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Revisiting the Past Treatments and Condition Assessment of the Painted Sanctuary at Tumacacori

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Revisiting the Past Treatments and Condition Assessment of the Painted Sanctuary at Tumacacori

Abstract
This thesis focuses on the painted walls in the Sanctuary of the Mission Church of San Jose de Tumacacori, which has been managed by the National Park Service since 1918 and has been treated several times in the past years. The treatments from different periods overlaid on the surface of the Sanctuary offer interesting evidence of different types of conservation treatments conducted on in situ murals and decorative paintings over the past century. However, these treatments have never been closely examined nor distinguished as individual campaigns of treatment. This thesis intends to differentiate and analyze the treatments and materials applied to the surfaces of the Sanctuary with the help of ultraviolet light examination and microscopical analysis. In the meantime, the current conditions of the painted surfaces will be recorded. An effort will be made to evaluate the effectiveness of different treatments. Finally, based on the findings of the thesis, it will try to provide recommendations for future interventions for the painted Sanctuary of Tumacacori.

Keywords
Tumacacori, wall painting, condition assessment, microscopy analysis, Ultraviolet light examination

Disciplines
Historic Preservation and Conservation

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REVISITING THE PAST TREATMENTS AND CONDITION ASSESSMENT OF THE PAINTED SANCTUARY AT TUMACACORI

Yifei Yang

A THESIS

In

Historic Preservation

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements of the Degree of

MASTER OF SCIENCE IN HISTORIC PRESERVATION

2022

______________
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Section 1  Introduction

The past century has been an era of continuous exploration and development in architectural conservation, during which preservation philosophy has changed, conservation methods progressed, and materials developed. As a building that has been continuously preserved over time and stewarded under the well-developed preservation standards of the National Park Service for the majority of the century, the church at San Jose de Tumacacori offers an excellent record of continuing conservation work during this time. It is significant not only as a 19th-century Spanish colonial church, but also as a physical document that communicates the great preservation efforts and practices of the NPS since 1918. The painted surfaces of the Sanctuary in the church have witnessed the changes in consolidation techniques and other interventions on architectural finishes. In the past a hundred years, different treatments ensued with the expectation of lengthening the lifespan of the surfaces.

Over the years, these treatments and associated materials have changed the paintings. Exploring and evaluating how they have affected their appearance, nature, and performance is warranted. Like many sites, documentation of previous treatments is incomplete. Unpublished or incomplete reports, or even non-reports, make it difficult to distinguish and evaluate previous treatments. Adding to the complication of understanding change to the painting at Tumacacori are the multiple campaigns of treatment, especially in the painted Sanctuary, which has been filled, reattached, consolidated, and retouched with different kinds of natural materials and synthetic materials over time. In addition to attempting to distinguish individual treatments, this research also seeks to make use of the
opportunity to understand better how the conservation of architectural finishes and in situ paintings have changed in the past century.

Thus, this thesis addresses the conditions of the painted surfaces of the Sanctuary in the Church of San Jose de Tumacacori, with the primary focus on differentiating treatment campaigns and exploring their effect on current conditions. While other factors, such as structural and moisture problems, have contributed to the conditions of the painted surfaces, this thesis will only address those conditions identified on the surfaces and primarily related to previous treatment.

The assessment of conditions addresses the north, west, and south walls of the Sanctuary from the floor to the top of the cornice. These walls, which include two exterior elevations, were chosen as representative of the worst conditions. Due to limitations on time, the interior east wall and the dome ceiling were not examined and documented and will require assessment in the future.

Research methods combine on-site and laboratory investigation with the review of documents, particularly those involving past treatment. In addition to conventional techniques of assessment, examination with ultra-violet visible light was explored as a method for identifying and differentiating previous treatment. It was used at the site, in the microscopic examination of cross-sectional samples by way of fluorescence microscopy, and on samples made in the lab of the materials used or likely to have been used at the site.
Section 2 History and background of the site

2.1. Brief History of the Mission San Jose de Tumacacori

The history of the Church San Jose de Tumacacori can be divided into three periods: (1). the early construction period, 1691-1848; (2).the abandonment period, 1848-1918; and (3).the National Park Service period, 1918-2022. Throughout its history, the painted surfaces of the Sanctuary were protected by the dome above and remained the best-preserved part of the church.

2.1.1 The early history: before the NPS (1691-1918)

Located in southern Arizona, the Mission San Jose de Tumacacori was part of the global Spanish mission system of colonization that attempted to create a self-sufficient agricultural community, convert local Indians to the Catholic religion, and generate revenue for Spain. It was among a chain of missions established by the Jesuit Father Eusebio Francisco Kino in the *Pimeria Alta*. First founded on the east side of the Santa Cruz River in January 1691, it was moved to its present location on the west side of the river following the Pima Revolt in 1751. A small adobe church was first built on the site by the year 1757, and the current church was constructed around 1800.

---

2 The *Pimería Alta* (upper land of the *Pimas*) encompassed parts of what are today southern Arizona and northern Sonora, Mexico, in the Sonoran Desert.
continued for over twenty years, and the church was put into use in the early 1820s. But it was never entirely completed\(^4\).

Figure 1 The church of San Jose de Tumacacori\(^5\)

In the 1840s, inhabitants abandoned the mission and moved to Mission San Xavier del Bac, 40 miles to the east of Tumacacori, because of the apache raids and other stress factors. Following abandonment, the structure of the church experienced severe deterioration, during which the timber roof of the nave, as well as the semicircular pediment and the choir arch, were destroyed due to neglect. A large earthquake in 1887\(^6\) also contributed to the damage to the church, causing cracks on the walls and weakening the strength of the structure. Treasure hunting was another factor that led to the deterioration


\(^6\) The 1887 earthquake, at an estimated 7.4 magnitude, is the largest historical earthquake of the southern geological Basin and Range Province.
of the church. The walls and floors in the Sanctuary and the nave were torn open in the search for the lost Tumacacori gold, leaving a significant number of holes on the painted surfaces.

The church and the surrounding protected area were given to the United States in 1908 and became the Tumacacori National Monument under a presidential proclamation. It was administered by the U.S. Forest Service with no actions to slow the deterioration of the church. Its abandoned situation and deterioration continued through 1918, when it was taken over by the National Park Service.

The church was designed in a “C”-shape plan, with a nave on the front, a sacristy on the northeast, a baptistry on the southeast, a bell tower on top of the baptistry, and a Sanctuary with a dome on the back. (Figure 2) It was a frontier building in the early stage of the Spanish colonization. The design of the church followed no specific architectural program and was a combination of the Spanish tradition and the adaptation to the abilities of Native American laborers and technics. The church structure combined abode earthen bricks and fired bricks, typical for Spanish Mission construction in Arizona and California. The surfaces and dome of the Sanctuary were painted with delicate murals. These paintings are still in relatively good condition due to the protection of the dome.

---

7 Moss, 2008.
8 Crosby, 7-11.
2.1.2 Management by the NPS (1918-2022)

In 1918 when Tumacacori was passed to the National Park Service, a new chapter of its preservation began. Superintendents responsible for the management of the site were appointed to oversee the restoration and maintenance of Tumacacori. It was listed on the National Register of Historic Places on October 15, 1966. In 1990 the site was designated a National Historical Park with an area of 360 acres.

Frank Pinkley was the first Superintendent of National Monuments in the Southwest in 1919. Two years later, Pinkley began the reconstruction of the destroyed nave

\[10\] HABS, 1975.
roof, as well as fillings holes and voids in both the interior and on the exterior walls of the church.\textsuperscript{11} The Civil Works Administration and the Federal Emergency Relief Administration took on conservation projects in the 1930s. Most of the early conservation work of the NPS involved structural repair of the church and plaster fills on the walls\textsuperscript{12}. In the 1940s, work started on the painted surfaces under the superintendence of Earl Jackson, who plastered the unprotected surfaces of the upper walls in the nave. A most important campaign of conservation took place in 1949, when conservator J. Rutherford Gettens\textsuperscript{13} of the Harvard University’s Fogg Art Museum and NPS employee Charlie R. Steen\textsuperscript{14} stabilized the plaster, consolidated the paint films, and cleaned the surfaces of the paintings in the Sanctuary following a survey of the conditions.\textsuperscript{15}

Documentation of the church also took place over the years. The HABS (Historic American Buildings Survey) conducted two surveys with drawings of the church, first in 1937 and then again in 1975\textsuperscript{16}.

Another overall preservation project at Tumacacori began in 1975 and lasted to 1982, with Anthony Crosby as the project architect. This work included architectural investigation, conservation intervention, environmental monitoring, and recommendation

\textsuperscript{11} Moss, 2008.
\textsuperscript{12} Crosby, 1985, 11-12.
\textsuperscript{13} Rutherford Gettens was a chemist and pioneering conservation scientist at the Fogg Art Museum at Harvard. He was chief of Museum Technical Research, and an active member in the development of the field of conservation as we know it today.
\textsuperscript{14} Charlie Steen was originally a park ranger of the National Park Service. He started working for the National Park Service in 1934 and as the first ranger of the Tonto Cliff Dwellings near Roosevelt, Arizona. He was working as an employee of the National Park Service when the conservation project in 1949 took place.
\textsuperscript{16} HABS, 1937. HABS, 1975.
for additional treatment\textsuperscript{17}. Several additional campaigns of treatment have occurred in the past 40 years, including a 10-year cyclic maintenance project in 1992-94\textsuperscript{18}, a restoration project in the Sanctuary by Tohono Restoration in 2000-01, and an assessment and treatment of painted plaster by the University of New Mexico in 2013. In addition to these treatments, daily maintenance, monitoring, and exhibition have been conducted by the NPS. Over the years, the church of Tumacacori was treated as a ruin with little restoration or reconstruction.

More information about the previous treatments will be discussed in Section 2.3.

\subsection*{2.1.3 Significance and value of the site}

The Mission San Jose de Tumacacori, located on the chain of \textit{Pimeria Alta}, is one of the first Spanish missions built in the Southwest. It represents the history of the Spanish mission frontier of New Spain, the impact of European colonization upon native Americans, and the communication between Spanish, Mexican, and Indian cultures. The church is a typical Spanish colonial building of the early 19\textsuperscript{th} century and a significant example of Spanish mission architecture and decoration,\textsuperscript{19} demonstrating a combination of Spanish tradition and the adaptation to the abilities of Native American laborers and building technologies.

The church was preserved as a ruin following its designation as a National Historic Monument. This preservation philosophy, which favored stabilization and presentation as

\textsuperscript{17} Crosby, 1985.
\textsuperscript{19} “Mission San Jose de Tumacacori, National Register of Historic Places Inventory – Nomination Form” (National Park Service, 1986).
a site as it exists in time, took hold in the early twentieth century and was especially prevalent in the American Southwest. In keeping with this approach, the first Superintendent, Frank Pinkley, decided to preserve and interpret Tumacacori as “a stabilized ruin.”

The painted Sanctuary offers interesting evidence of the types of conservation treatments that were often conducted on *in situ* murals and decorative painting over the past century, when the field of conservation was developing and new synthetic materials were becoming available. The existence of a range of approaches and materials, including both natural and synthetic materials, such as animal glue, vinyl resin, polyvinyl acetate, and acrylic resin, presents an opportunity to explore methods of identifying and evaluating the impact of these different materials on the condition of the *in situ* paintings over time.

*Figure 3 Sanctuary of the Church of Tumacacori*[^20]

[^20]: National Park Service. https://www.nps.gov/places/tumacacori-church-Sanctuary.htm
2.2. **Summary of the painted surfaces in the Sanctuary**

2.2.1 **Description of the painted surfaces**

The paintings in the Sanctuary are one of the most delicate parts of the church. Located at the north end of the nave, the Sanctuary is a square plan of 17 feet on each side. An arch divides the nave and Sanctuary on the south side; the principal north wall contains a reredos; the west exterior wall has one large window, while the east elevation opens to the Sacristy through a doorway. A molded cornice appears at the upper walls and forms the spring line for the dome above. Four pendentives\(^\text{21}\) with unidentified symbolic patterns appear at each of the four corners.

2.2.2 **Structure of the substrate wall, plaster, and paint film**

The walls of the Sanctuary are constructed of unfired adobe, capped with low-fired bricks in some places, and laid with adobe mortar\(^\text{22}\). These walls are finished with two layers of lime plaster of varying thicknesses, with the average thickness of each layer approximately one inch. The lime plaster is made of approximately three parts of sand and one part of lime\(^\text{23}\). On top of the preparatory layer of plaster is another layer of finely ground white finish, which is only 1-2 millimeters thick\(^\text{24}\). The white material is mainly

\(^{21}\) The structures at the corners between the side walls and the dome are described as pendentives in previous reports. According to the project architect Alex Lim at Tumacacori, they are better to be called squinches in this case.


\(^{23}\) Jean Jang, “Performance Evaluation of Commercial Nanolime as a Consolidant for Friable Lime Based Plaster,” Theses (Historic Preservation), 2016, 22.

\(^{24}\) According to the Italian system, the first layer of lime plaster is called Arriccio; the second layer should be called Intonaco; and the fine ground gypsum layer should be called Intanochino. In the following text, these terms will be used to describe the plaster.
burned gypsum (CaSO$_4$.2H$_2$O).\textsuperscript{25} (Figure 4) Paints on top of the gypsum layer are purported to have been applied as distemper with an aqueous medium.\textsuperscript{26}

Gettens and Steen thoroughly examined and reported on the paints in their 1949 report. They analyzed pigments found in the Sanctuary and found that the bright red color was natural vermilion, called cinnabar vermilion below; ocherous hematite for the orange-red color; copper mineral as green, indicating malachite; indigo as blue; and charcoal as black and grey on the surface.\textsuperscript{27} In 2001, another pigment analysis by Tim Lewis and

\textsuperscript{25} The raw gypsum is heated to form hemihydrate (2CaSO$_4$.H$_2$O) and then rehydrated in the process of application to the wall.

\textsuperscript{26} Steen and Gettens, “Tumacácori Interior Decorations,” 1949, 28.

\textsuperscript{27} Steen and Gettens, 1949, 37-45. 20 samples of were taken from the church of Tumacacori, 16 of them were from the painted sanctuary, 1 from the arch between nave and sanctuary, 2 from the nave, and one from the exterior north wall. The identification of pigments used the methods of polarized light microscopy and X-ray powder patterns of the pigments. However, the exact methods used had not been carefully introduced and discussed in the report.
Matilde Rubio\textsuperscript{28} improved and approved the result from Gettens. Their findings of pigments in the Sanctuary are listed below\textsuperscript{29}:

\textit{Table 2-1 Pigments Found in the Interior Decoration at Tumacacori}

<table>
<thead>
<tr>
<th>Color</th>
<th>Pigment</th>
<th>Formula</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright Red</td>
<td>Cinnabar vermillion</td>
<td>HgS (mercury II sulfide)</td>
<td>R.J. Gettens, 1949; Lewis &amp; Rubio, 2001</td>
</tr>
<tr>
<td></td>
<td>Cadmium red</td>
<td>CdS and CdSe</td>
<td>Lewis &amp; Rubio, 2001</td>
</tr>
<tr>
<td>Red, Orange-Red,</td>
<td>Ocherous hematite</td>
<td>FeO(OH)(n)H(_2)O (yellow ochre) Fe(_2)O(_3) (red ochre)</td>
<td>R.J. Gettens, 1949</td>
</tr>
<tr>
<td>Orange-Yellow, Pale</td>
<td>Copper chloride</td>
<td>CuCl(_2)</td>
<td>Lewis &amp; Rubio, 2001</td>
</tr>
<tr>
<td>Pink</td>
<td>Chromium green</td>
<td>Cr(_2)O(_3)</td>
<td>Lewis &amp; Rubio, 2001</td>
</tr>
<tr>
<td>Blue</td>
<td>Indigo (stain)</td>
<td>C(<em>{16})H(</em>{10})N(_2)O(_2)</td>
<td>R.J. Gettens, 1949; Lewis &amp; Rubio, 2001</td>
</tr>
<tr>
<td></td>
<td>Prussian blue</td>
<td>C(_{16})Fe(<em>7)N(</em>{18})</td>
<td>Lewis &amp; Rubio, 2001</td>
</tr>
<tr>
<td>Metallic Brown Gray</td>
<td>Bronze gilt</td>
<td>Copper-zinc alloy</td>
<td>R.J. Gettens, 1949</td>
</tr>
<tr>
<td>White</td>
<td>Gypsum</td>
<td>CaS(<em>{0.4})H(</em>{2})O</td>
<td>R.J. Gettens, 1949; Lewis &amp; Rubio, 2001</td>
</tr>
<tr>
<td>Black, Gray</td>
<td>Charcoal</td>
<td>C</td>
<td>R.J. Gettens, 1949; Lewis &amp; Rubio, 2001</td>
</tr>
</tbody>
</table>

\textsuperscript{28} Tim Lewis and Matilde Rubio, “Study of materials present in twenty-one micro samples taken from the painted murals at Tumacacori Mission” (National Park Service, 2001). Following technical analytical methods were used in the identification of pigments in this work: optical microscopy, selective tinctures, high resolution thin layer chromatography, micro analytical sweep electronic microscopy (SEM) by X-ray energy dispersion, infrared spectroscopy by Fourier metamorphosis.

\textsuperscript{29} The chart was summarized by Jocelyn Chan and Gabrielle Goldstein in their reports. Chan, 2015, 64-65. Goldstein, Gabrielle, "Revisiting a Past Treatment of the Painted Interior of San José de Tumacácori” (2021). Theses (Historic Preservation). 713. https://repository.upenn.edu/hp_theses/713, 5-6.
2.3. Previous treatments on the painted surfaces of the Sanctuary

Conservation assessment and treatment projects over time have addressed all parts of the church, including the exterior, the Nave, the Baptistery, and the Sanctuary. Reports document projects involving condition assessments, investigation, environmental monitoring, and structural stabilization. Augmenting those efforts, this thesis focuses only on the conditions and previous interventions on the painted walls of the Sanctuary. It does not include the Sanctuary dome or other parts of the building. Neither does it delve into contributing factors, such as damp penetration, thermal fluctuations and structural shifting.

The Sanctuary paintings have experienced five major campaigns of treatment and several minor treatments since the 1940s. These treatments involved cleaning, filling of losses, application of edging around plaster losses, plaster reattachment, and consolidation of friable plaster, consolidation of paint, and retouching of paint losses. At least seven consolidants have been reportedly used. They include polyvinyl acetate (PVAc) emulsion, acrylic resin, ethyl methacrylate copolymer (Paraloid B-72), and acrylic emulsion (Rhoplex); caseinate derivatives, ethyl silicate, cactus glue, and animal glue.

2.3.1 1949 treatment: consolidation by Polyvinyl Acetate (PVAc)

Early stabilization work in the 1920s and 1930s included filling holes, stabilizing plaster edges by adding fill material to the edges, and reconstructing architectural elements. In 1935, an experimental vinyl resin was used to consolidate the surfaces; however, the work was limited to the exterior façade and the interior of the nave.\(^3\)

---

30 Edging refers to the treatment that adding fill material to the edges of large areas of plaster losses to help stabilize the plaster.
31 Crosby, 1985, 64. The experimental vinyl resin was called NPSX.
As already noted, the first treatment on the Sanctuary painting was conducted by Rutherford Gettens from the Fogg Museum and Charlie Steen from NPS. At that time, the plaster was in relatively good condition, while the paints were found to be slightly chalky and needing stabilization\textsuperscript{32}. A specific polyvinyl acetate (PVAc) called Vinylite A\textsuperscript{TM}\textsuperscript{33} with medium viscosity was used as a spray to consolidate the painted surfaces\textsuperscript{34}. The formula is recorded as below in Steen and Gettens’ report:

Vinylite A\textsuperscript{TM}, medium viscosity (polyvinyl acetate), 50 grams

Solvent: toluene, 700 ml
ethylene dichloride, 200 ml
cellosolve (trade name for ethylene glycol monoethyl ether), 40 ml
cellosolve acetate, 40 ml
dibutyl phthalate, 20 ml

Although the 1949 report indicated all the surfaces in the Sanctuary were treated with PVAc emulsion (Vinylite A\textsuperscript{TM}), the actual coverage was less than complete according to the evaluation in January 1980. More deterioration occurred after the work\textsuperscript{35}. It is unclear if that deterioration was related to the treatment.

\textsuperscript{33} Vinylite was the brand name for products made of vinyl resins made by Carbide and Carbon Chemicals Corporation and put on the market in 1930. It was marketed as an ‘elastic plastic’ because it could be made into products that could be stretched and then return to their original shape. Vinylite A\textsuperscript{TM} was one of the Vinylite series, which was a precursor to the more commonly known AY resin series. The series consisted of five different types of PVAc based on their molecular weights. The Vinylite A\textsuperscript{TM} used by Steen and Gettens of medium viscosity was a precursor to AYAF. C. V. Horie, Materials for Conservation: Organic Consolidants, Adhesives and Coatings (London; Butterworths, 1987), 94.
\textsuperscript{34} “Vinylite: The Versatile Plastic,” Union Carbide and Carbon Corporation, 1934.
\textsuperscript{35} Crosby, 1985: 65.
2.3.2 1975-1982 treatment

Project architect, Anthony Crosby managed a series of treatments for the NPS in the 1970s and 1980s. The most important campaign was the conservation work in 1982 by a team of six NPS employees and three mural painting conservators from ICCROM\textsuperscript{36}: Paul Schwartzbaum, Carlo Giantomassi, and Dontatella Zari. Following analysis of the effectiveness of various materials, the conservators conducted treatment.\textsuperscript{37} The majority of their work involved surface cleaning, filling of losses, edging, reattachment and consolidation. Japanese tissue and water were used for plaster reattachment; PVA emulsion was used for plaster reattachment and consolidation.\textsuperscript{38}

2.3.3 1992-1994 treatment

The next campaign of treatment occurred from 1992 to 1994, and was planned and coordinated by David Yubeta\textsuperscript{39} of the National Park Service to meet the 10-year cyclic maintenance requirements for the church as laid out in the 1982 NPS Historic Preservation Guide. Most of the work followed the guidance and recommendations of the 1982 treatment. It focused on cleaning the decorated interior surfaces and the dome damaged by leakage. In addition to the materials suggested by the 1982 treatment, an unspecific

\textsuperscript{36} The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) is an intergovernmental organization dedicated to the preservation of cultural heritage worldwide through training, information, research, cooperation and advocacy programs. It aims to enhance the field of conservation-restoration and raise awareness to the importance and fragility of cultural heritage.

\textsuperscript{37} Crosby, 1985: 76-87.

\textsuperscript{38} The work lasted six weeks with a great success. However, there was no report from this treatment according to Anthony Crosby.

\textsuperscript{39} David Yubeta is an adobe brick maker and conservator of earthen architecture. He spent 25 years preserving earthen resources in the arid Southwest for the National Park Service.
Rhoplex product\textsuperscript{40} diluted in water and alcohol, and Acryloid B-72 in acetone were introduced for plaster reattachment and surface consolidation\textsuperscript{41}. This treatment is less influential than the previous ones as the conservation crew was limited to two to three conservators, and their time on-site was limited to four weeks in the three-year duration\textsuperscript{42}.

2.3.4 2000-2001 treatments

Between 2000 and 2001, two campaigns of treatments were carried out by different teams. From 2000 to 2001, Tohono Restoration conducted another campaign of treatment to the Sanctuary under the supervision of David Yubeta. Their work included surface cleaning, plaster reattachment, and surface consolidation. Some of the previous fills were removed. According to their report, the decay of original plaster observed to be adjacent to these fills might be caused by the lower vapor permeability of the resin amendments\textsuperscript{43}.

In 2001, Mexican conservators Angelica Gonzalez and Mayela Garcia, who had been kept a close relationship with the site, reported on their work on the upper part of the north wall.\textsuperscript{44} They used rabbit skin glue to consolidate plaster and surface and calcium

\textsuperscript{40} Rhoplex is the brand name for a series of products made by Rohm and Haas Company, which was a manufacturer of specialty chemicals for markets such as building and construction. The company was by Dow Chemical Company in 2009. Rhoplexes are water-based acrylic emulsions used in a multitude of conservation applications. There are several different Rhoplex formulations available in the market. However, the certain type of Rhoplex used in the church of Tumacacori is unknown according to the report. What we know about the treatment is some kind of Rhoplex has been applied.

\textsuperscript{41} Peirson and San Miguel, 1994.

\textsuperscript{42} School of Architecture & Planning, University of New Mexico, “Assessment, Emergency Stabilization and Treatment of Painted Plasters in the Mission Church, Tumacacori National Historic Park” (National Park Service, December 2013), 7-8.

\textsuperscript{43} Ibid., 9-10.

\textsuperscript{44} Angelica Gonzalez and Mayela Garcia, “Informe de los trabajos de conservacion: Muro frontal del presbiterio de la iglesia de san juan de Tumacacori pintura mural” (National Park Service, October 2001).
caseinate to reattach the detached plaster. They retouched losses with acrylic paints mixed with clay and milk lime.

### 2.3.5 2012-2013 treatment

In 2012, more work was done by the team from the University of New Mexico, when they worked on the dome and the west wall of the Sanctuary. The conservators reattached loose plaster on the wall surfaces above and on either side of the west window by injecting a grout mixture of hydrated hydraulic lime (NHL3.5) and ceramic microspheres\(^\text{45}\).

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\(^{45}\) School of Architecture & Planning, University of New Mexico, “Assessment, Emergency Stabilization and Treatment of Painted Plasters in the Mission Church, Tumacacori National Historic Park,” (National Park Service, December 2013), 45-56.
2.3.6 Methods and materials used in previous treatments

The following table chronologically outlines previous treatments:

<table>
<thead>
<tr>
<th>Year</th>
<th>Conservator</th>
<th>Treatment/Material</th>
<th>Application Area</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>unknown</td>
<td>Consolidation with an experimental vinyl resin called NPSX</td>
<td>Exterior façade, interior of the nave</td>
<td>Not mentioned in Gettens’ report(^{46})</td>
</tr>
<tr>
<td>1949</td>
<td>Steen &amp; Gettens</td>
<td>Filling of losses: Rough surface texture</td>
<td></td>
<td>According to the examination in 1980, “the coverage was less than complete,” more deterioration occurred after the work</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surface consolidation: Polyvinyl acetate (PVAc Vinylite A™ medium viscosity) spray</td>
<td>All surfaces in the Sanctuary and nave</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Filling of losses: Lime &amp; sand mortar (1:4 by volume) to a level of 1-3mm below the surface</td>
<td>Sanctuary below the window sills</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Edging: At an angle of approximately 60 degrees</td>
<td>Sanctuary</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lime &amp; sand mortar (1:4) Stabilized with Japanese tissue and Acryloid B-72</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plaster reattachment and consolidation: PVA emulsion</td>
<td>Extensively used. Especially on the north of the west Sanctuary window, and on the north</td>
<td></td>
</tr>
</tbody>
</table>

\(^{46}\) Gettens’ report didn’t mention filling losses, however, conservator Giffords mentioned previous fills in his report in 1976, describing the “Spackling applied during the Steen ad Gettens conservation project. Very often the repair is not confined to the holes, but is simply smeared in and out, covering the plaster area round it, and with no attempt to smooth the patch, dirt accumulates. The unevenness also provides an unsatisfactory esthetic appearance.” (Crosby, 1985, 146).
<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2001</td>
<td>Tohono Restoration</td>
<td>Filling of losses: Lime &amp; sand mortar Multi or single layers, lower layers are coarse, final layers are finer, using screened sand Edging: Lime &amp; sand mortar with ammonium caseinate Plaster reattachment: Ammonium caseinate / lime Plaster consolidation: Ethyl silicate Cactus glue &amp; casein derivatives Plaster Reattachment: Cactus Glue Surface consolidation: Cactus glue &amp; casein derivatives</td>
</tr>
<tr>
<td>2001</td>
<td>Angelica Gonzalez-Mayela Garcia</td>
<td>Filling of losses: Clay paste mixed with sand Lime paste mixed with sand and prickly pear extract, Volcanic rocks, brick, pins Plaster reattachment: Calcium caseinate Plaster consolidation: Rabbit skin glue with 95% water Milk lime, sand, and casein Protection tissue: Japanese rice paper, paste Surface Consolidation:</td>
</tr>
<tr>
<td>2012-2013</td>
<td>University of New Mexico</td>
<td>Rabbit skin glue with 92% water</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td></td>
<td>University of New Mexico</td>
<td>Plaster reattachment and consolidation: Grouting 1:1 hydrated hydraulic lime (NHL3.5) and ceramic microspheres</td>
</tr>
<tr>
<td></td>
<td>University of New Mexico</td>
<td>Plaster Reattachment: Gelatin and glycerin solution</td>
</tr>
<tr>
<td></td>
<td>University of New Mexico</td>
<td>Salts poulticing</td>
</tr>
</tbody>
</table>
Section 3  Recording current conditions

3.1.  On-site examination and recording of conditions

In the January of 2022, an on-site examination of the current conditions of the murals in the Sanctuary was conducted by mural painting conservator Cassie Myers and the author, with help from Alex B. Lim, the Architectural Conservator of Tumacacori National Historical Park, and other staff from the park. The examination lasted a week, from Jan 10-16, 2022. Restricted by the time on site, the team only examined three sides of the Sanctuary (north, west, and south walls). The east wall, which was in better condition, was left for further examination in the future.

After a preliminary investigation, a set of symbology was created for recording conditions. Prints of the digital photomontage by a team from the University of Arizona in 2016 were used for the recording. Plaster conditions and surface conditions were recorded separately on two sets of drawings. Plaster conditions include material loss, cracks, deep and superficial detachment, planer distortion, crumbling, and disaggregation. Surface conditions include yellowing, white veils, scratches, graffiti, biological remains, and other residues. In addition to current conditions, traces of previous interventions were also recorded, including different kinds of fills, edging, coating, retouching, injection, tissue, and poultice.

After the on-site examination and hand drawing record, the current conditions and treatments were transcribed digitally in AutoCAD and overlaid on the photomontage of the Sanctuary walls. (Appendix B)
3.2. Summary of current conditions

The majority of the Sanctuary surfaces are in relatively poor condition. The main cause of current conditions appears to derive from moisture penetration through the walls. However, this examination will only focus on the Sanctuary paintings, which refer to the plasters and paint film. While some conditions are prevailing on all the surfaces of the sanctuary, the severity of the condition differs in different areas of the walls. The west wall at the location of the window is experiencing the most severe structural problems. There is a major crack extending from the top of the dome to the bottom of the wall, which leads to many other conditions such as material loss, disaggregation, and planer distortion. The north wall has more decoration than the other sides and is most impacted by the activities of birds and bats, as seen by scratches and guano on the surfaces. The northwest pendentive has the most severe moisture problem apparently resulting from damp penetration through the walls. The paint film has been removed from the northwest pendentive resulting in a large area of plaster loss. Due to their protection from external conditions, the south and east interior walls are in better condition. (Appendix A)

3.2.1 Loss and holes

The majority of the plaster on the lower part of the walls has been lost, possibly as a result of rising damp. Many minor plaster losses are distributed on the surface of the upper part of the wall. A number of large plaster losses have been filled in previous treatments, but many recent losses are not treated. (Figure 5) It is unclear when these losses occurred. There are also deep holes observed on the surface and severe loss of plaster around the holes that might be caused by the previous injection of grouting. Some structural
losses appear on the cornice on top of the wall. The problem of plaster loss is more severe on the cornice, the upper part of the north wall, and the northwest pendentive. Moisture from outside of the wall appears to contribute to the plaster loss in these areas.

![Image of plaster losses](image)

Figure 5 Plaster losses on the northwest pendentive

3.2.2 Detachment

The intralayer separation between the substrate and surface is widespread and can be detected through the sound produced by tapping the surface with knuckles and with a small rubber-headed tool. Two major types of detachment are found in the Sanctuary: deep and superficial detachment. Deep detachment refers to the separation between the plaster and substrate wall. Superficial detachment, or shallow detachment, refers to the separation between plaster and the gypsum finishes layer. It should be noted that sounds may be misleading and indicate the presence and materials of substrate and superstructure. Furthermore, the nature of the structure in the location may generate different sounds. For
example, in the arch of the south wall, the hollow sound may result from the wall that is thinner than the other part of the building. Sometimes, hollow sounds may also result from the type of materials construction of the support. For example, tapping on adobe versus ceramic bricks generates different sounds.

Plaster detachment is not visible. The majority of detachment in the Sanctuary is not severe. More severe detachment is found in the upper part of the walls, especially on the cornice, in areas of the north wall, as well as areas near the pendentive and the window frame. Considering the amount of detachment on the south wall with no traces of grouting, the detachment seems relatively new and appears to be after the 1990s treatment.

3.2.3 Planer distortion

Planer distortion refers to the areas that the plaster or paint film separates from the plane of the wall surface. Planer distortion happens on the upper part of the wall and often appears in conjunction with disaggregation. Most of the planer distortion has been consolidated, either by fills, or grouting injection. Some of it has been held in place with tissue and adhesive. (Figure 6) A few new areas with planer distortion appear on the upper part of the west wall and north wall near the pendentive, which may need immediate intervention and consolidation.
3.2.4 Crumbling & Disaggregation

Crumbling refers to the fragile surface breaking into small fragments that may fall down at any time. Most of the crumbling areas have been consolidated in previous treatments. However, some areas showing this condition need immediate intervention now. Examples include the upper part of the north wall and some small areas on the south wall. Crumbling often relates to cracks and areas that have been treated several times.

Figure 6 Planer distortion on the upper part of the north wall

3.2.5 Cracks

There are two kinds of cracks in the Sanctuary. Major cracks refer to the structural gap on the wall, especially the large crack on the west wall extending from the dome through the window frame to the lower part of the wall. Minor cracks refer to finer fissures in the paint and plaster. Most of the cracks in the Sanctuary are minor cracks. Minor cracks
often appear along the intersection of walls, especially on the wall near the pendentive and near the niches.

3.2.6 White veil

A white veil refers to the presence of a white translucent material, which may have been intentionally applied and altered over time; or may be evidence of deterioration or both. It can be found on the colored surface of the middle corbel on the north wall and the blue decoration on the bottom of the south wall. The white veil may result from residue from previous applications, but needs further examination and identification.

3.2.7 Yellowing

Yellowing occurs on the surface of the painted surfaces. It appears to result from deterioration or residue of a previous application of materials. Large areas of yellowing can be found on the blue and green band under the cornice, on the northwest pendentive, and on the upper part of the north wall near the middle corbel. (Figure 7) There are traces of residue in these areas. However, the yellowing may result from different causes and need further work to determine if different types of materials are involved. Drips of yellow residue can be found in some separate areas, especially on the upper part of the north wall and west wall. The drips often appear to be related to locations of injection of grouting or large areas of yellowing. The composition of the material of the drips also needs further examination and identification.
3.2.8 Graffiti

Three kinds of graffiti appear on the Sanctuary walls: scratched pattern graffiti, graffiti drawn with a writing implement, and graffiti *sgraffito*, which refers to characters scratched onto the wall. Graffiti can be found on all four walls, but is more concentrated on the lower part of the north wall. There are hundreds of graffiti on almost every inch of the north wall. (Figure 8) As a result, the graffiti is not recorded on the condition drawings. Examples of it are illustrated in photographs.
3.2.9 Scratches

Dense scratches, which appear to result from birds attempting to cling to the walls with their feet, can be found on the upper part of the north wall. Scratches have abraded and damaged the paint and finish plaster layers. (Figure 9)

3.2.10 Guano

There are a lot of traces of animal activities in the Sanctuary. Guano and stains from bird and bat excrement can be found on all four walls and are concentrated in the areas with scratches. (Figure 10) According to the project architect at Tumacacori, the animal activities have not been present in the Sanctuary since the Park took measures to keep the bats out, such as adding a door on the entrance and keeping the door closed at night.
Figure 9 Scratches on the upper part of the north wall

Figure 10 Guano on the upper part of the north wall
3.3. **Evidence of previous treatments**

Several different kinds of previous interventions from different time periods can be observed on the painted walls of the Sanctuary. Fills, edgings, and coatings have been applied to the areas with losses, using similar materials. Fills were applied to the plaster losses. Edging was applied to the boundary of plaster, while coatings were applied to the surface of the losses of structural decorations. Retouching can be found on the upper part of the north wall, where trompe l’oeil paintings of scrolls are located. (See Figure 9 above.) Residues of consolidation and reattachment of plaster can be found on all the Sanctuary walls at the location of injection holes and elsewhere. Evidence of previous poultices and tissue have been left on the surface after treatment in the areas with severe planar distortion and crumbling. There are more interventions in the areas with more severe conditions, such as on the scrolled decorations on the north wall and the northwest pendentive, which have been consolidated and retouched several times. (Appendix A)

3.3.1 **Fills of plaster & coating**

Five different kinds of plaster fills can be found in the Sanctuary. First is a kind of grey fills with rough surfaces. The fill is applied to a depth of about 1mm beneath the original surface so as to differentiate between the original and later intervention. The rough fill can be found everywhere on all four walls. The second type of fill is characterized by a very smooth surface. These fills are concentrated on the upper part of the north wall beside the middle corbel. Evidence of the smooth fill applied over the rough fill is found in some areas. The third type of fill is white. It appears on the upper part of the north wall, the west wall and the northwest pendentive. It can be found on top of the original rough fill in some
areas. On the upper part of the west wall, the fill is retouched in pink to match the color of the painted wall. Fourth is a kind of white-yellow fill with a very smooth surface, which seems to be a commercial synthetic product. This white-yellow fill is concentrated on the lower part of the north wall. The material has been unskillfully applied and is in poor condition. It may need to be removed for future treatment. Fifth is a dark brown fill on the lower part of the north wall and west wall, which appears to be adobe and only fills the first layer of the substrate plaster.

Fills of plaster can be found in all the areas with plaster losses, and are sometimes related to the condition of planer distortion to consolidate the crumbling surface.

![Figure 11 Coatings and fills of plaster on the north wall](image)
3.3.2 Edging

Edging refers to the fill material added to the edges of large areas of plaster losses. This edging both stabilizes the plaster and aids in grouting by sealing any gaps. More than three kinds of edging of the same materials as the fills of plaster can be found in the Sanctuary. First is the rough edging, which accounts for the majority part of edging. It is applied to most of the boundaries of plaster losses with an angle of 60 degrees to the surface. (Figure 12) Second is the white edging, which can be found in a few areas on top of the north wall and on the lower part of the west wall in the niche. The third is the white-yellow edging. It is concentrated on the lower part of the north wall, in the same area as the white-yellow fills. Some of the white-yellow edgings are applied on top of the original rough edging.

Figure 12 Edging of the plaster with rough surface on the east wall
3.3.3 Injection Grouting for Reattachment of Plaster

The only way of identifying previous plaster re-attachment and consolidation is through evidence of holes created for injecting grout, or in some cases, through evidence of residue. Grouting can be found in the areas with plaster separation and planer distortion, especially on the upper part of the west wall near the window frame. Yellow drips of residue can be found beneath the areas of grouting. Other traces of reattachment by injection grouting appear on the middle and lower part of the west wall and north wall, leaving numerous deep holes on the surface of the wall.

3.3.4 Retouching

Retouching can be found on the scrolled decorations on the upper part of the north wall. Lost passages of the scrolled decoration were retouched with paints of unknown composition. (Figure 13) The work appears to have been conducted by Angelica Gonzalez and Mayela Garcia in 2001, using clay, milklime, and acrylic pigments.47 The retouching is not obvious at distance, but can be distinguished at a close examination.

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3.3.5 Residue

Large areas of yellowing can be found on the blue and green band under the cornice, on the northwest pendentive, and on the upper part of the north wall near the middle corbel, indicating the presence of residue from previous intervention. However, the yellowing needs further study as it may derive from more than one source. Drips of yellow residue can be found in some areas, especially on the upper part of the north and west walls. The drips often relate to injection of grouting or large areas of yellowing. The composition of drips also needs further examination and identification.
3.3.6 Poultice & Tissue

Traces of poultice and tissue have been found on the surface in areas of severe planar distortion and crumbling, such as the northwest pendentive and and cornice of the west wall. The presence of tissue on the surface indicates, to some extent, the application of other types of treatment. (Figure 14) Apparently, the tissue was applied to the surface to hold fragile plaster and paint in place and prevent it from falling. This type of tissue facing is often applied to delicate surfaces in advance of other types of treatment, such as injection grouting and surface consolidation. Evidence of poultice material, apparently used to remove surface accretions, is found on the northwest pendentive. Traces of tissue can be found on a large crack on the upper part of the west wall near the pendentive, and on the west cornice.

Figure 14 Tissue on the upper part of west wall
Section 4  Ultra-Violet light examination

4.1.  Principle and application of Ultra-Violet light

Examination with ultra-violet light helps to distinguish and identify different materials based on the fact that certain materials fluoresce under stimulation or excitation by ultra-violet radiation. After absorbing light in the near-visible and ultra-violet light range, the substance will emit light with a longer wavelength than the absorbed radiation. When the absorbed radiation is in the ultra-violet region of the spectrum, which is invisible to the human eye, the emitted light can be in the visible region, giving the substance a distinct fluorescent color under UV light\textsuperscript{48}.

A molecule, atom, or nanostructure will be excited by absorbing the energy of the radiation, and then relax to a lower energy state through the emission of a photon. Fluorescence is the emission of a photon accompanying the relaxation of the excited state to the ground state, which is unique to each kind of material\textsuperscript{49}. (Figure 15) Thus, different materials fluoresce differently under UV light, enabling them to be distinguished.

UV light is a form of electromagnetic radiation, with shorter wavelengths than visible light and cannot be seen by the human eye. UV light refers to a broad range of radiation from wavelengths of 180nm to 400nm. It can be categorized into three parts: 1). long-wave (UV-A) 315-400nm, 2). mid-wave (UV-B) 280-315nm, 3). short-wave (UV-C) 100-280nm\textsuperscript{50}. (Figure 15) Colors of the fluorescence that can be observed depend on

not only the type of material, but also on the wavelength of UV light used. For example, many adhesives fluoresce under UV-A but do not fluoresce under UV-C, while many mineral specimens only fluoresce under short-wave UV\(^5\).  

![Diagram of light spectrum](image)

\textit{Figure 15 Theory of fluorescence and wavelength of ultra-violet light}

The application of UV light in the surface examination can be dated back to the end of the 1920s by art historians and museum curators to detect signs of hidden repairs and forgery in works of art. Later, it is adopted by conservators for its non-destructive diagnostic capabilities to help detect damage and surface coating, uncover areas of the previous restoration, and identify materials. The application of ultraviolet light examination is widely used in museum conservation and, as fluorescence microscopy, in

the analysis of paints and finishes. It is most beneficial to determine the presence of organic materials, such as adhesives, consolidants, binders, varnishes, and coatings. It can also be useful for characterizing some inorganic materials, such as pigments. The fluorescent color of broad categories of certain art and conservation materials is well known. For example, animal hide glue fluoresces yellow; shellac fluoresces orang;\textsuperscript{52} and polyvinyl acetate has milky blueish white fluorescence under long-wave UV.\textsuperscript{53}

Ultra-violet light examination is a useful tool for characterization of broad classes of materials; however, it is less useful for specific materials identification. First, many materials fluoresce similarly and it is hard to identify unknown or similar materials for qualitative analysis. Results will also vary under different energy sources. Second, the result may be misinterpreted due to age, surface dirt, or other factors. For example, fresh linseed oil is not fluorescent but fluoresces greenish-yellow after it has oxidized. Ambient conditions and previous exposure may also alter the color and intensity of fluorescence under UV light. Third, in the cases of mixtures, some materials fluoresce stronger and will overpower the fluorescence of other molecules.

\textsuperscript{52}Simpson-Grant, M, ‘The Use of Ultraviolet Induced Visible-Fluorescence in the Examination of Museum Objects, Part 2’, Conserve-O-Gram 1/10, viewed 15 April 2000.
\textsuperscript{53}https://www.nps.gov/museum/publications/conserveogram/01-10.pdf.
4.2. On-site UV examination

In the examination of the painted Sanctuary of Tumacacori, Spectroline® Q-Series Ultraviolet lamp with long-wave UV-A was used as the source of UV light. The wavelength of the emitted light source was 365nm. The examination took place in the darkness between 6-7 pm in January, after sunset, under the protection of UV filtering safety glasses. Because of ease of use and time constraints, an iPhone 11 camera was used to capture the images.

Several different fluorescent colors were found on the painting surfaces, as described below. Colors of fluorescence varied from pale orange to bright blue-white. Most of the fluorescence appears to derive from materials previously used as consolidants, as well as urine and guano of birds and bats, while the original plaster paints and fills had no fluorescence. A greater color range was detected by the human eye than by the iPhone camera.\footnote{This happens because the three color channels of the human eye exceed the accuracy of the iPhone color bandwidth. Thus, a digital SLR camera is recommended to detect color with greater accuracy.}

4.2.1 Very bright yellow fluorescence

The most striking fluorescence appears on the corbel of the north wall, where the surfaces fluoresced a very bright yellow in UV light. This striking fluorescent color was surprising as no significant difference was noted in visible light with the other part of the wall. Therefore, the fluorescence suggests the presence of an anomalous material not commonly found elsewhere. This kind the fluorescence appears only on the upper part of
the north wall, mainly on the middle corbel and also scattered around the corbel and on the scrolled decorations.

![Figure 16 Very bright yellow fluorescence on the north wall](image)

### 4.2.2 Pale orange fluorescence

Pale orange fluorescence appears on the cornice of the west wall and the northwest pendentive. There are large areas of yellowing under normal light on the cornice and the northwest pendentive; however, these areas fluoresce differently in ultraviolet light. Some small areas appear to be pale orange in ultraviolet light, while the others appear to be yellow or light white, which may indicate several different kinds of residue on the surface. (Figure 17)
4.2.3 Dull yellow fluorescence

Dull yellow fluorescence appears on the cornice of the west wall and the northwest pendentive, near the material with orange fluorescence. It also appears on the upper part of the north wall around the foliated decoration. The intensity of fluorescence differs to some extent in these areas, but the difference is difficult to distinguish.\(^5\)

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**Figure 17** Orange and yellow fluorescence on the northwest pendentive

4.2.4 Bright white fluorescence

There are some drips of residue on the surface that fluoresce bright white. The residue is invisible under normal light, but fluoresce intensely in ultraviolet light. The material with bright white fluorescence appears on both the west and north wall, usually in the areas with fills and grouting. A kind of edging and fill also fluoresces bright white.

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\(^5\) Future UV photography with a DSLR camera and closer scrutiny of the resulting photographs may yield additional information.
4.2.5 Blue-white fluorescence

Several different kinds of surface materials fluoresce blue-white. It is difficult to distinguish the color quantitatively on site because this type of blue-white fluorescence is scattered on all the surfaces. This particular fluorescent color, which is only clearly visible in ultraviolet light, is associated with the presence of transparent coating seen in normal light. Typically, blue-white fluorescence appears on the scrolled decoration, the middle corbel on the upper north wall, and on the upper part of the north wall. (Figure 19, Figure 20) The appearance of blue-white fluorescence often relates to previous treatments of retouching, grouting, and reattachment.
Figure 19 Blue-white fluorescence on the scrolled decoration

Figure 20 Blue-white fluorescence on the foliated decoration
4.2.6 Green-white fluorescence

Green-white fluorescence can is found on the upper part of the north wall, around the middle corbel. Several drips of residue with green-white fluorescence appear on the east side of the middle corbel. The material has not been applied in large areas. The green-white fluorescence seems to be on top of the bright yellow fluorescence found on the middle corbel. (Figure 21)

Figure 21 Green white fluorescence on the middle corbel
4.2.7 Urine and guano fluorescence

Some residues on the surface with strong fluorescence appear to be urine and guano from birds and bats. These biological remains fluoresce bright white and can be easily distinguished by their shape. (Figure 22)

![Image](image-url)

*Figure 22 Fluorescence of urine and guano on the north wall*
4.3. **Reference Sample Preparation**

In an effort to provide a source of reference for fluorescence colors of materials used in the previous treatments and to help differentiate them, reference samples were made by applying materials indicated in reports on previous treatments to samples made of plaster. A selection of materials not recorded but sometimes used in wall paintings conservation and known to fluorescence were added to the reference sample group so as to broaden the range of references. Two to three samples were made for each material: one with a high concentration of the material; sometimes one with a weak concentration of the material; and a control sample of the substrate without a surface application. The resulting fluorescent colors of these samples will be compared with photographs of the fluorescence on-site and with cross-sectional microscopic samples examined with the fluorescence microscope.

To create a substrate for the samples, plaster of Paris was poured into plastic Petri dishes measuring two inches in diameter. The resulting dishes were approximately one inch in thickness. To ensure that any inherent fluorescence would be visible under ultraviolet light, four undiluted layers were applied to the surface of the samples creating the high concentration examples. The samples displaying weak concentrations were diluted in the appropriate solvent and applied in fewer applications. Then, the samples were examined and photographed with both visible light and ultraviolet light.\(^56\)

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\(^56\) The examination under ultraviolet light was conducted within a month after applying the materials. As a result, the materials being examined are not aged. In the future, the samples may need to be re-examined again under ultraviolet light to illustrate their fluorescence with aging.
The choice of materials for the reference samples more or less represents the materials used in previous treatments. Reports for five major campaigns of treatment have documented the use of consolidants, binders, and adhesives, including natural glues, synthetic resins, and synthetic emulsions. Some of the materials, such as polyvinyl acetate Vinylite A™, had to be substituted with similar materials of a different brand because they were not available at present. Additional materials not mentioned in reports but widely used in the treatment of wall paintings were added to the selection of materials. The materials are listed below:

- **Rhoplex.** A high solid, long-chain polymer acrylic resin emulsion used as a binder. The exact composition is proprietary. Additional Rhoplex emulsions have been mentioned in previous reports, although the specific type of product is not recorded. Thus, three types of Rhoplex were selected for application to reference samples, as indicated below:

- **Rhoplex 1950.** Also referred to as Rhoplex LC-76. A high solids acrylic binder for high-performing sealants and patching compounds. The exact composition is proprietary

- **Acrysol WS-24.** Also referred to as Primal or Rhoplex WS-24. An acrylic resin emulsion. The exact composition is proprietary.

- **Rhoplex M76.** A medium solid, acrylic resin emulsion of medium length polymer developed as a cement modifier. The exact composition is proprietary.

- **Jade 403.** Polyvinyl acetate. The polyvinyl acetate Vinylite A™, a copolymer of vinyl chloride and vinyl acetate, is recorded to have been used in the 1949 and 1982 treatments. However, the product is not available for this research. So, the
product Jade 403, also polyvinyl acetate emulsion, was used as a substitute. The exact composition of both Vinylite A and Jade 403 is proprietary.  

- A PVAc emulsion replication. A replicated emulsion of the materials used in Tumacacori in 1949, which was made by Gabrielle Goldstein a year before in her thesis research.  

- Paraloid B-72. An acrylic resin, which is a copolymer of 70:30w/w ethyl methacrylate and methyl acrylate. Paraloid B-72 is recorded in the 1982 and the 1990s treatments.  

- Paraloid B-67. An acrylic co-polymer resin composed of an isobutyl methacrylate polymer. The material is not mentioned in the previous report but is also commonly used in wall painting conservation.  

- Ammonium Caseinate and Calcium Caseinate. Casein derivatives have been mentioned in the 2000 treatment for plaster consolidation and reattachment. The casein derivatives were made in the lab. Ammonium caseinate was made with 1 part of milk casein, two parts of ammonium carbonate, and 16 parts of water. Calcium caseinate was made of the same formula as milk casein and quick lime.  

- Rabbit skin glue. Rabbit skin glue has been used in the 2001 treatment as plaster and surface consolidant. The rabbit skin glue used in this research was made of solid raw rabbit glue in the lab and diluted in water.

57 Vinylite A has became the standard material of long-playing phonograph records. Jade 403 was chosen because it was readily available. Other polyvinyl resin emulsions may more closely replicate the composition of Vinylite A.  

58 The PVAc emulsion replication was made by Gabrielle Goldstein following the formula recorded by Steen and Gettens. Goldstein, 2021.
- Cactus glue. Cactus glue has been mentioned in the 2000 treatment for plaster consolidation and reattachment. The cactus glue used in this research was made in the lab from fresh prickly pear cactus.

- Other natural resins augmented the reference sample selection, such as carnauba wax, bees wax, gum arabic, shellac, and dammer varnish. These natural resins are not mentioned in existing reports; however, they have been commonly used in conservation treatment over time and were added to augment the sample group.

- Flour paste. It is sometimes used as a facing adhesive in wall paint conservation.

- Lead white in linseed oil. We hypothesize that the bright yellow fluorescence on the middle corbel of the north wall might be a lead-containing material. Therefore, a handmade lead white paint composed of linseed oil and lead white pigment was applied to a reference sample to compare with the fluorescence color on-site.

- Linseed oil. Linseed oil without lead white pigment was applied as a reference.
4.4. Results of UV examination

The samples were photographed with visible light and with the same Spectroline® Q-Series ultraviolet lamp with long-wave UV-A 365 nm as used on-site. In addition to photographing them with the iPhone camera, as had been done on-site, they were also photographed with a digital SLR camera Canon EOS Kiss M. (Appendix A), which produced a greater range and more specific fluorescent colors. Table 4-1 below describes the samples and associated fluorescence.

The plaster of Paris alone does not fluoresce in ultra-violet light. It appears dark purple. However, most of the reference samples with a high concentration of materials display fluorescence when illuminated with UV light. Fluorescent colors vary in hue from white-blue to yellow to white-green and orange. The synthetic polymers fluoresce similarly in subtle variations of blue and blue-purple. Although some are lighter than others, they are not readily distinguishable. The Rhoplex acrylic emulsion samples, polyvinyl acetate sample, and samples of caseinate all fluoresce bright blue-white. Although slightly different in intensity, they are also difficult to differentiate. The acrylic resin Paraloid B-72 and B-67 display no fluorescence. A replication of PVAc emulsion was also examined. The material has very weak white-blue fluorescence that can only be perceived at high concentrations. (Table 4-1)

In the meantime, the fluorescence of protein-based animal glues⁵⁹ and gums⁶⁰ is more colorful and distinguishable. Rabbit skin glue shows a bright yellow-white fluorescence. Cactus glue fluoresces bright white-green. Beeswax fluoresces a very bright

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⁵⁹ These animal glues are amino acid molecules that form proteins are known to fluoresce.
⁶⁰ These triglyceride molecules that form reducing sugars such as gums are also known to fluoresce.
yellow. Shellac produces a very strong fluorescence in bright orange and pink. (Figure 23, Figure 24)

The unaged lead white linseed oil paint fluoresces bright white, while the pure unaged linseed oil fluoresces pink-orange. A fragment of aged lead white paint examined under ultraviolet light and shown to fluoresce bright yellow demonstrates the change in fluorescent properties with age.
Table 4-1 Result of fluorescence under ultraviolet light

<table>
<thead>
<tr>
<th>Number</th>
<th>Material</th>
<th>Notes</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>UVS-01.1</td>
<td>Acrysol WS-24</td>
<td>Acrylic resin</td>
<td>Undiluted</td>
</tr>
<tr>
<td>UVS-01.2</td>
<td></td>
<td></td>
<td>Diluted</td>
</tr>
<tr>
<td>UVS-02.1</td>
<td>Rhoplex 1950</td>
<td>Acrylic resin</td>
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</tr>
<tr>
<td>UVS-02.2</td>
<td></td>
<td></td>
<td>Diluted</td>
</tr>
<tr>
<td>UVS-03</td>
<td>Rhoplex M76</td>
<td>Acrylic resin</td>
<td>Undiluted</td>
</tr>
<tr>
<td>UVS-04.1</td>
<td>Jade 403</td>
<td>Polyvinyl Acetate</td>
<td>Undiluted</td>
</tr>
<tr>
<td>UVS-04.2</td>
<td></td>
<td></td>
<td>Diluted</td>
</tr>
<tr>
<td>UVS-05</td>
<td>Paraloid B-67</td>
<td>Acrylic resin: Isobutyl methacrylate polymer</td>
<td>Undiluted</td>
</tr>
<tr>
<td>UVS-06</td>
<td>Paraloid B-72</td>
<td>Acrylic resin: Ethyl methacrylate polymer</td>
<td>Undiluted</td>
</tr>
<tr>
<td>UVS-07</td>
<td>Keim Silan-100</td>
<td>Alkyl Alkoxyilsilane</td>
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</tr>
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<td>Carnauba Wax</td>
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<td>Diluted</td>
</tr>
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<td>UVS-10.1</td>
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<td>Diluted</td>
</tr>
<tr>
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<td>Undiluted</td>
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<tr>
<td>UVS-11.2</td>
<td></td>
<td></td>
<td>Diluted</td>
</tr>
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<td>UVS-12</td>
<td>Bee wax</td>
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<td>Undiluted</td>
</tr>
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<td>Dammer Varnish</td>
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<td>Flour paste</td>
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<td>PVAc-Tuma replication by Gabrielle</td>
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<td>Lead white in linseed oil</td>
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<td>UVS-20</td>
<td>Linseed oil</td>
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<tr>
<td>UVS-00</td>
<td>Blank-untreated plaster of Paris</td>
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</tbody>
</table>
Figure 23 Photograph of the reference samples under normal light

Figure 24 Fluorescence result of samples under ultraviolet light
Section 5  Microscopical Analysis

5.1.  Preparation of samples

A set of ten cross-sectional microscopic samples from the Sanctuary were examined with a fluorescence microscope in reflected visible and ultra-violet filtered light. Taken on-site from areas of severe deterioration, as well as locations with clear evidence of the materials of previous treatments, the samples included evidence of retouching, residues of materials used in previous conservation treatment, and white veils. (Appendix E.) The microscopical sample examination aimed to provide more information about previous treatments and see if the fluorescence of materials in the cross-sections viewed with the fluorescence microscope was consistent with fluorescence observed on site.

The samples from the site were prepared in Bioplastic\textsuperscript{61} and cut into cross-sections with a Buehler IsoMet.\textsuperscript{62} Thereafter the samples were polished with micromesh ranging from 400 grits to 15000 grits to a high polish and photographed.

5.2.  Laboratory analysis under microscope

5.2.1  Visible light microscopy

A Nikon Alphaphot-2 compound microscope fitted with fiber optic dual gooseneck reflected lights was used to analyze the cross-section samples. The photographs were taken by a Nikon DS Fi-1 camera and processed with Nikon Digital Elements BR software version 5.0.2. (Figure 25)

\textsuperscript{61} The Bioplastic is a two-part polyester resin produced by Ward’s Scientific.
\textsuperscript{62} The Buehler IsoMet is a precision instrument for cutting embedded cross sectional samples with a polycrystalline diamond blade. Stoddard’s solvent is used as the lubricant.
5.2.2 Fluorescence microscopy

In ultra-violet light, the samples were also examined using the same Nikon Alphaphot-2 compound microscope for fluorescence microscopy and the Nikon Digital Elements BR version 5.0.2 software. A super high-pressure mercury lamp provided the ultraviolet light source. The filter used for fluorescence is BV-1A, which has an excitation of 430-440 nm, dichroic of 455 nm, and an emission of 470 nm. The exciting light is purple, and the emitting light is yellow/green. (Figure 25) The Nikon DS Fi-1 was also used to take the fluorescence images.  

However, the camera is aged and has some problems in capturing the fluorescence color of the sample. To show the actual color seen from the microscope and supplement the images captured by the camera, an iPhone 11 camera was also used to capture images directly from the eyepieces. These images proved to be more reliable.
5.3. **Results of microscopical examination**

Samples taken from the painted surfaces on-site were prepared in cross-sections and microscopically analyzed as a supplement to the on-site ultraviolet light examination. The results of the microscopical analysis are more or less consistent with the findings of the on-site ultraviolet light examination. (Appendix F)

From the cross-sections, some white residue can be seen on top of the paint layer. For example, sample S-04, taken from the foliated decoration on the upper part of the north wall, where white drip residue has been observed on-site, displays strong white fluorescence under ultraviolet light on site. In cross-section, the layer of white residue shows limited white fluorescence; however, the intensity of fluorescence is very weak in comparison to the observation on-site.

White residue in sample S-09, taken from the blue paint from the south wall, can also be seen. However, the residue has no trace of fluorescence. The result is consistent with the ultraviolet light examination on-site. These two samples indicate two different kinds of residue on the surface.

Sample S-02 is taken from the middle corbel on the north wall, where strong yellow fluorescence has been observed on-site. From the cross-section, we can see the material with yellow fluorescence on the top seeping into the substrate.

Traces of previous treatment have been found microscopically in cross-sections and limited fluorescence is observed.  

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64 This result may partly result from the limited number of samples taken from the site. In the future, if more samples can be taken from areas with clear traces of previous applications, they may produce more evidence.
Figure 26 Cross-section of sample S-04 (left-visible light, right-ultraviolet light)

Figure 27 Cross-section of sample S-02 (left-visible light, right-ultraviolet light)
5.4. Microchemical analysis

The material observed on the middle corbel of the north wall with strong yellow fluorescence has been thought to be composed of paint containing lead pigment. In order to verify its composition, microchemical analysis was used to determine if lead was present in the sample.

Sample material fluorescing bright yellow in UV light was removed from the surface of the sample, collected in a slide, acidified, and tested with potassium dichromate (K₂Cr₂O₇). The principle of the lead test is that lead ions precipitate as lead chromate (PbCrO₄), which is yellow, in the presence of crystals of potassium dichromate.⁶⁵

\[
\begin{align*}
\text{K}_2\text{Cr}_2\text{O}_7 (s) + H^+ \rightarrow & \quad \text{H}_2\text{CrO}_4 (aq) \\
\text{Pb}^{2+} (aq) + \text{H}_2\text{CrO}_4 (aq) \rightarrow & \quad \text{PbCrO}_4 (s)
\end{align*}
\]

In the test, the sample powder is first dissolved in 15% acetic acid, and then mixed with potassium dichromate (K₂Cr₂O₇). The presence of a precipitate of yellow lead chromate confirms that the sample contains lead. The sample became yellow, indicating a positive for lead.

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⁶⁵ Nancy Odegaard, Scott Carroll, and Werner S. Zimmt, Material characterization tests for objects of art and archaeology. London: Archetype Publications, c2000. 70-71. The principle of the lead test is that lead ions precipitate as lead chromate (PbCrO₄) in the presence of crystals of potassium dichromate.
Section 6  Conclusions & Recommendations

6.1. Findings of current conditions and treatments

On-site examination and graphic recording, together with the review of documents and laboratory analysis, shed light on current conditions and previous treatments. Ultraviolet examination of reference samples and microscopic examination have helped to differentiate the materials used in previous conservation treatments. With these sources and the belief that comparing the results of laboratory analysis to on-site observation will help to identify previous treatments, the author will try to relate on-site evidence of interventions to specific campaigns of treatments. Characterizing these materials and their specific locations may also help in evaluating the effects of previous treatment.

Below is a summary of the observations and findings of differentiating the treatment materials and their possible relationship with the current conditions:

6.1.1 The bright yellow fluorescence suggests the presence of lead white paint

Three different kinds of fluorescence have been found on the surface of the middle corbel on the north wall: a bright yellow fluorescence all over the surface, a blue-white fluorescence near the detached area, and some green-white fluorescence in small spots. It is interesting to differentiate these three materials. (Figure 28)

The area with yellow fluorescence is white-grey in visible light and shows no significant difference from the areas without this fluorescence. It presents a texture suggesting brush application, which confirms that the fluorescence is not caused by guano or other animal activities. However, no similar fluorescence was observed from the reference samples in the lab, indicating that the fluorescence may be caused by a material
not included among the reference samples and not recorded in previous reports. As a result, the presence of fluorescent inorganic materials was considered. Knowing that lead white fluoresces bright yellow, sample material was collected. Chemical testing confirms the presence of lead in the sample. While an un-aged reference sample with lead white in linseed oil is examined under ultraviolet light and fluoresces a different color of white-yellow, a piece of aged lead white paint shows a similar bright yellow fluorescence, indicating that the material found on the middle corbel is lead white.

![Image](image_url)

*Figure 28 Ultraviolet light examination of the middle corbel*

Additionally, a cross-sectional sample from the same location was microscopically analyzed. The bright yellow fluorescence can be observed on top of the sample; however, no clear layers can be distinguished in the sample.\(^{66}\) (Figure 28) Moreover, previous reports

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\(^{66}\) The corbel substrate was unusually hard and difficult to extract. More samples are needed in the future to reveal the layer structure of the lead white applied to the corbel.
have no record of applying lead white in the sanctuary. The exact time and purpose of this application remain unknown.

The lead white was applied to the surface of the middle corbel. It seemed to be applied later as a consolidant to the surface of the corbel because no evidence of lead white was found on the other areas in the sanctuary. However, it is still unknown when the material was applied and who conducted the application. The lead white has contributed to the strength of the surface, making the corbel surface harder and more resistant than the other part of the Sanctuary.

6.1.2 Green white fluorescence might be cactus glue

A few spots with green-white fluorescence can be observed on the middle corbel. These spots are on top of the layer with bright yellow fluorescence and seem to be splashed onto the corbel during application. (Figure 28) The color of fluorescence shows a close similarity to the color of the reference sample with cactus glue. Given the clear record of using cactus glue in the 2000-2001 treatment by Tohono Restoration for plaster reattachment and surface consolidation on the upper part of the north wall, especially the area around the middle corbel, one may assume that the material with green white fluorescence might be cactus glue. However, more work is needed to examine the exact material.

The impact of cactus glue remains unclear. The materials found on the middle corbel that could be cactus glue were small drips splashed onto the surface. The impact of cactus glue might be assessed in the future if larger areas of application can be found.
6.1.3 *Synthetic resins fluoresce blue white*

Materials with blue-white fluorescence can be found on the middle corbel near the detached area. (Figure 21) The material is applied on top of the layer with bright yellow fluorescence, and might have been used to reattach and consolidate the detached plaster. Differentiating previous treatments with ultra-violet light examination on site is not straightforward, as many of the synthetic resins fluoresce blue-white. However, slight differences in the shade of blue color and in the intensity of fluorescence are noted in the reference samples. Some are lighter and more white than others. For example, Rhoplex 1950 fluoresces a considerably lighter blue-green-white color than other acrylic materials. On the other hand, the caseinate derivatives’ fluorescent color is similar to Rhoplex 1950. As a result, it is not clear which of the blue-white fluorescent colors, if any, belong to the 1949 campaign involving polyvinyl acetate by Steen and Gettens nor the 1982 treatment by the NPS and ICCROM. Neither can particular locations of treatment be assigned to the Rhoplex used in the 1992 treatment by the NPS and ICCROM interventions. Likewise, caseinate derivatives used in the 2000-2001 treatment by the Tohono Restoration fluoresce similarly to the synthetic materials used in earlier campaigns.

The blue-white fluorescence found on the middle corbel is also observed on the scrolled decoration on the upper part of the north and west walls. (Figure 29)

Moreover, the materials with blue-white fluorescence sometimes appear with other materials that fluoresce yellow-white or dull yellow. The layers with blue-white fluorescence often appear under other layers, indicating that these synthetic resins were applied earlier than the other materials.
Due to the similarity of fluorescent colors, it is difficult to link a particular fluorescent color with a specific material. However, one may observe sufficient differences in fluorescent color to merit further investigation with a digital SLR camera.  

The synthetic materials used to consolidate plaster and paint affected the surfaces differently, depending on the materials and application used and on the location of treatment. On one hand, most of the applications appear to have successfully reattached loose paint and plaster. For example, grouts mixed with aggregate or other fillers and used for reattaching plaster appear to have been successful. That is, the plaster remains well attached today and there is no evidence of deterioration in those locations nor in close proximity to them. On the other hand, it appears likely that the materials used to stabilize

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67 Additional methods to differentiate materials are warranted. They may include laboratory analysis of samples of materials from the site used for treatment.
loose paint have also added weight to the surface and probably changed vapor permeability, thus promoting the deterioration. Conditions such as shallow detachment and crumbling are prevalent in these locations.

6.1.4 White-yellow fluorescence might be rabbit skin glue

The scrolled decoration on the west side of the north wall displays the most evidence of previous treatments. It shows traces of retouching and the presence of different materials for surface consolidation. It is clear that the material with white-yellow fluorescence, associated with rabbit skin glue, was applied on top of the blue-white fluorescence associated with synthetic resins. (Figure 24) Given the mention of the application of rabbit skin glue in the 2001 treatment report by Angelica Gonzalez and Mayela Garcia for plaster and surface consolidation, one may surmise that the material observed on the scrolled decoration belongs to this campaign of treatment. Similar materials have also been observed on the surfaces around the middle corbel and the northwest pendentive. (Figure 30)

Rabbit skin glue seems to be effective in reattaching the detached paint layers. The areas treated with glue, as evidenced by white-yellow fluorescence, are presently stable. However, the glue has altered the appearance of the painting by creating large areas of yellow that can be observed in normal light.
6.1.5 Plaster fills and edgings

Four different kinds of plaster fills and edgings from different campaigns of treatments have been observed in the Sanctuary: a kind of grey fill with rough texture, which is often applied 1-2 mm below the surface of the wall; a grey fill with very smooth surface; a white fill; and a yellow-white fill. (Figure 11) The application subsequence can be discerned by the overlaying relationship of these fills and edgings. The rough fills, which are the earliest application and most expertly executed, can be found everywhere in the Sanctuary. The other three types of fills can be found on top of the rough fills. We assume that the fills and edgings with rough texture can be dated back to the 1982 treatment, and the others should belong to later campaigns.
There are also plaster losses in the Sanctuary that have not been treated. These plaster losses are often near existing fills, which indicates that they might occur recently after previous treatments.

Most of the plaster fills and edgings are effective in helping secure the plaster in place and presumably in facilitating grouting. However, the fills and edgings in white-yellow have been unskillfully applied and are in poor condition. Applied on the lower part of the walls, these fills appear to be impermeable and incompatible with the original plaster. They have detrimentally affected the appearance of the Sanctuary. In addition, the white-yellow fills and edgings have not prevented further plaster losses. More recent losses can be found along the boundaries of the fills.

6.1.6 Detachment and reattachment

The detachment between the substrate and surface is detected by tapping the surface by hand or with a small rubber-headed tool. Plaster has been reattached in the past as observed through evidence of holes used for injecting grout, or through evidence of residue in some cases. Areas of previous detachment and reattachment appear to be stable.

Many deep and shallow areas of detachment are detected on the upper part of the west wall; however, little trace of grouting has been found in these detached areas. Therefore, the detachment seems to have occurred recently and may need to be reattached after further investigation.

In conclusion, the work of reattachment is effective. It helps keep the plaster in place. Most areas with evidence of the previous reattachment are not detached at present. However, evidence of injection grouting has left deep holes and led to cracks on the surface.
of the Sanctuary, especially on the middle and lower part of the west wall. This has harmed the appearance of the sanctuary. Further treatment may be needed to prevent the cracks from developing into more severe conditions. (Figure 31)

*Figure 31 Holes and cracks resulting from the previous injection*
6.1.7  Cracks and crumbling near the pendentives

Conditions in the northwest and northwest pendentives include major cracks along the boundary of the pendentive and the walls. Severe detachment and crumbling occur in areas near these cracks. (Figure 32) There is residue dripping down the wall from the cracks, indicating previous reattachment and consolidation. Apparently, the treatment did not effectively correct the problems on the pendentive, as severe detachment and crumbling in large areas on the walls next to the pendentive currently exist and need immediate intervention. Conditions are much worse next to the two pendentives on the north elevation, while the two pendentives on the south are in better condition.

Figure 32 Cracks and crumbling near the pendentive
6.1.8 Crumbling in locations of repeated treatment

Severe crumbling has been observed in areas that have been treated several times, such as on the two scrolled decorations on the north wall. (Figure 33) The one on the west side of the north wall has been extensively treated in the past, as seen by the presence of plaster fills and extensive retouching. At least three kinds of consolidation materials are found on the decoration that, based on observation of fluorescence when examined with ultraviolet light, are made of both synthetic resins and natural glues. According to the reports, this decoration is a critical area that has been treated during each campaign of treatment. It might have been consolidated by materials like PVAc, acrylic resins, rabbit skin glue, cactus glue, etc. Despite these repeated treatments, the plaster remains detached; the paint layers have continued to deteriorate, as evidenced by paint crumbling and loss.

Thus, the impact of these previous treatments might be twofold. While treatment appears to have effectively re-adhered the loose paint and plaster for a short time, it appears to have contributed to additional crumbling in the area. Such locations where deterioration has persisted suggest that they result from a combination of unchecked architectural or environmental conditions and the treatments themselves. The exact cause of degradation merit further examination and evaluation.
Extensive evidence of repeated paint and plaster consolidation in the same locations addressing detached plaster and crumbling paint suggests that conditions leading to deterioration have persisted over time. It also raises the question of the extent to which treatments in the past have actually contributed to deterioration.\textsuperscript{68}

\textsuperscript{68} The exact composition of these past treatments needs to be determined and linked to treatment campaigns through instrumental analysis. See Recommendations for additional research.
6.2. **Recommendations**

Recommendations for additional research and for future treatment and for future treatment are outlined below:

6.2.1 **Recommendations for additional research**

The conditions and treatment in the painted Sanctuary of the Church San Jose de Tumacacori is a very complicated topic. This thesis should be considered a preliminary effort. The following suggestions should be considered for future research:

1. A more thorough ultraviolet light examination is recommended. Restricted by the time we spent on site, the ultraviolet examination has not been completed thoroughly. As noted, the photographs on site were taken with an iPhone with limited color bandwidth. As a result, the full range of fluorescence colors observed on site are not represented in the photographs. Additionally, there is inconsistency in how the images were photographically captured: The photographs on-site were taken with an iPhone and a specific light source; the photographs of the reference samples were taken with the same light source as that used on-site but with a Canon digital SLR camera; the cross-sectional samples were taken with a different Nikon digital camera and software attached to the microscope and with specially filtered excitation and emission light from the high power mercury arc lamp. This results in the difference in color capture of the fluorescence, which causes problems comparing the results between the on-site examination, the reference samples, and the microscopic samples. In addition, the camera used for microscopically photographing the cross-sectional
samples is not functioning properly and cannot capture the fluorescence color correctly. For future research, we would recommend using the same light source with the same wavelength of ultraviolet light to examine the surfaces on-site and the reference samples in the lab. Further, we recommend matching the excitation filter block as closely as possible to the excitation light of the Spectroline® Q-Series Ultraviolet lamp as well as the cross-sections under the microscope. The photographs should be taken with the same camera or camera settings, the same filters, and inconsistent circumstances. The parameters of the filter blocks on the fluorescence microscope should be matched as closely as possible with the excitation light of the handheld UV light source. In this way, the examination of the three sets of UV examination and documentation – on-site, reference samples, and microscopic samples - will be more meaningful.

2. Fluorescence of aged reference samples should be re-examined in the future. Restricted by the time of this research, the reference samples were examined under ultraviolet light within a month after the application before they were able to oxidize. The color of fluorescence may change as some materials age. We would recommend re-examining the aged samples and comparing the results with the on-site examination again in the future, which may help find more materials that can be matched with the on-site examination.

3. More cross-section samples might be taken and analyzed under the microscope. Restricted by the samples taken on-site, the microscopic analysis in this research was nominally helpful in differentiating the materials. For example, the highly fluorescent lead white layer on the middle corbel was not clearly seen
in the cross-section samples with the fluorescence microscope, as it should have been. We would recommend taking more targeted samples from areas with materials with fluorescence on the site, which may reveal the layers and subsequence of different materials on the surface. The problems with the camera and software for the fluorescence microscope also need to be remedied.

4. Additional methods are needed to identify synthetic resins and other materials. In this thesis, ultraviolet light has proved to be useful in differentiating given natural materials and synthetic resins with the help of reports of previous treatments. However, different kinds of synthetic resins, especially different kinds of acrylic resins and polyvinyl acetate, fluoresce similarly, which makes it difficult to differentiate through merely the method of ultraviolet examination. Better on-site photography, together with instrumental materials analysis, is recommended in future research to analyze the synthetic materials applied to the Sanctuary surface of Tumacacori.
6.2.2 **Recommendations for additional treatment in the Sanctuary**

Based on the investigation and documentation of current conditions, the following recommendations might be considered for treatments in the Sanctuary in the future:

1. Detached and crumbled areas near the pendentive, particularly on the upper part of the west wall near the southwest pendentive and the upper part of the north wall near the northwest pendentive, require treatment to be stabilized. The cracks that occur from the pendentive have caused severe detachment between the plaster and substrate and caused large areas of crumbling on the surface. This condition should be considered as a high priority and requires immediate intervention.

2. The areas that have been treated several times need further examination, especially the two scrolled decorations on the north wall, which are experiencing severe crumbling and disaggregation. The influence of previous treatments should be assessed, and it should be evaluated if further intervention is necessary, or if further intervention is possible.

3. There are plaster fills and edgings from different periods. The early treatments are in good condition; however, the white-yellow fills with a very smooth surface on the lower part of the north wall and the west wall are applied unskillfully and are in relatively poor condition. These fills and edgings have influenced the appearance of the Sanctuary wall. It is recommended that they are removed and replaced by more appropriate fill material in the future.

4. A significant amount of animal activity can be observed in the Sanctuary due to guano and the stain of guano from birds and bats on the upper part of the
north wall. According to the project architect from Tumacacori, actions have been taken to keep the bats out, and there are no longer bats inside the Sanctuary at present. However, there are still guano and stain of guano on the surface of the wall, which might be harmful to the paint and plaster. We would recommend further investigation of the animal activity in the Sanctuary to see what additional measures can be taken to prevent birds and bats from entering the church.
Bibliography


Goldstein, Gabrielle, "Revisiting a Past Treatment of the Painted Interior of San José de Tumacácori" (2021). Theses (Historic Preservation). 713. https://repository.upenn.edu/hp_theses/713


### Traces of previous treatments

<table>
<thead>
<tr>
<th>Description</th>
<th>Location</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster Fills: Smooth</td>
<td>Upper north wall</td>
<td>Upper part of north wall</td>
</tr>
<tr>
<td>Plaster Fills: Rough</td>
<td>North-west pendentive</td>
<td>Everywhere on the surface</td>
</tr>
</tbody>
</table>

* Fill of plaster smooth
* Fill of plaster rough
* Fill of plaster white
Plaster Fills: White
Location: Upper north wall
Other areas: Everywhere on the surface

Plaster Fills: White (painted)
Location: Upper west wall
Other areas: West wall, upper part, south side, painted pink

Plaster Fills: White yellow
Location: Lower north wall
Other areas: Lower part of north wall and west wall
Plaster Fills: Dark brown
Location: lower north wall
Other areas: lower part of north wall and west wall

Coating: Rough
Location: upper north wall, circle decorations and foliated decorations

Edging: Rough
Location: lower north wall
Other areas: lower part of the four walls
Edging: White
Location: upper north wall
Other areas: upper part of the north wall, lower part of west wall

Edging: White yellow
Location: lower north wall
Other areas: lower part of north wall

Retouching. Painting in areas of paint loss.
Location: upper north wall, scrolled decorations, west side
<table>
<thead>
<tr>
<th>Retouching. Painting in areas of paint loss. Location: upper north wall, scrolled decorations, east side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tissue. Thin paper attached to the surface with adhesive. Location: upper west wall, north side Other areas: upper part of west wall and north wall</td>
</tr>
<tr>
<td>Tissue. Thin paper attached to the surface with adhesive. Location: upper west wall, cornice</td>
</tr>
</tbody>
</table>
### Tissue
Thin paper attached to the surface with adhesive.
Location: upper west wall, above the window frame

### Poultice
Location: upper west wall, cornice

### Current conditions
Plaster loss. Loss of finishes plaster and sometimes the underlying plaster layers.
Location: north west pendentive
Other areas: Everywhere on the surface
Structural loss. Loss of bricks.
Location: north west cornice

Structural loss. Loss of niche.
Location: middle west wall, niche
Other areas: west wall and south wall niches

Deep holes (resulting from injection grouting)
Location: lower part of north wall
Other areas: Everywhere on the surface, middle part of west and north wall
<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
<th>Location</th>
<th>Other Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planer distortion. Uneven wall surface.</td>
<td></td>
<td>upper west wall, south of the window frame</td>
<td>Everywhere on the surface, with fill of plaster; especially on the upper part of wall and cornice</td>
</tr>
<tr>
<td>Planer distortion. Uneven wall surface.</td>
<td></td>
<td>upper north wall, west to the foliated decoration</td>
<td>Everywhere on the surface, with fill of plaster; especially on the upper part of wall and cornice</td>
</tr>
<tr>
<td>Crumbling. Fragmentation of paint and plaster.</td>
<td></td>
<td>upper north wall, scrolled decoration, west side</td>
<td>Everywhere on the surface, especially on the upper part of north wall and areas near pendentive</td>
</tr>
<tr>
<td>Condition</td>
<td>Description</td>
<td>Location</td>
<td>Other areas</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>Crumbling</td>
<td>Fragmentation of paint and plaster.</td>
<td>Upper north wall, west side near the north west pendentive.</td>
<td>Everywhere on the surface, especially on the upper part of north wall and areas near pendentive.</td>
</tr>
<tr>
<td>Major crack</td>
<td>Crack more than 1mm wide and penetrating through the paint and finish plaster layers.</td>
<td>West wall, under the window frame.</td>
<td>West wall from top of the dome to lower part of the wall.</td>
</tr>
<tr>
<td>Minor crack</td>
<td>Cracks less than 1mm wide and shallow in depth.</td>
<td>Intersection between north west pendentive and north wall.</td>
<td>Cornice, intersection, near pendentive.</td>
</tr>
</tbody>
</table>
Yellowing. Presence of various shades of yellow color inconsistent in color with similar surfaces.
Location: upper north wall, east to the foliated decoration
Other areas: upper part of the walls, pendentive, cornice

Yellowing. Presence of various shades of yellow color inconsistent in color with similar surfaces.
Location: west wall cornice
Other areas: upper part of the walls, pendentive, cornice

Yellow drip residue. Drip shaped yellow in color.
Location: north west pendentive
Other areas: Everywhere on the surface
<table>
<thead>
<tr>
<th>Shinyness. The presence of gloss. Location: west wall, upper, north side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip residue. Drip shaped accretions not yellow. Location: lower north wall</td>
</tr>
<tr>
<td>Drip residue. Drip shaped accretions not yellow. Location: west wall middle part</td>
</tr>
</tbody>
</table>
Yellow drip residue. Drip shaped yellow in color. Location: upper north wall west to the foliated decoration

White veil. Translucent thin white layer on surface. Location: north wall middle corbel

White veil. Translucent thin white layer on surface. Location: south wall, under the cornice
<table>
<thead>
<tr>
<th>Nails</th>
<th>The presence of hardware. Location: lower north wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratches</td>
<td>Thin lines of paint and superficial plaster loss. Location: upper north wall Other areas: north wall, upper part</td>
</tr>
<tr>
<td>Graffiti</td>
<td>Letters or shapes applied in paint, pen or crayon. Location: lower north wall Other areas: everywhere on the surface</td>
</tr>
<tr>
<td><strong>Graffiti</strong> (written). Letters or shapes applied in paint, pen or crayon. Location: lower north wall Other areas: everywhere on the surface</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>Guano</strong>. Animal excrement. Location: everywhere on the surface, especially on the upper part of north wall</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B  Condition Drawings

Drawing list:

TUMA-SI-C-001: West elevation of Sanctuary
TUMA-SI-C-002: North elevation of Sanctuary
TUMA-SI-C-003: South elevation of Sanctuary
TUMA-SI-C-004: West elevation – Conditions
TUMA-SI-C-005: West elevation – Treatments
TUMA-SI-C-006: North elevation – Conditions
TUMA-SI-C-007: North elevation – Treatments
TUMA-SI-C-008: South elevation – Conditions
TUMA-SI-C-009: South elevation – Treatments
North Elevation - Conditions

Church of San José de Tumacácori
1891 I-19 Frontage Rd, Tumacacori-Carmen, AZ 85640

Program in Historic Preservation
School of Design
University of Pennsylvania

YANG Yifei
Drawn by YANG Yifei

Catherine S. Myers
Jan, 2021

Page TUMA-SI-C-006

Scale 1:25

Surveyed by
Condition Drawings

01 1/2 METERS 1:25
01 23 FEET
104

Crack
Surface-Scratches
Surface-Yellow
Surface-Residue
Plaster-Crumbling
Plaster-Disaggregation
Plaster-Deep Detachment
Plaster-Shallow Detachment
Plaster-Planer Distortion
Plaster-Loss

Annotations:
North Elevation - Treatments

- Plaster-Fill-Smooth
- Plaster-Fill-Rough
- Plaster-Fill-White
- Plaster-Fill-White/yellow
- Plaster-Injection

- Surface-Retouching
- Surface-Poultice
- Surface-Tissue

- Plaster-Edging-Rough
- Plaster-Edging-White
- Plaster-Edging-White/yellow

- Plaster-Coating
- Surface-Yellow
- Surface-Residue
Appendix C  Result of On-site UV Examination

The following photographic details of the Sanctuary walls illustrate previously treated locations in visible light at left and in ultra violet/visible light at rights. All photographs were taken with an iPhone11.

<table>
<thead>
<tr>
<th>Number: UVP-01</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Photograph 1" /> <img src="image2.jpg" alt="Photograph 2" /></td>
</tr>
<tr>
<td>Location: north wall, middle corbel, east side.</td>
</tr>
<tr>
<td>Description: bright yellow, green white, blue white fluorescence on both sides of the corbel.</td>
</tr>
<tr>
<td>Condition and treatment: detachment and reattachment.</td>
</tr>
<tr>
<td>Number: UVP-02</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Location:</strong></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
</tr>
<tr>
<td><strong>Condition and treatment:</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number: UVP-03</th>
<th><img src="image3.png" alt="Image 3" /></th>
<th><img src="image4.png" alt="Image 4" /></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location:</strong></td>
<td>north wall, foliated decoration.</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>bright blue white fluorescence, drip residue on the foliated decoration.</td>
<td></td>
</tr>
<tr>
<td><strong>Condition and treatment:</strong></td>
<td>drip residue.</td>
<td></td>
</tr>
</tbody>
</table>

**Number: UVP-04**
| Location: north wall, foliated decoration, east side. |
| Description: dull yellow fluorescence and light blue white fluorescence near the foliated decoration; bright white fluorescence of guano. |
| Condition and treatment: yellow residue. Consolidation. |

| Number: UVP-05 |
| Location: north wall, upper part, east side. |
| Description: dull yellow fluorescence. |
| Condition and treatment: yellow residue. Consolidation. |
| Number: UVP-06 |
Location: north wall, scrolled decoration, west side.
Description: bright yellow fluorescence; bright white drip residue.
Condition and treatment: crumbling. Reattachment, consolidation, retouching.

Number: UVP-07

Location: north wall, scrolled decoration, west side.
Description: bright blue white fluorescence; dull yellow fluorescence.
Condition and treatment: crumbling. Reattachment, consolidation, retouching.
Number: UVP-08
<table>
<thead>
<tr>
<th>Location: intersection between north wall and north-west pendentive.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description: bright blue white fluorescence; dull yellow fluorescence.</td>
</tr>
<tr>
<td>Condition and treatment: detachment. Residue.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number: UVP-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: north-west pendentive.</td>
</tr>
<tr>
<td>Description: pale orange fluorescence; dull yellow fluorescence; bright white fluorescence.</td>
</tr>
<tr>
<td>Number: UVP-10</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number: UVP-11</th>
<th>Location: west wall, upper part, near south side of the window frame.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Description: bright blue white fluorescence in cracks.</td>
</tr>
<tr>
<td></td>
<td>Condition and treatment: planer distortion, detachment. Grouping injection, reattachment.</td>
</tr>
</tbody>
</table>
Number: UVP-12

Location: south-west corner of the west wall, upper part.
Description: pale orange fluorescence; tissue.
Condition and treatment: major crack, detachment, crumbling. Reattachment, consolidation, tissue.

Number: UVP-13

Location: west wall, cornice.
Description: dull yellow fluorescence.
Number: UVP-14
Location: west wall, middle, on top of the window frame.
Description: tissue, bright yellow fluorescence.
Condition and treatment: major crack, detachment. Reattachment, consolidation, tissue.

Number: UVP-15

Location: west wall, cornice.
Description: bright white fluorescence; dull yellow fluorescence.
Condition and treatment: planer distortion, plaster loss. Plaster fill, reattachment, consolidation.
Number: UVP-16
| Location: west wall. | Description: bright white fluorescence on drip residue; guano. |
| Number: UVP-17 | Condition and treatment: drip residue. |

<p>| Location: west wall, frame of the niche. | Description: bright white fluorescence on edging. |
| Number: UVP-18 | Condition and treatment: plaster fill, edging. |</p>
<table>
<thead>
<tr>
<th>Number</th>
<th>UVP-19</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location:</strong> dome of the baptistry.</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong> bright white fluorescence under the fill.</td>
<td></td>
</tr>
<tr>
<td><strong>Condition and treatment:</strong> plaster fill.</td>
<td></td>
</tr>
</tbody>
</table>

| **Location:** dome of the baptistry. |
| **Description:** no fluorescence. |
| **Condition and treatment:** no previous treatment. |
## Appendix D  Result of Laboratory UV Examination

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-01</th>
<th>[Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material:</strong></td>
<td>Acrysol WS-24 Acrylic resin</td>
<td>[Image]</td>
</tr>
<tr>
<td><strong>Result:</strong></td>
<td>Light purple white fluorescence</td>
<td>[Image]</td>
</tr>
<tr>
<td></td>
<td>Diluted 20%</td>
<td>High concentration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-02</th>
<th>[Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material:</strong></td>
<td>Rhoplex 1950 Acrylic resin</td>
<td>[Image]</td>
</tr>
<tr>
<td><strong>Result:</strong></td>
<td>Bright blue white fluorescence</td>
<td>[Image]</td>
</tr>
<tr>
<td></td>
<td>Diluted 20%</td>
<td>High concentration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-03</th>
<th>[Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material:</strong></td>
<td>Rhoplex M76 Acrylic resin</td>
<td>[Image]</td>
</tr>
<tr>
<td><strong>Result:</strong></td>
<td>Bright blue white fluorescence</td>
<td>[Image]</td>
</tr>
<tr>
<td></td>
<td>High concentration</td>
<td>Untreated plaster</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-04</th>
<th>[Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material:</strong></td>
<td>Jade 403 Polyvinyl Acetate</td>
<td>[Image]</td>
</tr>
<tr>
<td><strong>Result:</strong></td>
<td>Pale blue white fluorescence</td>
<td>[Image]</td>
</tr>
<tr>
<td></td>
<td>Diluted 20%</td>
<td>High concentration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-05 UVS-06</th>
<th>[Image]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material:</strong></td>
<td>Paraloid B-67 Paraloid B-72</td>
<td>[Image]</td>
</tr>
<tr>
<td><strong>Result:</strong></td>
<td>No strong fluorescence</td>
<td>[Table]</td>
</tr>
<tr>
<td></td>
<td>B-72</td>
<td>B-67</td>
</tr>
<tr>
<td>Number</td>
<td>UVS-07</td>
<td>Silan-100</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Material</td>
<td>Keim Silan-100 Alkyl Alkoxy silane</td>
<td></td>
</tr>
<tr>
<td>Result</td>
<td>No fluorescence</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-08</th>
<th>High concentration</th>
<th>Diluted</th>
<th>Untreated plaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Carnauba Wax</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result</td>
<td>Bright yellow white fluorescence</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-09</th>
<th>Diluted</th>
<th>High</th>
<th>Untreated plaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Gum Arabic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result</td>
<td>Very pale lavender</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-10</th>
<th>High concentration</th>
<th>Diluted</th>
<th>Untreated plaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Shellac</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result</td>
<td>Very bright orange/pink fluorescence</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-11</th>
<th>Diluted</th>
<th>High</th>
<th>Untreated plaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Rabbit skin glue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result</td>
<td>Very Bright yellow white fluorescence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>UVS-12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Beeswax</td>
<td>Result: <strong>Very bright yellow fluorescence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beeswax</td>
<td>Untreated plaster</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-13</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Dammer Varnish</td>
<td>Result: <strong>No fluorescence</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dammer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-14</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Cactus glue</td>
<td>Result: <strong>Bright green fluorescence</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cactus glue</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-15</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Ammonium Caseinate</td>
<td>Result: <strong>Pale white lavender fluorescence</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Untreated plaster</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-16</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Calcium Caseinate</td>
<td>Result: <strong>Pale white blue fluorescence</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Untreated plaster</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>UVS-17</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Result</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------------------</td>
<td></td>
</tr>
<tr>
<td>Flour paste</td>
<td>Very pale white fluorescence</td>
<td></td>
</tr>
<tr>
<td>Paste</td>
<td>Untreated plaster</td>
<td></td>
</tr>
<tr>
<td>UVS-18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVAc-Tuma replication Gabrielle</td>
<td>Very pale fluorescence</td>
<td></td>
</tr>
<tr>
<td>Untreated plaster</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix E   Locations of Cross-Section Samples

Drawing list:

TUMA-SI-C-010: North elevation – Samples
TUMA-SI-C-012: North elevation – Samples
TUMA-SI-C-013: South elevation – Samples
North Elevation - Samples

Church of San José de Tumacácori
1891 I-19 Frontage Rd, Tumacacori-Carmen, AZ 85640

Program in Historic Preservation
School of Design
University of Pennsylvania

YANG Yifei
Drawn by
Catherine S. Myers
Jan, 2021
Date

Page TUMA-SI-C-010

Scale 1:25

Surveyed by
Condition Drawings

01 1/2 METERS 1:25

01 2 3 FEET

127
Interior of Sanctuary
South Elevation - Samples
Church of San José de Tumacácori
1891 I-19 Frontage Rd, Tumacacori-Carmen, AZ 85640
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YANG Yifei
Drawn by YANG Yifei
Catherine S. Myers
Jan, 2021
Date
Page TUMA-SI-C-012
Scale 1:25
Surveyed by
Condition Drawings
Appendix F  Result of Cross-Section Microscopy Analysis

<table>
<thead>
<tr>
<th>Sample: S-01-1</th>
<th><img src="image1" alt="Visible Light" /> <img src="image2" alt="Ultraviolet Light" /></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visible Light</strong></td>
<td><img src="image1" alt="Visible Light" /> <img src="image2" alt="Ultraviolet Light" /></td>
</tr>
<tr>
<td><strong>Location:</strong> Sanctuary North wall, upper part, east scrolled decoration.</td>
<td></td>
</tr>
<tr>
<td><strong>Conditions &amp; Observations:</strong> residue, retouching, crumbling</td>
<td></td>
</tr>
<tr>
<td><strong>Sampled by:</strong> Catherine S. Myers &amp; Yifei Yang</td>
<td><strong>Sampled on:</strong> Jan 15, 2022</td>
</tr>
<tr>
<td><strong>Analyzed by:</strong> Yifei Yang</td>
<td></td>
</tr>
<tr>
<td><strong>Microscope:</strong> Nikon Alphaphot-2</td>
<td><strong>Light Source:</strong> Visible &amp; UV (Mercury Lamp)</td>
</tr>
<tr>
<td><strong>Camera:</strong> Nikon DS Fi-1; NIS Elements BR</td>
<td><strong>Magnification:</strong> 40x</td>
</tr>
<tr>
<td><strong>Description:</strong> A few traces of residue with some white blue fluorescence.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample: S-01-2</th>
<th><img src="image3" alt="Visible Light" /> <img src="image4" alt="Ultraviolet Light" /></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visible Light</strong></td>
<td><img src="image3" alt="Visible Light" /> <img src="image4" alt="Ultraviolet Light" /></td>
</tr>
<tr>
<td><strong>Location:</strong> Sanctuary North wall, upper part, east scrolled decoration.</td>
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</tr>
<tr>
<td><strong>Conditions &amp; Observations:</strong> residue, retouching, crumbling</td>
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<td><strong>Sampled by:</strong> Catherine S. Myers &amp; Yifei Yang</td>
<td><strong>Sampled on:</strong> Jan 15, 2022</td>
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<td><strong>Analyzed by:</strong> Yifei Yang</td>
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<tr>
<td><strong>Microscope:</strong> Nikon Alphaphot-2</td>
<td><strong>Light Source:</strong> Visible &amp; UV (Mercury Lamp)</td>
</tr>
<tr>
<td><strong>Camera:</strong> Nikon DS Fi-1; NIS Elements BR</td>
<td><strong>Magnification:</strong> 40x</td>
</tr>
<tr>
<td><strong>Description:</strong> No evidence of applications and fluorescence.</td>
<td></td>
</tr>
</tbody>
</table>
### Sample: S-02

<table>
<thead>
<tr>
<th>Visible Light</th>
<th>Ultraviolet Light</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Visible Light Image" /></td>
<td><img src="image2.png" alt="Ultraviolet Light Image" /></td>
</tr>
</tbody>
</table>

**Location:** Sanctuary North wall, upper part, middle corbel.

**Conditions & Observations:** Bright yellow fluorescence under UV light.

**Sampled by:** Catherine S. Myers & Yifei Yang  
**Sampled on:** Jan 15, 2022

**Analyzed by:** Yifei Yang

**Microscope:** Nikon Alphaphot-2  
**Light Source:** Visible & UV (Mercury Lamp)

**Camera:** Nikon DS Fi-1; NIS Elements BR  
**Magnification:** 40x

**Description:** Bright yellow fluorescence of top of the surface.

### Sample: S-03-1

<table>
<thead>
<tr>
<th>Visible Light</th>
<th>Ultraviolet Light</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.png" alt="Visible Light Image" /></td>
<td><img src="image4.png" alt="Ultraviolet Light Image" /></td>
</tr>
</tbody>
</table>

**Location:** Sanctuary North wall, upper part, foliated decoration.

**Conditions & Observations:** Red orange color with green underneath.

**Sampled by:** Catherine S. Myers & Yifei Yang  
**Sampled on:** Jan 15, 2022

**Analyzed by:** Yifei Yang

**Microscope:** Nikon Alphaphot-2  
**Light Source:** Visible & UV (Mercury Lamp)

**Camera:** Nikon DS Fi-1; NIS Elements BR  
**Magnification:** 40x

**Description:** No evidence of fluorescence on the top layer of paint.
<table>
<thead>
<tr>
<th>Sample: S-03-2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visible Light</strong></td>
<td><strong>Ultraviolet Light</strong></td>
</tr>
<tr>
<td>Location: Sanctuary North wall, upper part, foliated decoration.</td>
<td></td>
</tr>
<tr>
<td>Conditions &amp; Observations: Red orange color with green underneath.</td>
<td></td>
</tr>
<tr>
<td>Sampled by: Catherine S. Myers &amp; Yifei Yang</td>
<td>Sampled on: Jan 15, 2022</td>
</tr>
<tr>
<td>Analyzed by: Yifei Yang</td>
<td></td>
</tr>
<tr>
<td>Microscope: Nikon Alphaphot-2</td>
<td>Light Source: Visible &amp; UV (Mercury Lamp)</td>
</tr>
<tr>
<td>Camera: Nikon DS Fi-1; NIS Elements BR</td>
<td>Magnification: 40x</td>
</tr>
<tr>
<td>Description: No evidence of fluorescence on the top layer of paint.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample: S-04-1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visible Light</strong></td>
<td><strong>Ultraviolet Light</strong></td>
</tr>
<tr>
<td>Location: Sanctuary North wall, upper part, foliated decoration.</td>
<td></td>
</tr>
<tr>
<td>Conditions &amp; Observations: White drip residue.</td>
<td></td>
</tr>
<tr>
<td>Sampled by: Catherine S. Myers &amp; Yifei Yang</td>
<td>Sampled on: Jan 15, 2022</td>
</tr>
<tr>
<td>Analyzed by: Yifei Yang</td>
<td></td>
</tr>
<tr>
<td>Microscope: Nikon Alphaphot-2</td>
<td>Light Source: Visible &amp; UV (Mercury Lamp)</td>
</tr>
<tr>
<td>Camera: Nikon DS Fi-1; NIS Elements BR</td>
<td>Magnification: 40x</td>
</tr>
<tr>
<td>Description: No evidence of fluorescence on the top layer of paint.</td>
<td></td>
</tr>
</tbody>
</table>
Sample: S-04-2

Visible Light | Ultraviolet Light
---|---

**Location:** Sanctuary North wall, upper part, foliated decoration.

**Conditions & Observations:** White drip residue.

**Sampled by:** Catherine S. Myers & Yifei Yang  |  **Sampled on:** Jan 15, 2022

**Analyzed by:** Yifei Yang

**Microscope:** Nikon Alphaphot-2  |  **Light Source:** Visible & UV (Mercury Lamp)

**Camera:** Nikon DS Fi-1; NIS Elements BR  |  **Magnification:** 100x

**Description:** No evidence of fluorescence on the top layer of paint.

---

Sample: S-05-1

Visible Light | Ultraviolet Light
---|---

**Location:** Sanctuary North wall, upper part, east side of the middle corbel.

**Conditions & Observations:** Yellow stain residue.

**Sampled by:** Catherine S. Myers & Yifei Yang  |  **Sampled on:** Jan 15, 2022

**Analyzed by:** Yifei Yang

**Microscope:** Nikon Alphaphot-2  |  **Light Source:** Visible & UV (Mercury Lamp)

**Camera:** Nikon DS Fi-1; NIS Elements BR  |  **Magnification:** 40x

**Description:** A layer of yellow on the top with light fluorescence.
<table>
<thead>
<tr>
<th>Sample: S-05-1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visible Light</strong></td>
<td><strong>Ultraviolet Light</strong></td>
</tr>
<tr>
<td><strong>Location:</strong> Sanctuary North wall, upper part, east side of the middle corbel.</td>
<td></td>
</tr>
<tr>
<td><strong>Conditions &amp; Observations:</strong> Yellow stain residue.</td>
<td></td>
</tr>
<tr>
<td><strong>Sampled by:</strong> Catherine S. Myers &amp; Yifei Yang</td>
<td><strong>Sampled on:</strong> Jan 15, 2022</td>
</tr>
<tr>
<td><strong>Analyzed by:</strong> Yifei Yang</td>
<td></td>
</tr>
<tr>
<td><strong>Microscope:</strong> Nikon Alphaphot-2</td>
<td><strong>Light Source:</strong> Visible &amp; UV (Mercury Lamp)</td>
</tr>
<tr>
<td><strong>Camera:</strong> Nikon DS Fi-1; NIS Elements BR</td>
<td><strong>Magnification:</strong> 100x</td>
</tr>
<tr>
<td><strong>Description:</strong> A layer of yellow on the top with light fluorescence.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample: S-06</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visible Light</strong></td>
<td><strong>Ultraviolet Light</strong></td>
</tr>
<tr>
<td><strong>Location:</strong> Sanctuary North west pendentive.</td>
<td></td>
</tr>
<tr>
<td><strong>Conditions &amp; Observations:</strong> Yellow stain residue.</td>
<td></td>
</tr>
<tr>
<td><strong>Sampled by:</strong> Catherine S. Myers &amp; Yifei Yang</td>
<td><strong>Sampled on:</strong> Jan 15, 2022</td>
</tr>
<tr>
<td><strong>Analyzed by:</strong> Yifei Yang</td>
<td></td>
</tr>
<tr>
<td><strong>Microscope:</strong> Nikon Alphaphot-2</td>
<td><strong>Light Source:</strong> Visible &amp; UV (Mercury Lamp)</td>
</tr>
<tr>
<td><strong>Camera:</strong> Nikon DS Fi-1; NIS Elements BR</td>
<td><strong>Magnification:</strong> 40x</td>
</tr>
<tr>
<td><strong>Description:</strong> A layer of yellow on the top with no fluorescence.</td>
<td></td>
</tr>
</tbody>
</table>
**Sample: S-08**

<table>
<thead>
<tr>
<th>Visible Light</th>
<th>Ultraviolet Light</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Location:** Sanctuary, west wall, cornice in the middle.

**Conditions & Observations:** Yellow brown stain on top of blue paint.

**Sampled by:** Catherine S. Myers & Yifei Yang  
**Sampled on:** Jan 15, 2022

**Analyzed by:** Yifei Yang

**Microscope:** Nikon Alphaphot-2  
**Light Source:** Visible & UV (Mercury Lamp)

**Camera:** Nikon DS Fi-1; NIS Elements BR  
**Magnification:** 40x

**Description:** A layer of yellow on the top with no fluorescence.

---

**Sample: S-08**

<table>
<thead>
<tr>
<th>Visible Light</th>
<th>Ultraviolet Light</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Location:** Sanctuary, west wall, cornice in the middle.

**Conditions & Observations:** Yellow brown stain on top of blue paint.

**Sampled by:** Catherine S. Myers & Yifei Yang  
**Sampled on:** Jan 15, 2022

**Analyzed by:** Yifei Yang

**Microscope:** Nikon Alphaphot-2  
**Light Source:** Visible & UV (Mercury Lamp)

**Camera:** Nikon DS Fi-1; NIS Elements BR  
**Magnification:** 100x

**Description:** A layer of yellow on the top with no fluorescence.
<table>
<thead>
<tr>
<th>Sample: S-09-1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Visible Light" /></td>
<td><img src="image2" alt="Ultraviolet Light" /></td>
<td></td>
</tr>
<tr>
<td><strong>Location</strong>: Sanctuary, south wall, west side, under cornice.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Conditions &amp; Observations</strong>: White veil on blue paint.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sampled by</strong>: Catherine S. Myers &amp; Yifei Yang</td>
<td><strong>Sampled on</strong>: Jan 15, 2022</td>
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</tr>
<tr>
<td><strong>Analyzed by</strong>: Yifei Yang</td>
<td></td>
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</tr>
<tr>
<td><strong>Microscope</strong>: Nikon Alphaphot-2</td>
<td><strong>Light Source</strong>: Visible &amp; UV (Mercury Lamp)</td>
<td></td>
</tr>
<tr>
<td><strong>Camera</strong>: Nikon DS Fi-1; NIS Elements BR</td>
<td><strong>Magnification</strong>: 40x</td>
<td></td>
</tr>
<tr>
<td><strong>Description</strong>: White residue on the top with no fluorescence.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample: S-09-2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Visible Light" /></td>
<td><img src="image4" alt="Ultraviolet Light" /></td>
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</tr>
<tr>
<td><strong>Location</strong>: Sanctuary, south wall, west side, under cornice.</td>
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<tr>
<td><strong>Conditions &amp; Observations</strong>: White veil on blue paint.</td>
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<td><strong>Sampled on</strong>: Jan 15, 2022</td>
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<tr>
<td><strong>Analyzed by</strong>: Yifei Yang</td>
<td></td>
<td></td>
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<tr>
<td><strong>Microscope</strong>: Nikon Alphaphot-2</td>
<td><strong>Light Source</strong>: Visible &amp; UV (Mercury Lamp)</td>
<td></td>
</tr>
<tr>
<td><strong>Camera</strong>: Nikon DS Fi-1; NIS Elements BR</td>
<td><strong>Magnification</strong>: 40x</td>
<td></td>
</tr>
<tr>
<td><strong>Description</strong>: White residue on the top with no fluorescence.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample: S-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Visible Light</strong></th>
<th><strong>Ultraviolet Light</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Visible Light Image" /></td>
<td><img src="image2" alt="Ultraviolet Light Image" /></td>
</tr>
</tbody>
</table>

**Location:** Sanctuary, south wall, west side, under cornice.

**Conditions & Observations:** White veil on red paint.

**Sampled by:** Catherine S. Myers & Yifei Yang  
**Sampled on:** Jan 15, 2022

**Sampled by:** Yifei Yang

**Microscope:** Nikon Alphaphot-2  
**Light Source:** Visible & UV (Mercury Lamp)

**Camera:** Nikon DS-Fi-1; NIS Elements BR  
**Magnification:** 40x

**Description:** A layer of red paint.
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