Technical Notes on Michele da Firenze's *Virgin and Child*: Examination, Analysis, and Treatment

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After the Yale University Art Gallery completed its ambitious renovation in December 2012—which required reinstallation of over four thousand artworks and conservation of many—there remained a considerable queue of curatorial requests for conservation, including Michele da Firenze's *Virgin and Child* (fig. 1). Once the huge backlog of conservation treatments began to clear, conservators and conservation scientists could turn their attention to examination, analysis, and treatment of this painted and gilded high-relief terracotta sculpture. Acquired in 1964, long before the Gallery hired its first full-time objects conservator in 2008, the sculpture was in such unstable condition that it could not be exhibited for decades. In 2013 Paola D'Agostino was hired as the Gallery's Nina and Lee Griggs Assistant Curator of European Art. With her full support and participation, the collaborative conservation project moved forward and became part of a postgraduate fellowship experience.[1] It was impossible to know at that time what new discoveries would be made during the conservation treatment.

Fig. 1. Michele da Firenze, *Virgin and Child* (before conservation treatment), ca. 1435–45. Terracotta with traces of polychromy and gilding, 54 x 25¾ in. (137.2 x 65.4 cm). Yale University Art Gallery, Maitland F. Griggs, B.A. 1896, Fund, 1964.43

EXAMINATION

In order to ascertain the condition of the terracotta relief, it was important to understand how it was fabricated and how it was used. The relief consists of two sections: the upper section portrays the Holy Father supported by two angels, and the lower section shows the Virgin and Child. Both sections contain ornate architectural details: columns, an arched niche above the Virgin with drapery behind her, and over the Holy Father a triangular pediment edged with cherub heads and floral scrolls.

To make the two sections, the artist wedged the earthenware clay to remove air bubbles and rolled it out to form thick slabs. The surfaces may have been carved down to create areas of background low relief, and then sculptural elements in high relief were added. It is quite likely that some of these high-relief elements were made in molds and were worked further once they were attached to the relief with wet clay. According to Aldo Galli (see "The Yale University Art Gallery's *Virgin and Child*," p. 24), the relief was made from one slab cut in two, but it is also possible it was made in two sections that were designed to fit together so that the whole piece rested securely against the wall in the niche or above the shelf where it was installed. The subject and relatively small size of this type

Fig. 2. Archival photograph of fig. 1, n.d. Kunsthistorisches Institut, Florence, 154407

of relief indicate that it may have been used in a side altar or a private chapel.[2]

After the two sections were fired in a kiln, the terracotta relief was elaborately decorated with polychromy and gilding. Due to its use as a devotional image, the relief would have been touched frequently, and thus it was repainted and regilded many times. Examination with ultraviolet illumination suggested that oil was used as a binder in the upper paint layers, as well as natural varnish and shellac, which may have been used for repairs. More information about the paint layers is provided in the description of analysis later in this essay.

An undated black-and-white photograph of the *Virgin and Child* (fig. 2), taken before the relief was acquired by the Gallery, seems to show a better-preserved surface with flesh tones appearing distinctly lighter than the other colors as compared to what is preserved now. The current surface is overall a dull grayish brown. It was also apparent that restorations for missing areas, such as the lower corners, were made after the black-and-white photograph was taken. X-radiography of the relief was done to penetrate through the paint layers and the fired terracotta body. The X-ray images revealed repaired cracks in the relief as well as creases and irregularities in the original working of the clay.

While the repairs seemed relatively stable, the extremely unstable nature of much of the surface on the front of the relief caused great concern. The layers of paint had suffered significant losses, and many areas of the terracotta substrate had been lost or were on the verge of flaking off. Other terracotta reliefs by Michele da Firenze show similar or even worse deterioration of the surface.[3] This kind of unstable condition is often caused by low firing temperatures of the terracotta combined with centuries in uncontrolled environments, such as private chapels. However, in the case of the Gallery's relief, scientific analysis uncovered another major cause for the fragile condition of the object: the introduction

of reactive materials as a result of previous restoration campaigns.

Preliminary chemical tests identified the presence of chloride and sulfate salts—that is, chemical compounds formed from the reaction of acids and bases. They are known to cause damage when exposed to an uncontrolled environment, where changes in humidity can cause the salt crystals to go in and out of solution, migrate toward the surface, and recrystallize at or below the surface. Before treatment could begin, it was necessary to identify what salts were present by performing more sophisticated analytical techniques on microsamples, such as X-ray powder diffraction and Raman microspectroscopy, in addition to optical microscopy.

ANALYSIS

Scientific analysis was undertaken by the Technical Studies Laboratory at Yale University's Institute for the Preservation of Cultural Heritage (IPCH) in order to characterize the salts, learn more about the artist's materials and techniques, and ultimately understand more about why the object was in such poor condition.

First, fourteen samples were taken from various parts of the object and prepared as cross sections, which make visible the layer structure of the surface decoration. It was clear through visual examination of areas of surface loss that the piece had been subjected to multiple campaigns of repainting in its nearly six-hundred-year history. Examination of the samples confirmed this; nearly all had a rich stratigraphy of different paints, coatings, preparatory layers, and other materials. Significant color changes were usually not made from one repainting campaign to the next. For example, at least three different applications of blue paint layers were discovered in the Virgin's robe, and although the pigment composition and particle size dispersion differ between layers, the robe appears to have always been some shade of blue. This was also noted in the red background behind the central figures, where at least four different campaigns of red layers were present.

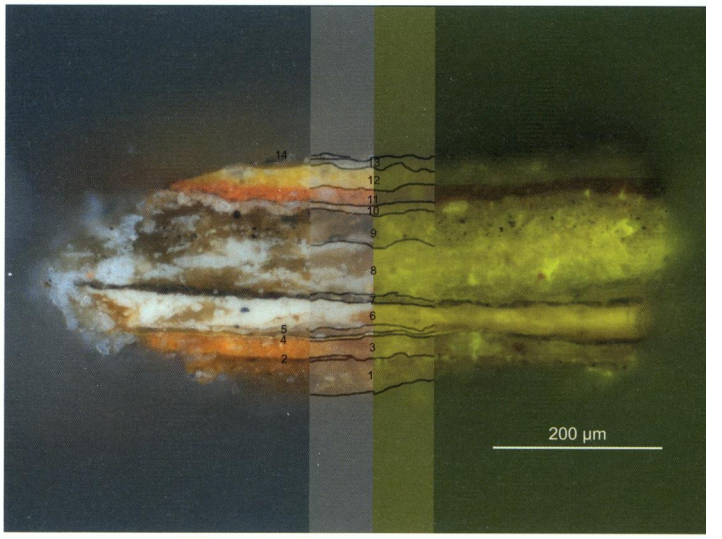

Fig. 3. Cross section of fig. 1 from architectural decoration on the upper proper-right side of the relief, dark-field visible-light image (left) and ultraviolet-induced visible fluorescence (right). At least fourteen distinct layers of surface decoration are present in this sample.

Other areas had undergone more significant changes to style and color. For example, in a sample taken from an area of yellow architectural decoration on the upper proper-right side of the top section of the relief, it was noted that older layers once contained gilding (fig. 3). A similar stratigraphy was also observed in the yellow wings of an angel nearby. The substitution of yellow paint in lieu of gilding may have been done because it was less costly.

Not every area of the object had a multilayered decorative stratigraphy. A sample taken from the Virgin's hand (fig. 4) indicates that only one paint campaign is present; it consists of a single paint layer and a single clear coating layer. It is not clear if the layer is original or a result of a later campaign. Given the largely intact condition of these areas, it may also be possible that previous layers once existed but were removed before the application of this current paint.

It is unclear how much of the surface decoration, if any, is original. However,

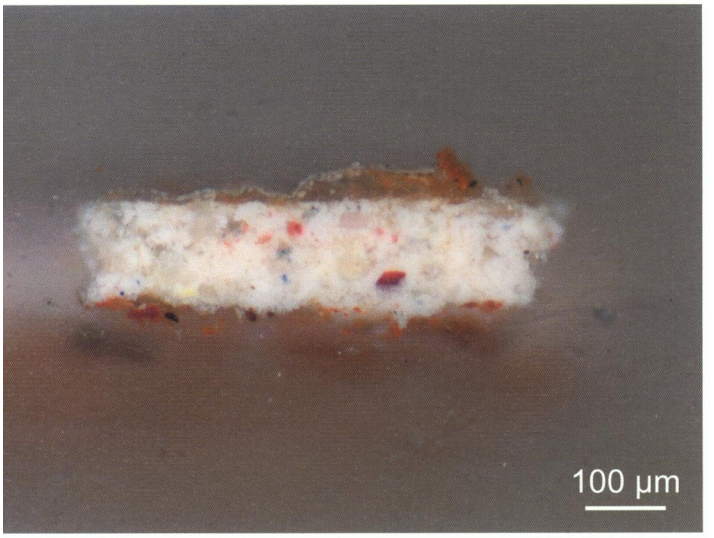

Fig. 4. Cross section of fig. 1 from the Virgin's hand, dark-field visible-light image

Fig. 5. Cross section of fig. 1 from an area of red background behind the Virgin's robe, dark-field visible-light image. Challacolloite salts can be seen as white clusters growing in between surface decoration layers.

pigment particle sizes in paint layers differ widely overall, indicating that repainting campaigns may have been applied over a long span of time and during different eras of paint-making technologies. In general, pigment particles in paint layers closer to the terracotta substrate are much larger and more irregularly shaped (consistent with pigments that were hand-ground, as they were before the nineteenth century), and pigment particles in paint layers closer to the surface of the object are much finer and regularly shaped (consistent with pigments that were machine-ground and/or synthetically produced, as they most commonly have been in more recent history).

Examination of cross-sectional samples indicated that restorations and alterations contributed to multiple changes in the overall visual appearance of the object over time. The large number of layers in some areas suggests that the restoration history of the object is long. Differences in the overall number of layers from one area to another and changes in color in some of the pictorial elements suggest that the approaches taken to restoring the work were not uniform.

Following analysis of the stratigraphy in the decoration of the object, examination of cross-sectional samples shed more light on the nature of the dull, gray efflorescence observed on the relief's surface. Under magnification, it was clear that salts were not only present on the top layer but also forming and crystallizing in situ between layers throughout. This phenomenon is particularly evident in a sample taken from an area of red background behind the Virgin's robe (fig. 5). It was evident that the serious deterioration and delamination overall was indeed related to this highly pervasive formation of salts.

Further analytical work was undertaken to understand more about the decorative layers and, most importantly, about the nature of the problematic salts. Techniques included X-ray fluorescence (XRF) spectroscopy, Fourier-transform infrared (FTIR) spectroscopy, scanning-electron microscopy with

energy-dispersive X-ray spectroscopy (SEM-EDS), Raman microspectroscopy, and X-ray powder diffraction (XRD). All work was conducted at IPCH excluding XRD, which was performed in the facilities of Yale's Chemical and Biophysical Instrumentation Center.

XRD analysis identified a very unusual potassium lead chloride compound, challacolloite (KPb_2Cl_3), in addition to gypsum ($CaSO_4 \cdot 2H_2O$), in the gray deposits present over the surface decoration. Raman microspectroscopy and SEM-EDS were used to detect and map the distribution of challacolloite within and between decorative layers under the surface. This finding was significant, because although mixed salts of potassium and lead and lead chlorides have been reported in similar objects, challacolloite has never before been documented in or on a work of art.[4] In nature, this compound has been found in Chilean silver mines and in volcanoes in Italy and Japan.[5] In the *Virgin and Child*, the form and distribution of the challacolloite grains suggest that this compound formed in situ and was not deposited from its environment. The pervasive growth of this material is visible in the backscattered electron image of the sample in figure 3 (fig. 6), as well as through the distribution of potassium (K), lead (Pb), and chlorine (Cl) elements mapped with the technique of SEM-EDS.

Although the sources of these elements and the mechanism of challacolloite formation in the *Virgin and Child* are not fully understood, the composition of the decorative layers and the terracotta, combined with published literature on salts and historic treatment techniques, provides important clues. Lead ions appear to have come from lead-based pigments (such as lead white) in the paint layers, and possibly also from external environmental pollutants.[6] Potassium and chloride ions appear to have been contributed by external sources, likely through the course of previous restoration campaigns.[7] The use of potash lye, a strong base prepared by soaking and boiling plant ashes in water, is mentioned in many historic recipes for solutions to be used for the cleaning of painted surfaces, and such solutions would serve as a source of potassium ions. Chloride ions, on the other hand, could have been introduced through the use of hydrochloric acid (also known as muriatic acid), a strong acid that has been used historically to rid ceramics of disfiguring surface deposits.[8] Although there is no documented information about the relief's treatment history predating its acquisition by the Gallery in 1964, it is clear that it has endured multiple campaigns of restoration over time that have included both structural repairs and repainting. It would be logical to presume that cleaning occurred during one or more of these restoration campaigns.

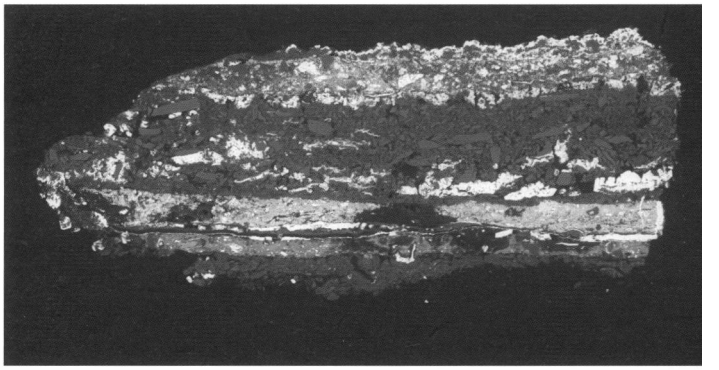

Fig. 6. SEM backscattered electron image of the cross section in fig. 3, showing the growth of challacolloite salts in between surface decoration layers

The discovery and documentation of challacolloite, such an uncommon material in a work of art, will undoubtedly serve in the future to influence the study of similar objects with comparable condition problems by conservators and conservation scientists.[9] For the *Virgin and Child*, the characterization of salts and overall technical findings helped the conservation team to understand why the surface of the object was in such an advanced state of deterioration and also contributed to treatment discussions.

TREATMENT

The first and foremost goal for treatment of the relief was stabilization, to allow the *Virgin and Child* to be displayed in a vertical orientation. There were no aspirations or expectations from the Gallery's curators that the general appearance of the work would change, and there was certainly no intent by the curators and conservators to remove layers of repainting and regilding. Rather the appearance was to remain unchanged, and even the damaged surfaces were considered an acceptable aesthetic.

When a porous material such as terracotta has been contaminated with salts, the conservator's first inclination is to perform a thorough desalination process involving rounds of soaking the object in deionized water until all soluble salts have been removed. However, before such a treatment decision is made, many other factors and questions come into play: What is the structural integrity of the object? How porous is it? How soluble are the salts? How far have the salts penetrated into the object? What other components in the clay body may be leached out by soaking in water? How would layers of polychromy and gilding be affected by soaking in water? In sum, one must weigh the risks with the potential for successful desalination.

Treatment options were limited for a polychromed terracotta in such a deteriorated condition. The surface was so unstable that the relief had to be kept in a horizontal position before and during treatment to prevent further losses. The surface could barely be touched with a soft brush without risk of causing damage. The low-fired terracotta had been repaired previously, but the extent of structural damage was not completely evident. It was also impossible to know how evenly fired the terracotta was when the object was fabricated. The layers were separating at different levels among the gesso, paint, and gilding.

Taking into account all of these factors, it was determined that desalination by soaking was not an option. While it would have been preferable to remove water-soluble salts using this method, the need for desalination was thought to be not critical since the relief would be exhibited in a stable museum environment with a relative humidity of 45 to 50 percent and a temperature of 70°F +/- 5°. This environment is presumably far more stable than the small chapel and less-than-ideal storage environments where the object previously resided, and it would slow or arrest the formation of additional water-soluble salts in the future. Therefore, the decision was made to carefully clean the fragile surfaces and then stabilize the front of the relief to halt the ongoing active loss of surface. The sides and reverse of the relief did not have polychromy and did not require consolidation.

Surface cleaning began by using a micro attachment on a high-efficiency particulate arrestance (HEPA) vacuum to carefully remove debris and dirt from low areas of the relief. Dislocated flakes of gesso and paint were collected and saved in plastic vials, with a note about the area from which they were collected. Further cleaning was done using cotton swabs with water and ethanol in areas stable enough to allow swabbing of the surface. For the stabilization part of the treatment, two different but compatible synthetic polymers were chosen as consolidants: one for areas of exposed, friable terracotta, and the other for the layers of polychromy. The treatment achieved the goal of stabilizing the relief and allowed it to be put on display in the European art galleries (see Galli, "The Yale University Art Gallery's *Virgin and Child*," fig. 1).

Through this collaborative technical study and treatment, a better understanding of past treatments and current condition allowed for long-term preservation. Restoration to an as-new condition was neither possible nor desirable. Even in its current state, the *Virgin and Child* is an exquisite example of polychromed terracotta by Michele da Firenze.

1. Elena Torok, one of the authors of this article, assisted with this project as a conservation fellow and has stayed on at the Gallery as a Project Conservator.

2. A similar relief by Michele da Firenze, *Virgin and Child Enthroned with Saint John the Baptist and Saint James* (ca. 1440, Victoria and Albert Museum, London), measures 68⅛ x 30⅞ x 9⅞ in. (173 x 78.4 x 24 cm). See also John Charles Robinson, *Italian Sculpture of the Middle Ages* (London: Chapman and Hall, 1862), 6; John Pope-Hennessy, *Catalogue of Italian Sculpture in the Victoria and Albert Museum* (London: HMSO, 1964), no. 56; Giuseppe Fiocco, "Michele da Firenze," *Dedalo* 12 (1932): 542–63; Lidia Righi Guerzoni, "Una Madonna di Michele da Firenze nel Modenese," *Musei Ferraresi Bolletino Annuale* 9–10 (1979–80): 67–75; Giancarlo Gentilini, "Michele di Firenze, San Leonardo," in *Da Biduino ad Algardi: Pittura e scultura a confronto*, ed. Giovanni Romano, exh. cat. (Turin, Italy: Allemandi, 1990), 25–38; "Inventory of Art Objects Acquired in the Year 1861," in *Inventory of the Objects in the Art Division of the Museum at South Kensington, Arranged According to the Dates of Their Acquisition* (London: George E. Eyre and William Spottiswoode for HMSO, 1868), 1:19; and Eric Maclagan and Margaret Helen Longhurst, *Catalogue of Italian Sculpture: Text* (London: Victoria and Albert Museum, 1932), 17.

3. Massimo Ferretti, "Nota su Michele da Firenze (e Nanni di Bartolo)," in *Scritti per l'Istituto Germanico di Storia dell'Arte di Firenze*, ed. Cristina Acidini Luchinat et al. (Florence: Le Lettere, 1997), 104.

4. Petria Noble and Annelies van Loon, "Rembrandt's *Simeon's Song of Praise*, 1631: Pictorial Devices in the Service of Spatial Illusion," *Art Matters: Netherlands Technical Studies in Art* 4, no. 19 (2007): 20–36; Eva Kotulanová et al., "Degradation of Lead-Based Pigments by Salt Solutions," *Journal of Cultural Heritage* 10, no. 3 (2009): 367; Annelies van Loon, Petria Noble, and Jaap J. Boon, "White Hazes and Surface Crusts in Rembrandt's *Homer* and Related Paintings," in *ICOM-CC 16th Triennial Conference, Lisbon, 19–23 September 2011*, preprints, ed. Catherine Antomarchi et al. (Lisbon: Critério, 2011), n.p.; Annelies van Loon, Petria Noble, and Jaap J. Boon, "The Formation of Complex Crusts in Oil Paints Containing Lead White and Smalt: Dissolution, Depletion, Diffusion, Deposition," in *Historical Technology, Materials, and Conservation: SEM and Microanalysis,* ed. Nigel Meeks et al. (London: Archetype, 2012), 205–7; Carolina Cardell-Fernández and Carmen Navarrete-Aguilera, "Pigment and Plasterwork Analyses of Nasrid Polychromed Lacework Stucco in the Alhambra (Granada, Spain)," *Studies in Conservation* 51, no. 3 (2006): 161; David Hradil et al., "Crocoite $PbCrO_4$ and Mimetite $Pb_5(AsO_4)_3Cl$: Rare Minerals in Highly Degraded Mediaeval Murals in Northern Bohemia," *Journal of Raman Spectroscopy* 45, no. 9 (2014): 848.

5. Jochen Schlüter, Dieter Pohl, and Sergey Britvin, "The New Mineral Challacolloite, KPb_2Cl_5, the Natural Occurrence of a Technically Known Laser Material," *Neues Jahrbuch für Mineralogie-Abhandlungen* 182, no. 1 (2005): 95–101; S. I. Tkachenko et al., "Mineral- and Ore-Forming Processes from High-Temperature Fumarolic Gases at Kudryavyi Volcano, Iturup Island, Kuril Archipelago," *Geokhimiya* 4 (1999): 410; Italo Campostrini et al., "Hephaistosite, $TlPb_2Cl_5$, a New Thallium Mineral Species from La Fossa Crater, Vulcano, Aeolian Islands, Italy," *Canadian Mineralogist* 46, no. 3 (2008): 701.

6. Celia Maqueda, José Luis Pérez Rodríguez, and Angel Justo Erbez, "Degradation of Ceramic Sculptures on the Cathedral of Seville," *Mineralogical Petrography Acta* 29-A (1985): 591; José Luis Pérez-Rodríguez et al., "Characterization of Decayed Ceramic Sculptures Decorating the Pardon Portico of Seville Cathedral, Spain," *Applied Clay Science* 9, no. 3 (1994): 211; José Luis Pérez-Rodríguez et al., "Effect of Pollution on Polychromed Ceramic Statues," *Atmospheric Environment* 32, no. 6 (1998): 993.

7. Although potassium is present in the terracotta substrate and certain pigments, these were deemed not to be major contributing sources because potassium-containing compounds in these areas are either not in high enough concentration or not in a soluble form.

8. Maartje Stols-Witlox, "Historical Restoration Recipes: The Cleaning of Oil Paintings 1600–1900," in Antomarchi et al., *ICOM-CC Abstracts, 16th Triennial Conference, Lisbon, 19–23 September 2011*, preprints, n.p.

9. Anikó Bezur, Gwénaëlle Kavich, Jens Stenger, Elena Torok, and Carol Snow, "Discovery of Challacolloite, an Uncommon Chloride, on a Fifteenth-Century Polychrome Terracotta Relief by Michele da Firenze," *Applied Physics A* 121, no. 1 (October 2015): 83–93.