pogut precisar.³³ L'estat de conservació és bo i no hi ha els despreniments tan freqüents que s'observen en altres conjunts pictòrics del mateix moment. Malgrat tot, sí que es produeix enfosquiment i variacions cromàtiques que són molt evidents en les superfícies grans, com ara el fons de les escenes. Aquest enfosquiment respon en part a l'efecte causat pels fixatius aplicats en antigues intervencions, que prenen una coloració entre marró i ocre que intensifica la tendència natural cap a el verd que caracteritza al pigment atzurita. La humitat i la presència de diòxid de sofre (vapors de sofre) també poden haver-hi intervingut. On l'alteració modifica més substancialment el treball fet per l'artista és als mantells de la Verge i de Crist. L'enfosquiment provocat pels fixatius en l'atzurita ha dissipat el contrast en el modelat dels plecs, i no es perceben tal com van ser creats, sinó com a superfícies més planes. Si s'hagués emprat el procediment que descriu Cennino, l'atzurita s'hauria aplicat amb cola animal i rovell d'ou, i el modelat s'aconseguiria aplicant ombres

the surface took on a brownish tone in the top layer (maintaining its original colour inside the work), but this change in the outer layer, which was exposed to light, has been observed in numerous works. This effect is likely tied to ultraviolet radiation or perhaps to an element in the environment, such as oxygen.

Azurite

Azurite (basic copper carbonate) was applied on top of a grey fresco layer.³² It is well known that this undercoat served a twofold purpose: it caused the light transmitted by the azurite crystals to reflect a deeper blue and allowed the painters to reduce the amount of pigment they used. During the painting process, the blue pigment was mixed with a low proportion of calcium carbonate and a protein-based binding agent that we have not yet been able to identify.³³ This part of the work has stood up well to the test of time, and has suffered less frequent losses than we see in other pictorial ensembles dating from the same period. Nevertheless, darkening and chromatic variations were very visible in large sections, such as the backgrounds of the scenes.

This darkening was partly the result of the fixatives applied during previous restorations; these took on a colour between brown and ochre which intensified the greenish colour that tends to appear as azurite ages. Humidity and sulphur dioxide (sulphur vapour) may have also played a role.

The cloaks worn by Mary and Jesus showed the most significant alterations. The fixatives darkened the azurite and washed out the contrast in the folds of their garments; they no longer appear as they originally did, but rather, seem like flat surfaces. If the painters had followed the technique described by Cennino, they would have applied azurite using animal glue and egg yolk and added shadows using indigo and black. Indigo is a colour that tends to dissipate due to light, and could have

Anàlisi estratigràfica d'una micromostra de laca vermella corresponent a la túnica de Crist a l'escena El Camí del Calvari

Stratigraphic analysis of a micro-sample of red lake in Christ's tunic. Scene depicting the Path to Calvary

32. Ja Teòfil esmenta aquesta capa de color gris fred, que ell denomina *veneda*, una base sota els blaus que s'aplicaran posteriorment. El *veneda* s'aplica al fresc, emprant el pigment negre vinyes i l'hidròxid càlcic. THEOPHILUS, *On Divers Arts* (tit. original *Schedula diversarium artium*, trad. a l'anglès i notes de J. G. Hawthorne i C. Stanley Smith), Nova York, Dover Publications, 1979, I, XV, pàg. 23.

33. Com hem dit més amunt, el bon estat de conservació dels fons blaus d'atzurita pot relacionar-se amb la utilització d'algun aglutinant que suporti l'envelliment del pas del temps. En el cas de l'atzurita, Cennini recomana emprar-la al mur al sec, lligada amb tremp de cola o de rovell d'ou. És possible que aquest últim sigui present als blaus de Pedralbes, encara que la poca quantitat de material proteic identificat fa necessari seguir completant l'estudi. CENNINI, *Il libro...*, LX, pàg. 102-103.

32. Centuries beforehand, Theophilus noted that blue should be applied on top of this cold grey layer, which he called *veneda*. *Veneda* was applied to the fresco layer using vine black and slaked lime. THEOPHILUS, *On Divers Arts* (original title: *Schedula diversarum artium*, English translation and notes by J. G. Hawthorne and C. S. Smith), New York, Dover Publications, 1979, I, XV, p. 23.

33. As mentioned, the azurite blue backgrounds may have been well conserved due to a binding agent that held up well during the ageing process. Cennini recommends using the *a secco* technique to apply azurite, which should be tempered and affixed with glue or egg yolk. The latter may have been used in the blue pigments in the Pedralbes monastery; in light of the small amount of protein-based material we detected, we will need to continue to study this issue in more detail. CENNINI, *Il libro*, LX, p. 102-103.



Blanc de plom
colorant vermell
White lead
Red colourant

INTONACO



fetes amb blau d'indi i negre. El blau d'indi és un color que sol esvair-se a causa de la llum i podria haver contribuït a la pèrdua de matisos als vestits.

L'atzurita també s'ha aplicat de manera molt localitzada sobre un estrat de color vermell fosc, fet amb terres a base d'òxids de ferro i aplicat al fresc, als motius geomètrics de la sanefa, a fi i efecte que el blau adquireixi una tonalitat més violàcia, més propera al blau ultramar. Aquest blau es manté bé, però el pintor va aplicar-lo en una capa molt prima, on és possible apreciar, sense interferències, la gruixuda granulometria del pigment. Com a alteració del pigment, hi ha casos aïllats de

helped wash out some of the detail in the clothing.

In a few concrete cases, azurite was also applied on top of a dark red fresco layer made with iron oxide-based pigments. These were used in the geometric motifs in the friezes, leading the blue to take on a tone that tended towards violet and was more typical of lapis lazuli. This blue held up well, but the painter applied only a very thin layer of it, and consequently, we can clearly see the pigment's thick granulometry.

There are also isolated cases where azurite was transformed into a green-coloured pigment. In some cases, this

Alteració del vermell de cinabri de la túnica d'un soldat a l'escena de L'oració a l'hort i el Prendiment

Red cinnabar in a soldier's tunic was altered in the scene of the Prayer in the Garden and the Arrest of Jesus



transformació, per causes diverses, de l'atzurita en un pigment de color verd. En unes ocasions es tracta d'un fenomen associat a l'acció de l'aigua que va filtrar-se durant un temps pel mur sud-est de la capella i va afectar els fons blaus al voltant d'una esquerra que deixava pas a la humitat. En altres, és un efecte de degradació del pigment, provocat involuntàriament pel pintor mateix en el procés d'execució dels murals. Això es pot observar al voltant d'alguns nimbes en l'escena principal, el Triomf de la Verge, on es veu la transformació del color blau original en un verd clar molt intens quan l'artista incidí sobre l'*intonaco* amb el ganivet per retallar el full d'estany colrat sobrant. Probablement, el pigment blau entraria en contacte amb la humitat del morter, transformant-lo en un altre carbonat de coure (malaquita).³⁴ Una altra possibilitat és que no es tracti de malaquita, sinó de clorurs de coure (atacamita o paratacamita, de color verd clar), que es formen en entrar en contacte el pigment amb l'ió Cl.³⁵ Finalment, podem observar una altra alteració del pigment provocada directament per l'aplicació de la tècnica, quan en pintar al sec utilitzant el blanc de calç, el pintor passà, esporàdicament, pel damunt d'una zona amb atzurita. En aquest cas,

34. En aquesta transformació els cristalls de malaquita mantenen la seva forma, de manera que l'únic canvi a simple vista és el color.

35. Luigi DEI, Andreas AHLE, Piero BAGLIONI, Daniela DINI, Enzo FERRONI, «Green degradation products of azurite in wall paintings: identification and conservation treatment», *Studies in Conservation*, 43, 2, 1988, pàg. 80-88.

came about because water leaked into the blue backgrounds surrounding a crack in the southeast wall of the chapel, letting in humidity for a period of time. In others, it was related to the degradation of the pigment, a process the painter himself accidentally caused when painting the murals. This effect is visible around some of the aureoles in the main scene, the Triumph of the Virgin, where the original blue colour was transformed into an intense light green when the artist used a knife to cut the excess bronzed tin leaf from the *intonaco*. The blue pigment probably came into contact with the humidity in the mortar, transforming it into another copper carbonate, malachite.³⁴ Alternatively, this might not be malachite, but rather, copper chloride (atacamite or paratacamite, both of which are light green), which was formed when the pigment came into contact with the Cl⁻ ion.³⁵

Finally, another azurite alteration came about because of the painting technique: when the painter used lime white to paint *a secco*, he sometimes painted over an area done with azurite. When the artist painted over the blue pigment with this white colour, the alkalinity of the lime white transformed the underlying pigment into copper oxide.³⁶ This later

34. The malachite crystals kept their shape, so the only visible change was in the colour.

35. Luigi DEI, Andreas AHLE, Piero BAGLIONI, Daniela DINI, Enzo FERRONI, «Green degradation products of azurite in wall paintings: Identification and conservation treatment», *Studies in Conservation*, 43, 2, 1988, p. 80-88.

36. For more information on this transformation, see

l'alcalinitat de la pinzellada blanca transformà en òxid de coure el pigment blau subjacent,³⁶ que experimenta una oxidació per contacte i es torna d'un color bru, parcialment soluble, que ha impregnat també la massa de la pinzellada blanca.

La utilització de laques i colorants vermells

La túnica de Crist, entre altres elements, s'ha pintat amb un color púrpura que en alguns casos s'ha anat desprenent de l'*intonaco* en forma de petites escates disperses que acaben essent llacunes importants i, fins i tot, pèrdues quasi totals. S'observa una certa tendència que aquest fenomen es produeixi de manera preferent als plecs foscos de les túniques, mentre que les zones clares fetes amb blanc de plom són més resistents. En canvi, no s'hi observa cap descoloriment significatiu. Aquests púrpures vistos amb llum ultraviolada presenten una forta fluorescència taronja-rosada que podria correspondre a la presència d'una laca vermella, possiblement la laca procedent d'alguna planta de la família de les *Rubiaceae* (laca de roja). En aquest sentit, els resultats de les anàlisis instrumentals identifiquen un colorant vermell, sense més precisió, mesclat amb carbonat de plom i un oli assecant com aglutinant. Es dona la circumstància que la laca de roja, a banda de presentar habitualment una forta fluorescència taronja, és la més econòmica de les laques procedents d'insectes i la menys fotosensible, elements que podrien coincidir amb el nostre cas.

La mescla amb pigment blanc proporciona opacitat i major estabilitat front la degradació de la llum a la qual són proclius totes les laques,³⁷ per la qual cosa el deteriorament pot estar relacionat amb l'efecte barrera del film que genera la mescla amb el lligant, en aquest cas l'oli, tal com s'ha plantejat amb el *verdigris*.

Pel que fa als violacis o malves al sec només coneixem amb un cert detall la barreja de pigments i colorants emprada per fer una policromia esgrafiada sobre metall (Triomf de la Verge). En aquest cas s'han obtingut mesclant el colorant vermell amb pigments minerals, com el blau d'atzurita i el blanc de plom, que han proporcionat, igualment, major estabilitat front l'acció de degradació de la llum, a la qual els colorants són tan sensibles. Però, probablement, l'oxidació del metall subjacent

oxidised and turned into a brown, partially soluble colour that impregnated the area that had been painted white.

Lakes and red colourant

Jesus' tunic was one of several elements painted with a purple colour that sometimes flaked off the *intonaco* in small, scattered areas. These ended up turning into major gaps and, in some cases, nearly total losses, especially in the dark folds of tunics; lighter areas painted using white lead held up better. However, no major discolourations were visible. Under ultraviolet light, these purple colours gave off strong orange and pink fluorescence, which may indicate that a red lake was used; this lake may have been derived from a plant in the *Rubiaceae* family (madder). Our instrumental analyses identified a red colorant that had been mixed with lead carbonate and a drying oil that served as a binding agent. In addition to its strong orange fluorescence, madder is also the least expensive, least photosensitive insect-based lake; such properties further support the idea that the colorant was used in this work.

All lakes are susceptible to light-related degradation, but when this one was mixed with the white pigment, it gained body (opacity) and greater stability.³⁷ Consequently, deterioration may be tied to the filmy barrier produced when mixing the lake with the binding agent (in this case, oil), as we suggested was the case for the *verdigris*.

As for the violet or mauve colours painted using the *a secco* technique, we have a limited knowledge of the mixture of pigments and colourants used to create the *sgraffito* polychromy on metal in the Triumph of the Virgin. These were obtained by mixing the red colourant with mineral pigments like azurite blue and white lead, which were less susceptible to light-induced degradation. Again, however, oxidation of the underlying metal and the layers of linseed oil gave rise to serious alterations in these layers, causing the polychromy to disappear almost completely.

Vermilion / cinnabar

Though we did not conduct an instrumental analysis, visual observation of the work allowed us to identify sections that were almost

36. Sobre aquesta transformació, vegeu: Rutherford J. GETTENS, Elisabeth W. FITZHUGH, «Azurite and Blue Verditer» dins Ashok ROY, *Artists' pigments. A handbook of their history and characteristics*. Cambridge i Washington, Cambridge University Press i National Gallery of Art, 1993, II pàg.27

37. HOWARD, *Pigments of English...*, pàg. 124-125.

Rutherford J. GETTENS, Elisabeth W. FITZHUGH, «Azurite and Blue Verditer», in Ashok ROY, *Artists' Pigments: A Handbook of Their History and Characteristics*, Cambridge and Washington, Cambridge University Press and National Gallery of Art, II, 1993, p. 27.

37. HOWARD, *Pigments of English*, p. 124-125.

i, una vegada més, les capes d'oli de llinosa han provocat una alteració molt severa d'aquestes capes, de manera que la policromia gairebé ha desaparegut per complet.

El vermelló o cinabri

L'observació directa de l'obra ha permès identificar els elements que amb quasi tota seguretat, i a falta de fer-ne l'anàlisi instrumental, han estat realitzats amb cinabri.³⁸ El reconeixem per la seva coloració vermella viva i també per les alteracions que li són pròpies, com ara el conegut fenomen d'ennegrimment causat per la seva transformació en metacinabrita, la modificació grisosa o negra del pigment. Tradicionalment s'ha relacionat aquesta transformació amb l'exposició del pigment a la llum,³⁹ però la irregularitat d'algunes zones afectades —exposades a la llum d'igual manera—, suggereix, d'una manera molt gràfica, la concurrència forçosa d'altres factors. Estudis recents⁴⁰ han analitzat exemples de vermelló alterat on s'ha detectat la presència de clorurs, seguint la hipòtesi que aquest podria ser un dels desencadenants de l'esmentada transformació, junt amb la humitat i la llum. Però el debat científic encara continua obert.

Ara per ara, és complex determinar definitivament la causa de l'alteració i caldrà analitzar altres factors, com el tipus de lligant —aquós o no—, la presència d'impureses, la mòlta del

certainly created using cinnabar.³⁸ This pigment can be recognised by its red colour and its characteristic alterations, such as the well-known darkening phenomenon that arises when it is transformed into metacinnabar, the grey or black variation of the pigment. Traditionally, this transformation has been associated with light exposure,³⁹ but in our case, given that all areas were exposed to identical light but the transformation only took place in some of them, we have quite visible evidence that other factors also played a role. Recent studies⁴⁰ have analysed deteriorated vermilion samples and detected the presence of chloride, supporting the hypothesis that this element, along with humidity and light, may have caused blackening. However, the scientific verdict is still out.

At this point, it is difficult to draw definitive conclusions about what caused this darkening, and we will need to analyse other factors, such as the type of binding agent used (aqueous or not), whether impurities are present, the way in which the pigment was ground, the porosity of the mortar, pH changes in the pictorial layer, and products added in previous restorations. These factors may also have acted in combination. As indicated in the bibliography cited herein, we should be highly conscious of the role humidity may have played, as it is the ideal vehicle for transporting various substances between the layers in the wall painting and may therefore have led to cinnabar dark-

38. Pensem que el vermell que es va utilitzar a la capella és el cinabri artificial, perquè en aquella època ja s'havia estès el seu procés de síntesi en sec, a partir de mercuri i sofre. Cennino Cennini comenta que és un color que es fa per alquímia, és a dir, químicament. CENNINI, *Il libro...*, XL, pàg. 91-92. El que no exclou, però, és el fet que pugui tractar-se del cinabri natural molturat que s'emprava des de l'antiguitat clàssica, cosa que seria més improbable, ja que el seu ús va començar a decaure a partir de l'edat mitjana, precisament amb l'auge de la seva fabricació. No obstant això, els resultats de les anàlisis fetes a l'espai contigu a la capella (tomba de la reina) han identificat la presència de cinabri natural. CETEC PATRIMONI, «Estudi analític per a...».

39. Cennini ja adverteix que el pigment ennegreix en contacte amb l'aire, sobretot en mur, més que en pintura sobre taula. CENNINI, *Il libro...*, XL, pàg. 91-92. També Plini i Vitruvi fan menció de l'ennegrimment del cinabri, en aquest cas, natural.

40. Marika SPRING, Rachel GROUT, «The Blackening of Vermilion: An Analytical Study of the Process in Paintings», *Technical Bulletin* (Londres), 23, 2002, pàg. 50-61; Marine COTTE, Jean SUSINI, V. Armando SOLÉ, Yoko TANIGUCHI, Javier CHILLIDA, Emilie CHECROUN, Philippe WALTER, «Applications of synchrotron-based micro-imaging techniques to the chemical analysis of ancient paintings», *Journal of Analytical Atomic Spectrometry* (Cambridge), 23, 2008, pàg. 820-828; F. DA PIEVE, C. HOGAN, D. LAMOEN, J. VERBEECK, F. VAN MEERT, M. RADEPONT, M. COTTE, K. JANSSENS, X. GONZE, G. VAN TENDELOO, «Casting light on the darkening of colors in historical paintings», *Rhys. Rev. Lett.*, 111, pàg. 208302-208307.

38. We believe that the red used in the chapel was artificial cinnabar; by that time, using the dry process to prepare vermilion from mercury and sulphur had become commonplace. Cennino Cennini mentions that the colour was made via alchemy, i.e. chemically. (CENNINI, *Il libro*, XL, p. 91-92.) That said, the work may still have been executed using the natural grinding process that had been employed since classical antiquity. This is less likely, since the popularity of natural cinnabar began to dwindle in the Middle Ages when the artificial manufacturing process was discovered. Nonetheless, the analyses conducted in the adjacent room (the Queen's Tomb) detected natural cinnabar. CETEC PATRIMONI, «Estudi analític...».

39. Cennini pointed out that the pigment blackens when exposed to the air; this blackening was more pronounced on walls than on panels. CENNINI, *Il libro*, XL, p. 91-92. Based on their observations of natural cinnabar, Pliny the Elder and Vitruvius also noted that cinnabar darkened.

40. Marika SPRING, Rachel GROUT, «The Blackening of Vermilion: An Analytical Study of the Process in Paintings», *Technical Bulletin* (London), 23, 2002, p. 50-61; Marine COTTE, Jean SUSINI, V. Armando SOLÉ, Yoko TANIGUCHI, Javier CHILLIDA, Emilie CHECROUN, Philippe WALTER, «Applications of synchrotron-based micro-imaging techniques to the chemical analysis of ancient paintings», *Journal of Analytical Atomic Spectrometry* (Cambridge), 23, 2008, p. 820-828; F. DA PIEVE, C. HOGAN, D. LAMOEN, J. VERBEECK, F. VAN MEERT, M. RADEPONT, M. COTTE, K. JANSSENS, X. GONZE, G. VAN TENDELOO, «Casting light on the darkening of colors in historical paintings», *Rhys. Rev. Lett.*, 111, pàg. 208302-208307.

Alteració del mini de plom en les pinzellades d'una torxa de l'escena de L'oració a l'hort i el Prendiment

Minium in the brush-strokes of a torch was altered in the scene depicting the Prayer in the Garden and the Arrest of Jesus



pigment, la porositat del morter, els canvis de pH en l'estrat pictòric, els productes afegits en restauracions anteriors o les combinacions d'alguns d'aquests aspectes. Tal com es fa palès en la bibliografia, la humitat és un factor que cal tenir molt en compte, ja que representa el vehicle ideal per al transport de substàncies diverses entre els estrats que componen la pintura mural i que podrien tenir una incidència en l'alteració del cinabri. Aquesta podria haver estat la causa que expliqués la transformació del pigment aplicat en la decoració d'una sanefa a la zona just a tocar la junta entre *giornate*.

Les pèrdues de policromia coincideixen principalment amb les tonalitats fosques, ja que se li superposen capes de laca roja, més impermeables, que produeixen un *strappo* per excés d'aglutinant. Però per precisar tot això caldrà fer més investigacions.

Mini de plom

El mini de plom (un òxid de plom) és un pigment vermell, però de tonalitat ataronjada, que es preparava, des de temps antics, artificialment. A les pintures de Pedralbes el trobem aplicat al sec, generalment per fer les decoracions dels rics teixits que acompanyen les figures. La majoria de vegades es combina amb vermelló, que aporta el color principal de fons, mentre que el mini es destina als detalls i acabats finals.⁴¹ L'hem localitzat al pali i els

ening. This might explain the transformation in the pigment applied to a decorative frieze in the area between *giornate*.

The original polychromy was lost mostly in the darker-shaded areas. These were painted over with layers of less permeable red lake, and the excess binding agent caused these areas to become detached. In any case, further research will be necessary to paint a more complete picture of this issue.

Minium

Minium (a lead oxide) is a red pigment with orange hues that has been prepared artificially since ancient times. In the chapel, it was applied *a secco*, usually to decorate the rich fabrics framing the figures. Minium was used for detail work and finishing touches and was usually combined with vermilion, which provided the main background colour.⁴¹ Our study found that minium was present in the pallium and the drapery around the main figure, the Virgin. In general, it was well-conserved. It seems to have been mixed with a thick binding agent that covered the pigment grains and prevented them from being transformed into lead dioxide (which is black in colour). That said, we did find one very visible example of this blackening in the flames of

41. Els murals de la capella reproduïxen, amb tota fidelitat, la pràctica que recull Cennini per imitar els

41. The wall paintings in the chapel faithfully followed the process Cennini laid out for imitating silk fabrics: "[...] se vuoi far drappo di seta, o in tavola o in muro, campeggi di cinabro e palia, o ver viticha, di minio [...] campeggia schura e palia chiaro". CENNINI, *Il libro*, CXLIV, p. 166-167.

cortinatges al darrere de la figura principal de la Verge. El seu estat de conservació és generalment bastant bo, ja que sembla estar barrejat amb un aglutinant de caràcter gras que recobreix els grans de pigment i n'impedeix la transformació en biòxid de plom, de color negre. Amb tot, hi ha algun exemple d'aquest ennegriment, molt palès, en la flama de les torxes que porten els soldats en l'escena del Prendiment. Ja Cennino ens prevé d'usar-lo al mur, perquè, si està en contacte amb l'aire, esdevé ràpidament negre i perd el seu color.⁴²

No es coneix exactament quin és el mecanisme d'alteració, encara que se sap que reacciona amb els sulfurs presents al medi. En aquest cas, l'aplicació del pigment, potser amb poc aglutinant, sobre una base de vermelló (sulfur de mercuri) podria haver estat una de les causes de la degradació.

Làmines metàl·liques

L'alteració més important, pel percentatge en què afecta al conjunt d'elements treballats amb aquesta tècnica, correspon sens dubte a les decoracions fetes amb làmines metàl·liques, tant pel grau de deteriorament com perquè implica de forma generalitzada tots els elements on han estat aplicades. Són fetes amb fulles de metall els nimbes, els filets que decoren les vores de totes les vestimentes, la decoració del rics teixits i alguns detalls de les arquitectures, i també els vasos i les puntes de llança i els cascs dels soldats que en el seu conjunt enriqueixen els murs amb els seus reflexes metàl·lics. Inclouem aquí també la policromia esgrafiada. Gran part d'aquests elements ha desaparegut per complet, però les restes que han romàs, profundament alterades i ennegrides, manifesten una riquesa decorativa i l'aplicació d'un ventall amplíssim de tècniques.

Concretament en el cas de les làmines de plata o plata-estany, solament es conserven en bon estat a zones molt puntuals. La majoria estan molt ennegrides i només queden els productes de l'alteració, havent desaparegut sovint la plata metàl·lica (en una de les mostres han estat identificats sulfats i clorurs de plata).

El contacte amb l'atmosfera contaminada amb substàncies com el sulfur d'hidrogen, el sulfur de carboni i el clorur de sodi dona lloc a la formació de clorurs i sulfurs. Els clorurs provenen de l'esprai marí propi d'una ciutat propera al mar com Barcelona, tot i que el clor i el sofre també poden provenir dels materials

the torches the soldiers are carrying in the scene depicting the Arrest of Jesus. Indeed, as minium rapidly blackens and loses its colour when it comes into contact with air, Cennino had warned against using it on walls.⁴²

We do not know exactly how the transformation process took place, but we do know that the minium reacted to sulphur in the environment. In this case, the fact that the pigment was applied over a vermilion undercoat (mercury sulphide) – perhaps using a small amount of the binding agent – may have contributed to this deterioration.

Metal leaf

Undoubtedly, the most important changes in the work pertain to the extensive metal leaf decorations used. These changes were significant both in terms of the degree to which the metal leaf deteriorated and the fact that it affected all of the areas where it was applied. Metal leaf was used to decorate the aureoles, the gilded edges of clothing, the richly embellished fabrics, some architectural details, the vases, the tips of the soldiers' spears and their helmets. As a whole, this metal leaf and the reflections it generated served to embellish the wall paintings, which was also the case with the *sgraffito* polychromy. The majority of this decorative work has been lost completely, but the significantly altered, darkened bits that do remain are richly decorative and demonstrate that an extremely wide range of techniques was utilised.

There are very few examples of the silver and silver-tin leaf surviving in good condition. Most of these elements have darkened significantly; often, the metal leaf disappeared entirely and the only traces of it lie in the products of the deterioration process. (For example, we detected sulphates and silver chloride in one of the samples.)

Contact with the environment – which was polluted by substances such as hydrogen sulphide, carbon disulphide, and sodium chloride – led to the formation of chlorides and sulphides. Chlorides came from the sea air typical of a seaside city like Barcelona; chlorine and sulphur may also have come from the materials that were used as binding agents, such as egg yolk or animal glue (i.e., the binding agents that were used to paint may have been the source of pollutants).

Metal leaf acted similarly to the Greek pitch described above, which was applied underneath the verdigris layer to insulate it.

teixits de seda: «[...] se vuoi far drappo di seta, o in tavola o in muro, campeggi di cinabro e palia, o ver viticha, di minio [...] campeggia schura e palia chiaro». CENNINI, *Il libro...*, CXLIV, pàg. 166-167.

42. CENNINI, *Il libro...*, XLI, pàg. 92.

42. CENNINI, *Il libro*, XLI, p. 92.

que s'utilitzen com a adhesius, com el rovell d'ou o les coles animals (és a dir, que els lligants mateixos emprats per pintar poden haver constituït una font de contaminants).

Aquestes làmines metàl·liques han exercit una acció similar a la que hem vist anteriorment amb l'estrat de colofònia aplicat com a aïllant sota la capa *verdigris*. Una làmina no permet el pas del vapor d'aigua, i entre la làmina i l'*intonaco* es poden formar cristalls de clorurs o d'altres productes que generen clixelles que trenquen les zones febles. La corladura, mentre s'ha mantingut damunt el metall, l'ha protegit de l'acció ambiental, però un cop s'han obert vies de penetració de l'aigua, les alteracions han estat profundes.

Conclusions

Els tallers medievals buscaven els efectes de lluentor, lluminositat i transparència. Per aconseguir-los calia mesclar els pigments amb aglutinants orgànics que, malauradament, no són els més resistents al pas del temps. El sec emprat en aquesta pintura mural ha demostrat ser una tècnica pictòrica molt rica en matisos però propensa al deteriorament per la seva densitat o empastament, encara que amb una evolució desigual segons la tècnica específica i els components de cada zona pintada d'un color determinat. Pel seu abast, el despreniment del film pictòric selectiu i el deteriorament de les làmines metàl·liques són les alteracions que destaquen sobre moltes altres de menor envergadura.

En el moment d'execució de la pintura el pintor va fer l'elecció de materials que han definit l'evolució de l'obra. En uns casos va triar materials de baixa qualitat i, per tant, més susceptibles al deteriorament, com ara les làmines a base d'aliatge d'or amb baix percentatge d'aquest metall i la plata o la doble làmina d'estany-plata (quan el contracte especificava que s'utilitzés l'or fi). Una modificació que devia respondre a motius econòmics, ja que era ben conegut que aquests metalls s'oxidaven, tal com recullen els diversos tractats. El contacte d'alguns d'aquests metalls o dels seus productes d'alteració amb mordents o vernissos oliosos que contenien sals de coure ha provocat la formació de subproductes que alteren la visió d'algunes zones. Aquestes degradacions s'han vist afavorides per la participació dels agents mediambientals, com també hi poden haver intervingut altres components de la pintura mateixa.

Per contra, l'aplicació conscient d'una sèrie de capes aïllants per prevenir el pas de la humitat cap a certes capes pictòriques i evitar la reacció d'alguns pigment ha propiciat, a llarg

Water vapour cannot pass through metal leaf, and chlorides or other products can crystallise between the metal leaf and the *intonaco*, giving rise to fractures that lead to cracking in weak areas. When the gold-tinted varnish remained on the metal, it protected it from environmental factors, but once water started to seep through it, serious damage occurred.

Conclusions

Mediaeval workshops aimed to create bright, light and transparent works. To achieve these effects, they needed to mix pigments with organic binding agents, but unfortunately, these did not always stand the test of time. The painting at hand utilised the *a secco* technique, which proved to allow for a richness of detail but was also prone to deteriorate due to its density or thickness. That said, it should be noted that different parts of the work evolved in different ways depending on the specific techniques used and the colours with which each area were painted. Due to their scope, the loss of some parts of the pictorial layer and the deterioration of metal leaf proved to be the most significant alterations affecting this work.

The materials originally selected by the painter significantly influenced later changes that the work would undergo. In some cases, the artist selected low-quality materials which were consequently more likely to deteriorate, such as an alloy of gold leaf with a low percentage of gold as well as silver and tin double metal leaf; these were used despite the fact that the contract called for fine gold. This decision must have been made for financial reasons, since artists were well aware that these metals were prone to oxidation; indeed, this fact was well known and appears in several treatises. When some of these metals or their derivatives (the result of alterations) came into contact with oily mordants or varnishes containing copper salts, sub-products formed, changing the appearance of parts of the work. Environmental factors as well as other components in the paint itself further exacerbated this deterioration.

The painter also chose to apply a series of insulating layers to keep humidity from reaching some pictorial layers and prevent the pigments therein from reacting. In the long run, this caused part of the pictorial layer which was too thick, rigid, and impermeable to lift away from the underlying layers. Layers painted with drying oil – used as a binding agent, an insulating layer, or an adhesive for metal leaf – underwent the most

termini, l'alteració en forma d'aixecament d'una capa pictòrica que resulta massa gruixuda, rígida i impermeable. Els films en els quals participa l'oli assecant, sia en forma d'aglutinant o com a estrat aïllant o adhesiu de les làmines metàl·liques, són els més deteriorats, amb excepció dels que es combinen amb blanc de plom, que formen una patina molt resistent i prou elàstica. En canvi, els estrats fets amb determinats materials proteics han permès una certa porositat que els fa més estables als aixecaments.

Altres accions de la mà del pintor tenen un abast molt localitzat perquè es produeixen puntualment en la zona de confluència de materials que són incompatibles: les incisions per tallar l'estany, que provoquen la migració cap a la superfície de la humitat, que altera l'atzurita, la qual es transforma en un material de to verd intens; l'aplicació ocasional de pinzellades de blanc de calç sobre l'atzurita, que provoca l'ennegriments d'aquesta; o el contacte entre vermelló i mini de plom amb el consegüent ennegriments d'aquest últim.

Finalment, també cal tenir en compte altres processos de la tècnica d'execució que no es refereixen estrictament a la capa pictòrica però que han tingut una repercussió directa en el seu estat de conservació. Ens referim a la fase de preparació del mur per poder pintar al fresc. S'ha pogut constatar que l'aprofitament d'un enlluït preexistent, reciclat per funcionar com a *arriccio*, no ha ofert un ancoratge tan perfecte com si aquest s'hagués fet de bell nou, dotant-lo de la textura rugosa corresponent. Això es fa palès a les zones de les parets que més cops han sofert per obres de remodelació de l'espai, i on es concentren la majoria de bufats o separacions entre els estrats dels morters.

El pas del temps també ha posat en evidència algunes impureses contingudes en la pasta de l'*intonaco*: petits percentatges del mineral mica, contingut natural de les sorres silícies amb les quals es va confeccionar el morter, han provocat micropèrdues a les zones que han estat més exposades a la humitat directa, com les parets sud-oest de la capella. Altres alteracions puntuals relacionades amb la tècnica d'execució dels morters són la presència d'alguns caells que emergeixen i deterioren puntualment la superfície pictòrica i que han completat el seu procés de transformació després de l'execució de la pintura, i han provocat microaixecaments a la zona del timpà. La causa d'una alteració tan localitzada la podem buscar, segurament, en el suport de la contrafaçana, orientada a Occident, al sol ponent i molt més exposada a la intempèrie que la resta de murs que conformen la capella.

serious deterioration, with one exception: those layers where drying oil and white lead were combined, forming a highly resistant, sufficiently flexible patina. In contrast, the layers made with certain protein-based materials proved to be sufficiently porous to avoid this lifting effect.

Other choices the painter made tended to have a much more localised effect; their impact was only visible in the area where incompatible materials were combined. This was the case where the tin was cut, drawing humidity towards the surface and thereby causing the azurite to take on an intense green colour; when white lime was applied onto azurite, causing darkening; and when vermilion and minium came into contact, leading the latter to blacken.

Finally, the stage of preparing the wall for the fresco also impacted the way it would hold up over time. Although this is not strictly related to the pictorial layer, it did have direct repercussions on conservation. The painters recycled a pre-existing coat of plaster and used it as the *arriccio*; our study revealed that this surface was not as ideal as a brand new, ruggedly textured coat would have been. This was clear in those parts of the walls which suffered through multiple renovations, where the detachment with void or separations between layers of mortar are particularly prominent and visible.

The passing of time also brought to light some impurities in the *intonaco*. Small percentages of mica, a natural mineral contained in the silica sand used to prepare the mortar, gave rise to tiny losses in areas most exposed to direct humidity, like the chapel's southwest-facing walls. The way the mortar was applied also led to another type of alteration: as expanding unslaked lime lumps appeared after the painting had been finished, they lifted up tiny areas in the tympanum, causing damage in these small parts of the pictorial surface. Such localised damage is undoubtedly related to the counter-façade, which faced west towards the setting sun and was much more exposed to the elements than the other walls in the chapel.

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