# The Technical Examination of a Painting that Passed through the Hands of Sienese Restorer and Forger Icilio Federico Joni

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ABSTRACT

A panel painting of the Crucifixion belonging to the Fogg Art Museum and attributed to an imitator of the 14th-century northern Italian painter Altichiero was technically examined in order to address questions about its authenticity. Suspicions about the painting had been raised on technical grounds and because it was purchased from the famous Sienese restorer and forger Icilio Federico Joni (1866-1946). The materials and technique of the painting were studied and compared to 14th-century Italian panel painting practices and to restoration and forging techniques described by Joni. The examination shows that the distinction between a heavily restored painting and a fake can be ambiguous, particularly when only a vestige of the original remains. The issues raised when dealing with such 'renovated ruins', as well as the social context that created an environment conducive to the production and marketing of fakes in Italy in the late 19th and early 20th centuries, are also discussed.

Introduction

The subject of this study is a small panel painting (fig. 1), which depicts a crowded Crucifixion scene comprising twenty-three figures (Imitator of Altichiero, Crucifixion, Fogg Art Museum, Harvard University Art Museums, Cambridge, Mass., 1965.85). The panel has been carved, with its frame, from a single piece of wood. The overall, maximum dimensions of the work are 29.6 cm in height x 14.5 cm in width x 1.9 cm in thickness. The recessed image area measures 17.0 cm x 9.0 cm x 0.8 cm.

Although the painting had been exhibited in the past, it was in storage for some time due to uncertainties about its authenticity. The technical examination was prompted by the following aspects of the painting's physical structure and composition. The pronounced cracks on the gilded frame appear to have been intentionally scratched into the surface in places. Some cracks have occurred naturally in response to the expansion and contraction of the underlying layers, however, others, which are quite straight and oriented perpendicular and parallel to the edges of the frame seem to have been scored into the gilding with a sharp instrument, even bisecting one another in places (fig. 2). While it would not be unusual for a painting of this age to have restorations and repairs, the incised cracks suggest that there was a deliberate attempt to make the frame's gilding appear older than it actually was. In addition, the poses and gestures of some of the figures seem anomalous. For example, the monk, dressed in a long white robe at the right side of the painting, appears to stand with his hand in his pocket. The soldier on horseback, at right (plate 1), rests his chin in his palm while his elbow rests on his horse's head. Both postures have a curiously modern feel.

The painting was given to the Fogg Art Museum at Harvard University, Cambridge in 1965 by Mrs. John Alden Carpenter, the niece of Arthur and Lucy Kingsley Porter, from whom she inherited the work. The painting was thought to be by the 14th-century northern Italian painter Altichiero, however, it is documented that the Kingsley Porters purchased the painting from the 'dealer, Ioni of Siena' (Curatorial file 1965.85). Icilio Federico Joni (1866-1946) was a well-known restorer and forger of early Italian paintings and his connection to the work naturally raises questions about how much he contributed to the painting as it appears today. Mazzoni has noted that "there was a time, around 1930, when the notoriety of Joni had grown to such a point that it conferred an air of uncertainty onto every gold ground painting that came from Sienese and Florentine antique shops" (Mazzoni 2001, 14).

Many restorations and forgeries of early Italian paintings in collections in Europe and North America have been linked to Joni (Frinta 1978; 1981; Mazzoni 2001). At times, works have been attributed to him more as a result of his notoriety than any documented connection, leading him to declare, "If I was really the author of all the pictures that are attributed to me, I should have to be an

Fig. 1 Imitator of Altichiero, Crucifixion, ca. 1350, tempera and oil on wood panel, 29.6 x 14.5 x 1.9 cm, Fogg Art Museum, Harvard University Art Museums, Cambridge, Mass., 1965.85

Argus with a hundred hands, instead of a hundred eyes" (Joni 1936, 336). Mazzoni has attempted to trace the forging activities of Joni and some of his contemporaries through archival documents including photographs, preparatory drawings, and the records of the Ufficio esportazione all'estero degli oggetti d'arte (Office for the Export of Art Objects), which list objects that received export licenses because they were identified as modern counterfeits (Mazzoni 2001).

In 2004, Mazzoni curated the exhibition Falsi d'autore: Icilio Federico Joni e la cultura del falso tra Otto e Novecento, at Santa Maria della Scala in Siena (Mazzoni 2004). The exhibition focused on the culture of fakes in 19th- and 20th-century Italy and showed works produced by Joni and his contemporaries. Mazzoni considers the 'tradition of forgery' to be an important and overlooked area of art history and deems many of these modern productions to be of such high quality that they should be considered works of art in their own right (Mazzoni 2004). Mazzoni's focus is on stylistic analysis and archival research, and although some of the catalog entries touch upon materials and condition, technical analyses are not included, even for paintings whose materials have been studied. As a result, there remains little published technical information about the materials and construction of paintings produced or restored by Joni. Notable exceptions include the work of Mojmir Frinta which considers the punch work on a number of restorations and forgeries linked to Joni (Frinta 1978; 1981) and a small number of shorter technical studies on paintings with possible Joni connections including a Madonna and Child with Saints triptych from the Courtauld Institute of Art, London (Jones 1990; Mazzoni 2001), a Virgin and Child with Angels by an imitator of Sano di Pietro in the Clevelend Museum of Art (Cleveland) and a Saint Catherine of Alexandria attributed to Andrea Vanni in the Musée d'art et d'histoire, Geneva (Natale and Ritschard 1997).

A technical examination of the Crucifixion was carried out as part of an advanced-level internship at the Straus Center for Conservation and Techni-

cal Studies of Harvard University Art Museums (Muir 2003). The aim of the study was to determine whether the painting is an authentic 14th-century work, whether it has been heavily restored or even repainted, or whether it is a 20th-century forgery. The painting was examined with ultraviolet (UV) and infrared (IR) illumination, X-radiography, cross-section analysis, polarizing light microscopy (PLM), X-ray fluorescence spectroscopy (XRF), Fourier transform infrared spectroscopy (FT-IR), gas chromatography-mass spectrometry (GC-MS) and radiocarbon (C14) dating. All instruments and procedures are described in Appendix 1.

Fig. 2 Crucifixion, detail, cracking pattern on frame, upper right side

Icilio Federico Joni

Icilio Federico Joni was born in Siena in 1866 and died there in 1946. He learned the skills of the gilder at a young age while working in a local workshop and studied intermittently at the Istituto di Belle Arti in Siena (Joni 1932; 1936). A booming antiques market in Italy persuaded Joni to apply his artisan training to the restoration of artworks and his acquaintance with Bernard Berenson introduced him to a network of wealthy foreign collectors and dealers who employed him to restore their damaged and fragmentary works, particularly those by early Sienese and Florentine painters (Joni 1932; 1936). Joni was sometimes entrusted with the sale of paintings on behalf of his associates, many of which he had restored himself (Joni 1932; 1936).

Around 1890, no doubt encouraged by the rising demand for early Italian paintings, Joni began creating original works in the style of the early Italian masters (Mazzoni 2001). A critical re-evaluation of early Italian painting and the success of shows, such as the 1904 Exhibition of pictures of the school of Siena at the Burlington Fine Arts Club in London (Exhibition of pictures 1904), made Siena a popular destination for tourists and foreign art collectors in the late 19th and early 20th centuries (Mazzoni 2001). This promoted a flourishing industry around the discovery, restoration and copying of trecento and quattrocento artworks (Mazzoni 2001). Joni began by making copies of the tavolette di Biccherna, the painted and gilded Tax Register book covers used by the Sienese government between the 13th and 17th

centuries (Joni 1932; 1936; Mazzoni 2001). These he sold to antique dealers in Florence and Rome as genuine works (Joni 1932; 1936).

For assistance, Joni drew from the pool of talent turned out by the Istituto di Belle Arti, of which he served as Superintendent from 1920 to 1923. As Mazzoni suggests, in an environment where contemporary art was eschewed in favor of the traditional arts of the Middle Ages, students from the Academy may have had little choice but to dedicate their skills to the profession of restoration and, perhaps inevitably, to the production of fakes:

> Under the crushing weight of a tradition so admired and venerated, as evidenced by the numerous workshops of decorators, gilders, engravers and joiners that perpetuate, in the tradition of Cennino Cennini, the techniques inherited from their ancestors, [it must have been difficult for young, modern artists working] in a city that aspired to the Middle Ages. (Mazzoni 2001, 19)

Joni himself commented that his early years in the workshop of his cousin seemed scarcely different from life in the medieval workshop, "for we lived still in the primitive, elementary tempo of the Middle Ages, and progress had not put in an appearance among us" (Joni 1936, 32). In an 1899 diary entry, Bernard Berenson's wife Mary describes Joni's workshop:

> We have run our forger to the earth – but a very easy matter it was – for 'he' is a rollicking band of young men, cousins and friends, who turn out these works in cooperation, one drawing, one laying in the colour, another putting on the dirt, another making the frames, and some children with a big dog keeping guard over the pictures that were put in the sunshine to 'stagionare' [dry out and season]. A real Renaissance group of jolly workers, intent on sport, burlo [rowdiness], and their trade, which they never think of as art. Their chief is Federico Ioni, a rakish-looking man of 30, very free and easy – a good fellow. They hide nothing. (Strachey and Samuels, 84)

In 1932, Joni published his memoirs under the title Memorie di un pittore di quadri antichi (Joni 1932). News of the publication did not sit well with some dealers and art historians who were no doubt nervous about the impact of his revelations on their reputations (Mazzoni 2001). The book, censored in parts to protect certain identities, was translated into English and published by Faber and Faber of London as Affairs of a painter in 1936 (Joni 1936). The work has recently been reprinted in an edition that provides the English translation alongside the original Italian text (Joni 2004). As Mazzoni notes, since both original editions had become increasingly difficult to find, the reprint makes Joni's writings more accessible and the side-by-side format allows the reader to see "by philological comparison of the two texts, the 'toning down' to which the lively 'painter of antique pictures' was subjected when his words were translated into [English]" (Joni 2004, 4). Although Joni presents a selective and at times cryptic account of his activities and associations, the book does provide some technical information about his working techniques, in particular his instructions for imparting an aged appearance to newly painted works.

Art historical analysis of the Crucifixion

Questions about both the authorship and the authenticity of the Crucifixion had been raised from the time of its entrance into the Fogg collection in 1965. Altichiero, an important painter of the

late Trecento, is best known today for his fresco cycles including those from the Chapel of San Giacomo, Il Santo and the Oratory of San Giorgio, both in Padua (Richards 2000). Although executed in different media and on different scales, comparison of the Fogg panel with Altichiero's Crucifixion frescoes reveals certain similarities. The crowded narrative format, with the figures divided into four groups - one mounted and one standing on either side of the Cross - is typical of Altichiero's compositional arrangements (Richards 2000). Some of the poses in the Fogg panel are very similar to those from Altichiero's compositions, however, there is not the same sense of spatial depth seen in the large-scale works of Altichiero and the relative proportions of the figures are problematic. The Fogg panel has the quality

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of a pastiche, which borrows elements from other works and brings them together in a somewhat awkward way. This kind of self-conscious execution can be a telltale sign of a copyist who concentrates on individual aspects of the scene rather than their relation to one another and the building of the composition as a whole. A similar awkwardness was judged in a painting attributed to Joni, Madonna of Humility (Allen Art Museum, Oberlin), where "the painter was probably so preoccupied with the stylistic arrangement of the drapery folds that he overlooked all structural logic, which does exist in genuine representations of the period" (Frinta 1978, 11).

The painting's curatorial file contains unpublished records describing the opinions of art historians who commented on the painting in the late 1960s (Curatorial file 1965.85). The documented views agree that the work is in the style of the 14th-century Paduan school, however, questions were expressed about its authorship and the degree to which the painting had been restored. In 1966, American art historian Millard Meiss said that the Crucifixion is "attributed, certainly not correctly, to Altichiero" (Meiss 1966). Federico Zeri, an Italian art historian and critic who catalogued the Italian paintings of several American collections, examined the work in 1968. He identified it as being close to Altichiero, but questioned its authenticity because the image seemed to have been repainted and the frame artificially aged:

> Although this panel has been outrageously refixed and repainted, and though it shows now baby-doll-like faces, I think it is old, both in the composition and in the frame. In the frame, the shape looks genuine, but extensive additions of new gesso and new gold have been finished adding craks [sic] with the help of a pin (this is very apparent in almost every part of the mouldings). The style of the composition and certain details that have escaped the hand of the restorer (such as the two Angels) show a position very close to Guariento, and, in any case, Paduan – not Veronese. (Zeri 1968)

Zeri (1968) further noted that the work reminded him of a small Madonna of Humility attributed to Guariento by Italian art historian and critic Roberto Longhi (Longhi 1957). In 1968, however, Longhi stated, "the frame points to Padua; but, perhaps, for the repaints I can't believe that the picture is by Guariento" (Longhi 1968). Punch mark specialist Mojmir Frinta examined the painting but found that there was insufficient punch work to warrant a change of attribution from Altichiero (Curatorial file 1965.85). The painting was listed as '14th century Paduan' by Fredericksen and Zeri in their 1972 Census of pre-nineteenth century Italian paintings in North American public collections (Fredericksen and Zeri 1972).

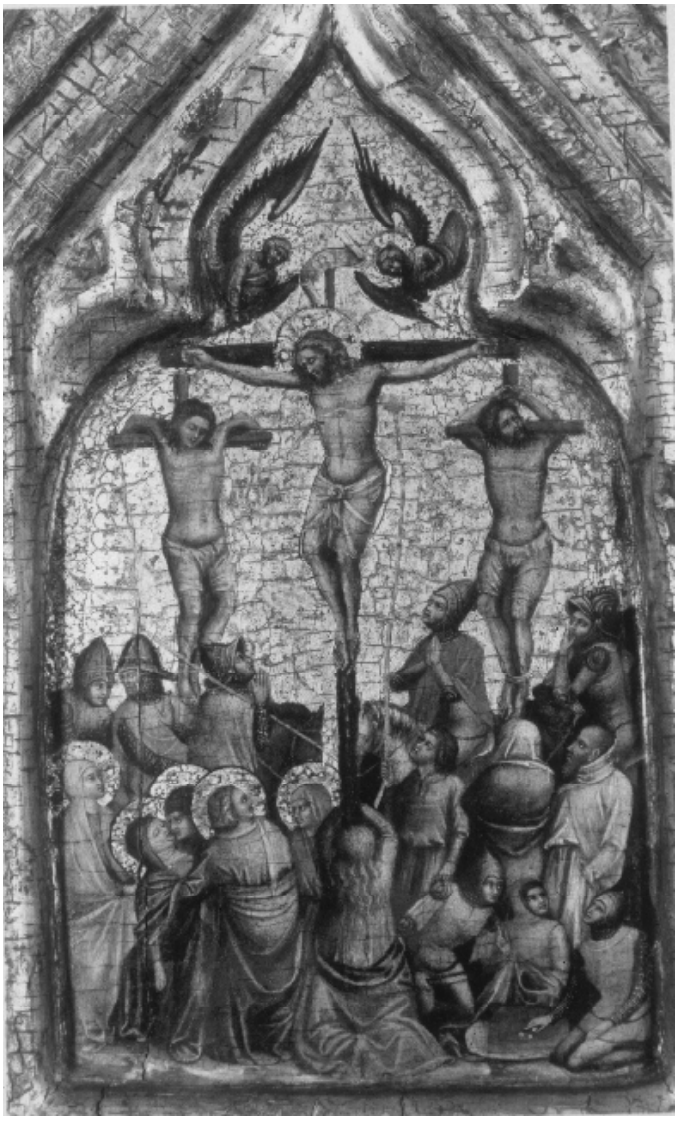

Fig. 3 Crucifixion, archival black-and-white photograph taken ca. 1966

The painting received minor conservation treatment by Fogg conservators while it was still in the possession of Lucy Kingsley Porter. This seems to have involved consolidation of the paint layer and the gilding of the frame. There is no record of conservation work on the painting since the Fogg acquired it in 1965. However, a black and white photograph, which was probably taken in 1966, shows the painting in a remarkably different state than it appears today (fig. 3). At the time of the photograph, the image was extensively overpainted, providing the figures with more detailed draperies, elaborate helmets and armor, and a higher degree of finish in the faces. The overpaint is primarily restricted to the main group of figures in the lower half of the painting. Most of this embellishing layer of repaint was removed

Fig. 4 Crucifixion, x-ray radiograph

during an undocumented cleaning of unknown date, leaving the painting in its present state with simpler draperies and hoods and, in some cases, only traces of the underlying faces. Compare, for example, the helmet of the soldier on horseback at the far right or the drapery of Mary Magdalene kneeling at the foot of the cross with their present appearances in figure 1. The black and white photograph likely represents the state of the object when Zeri examined it in 1968 and commented on the heavy overpainting and "baby-doll-like faces."

Technical examination of the Crucifixion

The panel support is made from a tangentially cut plank of wood that appears to be poplar. The panel and frame were carved together as one continuous piece. There are two checks running from the bottom edge of the panel (one 13.0 cm long near the left side of the painting, the other 7.0 cm long near the center). A thin strip of wood is attached to the bottom edge of the panel with three modern nails. The palmette at the apex of the frame is also a later addition, likely added to replace a damaged or missing element. The join is clearly visible in the X-radiograph (fig. 4) where it runs through the center of the circular part of the modern hanging device. The fact that the gilding continues, uninterrupted, from the main panel over these added parts, indicates that it was applied after the repairs to the frame were made. There is no evidence of thinning or other alterations to the overall dimensions of the panel. Radiocarbon (C14) age analysis of a sample from the wood panel indicates that the tree was felled between 1150 and 1230, an acceptable time range for a panel painted in the mid-14th century (see Appendix 1 for parameters of analysis).

Four small metal hinges, two on either side of the panel, suggest that it originally formed the central part of a small triptych. The X-radiograph clearly shows the hinges (see fig. 4), which consist of a metal pin that has been looped in half and inserted into the front edge of the frame at an

angle. The two ends of each piece which surface at the back of the panel are separated and hammered flat to hold the hinge in place. The hinges appear similar to those found on the small triptych depicting the Madonna and Child with Saints (Courtauld Institute of Art, London), which has been identified as a modern work by Joni (Jones 1990; Mazzoni 2001; 2004). Jones (1990) reproduces an X-radiograph of the Courtauld triptych that clearly shows the hinges.

Fig. 5 Crucifixion, detail, head of Virgin Mary, second figure from bottom left

There are several old woodworm holes in the panel, as one would expect in an object of this age. The X-radiograph shows the worm channels in the panel and confirms that the frame area has been re-gilded. The new preparation layer, applied before re-gilding, fills the channels on the front face of the frame, appearing lighter in the X-radiograph (see fig. 4). The preparation layer of the painted area, on the other hand, appears to be contemporary with the original construction of the panel painting since it was clearly applied before the worm damage occurred. The same conclusion, however, cannot necessarily be drawn about the overlying paint layers since they could be contemporary with the preparation layer, or they could be of more recent date, using the old panel and gesso layer as the ground for a new painting. Neither the panel nor the frame shows any evidence of fabric pieces having been applied to the support before application of the gesso layers.

Presumably the frame's gilding was so badly damaged that it was replaced in order to provide a more finished surface. The deliberate scratches, designed to emulate cracks in the gilding, were likely added to impart an aged appearance to the new gilding, more in keeping with the gilded background of the painting. Both the background and the frame have layers of red bole that are visually similar.

The gold ground of the painting is decorated with punch work consisting of a single point punch arranged in an ornamental pattern. The haloes are decorated with a six-sided, flower-shaped motif that measures less than 0.2 cm in diameter (fig. 5). A smaller version, less than 0.1 cm across, appears in the haloes of the two angels. As mentioned above, Frinta examined the punch marks but found that there was insufficient information to draw

any conclusions about the painting's attribution (Curatorial file 1965.85).

Frinta has examined a number of forgeries and restored areas of authentic works and connected them to a single workshop on the basis of a recurring punch motif found on paintings belonging to different schools and different periods (Frinta 1978; 1980). He attributes the restorations and forgeries to the workshop of Joni on the basis of documentary evidence that links Joni to one of the restorations. One must be cautious, however, about judging authenticity on the basis of punch mark evidence alone since it would not be unusual for an authentic painting, in the course of restoration, to have been re-gilded and re-tooled with new punches. A number of punches from Joni's workshop are known and have been examined by Skaug (Skaug 1994). None of the punches in the Joni archive that were published by Skaug, however, match the small hexa-rosettes seen here.

The painting was examined by infrared reflectography using the Straus Center's Inframetrics Infracam but no evidence of underdrawing was detected. Incised lines are visible around the figures, where the painted area meets the gilding, and around the haloes. These would have been scored into the gesso before gilding to delineate the boundary between the gilded and non-gilded areas.

Based on its appearance and handling, the paint medium was estimated to be egg tempera. The surface of the painting is quite smooth and flat and exhibits the fine, discrete brushstrokes characteristic of tempera painting. There is a fine network crackle in the paint in some areas, in addition to deeper cracks through the preparatory layers.

There is no evidence of green earth underpainting in the flesh areas, as is often found on paintings from this period (Bomford et al. 1989). The draperies are produced with an up-modeling technique where relatively pure color is used to create the shadows and various admixtures with white are used to render the volumes and highlights of the folds.

Under normal and ultraviolet (365 nm) light examination, the painting appears to be in reasonably good condition. The paint surface shows moderate abrasion, particularly noticeable in some of the faces where only traces of the painting remain and at the edges of the cracks in the paint and gilding layers. There is one significant paint loss at the bottom edge of the painting in the mauve-colored robe, which has remnants of watercolor retouching. There are a few other small paint losses related to the checks in the support, the wormholes and other minor damages. The wormholes were filled in a previous restoration, probably contemporary with the extensive repainting shown in the archival photograph. The fills were exposed when the overpaint was removed in the undocumented cleaning (see plate1). There is no evidence of major restoration and only localized areas of retouching associated with small damages.

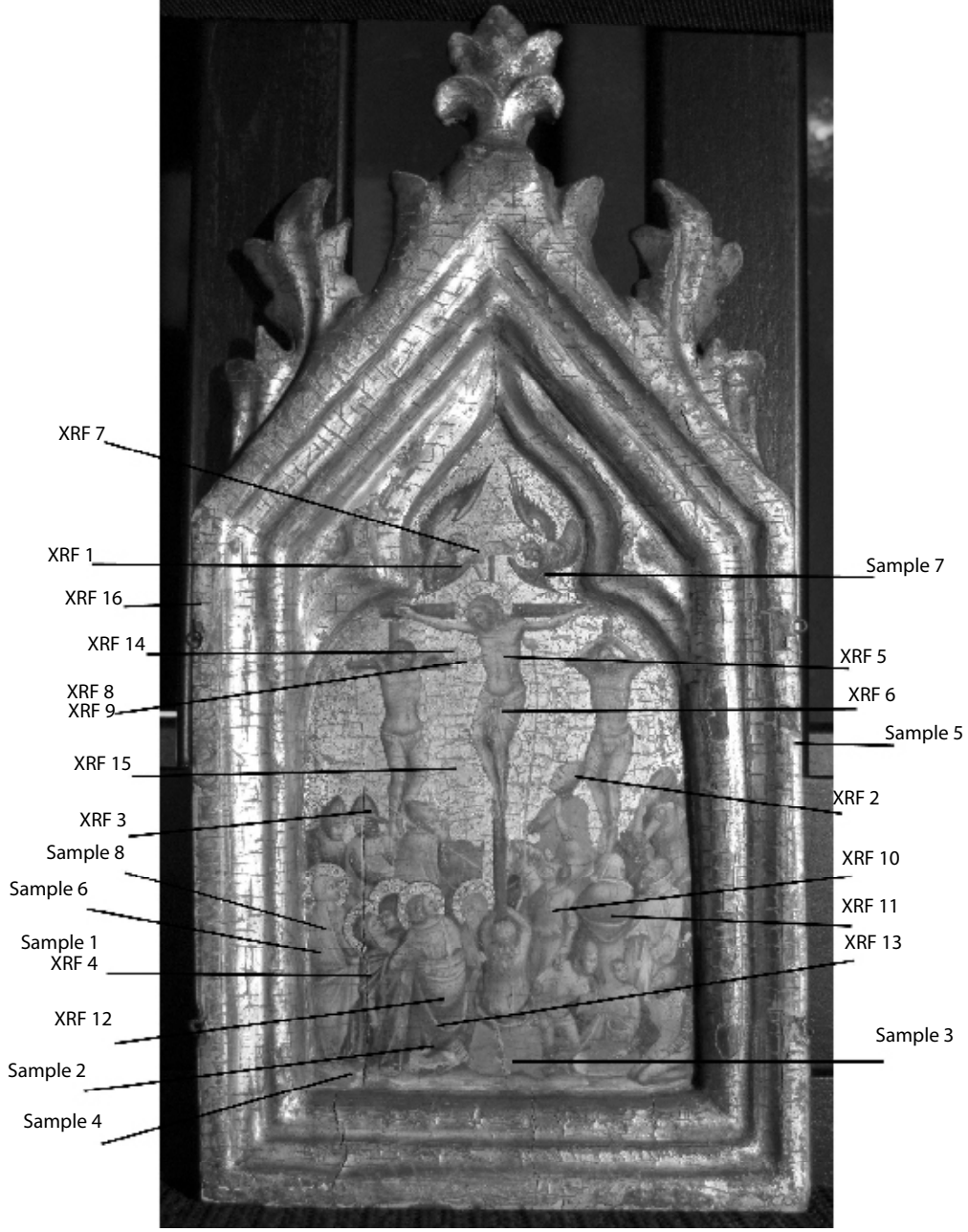


Fig. 6 Diagram of sample locations and XRF sites

When the paint surface was examined under the microscope, it was evident that traces of the overpaint layer, documented in the archival photograph, remained. In the yellow robe of the bottom left-hand figure, some of the white drapery folds pass over cracks in the underlying paint layer. This paint proved to be easily soluble in acetone in a small test carried out under the microscope. Other similar areas of overpaint were observed on the figures at the left side of the painting. The two left-most soldiers, for example, have retained parts of their embellished helmets and there are two different layers of red paint comprising the blood at Christ's right side (plate 2). A darker red paint extends over a brighter red layer, as well as over cracks in the underly-

Table 1. Locations of sample sites and analysis carried out on Crucifixion, Imitator of Altichiero, Fogg Art Museum, Cambridge, Massachusetts, 1965.85

| Sample # | Area | X,Y (cm) | FT-IR | GC-MS | PLM |
|---|---|---|---|---|---|
| 1 | Virgin's blue mantle | 4.3, 5.5 | paint: proteins, fatty acids | P/S=2.26 A/P=0.13 | _ |
| 2 | Green foreground at bottom edge | 6.3, 3.5 | _ | _ | _ |
| 3 | Red skirt of Mary Magdalen at foot of Cross | 7.6, 3.8 | paint: proteins, fatty acids ground: calcium sulfate (anhydrite) | P/S=2.32 A/P=0.06 | _ |
| 4 | Green foreground below figures at bottom left | 4.0, 3.3 | _ | _ | _ |
| 5 | Frame (gilding) | 14.3, 11.5 | _ | _ | _ |
| 6 | Yellow mantle of bottom left figure | 3.6, 6.2 | _ | _ | _ |
| 7 | Blue from proper right angel (scraping) | 9.2, 15.8 | _ | _ | Prussian blue |
| 8 | Dark crack-enhancing material (scraping) fromfigure in sample 6 | 3.8, 6.8 | proteins carbohydrates | _ | yellow lake charcoal |

P = palmitic acid; S = stearic acid; A = azelaic acid

Table 2. Locations and results of XRF analysis of Crucifixion, Imitator of Altichiero, Fogg Art Museum, Cambridge, Massachusetts, 1965.85

| Sample # | Color Area | X,Y (cm) | Major Elements | Minor Elements | Trace Elements |
|---|---|---|---|---|---|
| 1 | Blue - arm of left angel | 6.3, 14.8 | Pb, Ca, Fe | Cu | K |
| 2 | Blue - helmet of soldier to right of Christ (no trace of over paint) | 9.0, 9.8 | Pb, Ca, Fe | Cu | Mn |
| 3 | Blue - helmet of middle soldier on left side (traces of over paint) | 4.7, 9.2 | Pb, Ca, Co, Ba, Fe | | Cu, Zn, Cr |
| 4 | Blue – Virgin's sleeve | 4.1, 4.9 | Co, Pb, Fe, Ca | Cr, Ti | Hg, Zn, Cu |
| 5 | Flesh– Christ's chest | 7.6, 13.2 | Pb | Fe, Ca | |
| 6 | White – Christ's loin cloth | 6.9, 11.8 | Ca, Pb | Fe | |
| 7 | Red – letter 'N' in scroll above Christ | 7.0, 15.3 | Pb, Hg | Ca | |
| 8 | Red – blood from Christ's right side (underlying layer) | 6.8, 12.7 | Hg, Au, Fe | Pb, Ca | Cu, Ni, Cr, Ti |
| 9 | Red – blood from Christ's right side (overpaint) | 6.9, 12.8 | Hg, Pb, Fe, Ca, Au | Ti, Cr | |
| 10 | Yellow – tunic of figure swabbing Christ's wound | 8.4, 6.7 | Pb, Ca | Fe | Cu |
| 11 | Green – tunic of central figure on right side of Christ | 9.1, 6.7 | Cu, Pb, Ca | Fe | Ba, Hg, Mn |
| 12 | Mauve – skirt of figure fourth from bottom left | 5.2, 4.21 | Pb, Ca, Cu, Fe | Hg | Mn |
| 13 | White – highlight from mauve mantle of site #12 | 5.2, 4.0 | Pb, Ca | Hg | Fe, Cu, Mn |
| 14 | Gilding below Christ's proper right arm | 6.4, 15.0 | Ca, Fe, Au, Hg | Ba | Pb, Ag |
| 15 | Gilding – repair to left of Christ's leg | 6.3, 9.1 | Au, Fe, Hg, Ca | Sr, Ni, Ba | Zn, Cu |
| 16 | Gilding – frame | 0.5, 14.8 | Fe, Au, Ca | Ba, Zn | Cu, K |

ing gilding. It is unclear why the layer of overpaint was not completely removed from all areas of the painting, although this kind of exploratory cleaning, aimed at recovering the earliest image, was not unusual on early Italian paintings in the decades around the middle of the 20th century (Ciatti 1990; Hoeniger 1999; Garland 2003).

Eight samples were taken from the painting (fig. 6, table 1). All locations were examined between 5x and 63x magnification prior to sampling. This ensured that restorations were easily identified and that sampling was limited to the paint layers of interest. Six of the samples were prepared as cross-sections and studied using visible and UV light microscopy and staining techniques (see table 3, samples 1-5, 7; see Appendix 1 for cross-section preparation). Because of the small size of the painting, the size and number of samples was necessarily restricted. This obviously placed limitations on the kinds of analyses to which each sample could be subjected.

Sixteen areas on the panel were examined using X-ray fluorescence spectrometry (see fig. 6; table 2). It must be noted that the sample areas used for the qualitative XRF analyses are small (approx. 50 x 70 µm) and may not be fully representative of the entire area analyzed. XRF analysis of the paint layer mainly detected elements that are compatible with what one would expect to find in a trecento painting, indicating the use of lead white, red and yellow iron oxides, vermilion, and copper-based blues and greens (see table 2). The flesh appears to be comprised mainly of lead white with iron oxides. One would certainly expect to find such pigments in a 14th-century painting, but they would also have been available to Joni. Areas of blue paint examined on the two angels and the soldiers' helmets, however, gave high readings for iron, which suggest the use of Prussian blue, a pigment not available until 1704 (Berrie 1997). The identification of Prussian blue on the angel's robe was confirmed by polarizing light microscopy. A scraping was taken from this area where the blue paint lies directly over the gilding. Comparison of areas of blue paint on two different helmets, one with remnants of overpaint, the other with no traces of overpaint (see table 2, sites 2, 3), suggests that the lower paint layer consists primarily of lead white and Prussian blue, while the overpaint contains cobalt blue, not available until the early 19th century (Gettens and Stout 1966). Areas with remnants of overpaint showed the presence of barium, zinc and chromium, suggesting the use of other modern pigments such as zinc white, zinc yellow, barium white and/or barium yellow (see table 2, sites 3, 4). Further analysis would be required to definitively determine which pigments are present.

Although there appear to be traces of azurite in Mary's blue mantle, major amounts of iron and

Table 3. Locations and results os XRF analysis of Head of the Madonna, Icilio Federico Joni, Fogg Art Museum, Cambridge, Massachusetts, 1948.2

| Site# | Color Area | Major Elements | Minor Elements | Trace Elements |
|---|---|---|---|---|
| 1 | Blue - Virgin's mantle | Pb, Cr, Ca | Zn, Fe, Cu | Zn, Fe, Cu |
| 2 | Blue – sky | Pb, Cr, Ca, Zn | Fe | Cu |
| 3 | White – ground | Ca, Zn | Ca, Zn | K, Fe |

cobalt suggest the presence of Prussian blue as well as cobalt blue (see table 2, site 4). The presence of zinc, chromium and titanium suggests the use of other modern pigments such as zinc white and/or zinc yellow, both 19th- century pigments (Kühn 1986), and titanium white, not available until the 20th century (Laver 1997). Some of these pigments may be associated with residual overpaint. A cross-section from this area (plate 3) shows that the mantle is built up in five layers of blue paint with various admixtures of white. These layers all have a similar appearance, are in close contact with each other and lie directly over the ground layer. The paint layers have a very small and even particle size, which is not consistent with the hand-ground pigments one would expect to find in a painting from this period.

For comparison purposes, a small tempera demonstration piece, Head of the Madonna, painted by Joni, was also examined with XRF (table 3). Joni taught tempera painting technique to foreigners and notes in his memoirs that "students are sent from [the United States] every year by Mr. Forbes, the Director of the Fogg Art Museum at Cambridge" to study the art of tempera painting (Joni 1936, 326). As a result, the Straus Center possesses several tempera studies from that period. XRF examination of the Joni painting indicates the use of several modern pigments including Prussian blue, zinc white, zinc yellow and cadmium yellow showing that these modern pigments, some of which appear to have been used on the Crucifixion, were part of Joni's palette.

A sample of the gesso layer from Mary Magdalene's red skirt (sample 3) was analyzed by FT-IR (see Appendix 1 for parameters of analysis). The ground layer was identified as the anhydrite form of calcium sulfate, as one would expect to find in a layer of gesso grosso. In a cross-section prepared from Mary's blue robe (sample 1), two distinct layers of gesso are visible (see plate 3). This appears to correspond to the traditional preparation found in Italian painting, consisting of a thicker and coarser undercoating of gesso grosso, followed by layers of the finer gesso sottile (Bomford et al. 1989).

Two paint samples were analyzed by GC-MS (see Appendix 1 for parameters of analysis): the blue paint from the Virgin's mantle (sample 1) and red paint from the Magdalene's robe (sample 3). The analysis of fatty acids was chosen over proteins, as the samples were too small to risk their loss through the workup procedure necessary for protein analysis. The blue paint had ratios of P/S=2.26 and A/P=0.13. The red paint gave the values: P/S=2.32 and A/P=0.06 (A=azelaic acid; P=palmitic acid; S= stearic acid). The azelaic acid values are characteristic for egg tempera paint. Schilling et al. (1997) state

that an A/P ratio near 0.1 suggests egg tempera. Mills and White (1987) state that sometimes no azelaic acid is detected and sometimes amounts equivalent to about a quarter or a third of the palmitate peak are present in egg tempera. FT-IR results detected proteins and fatty acids, which fully supports the identification of egg tempera by GC-MS analysis. Staining tests with Amido Black 2 (Martin 1977) detected proteins, which is consistent with the presence of egg tempera.

If only egg tempera were present then one would expect closer correlation between the two A/P values. An increase in azelaic acid, as is seen in the blue paint, can be considered a contribution from a high azelaic acid-producing source, such as a drying oil. It is generally acknowledged that there are usually at least equal amounts of azelaic acid and palmitic acid in drying oil, i.e. A/P>1 (Mills and White 1987; Schilling et al. 1997). Staining tests with Sudan Black B (Johnson and Packard 1971) revealed that there is a discrete presence of oil in some of the blue paint layers (sample 1), quite apart from the naturally occurring oils in egg yolk (plate 4). The staining tests also rule out the likelihood that the oil came from varnish residues or retouching. The staining shows that there is more oil in the blue mantle sample than the red robe sample which accounts for the elevated azelaic acid value for the blue sample. It is noted that this is consistent with the Courtauld triptych attributed to Joni, which is described as comprising "oil and tempera" media (Jones 1990).

There is no overall surface coating on the painting. However, traces of varnish were observed in some areas such as the recesses of the punch marks and as interrupted layers in the cross-sections. The varnish was not analyzed. Under ultraviolet illumination, there is a bright orange fluorescence in the recesses of the frame molding, which has the appearance of shellac. This may have been rubbed onto the surface in places as a toning layer on the new gilding.

In several places on the paint surface, dark lines were observed in association with cracks in the paint layer. These lines mimic, but do not precisely follow the cracks and appear to have been applied to give them an aged appearance (plate 5). The dark lines are covered by the residual overpaint in places. A scraping of the material was analyzed by FT-IR. It was found to contain both protein and carbohydrate, possibly a glue-paste medium as suggested by a close match from standards in the Straus Center for Conservation FT-IR database (fig. 7). Yellow lake and charcoal pigment particles were also found by polarizing light microscopy and were likely added to the substance to give it the desired tone. The presence of this material suggests that some of the cracks in the paint layer were artificially produced since it was likely applied to give them the aged, dirt-filled appearance that naturally-occurring cracks would acquire over time.

A similar phenomenon has been observed in another painting that has been linked to Joni, Saint Catherine of Alexandria by Andrea Vanni (Musée d'art et d'histoire, Geneva). A published technical examination of this painting reveals that it has been heavily restored; while the wood support is old, little of the original painting actually remains beneath the more modern repainting (Natale and Ritschard 1997). The "restoration" was carried out sometime before 1921 and is attributed to Joni (Natale and Ritschard 1997). On the basis of examination of the painting under the microscope, the craquelure is described as being artificially produced with the use of a pointed instrument and then emphasized with a resinous material (Natale and Ritschard 1997). An image

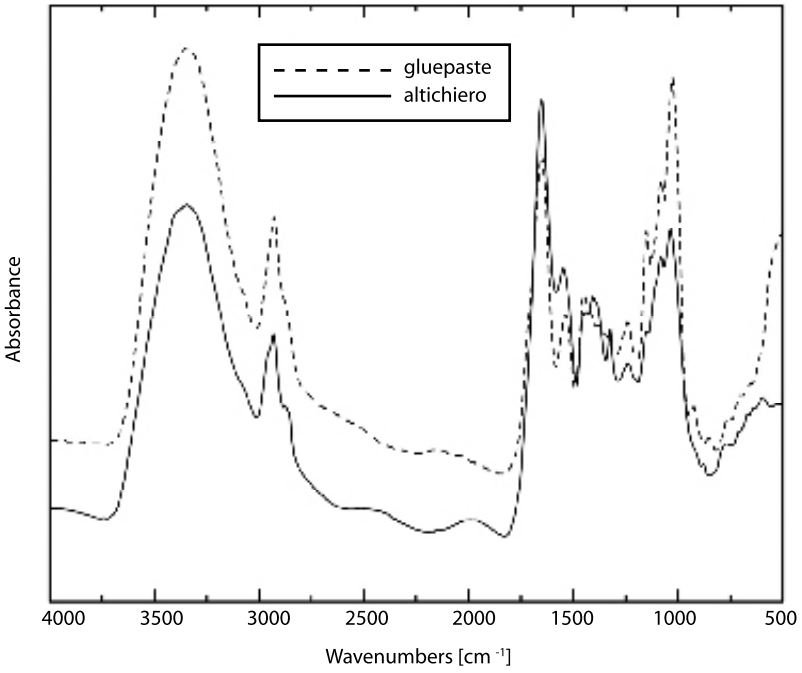


Fig. 7- FTIR spectra of the black material used to simulate cracks on the "Altichiero" panel and the glue-paste lining adhesive from Rossetti's "Blessed Damozel" from the FTIR database of the Straus Center for Conservation. The gluepaste lining adhesive was identified and characterized by Amy Snodgrass and entered as a standard: Index No. 9, Adhesives database, 7/97

of the cracks reproduced in Natale and Ritschard (1997) shows that they have a similar appearance to the enhanced cracks on the Fogg panel. Another work, an unaccessioned painting, Woman Playing a Lute (J. Paul Getty Museum, Los Angeles), which was acquired as an example of Joni's work, shows a similar kind of enhanced craquelure to the Fogg panel.

Discussion

The technical examination of the Crucifixion has determined that the painting is executed on a piece of wood that is sufficiently old to be compatible with the mid-14th century style of the painting. The molded frame, which is carved with the panel as one piece, shows no signs of significant alteration in size, indicating that this is an old picture support, which retains more or less its original dimensions. The preparation layer of the painting was applied to the panel before the insect damage occurred and is, therefore, probably contemporary with the original production of the panel painting. The frame was re-gilded at some point, including the application of a new preparation layer that filled in the worm channels at the surface.

There is no evidence that conclusively proves that Joni worked on the painting. However, since it was in his possession and given the nature of his business, it is entirely reasonable to assume that Joni, or one of his workshop assistants, had a hand in at least some of the modern additions that have been made to the panel. Whether or not there are any traces of an authentic 14th-century painting that could have provided the basis for the current painting could not be determined. No evidence of a 14th-century fragment was seen in the cross-sections; however, this could be a function of the locations from which the samples were extracted, usually near areas of loss or damage. It, therefore, remains uncertain whether the current painting was based on the remnants of an authentic 14th-century painting or whether the composition was invented by borrowing elements from contemporary works, in a kind of pastiche, applying them

to an authentic panel whose original paint layers were damaged or abraded away. To make an aged painting, Joni advises that the support should be "if possible, the panel of an old painting" (Mazzoni 2001, 181). In his memoirs, he admits to 'recycling' old panels, noting that a colleague once brought him "a little picture in which only the background remained and asked me to paint a Madonna over it" (Joni 1936, 184). On another occasion, he mentions that he "had found a fine old panel and painted on it an Adoration of the Magi" (Joni 1936, 222).

There are two distinct campaigns of painting on the panel. Although the overpaint medium was not analyzed, it is readily soluble in organic solvents, allowing its removal from the earlier layer in the post-1966 cleaning. In each campaign, there seems to be an intention to deceive the viewer. The earlier painting, at least in certain passages such as the Virgin's mantle and the angel, is executed with modern pigments, which lie directly on top of the ground layer. This layer also has the enhanced cracks, which were probably applied to give an aged appearance to new or freshly made cracks. The repainted image captured in the 1966 photograph embellishes the costumes and headgear and supplements details from the faces of the earlier version.

The presence of oil in the sample taken from the Virgin's blue robe is unexpected in a tempera painting. Drying oils have been identified in 13th- and 14th-century paintings but specifically associated with translucent pigments such as red lake and verdigris (Roy and Dunkerton 2003). Its presence in discrete layers of the blue paint seems unusual. Joni makes just one detailed reference in his memoirs to the materials he used for painting:

> For my first paintings in tempera, I used mostly the gouache colours made by the firm of Lefranc, which are extremely fine; but although they are mixed with egg, I found them antipathetic to moisture. If one paused an instant in laying on a colour, and put another brushful on top of it, the whole thing was spoiled; it made glazing especially difficult. Then I tried washing the stuff in water, before using it, and making a deposit of colour in a separate vase. But if the least particle of tempera remained, the result was the same. Then I hit on the idea of grinding my own colours; and I did this until the powdered colours of Winsor and Newton came on the market. (Joni 1936, 137)

This quote suggests that Joni continually adjusted his painting technique. However, it is difficult to infer precisely how he used these materials and whether or not any other media could have been added to the egg. In a technical note, Joni describes his methods for aging a tempera painting (Mazzoni 2001). To produce cracks in the paint layer:

> When the painting is thoroughly dry … begin to wet it with an atomizer and expose it to the sun or the fire. When the small and sharp cracking that is appropriate to antique paintings is achieved … heat the painting if there is no sun, by the fire, and apply the varnish … because the painting is dry from the heat, it absorbs so much of the varnish that when it is thoroughly dry, the painting becomes very strong. (Mazzoni 2001, 182)

Joni goes on to explain other methods for producing cracks based on extremes of temperature and humidity, including storing the painting in a damp cellar or loggia for a period of time, then exposing it to the heat and repeating the operation until the desired result is achieved. At this point, a varnish composed of cooked linseed oil, essence

of turpentine, and amber varnish is applied. The painting is then exposed to the air and the sun. Then a chamois or kid glove is used to rub the surface with sepia dust or very finely crushed pumice to give it the worn look of an antique painting. A blunt instrument is then employed to make the marks and damages expected on an old painting (Mazzoni 2001).

It is possible that one of these methods was used to achieve the smooth, hard, cracked surface of the Crucifixion painting, with the dark 'glue/paste' material employed to impart an aged, dirt-filled appearance to the new cracks. Joni's description of applying a varnish and then lightly abrading it in places is consistent with what was observed on the panel. This could account for the varnish residues that were observed in cross-section to be in close contact with the paint, as well as the abraded edges of the cracks in the paint and gilding layers.

It remains unclear why the repainting campaign, which embellished areas of the earlier painting, was carried out. It may have been part of a restoration aimed at bringing the earlier damaged painting, with its abrasions and wormholes, to a more finished level. The Crucifixion was likely purchased before the death of Arthur Kingsley Porter in 1933 and it is reasonable to assume that the repainting was executed in Italy, before the painting was brought to America. This was common practice at the time. Sir Charles Eastlake (1793-1865), the first Director of the National Gallery in London, had his new Italian acquisitions restored in Milan by the artist-restorer Giuseppe Molteni (1800-1867) before bringing them into the collection (Anderson 1994). Restorers like Joni and Molteni's pupil Luigi Cavenaghi (1844-1918) had busy practices restoring damaged and fragmentary works for American and British collectors. Berenson, a friend of Kingsley Porter, utilized Joni's restoration services on several occasions (Joni 1932; 1936).

The Kingsley Porters may even have commissioned the repainting themselves. If they believed that they were purchasing an authentic, but damaged, 14th-century painting from Joni, they may have asked him to restore the work in order to make it more presentable, according to the sensibilities of the time. Such a heavy and inventive intervention would not have been unusual in the 19th or early 20th century. Restoration practices in Joni's time could be quite invasive according to today's standards and often involved essentially repainting the image (Bomford 1994; Hoeniger 1999). Often, this is less a form of deception than a response to the tastes of the times, which favored completeness and a high degree of finish in the pictorial image (Jones 1990). Joni himself recognized that the private collector would not have accepted a minimal degree of restoration:

> There are two possible kinds of restoring: complete restoration in the proper sense, which does not present any great difficulties, when the missing parts are not the most vital part of the painting; and the other kind, which consists simply in matching up the missing parts in neutral colours of the right tone, so as to produce a pleasant general impression on the spectator, without attempting to deceive him … This is the right sort of restorations for museums; for private collectors it is different. (Joni 1936, 317)

A Madonna and Child attributed to the workshop of Benvenuto di Giovanni (Yale University Art Gallery, New Haven), whose restoration has been attributed to Joni (Mazzoni 2001), provides a good example of Joni's approach to the restoration of

a fragmentary painting. The painting was treated in 1953 as part of Yale's well-known de-restoration campaign of 1950-71 (Seymour 1970; Hoeniger 1999; Aronson 2003). After Joni's restoration of the painting, around 1924, it appears in a highly finished state. When the painting was cleaned, removing Joni's restoration, only a trace of the original painting remained with the ground layer exposed in significant areas (see Mazzoni 2001, fig. 153-154). This is not an uncommon state of preservation for paintings of this period. Hoeniger notes that of the small percentage of paintings from the early Italian period that have survived, many exist in "fragmentary and heavily damaged" conditions; few without "substantial restorations" (Hoeniger 2003, 277).

It cannot, however, be ruled out that the repainting was part of the deception. The more obvious attempts to give the new gilding of the frame an aged appearance do not try to hide this fact, as evidenced by the sharp cracks incised in the surface in unnatural, rectilinear arrangements. Perhaps attention was focused on the modernity of the repaired frame decoration in order to provide an obvious foil to the painting, which was purporting to be authentic but was, in fact, also modern. Joni understood that a pristine painting could arouse suspicion among potential clients. A painting from the 14th century would be expected to have damages and repairs. Perhaps the image was overpainted knowing that an educated buyer would likely investigate the authenticity of the painting by testing the solubility of the paint layer. A standard test used by Joni and his contemporaries involved wiping the paint surface with solvent in order to determine if the painting was modern or, if old, the extent of restoration and how much of the original remained beneath (Joni 1936). Discovering the more durable tempera painting underneath, the client might convince himself of the authenticity of the underlying painting. It has been noted that "particularly clever forgers damage the 'primitives' they have just painted and proceed then to 'restore' their own work, in order to put it above suspicion … The restorations are accepted as a certificate" (Kurz 1967, 30).

The kind of empiricism that pervaded much of restoration practice up to the early 20th century where restorations, today judged extensive and arbitrary, were carried out according to the tastes of owners and restorers, led art historians and critics to draw a correlation between restoration and fake (Brandi 1977; Catalano 1998). A restoration that concealed the extent of the damage to the point where it was difficult to distinguish between the hand of the restorer and that of the artist was considered a falsification.

As the work of art came to be recognized not only for its artistic qualities but as a historical document, a new conservation methodology emerged, which required that retouching be documented, restricted to areas of loss and executed in a medium that could be safely removed in the future if required (Brandi 1977).

In cases like the Fogg Crucifixion, the line between restoration and fake becomes somewhat ambiguous. When considering such 'renovated ruins', which comprise original components but carry significant modern additions, at what point is the work no longer authentic? When does the restored object become a forgery? Brandi (1977) argues that the object is only a fake as long as it is recognized as such and, therefore, falseness lies in the judgment and not in the object itself. This means that proof of fraud, both in terms of the production of the object and its sale is essential for the judgment of fake (Brandi 1977).

The difficulty in classifying such objects - not quite a restored original but not entirely a forgery –is reflected in Joni's own ambivalence about his productions. The title of his memoirs indicates that he considered himself a "painter of antique paintings." He saw himself as a creative artist, producing original works that were merely inspired by the paintings of the Middle Ages:

> An artist who creates a work of art of his own, in imitation of the style of an old master, is not a forger; he is at worst an imitator, and he is creating something of his own. And if he produces something that merely reflects the style of the 14th or 15th century, without imitation, it is something really and truly creative. (Joni 1936, 338)

It has been suggested that Joni's activity may be understood within the context of the Arts and Crafts Movement and the interests of the Pre-Raphaelites in early Italian techniques (Mazzoni 2001). Joni mentions discussions with Berenson about the possibility of selling his paintings under his own name:

> I had often said to Berenson that I should like to try to sell my things for what they were, on their own merit; in this way, as he himself said, I should cut out the possibility of others making illicit profits out of them. (Joni 1936, 276)

In fact, in an exhibition of his paintings executed in both antique and contemporary styles, Joni signed and dated those executed in the antique style

(Joni 1932; 1936). Original paintings by Joni, however, were not in high demand and his exhibition was poorly attended. Joni's productions may also be understood as a reaction against the commodification of culture, which saw a significant portion of Italy's artistic patrimony exported to foreign countries. He often complained about foreigners arriving in Siena to trovare l'America, or make a fortune (Joni 1932; 1936). Joni felt that this was often achieved by duping Italian dealers. Once, a man who had purchased one of his Biccherna book covers, thinking it was genuine, angrily confronted Joni, demanding to know if Joni had made it. Joni, who appears to have been quite candid about his workshop productions, answered affirmatively and then asked how much the man had paid for it. Upon hearing the paltry sum, Joni shot back, "Ah? So you think we Italians are such fools that we would sell a rare thing like that, if it was genuine, for four hundred lire?" (Joni 1936, 189).

FROM A PRESERVATION STANDPOINT, THE CRUCIFIXION DOES NOT REQUIRE ANY KIND OF CONSERVATION TREATMENT AND, IN FACT, THIS WAS NEVER CONSIDERED AS PART OF THE PROJECT. AS IT STANDS, THE PAINTING IS A VALUABLE DOCUMENT WHOSE INFORMATION IS BEST PRESERVED IN ITS CURRENT STATE.

There is no doubt that Joni knew his productions were on the market as authentic paintings. In his writing, he is forthcoming about both his methods for producing aged paintings and the pride he sometimes took in deceiving the most trained eyes (Joni 1936). Despite his openness, and the fact that it was often the dealers that bought his modern reproductions who passed them off as authentic works, his passive complicity in their dissemination as genuine works does not absolve him of responsibility.

From a preservation standpoint, the Crucifixion does not require any kind of conservation treatment and, in fact, this was never considered as part of the project. As it stands, the painting is a valuable document whose information is best preserved in its current state. Anything added or taken away could, in fact, confuse the questions posed by the painting even more. Future technologies may be able to address some of the problems that this study could not definitively answer. In terms of exhibiting the painting in the future, careful consideration about how it is presented to the public will be necessary. Obviously, given the significant modern additions, the painting cannot be exhibited as a 14th-century painting. It could, on the

other hand, form the focus of a didactic exhibition. The technical evidence, and the philosophical issues that stem from it, pose challenging questions about notions of authenticity and provide insights into a fascinating figure in the history of restoration.

## Conclusions

The technical examination of the Crucifixion provides physical evidence to support many of the suspicions voiced about its authenticity. The complexity of the work, with different campaigns of painting and restoration, however, does not permit a definitive pronouncement on this subject. The panel and the preparation layer are an appropriate age for a 14th-century painting. The frame has definitely been re-gilded. The presence of modern pigments, such as Prussian blue, cobalt blue and titanium white, however, suggests a much later date for the painting, in some cases, as recent as the early 20th century. The fact that Prussian blue was found in direct contact with the ground layer suggests that significant parts of the earlier painting are modern. The presence of any traces of a 14th-century paint layer remains unverified. The painting is a clever production that shows a good knowledge of the style and technique of the period; however, the modern materials used could not stand up to current analytical methods.

The investigation shows that questions of authenticity can be much more complex and nuanced than a simple determination of genuine or fake and some questions about the precise history of the object may never be answered. The term 'renovated ruin' was proposed for this type of object, which cannot be adequately described as either a restored original or a modern forgery. The information gained from the study provides a valuable source of technical data. Because the Fogg panel is known to have come through Joni, and because there has been little published technical

information of known works by him, the results of this study can provide a resource for further investigations into the authenticity and history of other questionable early Italian paintings. Anecdotal evidence suggests that other museums have examined works linked to Joni. It would be interesting to gather and compare the results.

## Appendix 1: Analytical Techniques

### Radiocarbon Age Analysis

An approximately 0.03 g sample of wood was taken from the back of the panel on the right side of the left crocket. The sample was taken by Eugene Farrell, Senior Conservation Scientist at the Straus Center. Before sampling, the area was cleared of extraneous surface material by scraping with a scalpel. Carbon-14 analysis was carried out at the Center for Applied Isotope Studies, University of Georgia using accelerator mass spectrometry. A routine sample size 80 µmol of carbon dioxide was used for the analysis. A stable isotope mass spectrometer was used to identify carbon-13. A routine sample size 100 µmol of the stable isotope was used for this analysis. The absolute weight of material was not critical as the isotope ratio was used to determine the age of the material.

### X-radiography

The panel was X-rayed at the Straus Center using the Lorad LPX-160 X-Ray unit with Kodak Industrial Ready Pack II M X-ray film. The panel was exposed for 45 seconds at 30 kV.

### X-ray Fluorescence Spectrometry

Areas were examined in situ using a Rontec ArtTAX µXRF Spectrometer equipped with an electronically cooled X-Flash detector, which contains a silicon drift detector and high-speed, low-noise electronics with a resolution of 160eV at a count rate of 10kcps. X-rays were produced by a low power tube with a molybdenum target. The beam was focused by polycapillary optics to a spot size of 70µm x 50µm. The analysis area was purged by a stream of helium. Analysis was carried out at 50kV for 200s. Bronk et al. (2001) have published a detailed description of this instrument.

### FT-IR

FT-IR spectrometric analyses were carried out using a Nicolet 510 instrument coupled to a Spectra-tech IR-plan infrared microscope with a 32x objective. The sample was compressed onto a diamond cell (2mm x 2mm) with a stainless steel roller and the sample area defined by double aper-

tures contained in the microscope. An absorbance spectrum (4000-500 wavenumbers) was measured (resolution setting 8cm$^{-1}$) and subtracted against a blank background. The spectrum was compared with a database of artist's materials at the Straus Center for Conservation.

### Cross-section Preparation

Cross-sections were mounted in Bio-Plastic liquid casting resin (Ward's Natural Science, P.O. Box 5010, San Luis Obispo, Cal. 93403-5010). Samples were ground and polished to reveal the paint stratigraphy and examined by normal and UV reflected light microscopy (Leitz Laborlux S). Khandekar (2003) provides a detailed description of cross-section preparation. Images were recorded digitally with a Phase One digital back (Phase One A/S, Roskildevej 39, DK-2000 Frederiksberg, Denmark).

### GC-MS

For GC-MS analysis, a sample that was visually homogenous was selected. Samples were weighed and a 2:1 mixture of Methprep II (Alltech Associates, 2051 Waukegan Road, Deerfield, IL 60015) and benzene added to an equivalent of 1:1 weight per volume. The sample was heated to 50°C for half an hour to complete the transesterification of the fatty acids. Samples were injected via autosampler onto a DB-5 MS column (30m x 0.25mm, 1µm phase coating) using a splitless injector heated to 300°C. The Agilent 6890N GC oven heated the column from an initial temperature of 50°C (2 minutes) to 300°C at a ramp rate of 10°C/minute and maintained the final temperature for 10.5 minutes. The mass spectrum of the separated components was collected using an Agilent 5973 mass selective detector.

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