A TECHNICAL STUDY OF THE MURAL PAINTINGS ON THE INTERIOR DOME OF THE CAPILLA DE LA VIRGEN DEL ROSARIO, IGLESIA SAN JOSÉ, SAN JUAN, PUERTO RICO

Cynthia Lynn Silva

A THESIS

In

Historic Preservation

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

MASTER OF SCIENCE IN HISTORIC PRESERVATION

[2006]

_____
Advisor
Frank G. Matero
Professor of Architecture

_____
Reader
Claire Munzenrider
Director of Conservation

_____
Program Chair
Frank G. Matero
Professor of Architecture

A TECHNICAL STUDY OF THE MURAL PAINTINGS ON THE INTERIOR DOME OF THE CAPILLA DE LA VIRGEN DEL ROSARIO, IGLESIA SAN JOSÉ, SAN JUAN, PUERTO RICO

Cynthia Lynn Silva

Year of Graduation: 2006
Advisor: Frank G. Matero
Reader: Claire Munzenrider

Total number of pages: 236
Total number of chapters: 7

Abstract

This is a technical study of the extant murals of the 17th *Capilla de la Virgen del Rosario* located within Iglesia San José, San Juan, Puerto Rico. The primary objectives of this investigation were to: document existing mural campaigns, establish a chronology of mural painting through analysis of materials and techniques, evaluate the conditions of the paintings and to determine possible deterioration mechanisms, and propose recommendations for their conservation and interpretation. In-situ documentation including color digital photography, extensive field notes, and mapping of visible painting campaigns were conducted. This was followed by a materials analysis of select campaigns' substrate, binders, and pigments. Test methods included gravimetric analysis and XRD of substrate plasters, examination of cross-sections and pigment dispersions, EDS analysis of pigments, and FTIR analysis of binders. The results of this study found six distinct mural campaigns and established a chronology which attributed painting phases to the Dominican, Jesuit, and Vincention orders of the Catholic Church. Notable iconography include the 17th century mer creatures (*la serena*), and the mid-19th century depiction of the Battle of Lepanto. Substrate analysis revealed a lean plaster mix in the *enfoscado* as an intrinsic cause of failure, further aggravated by continued water infiltration. Water ingress has created an environment supporting threatening deterioration mechanisms including abundant chloride salts, and biological growth contributing to failing paint layers and plasters. The Rosario Chapel murals are highly significant and warrant a comprehensive strategy for their conservation and interpretation through a collaborative process involving all stakeholders.

AKNOWLEDGMENTS

It has been a fantastic two years and I am grateful for all those who have helped me along the way. I must first extend special thanks to my advisor Frank Matero; he has been a dedicated and patient guide throughout this process. I am grateful to Dr. Tami Lassiter-Clare, for her expertise which provided answers to seemingly insurmountable analytic testing snafus. A special thanks to the Archdiocese of Puerto Rico for the opportunity to work on an amazing site, an experience that will maintain a lasting impression. To Beatrice del Cueto and Gus Pantel and for their body of research and dedication to Iglesia San José, and for providing logistical support in Puerto Rico. The acknowledgments would be incomplete if I did not mention my wonderful classmates from whom I have gained indispensable friendships, and who have provided a challenging and fulfilling learning experience. Finally to my family and loving husband Andy, I dedicate this thesis to you.

TABLE OF CONTENTS

List of Figures

(Figures by author unless so noted)

List of Maps

List of Tables

List of Charts

1 Statement of Purpose

This thesis is a technical study of the extant murals of the 17th *Capilla de la Virgen del Rosario* (Chapel of the Virgin of the Rosary) located within *Iglesia San José* (San Jose Church), San Juan, Puerto Rico. The primary objectives of this investigation were:

1) to document existing mural campaigns.

2) to establish a chronology of mural painting through analysis of materials and techniques.

3) to evaluate the conditions of the paintings and to determine possible deterioration mechanisms, and

4) to propose recommendations for their conservation and interpretation.

The Iglesia San José has been attributed as both the "oldest surviving and first significant" architectural work in Puerto Rico, and the "earliest extant example of Gothic-influenced architecture in the New World". [1] Iglesia San José was built between 1523 and 1641. Of particular significance is the Isabelline Gothic ribbed vault construction, which incorporates *tinajones* (Spanish ceramic amphora) between roof systems of the

[1] Rigau, "World Monument Fund Nomination." (San Juan:2004), 2.

sanctuary and transept of the church and the mural paintings located in the chapels. The most extensive of the remaining mural works are in the Rosario Chapel. While the church has remained in the hands of the Catholic Archdiocese throughout its history, stewardship has transferred between Dominican, Jesuit, and Vincention orders, each contributing to a complex evidentiary history. There is no greater example of this than on the interior dome of the Rosario Chapel. Early wall paintings depict folkloric images of mer-creatures (*la serena*) as well as a later representation of the 1571 Battle of Lepanto. The interior finishes of the Rosario Chapel are given additional significance due to a 1978-1981 restoration which removed all original plaster stucco in the church's lateral nave and main altar.[2]

Within the past year Iglesia San José was granted World Monument Fund Watch status. The church has been closed to the public for six years due in part to falling ceiling plaster posing a safety hazard. The murals in the Rosario Chapel are in a serious state of disrepair with areas of loss increasing at a rapid rate, and much of the fractured mural surface delaminated or detached. In order to preserve this unique and valuable cultural resource it is vital to study the technical aspects of the paintings in the Rosario Chapel as a first step in the mural conservation and interpretation process.

A condition survey as well as an initial mural emergency stabilization program is currently underway for the Rosario Chapel murals, by the Architectural Conservation Laboratory of the University of Pennsylvania. The scope of this investigation will

[2] Beatrice del Cueto, "Annotated Chronology of Iglesia San Jose, San Juan, Puerto Rico," (San Juan: Pantel, del Cueto & Associates, 2005).

therefore not include an in-depth discussion of current conditions as an entire report dedicated to the subject is in preparation.

2 Iglesia San José

Iglesia San José is thought to be one of the oldest structures built by Europeans in the New World, second only to the *Iglesia Santo Domingo* in the Dominican Republic.[3] The church is located on the highest point of the islet of what is now Old San Juan, Puerto Rico (Figures 1 and 2).

Iglesia San José was founded by the Dominican Order of monks and originally dedicated to *Santo Domingo* and later to *Santo Tómas de Aquino*. The church was built in multiple phases between 1532 and 1641 with major alterations in the 19th century. [4] The foundations of the sanctuary and transept were laid in 1532 with walls and vaults completed by the middle of the 16th century.[5] Juan Ponce de Leon's grandson, Don Juan Ponce de León, bought the rights of patronage to build a family crypt beneath the main chapel and arranged for his grandfather's remains to be moved to the family crypt in 1559. The construction of the main chapel and transept were completed by that date and the Ponce family coat-of-arms are still mounted on the north sanctuary wall today (Juan Ponce de León's remains were rediscovered in 1863 and moved to the Cathedral of San José).[6]

Iglesia San José was built in a Latin cross plan with the main nave flanked by smaller side chapels. The sanctuary and transept are described as Isabelline-Gothic in

---

[3] P.Emilio Tobar, *San Jose Church La Iglesia De San Jose: Templo Y Museo Del Pueblo Puertorriqueno* (San Juan: Imprenta la Milagrosa, 1963), 195. Built in phases between 1510-40.
[4] del Cueto, "Annotated Chronology of Iglesia San Jose, San Juan, Puerto Rico."
[5] Tobar, *San Jose Church La Iglesia De San Jose: Templo Y Museo Del Pueblo Puertorriqueno*, 250.
[6] Ibid., 202.

style due to the stelliform groin vaults (Figure 3), which were used to dramatically enclose the spaces built during the reign of Queen Isabella of Spain.[7] In addition to the sanctuary and transept, a number of lateral side chapels also date from the 16th and 17th centuries including: the Chapels of the *Nazareno* and *Cristo de los Ponces* on the north side of the main nave and on the south side, the Chapel of the *Virgen del Rosario*, the Chapel of *Santa Teresa de Jesus*, and one section of the Chapel of the *Virgen de Belén* (Figure 4).

A highly significant Roman-Catalan construction method was used in building Iglesia San José which incorporated *tinajones,* (Spanish ceramic amphora), between interior vault systems and exterior roof. The use of lightweight ceramic jars was integral to Catalan construction methods for their potential to reduce vault load and for their acoustic properties.[8] Similar construction techniques in the Mausoleum of *Galla Placidia* in Ravenna (420), the Chapel *del Santissimo en el Pino* (1306), and *La Boveda del capitulo de Pedralbes* (1324), in Barcelona have been discovered.[9] While the early Gothic construction phase of the sanctuary and transept of Iglesia San José is notable for its architectural impact, Roman-Catalan construction method and early construction dates, it is only a partial story of the church. Features like the later barrel vault of the main nave and the Chapel of *San Antonio* are attributed to later Italian Renaissance

---

[7] Ibid., 206.

[8] Martin Weaver, "Preliminary Conservation Study Interim Emergency Report on the Vault of the Sacristy of the Church of San Jose, Old San Juan, Puerto Rico.," (Martin Weaver Conservation Consultant Inc. and UMA Engineering Ltd., 1998).

[9] Juan Bassegoda Nonell, *La Ceramica Popular De La Arquitectura Gotica*, *Serie De Historia De La Arquitectura Y Del Urbanismo ;; No. 8; Publicaciones De La Universidad Politécnica De Barcelona; Variation: Publicaciones De La Universidad Politécnica De Barcelona.; Serie De Historia De La Arquitectura Y Del Urbanismo ;; No. 8.* (Barcelona: Ediciones de Nuevo Arte Thor, 1978).

sensibilities, while many of the carved stone moldings, window surrounds, and the main west façade are Baroque in style. In conjunction with multiple construction phases, there have clearly been extensive renovations and remodeling to Iglesia San José over the centuries.

3 The Capilla de la Virgen del Rosario

3.1 History of Iglesia San José and the Capilla de la Virgen del Rosario

The focus of this study is the mural painting of the Chapel of the Virgen del Rosario. Currently, there is no written history specific to this chapel, and little written or graphic documentation has been found.

An annotated chronology of Iglesia San José first mentions the Rosario Chapel in the 1582 *Memoria* of Ponce de Leon.[10] The patrons of the chapel at this time are believed to have been Juan Guilarte and his sister-in-law Doña Luisa de Vargas who donated funds to the chapel for use as a family crypt.[11] Between 1635 and 1641, major renovations to the church occurred with the support of Governor Iñigo Mota de Sarmiento; this governor raised funds through the Infantry of the Royal *Presidio* of San Juan, after the 1625 Dutch attack.[12] These renovations included the completion of a gabled wooden roof over the incomplete main nave, reconstruction of the transept, and the remodeling of the free-standing Rosario Chapel as a "pantheon for the governors of the island".[13] This description helps to date the dome construction of the Rosario Chapel to the mid 17th century. Over 60 people were buried in the crypt beneath this chapel, many of them early governors of Puerto Rico.

---

[10] Antonio Cuesta Mendoza, *Historia Eclesiastica Del Puerto Rico Colonial: 1508-1700.*, trans. Beatrice del Cuento (Rupublica Dominica: Arte y Cine, 1948).
[11] Tobar, *San Jose Church La Iglesia De San Jose: Templo Y Museo Del Pueblo Puertorriqueno*, 209.
[12] Auturo Davila, "Arzobispado De Santo Tomas De Aquino Y La Cultura Puertorriquena," *San Juan: Boletin de la Academia Puertorriquena de la Historia* XIX, no. 55 (1998).
[13] Cuesta Mendoza, *Historia Eclesiastica Del Puerto Rico Colonial: 1508-1700.*

Three major hurricanes struck Puerto Rico between 1738 and 1740, causing severe damage to Iglesia San José. The Church was described as "close to ruins" for over 30 years.[14] It was not until funds from King Carlos III of Spain were sent in 1772 that the damage could be repaired, including the construction of a "brick barrel vault over the main nave and repairs to stone or brick cupolas, domes or vaults of the side chapels" (Figure 5).[15] The repairs and renovations have been attributed to Field Marshall and Inspector General of Cuba and Puerto Rico, Engineer Aljandro O'Reilly as well as to military Engineer Lieutenant Colonel Thomás O'Daly Blake.[16]

In 1776, four years and two hurricanes later, 4,000 pesos were sent by the King of Spain for repairs.[17] It is at this time that buttresses are thought to have been added to help support the newly constructed brick barrel vault of the main nave. [18] Some of theses buttress supports rest on the lower roofs of the side chapels including the dome of the Rosario Chapel and clearly post date the construction of the chapel (Figure 6).

The next significant period in the chapel's history is one marked by neglect. Between 1821 and 1824, laws of the *exclaustracíon de religiosos* (suppression/secularization of religious orders) were enforced over the Island's convents.[19] This required that rent be paid for rooms in the convent. The rates were too costly, and all but one monk left the Church convent. *Fray Joaquín Domingo de Aldea*

---

[14] Osiris Delgado Mercado, *Historia General De Las Artes Plasticas En Puerto Rico*, trans. Beatrice del Cuento, *Iglesia Conventual De Santo Tomas (Hoy De San Jose)* (San Juan: Tomo I, 1994).
[15] Ibid.
[16] Ibid.
[17] Ibid.
[18] del Cueto, "Annotated Chronology of Iglesia San Jose, San Juan, Puerto Rico," 11.
[19] Adolfo De Hostos, *Historia De San Juan, Ciudad Murada*, trans. Beatrice del Cueto (Barcelona: Manuel Pareja, 1966).

Urríes y Blanco was the lone caretaker of Iglesia San José for over 30 years; he repeatedly and urgently requested funds for repairs to the church, which were denied. [20]

It was not until 1858 that the church was transferred to the Jesuit Order, and with their stewardship came the much needed financial support for repairs, renovations, and maintenance.[21] It was at this time that the church was dedicated to *San José*. An 1858 budget document submitted by *José María Pujol,* the church caretaker, included costs for roof repairs and resurfacing treatments using burnished mortar, replacement of plaster stuccos, application of lime-washes, the construction of new *retablos* and furnishings, as well as the purchase of ornaments.[22] A new sacristy was built in 1855 by the Jesuits, just prior to the official hand-over from the Dominican Order.[23] This was the most significant transformation of the church since its original construction phases.

The work continued on the interior of Iglesia San José between 1860 and 1863, this time reflecting mid-century neoclassical tastes. Efforts were made to "harmonize" an interior that was built in multiple phases by standardizing the nave's arcade.[24] A gray and white checked "Genovese" marble floor was installed and the interior Gothic ceilings were painted sky blue.[25] The Jesuit order administered over the church until 1887 when the Vincention Fathers assumed the role which they continue to hold today.[26]

---

[20] Ibid.
[21] Davila, "Arzobispado De Santo Tomas De Aquino Y La Cultura Puertorriquena."
[22] del Cueto, "Annotated Chronology of Iglesia San Jose, San Juan, Puerto Rico," 14.
[23] Ibid.
[24] Davila, "Arzobispado De Santo Tomas De Aquino Y La Cultura Puertorriquena."
[25] Tobar, *San Jose Church La Iglesia De San Jose: Templo Y Museo Del Pueblo Puertorriqueno*, 209.
[26] Ibid., 252.

A 1910 photograph (Figure 8), of the transept looking east toward the sanctuary, reveals the stelliform vaulted ceilings clearly are decorated with star ornaments, which have been described as "gold leafed, gypsum plaster elements".[27] An earlier 1890's image (Figure 7), shows the *trompe l'oeil* painted coffers with rosettes that once decorated the intradoses of the arches of the nave. The church has been described in interviews as having had all its plaster surfaces painted with both geometric as well as floral motifs.[28] By 1935, all the previously mentioned decorative elements were completely over painted in white faux ashlar blocks (Figure 9).[29]

In 1941-42 the Historic American Building Survey recorded Iglesia San José producing photographs and measured drawings of the church.[30] Two restoration and archeological investigations took place in the 1960's and late 1970's under Dr. Ricardo Allegría, producing an unpublished report *La Iglesia de Santo Tomás Aquino, Hoy San José*, which provides valuable insight on the church.[31] Unfortunately, this restoration removed much of the architectural information needed to understand the evolution of the interior finishes of the church. Allegría removed almost all plaster finishes in the sanctuary, transept and nave while leaving the Rosario Chapel untouched; the Chapel is thus a unique survivor within the church for its painted surfaces. Figure 10 shows the ca. 1980 restoration and excavation of the transept and nave. The Rosario Chapel murals are therefore the only complete stratigraphic history of interior finishes in Iglesia San José dating back to the 17th century.

---

[27] del Cueto, "Annotated Chronology of Iglesia San Jose, San Juan, Puerto Rico."
[28] Ibid., 21.
[29] Ibid.
[30] HABS Collection. Call No. HABS, PR, 7-SAJU,1-20
[31] del Cueto, "Annotated Chronology of Iglesia San Jose, San Juan, Puerto Rico."

3.2 Architectural Description of the Capilla de la Virgen del Rosario

The Capilla de la Virgen del Rosario is essentially a 26' square plan with a 26'x10' sanctuary projecting on the south end (Figure 11). The space is surmounted by a brick dome and lantern supported by four Roman arches (Figures 12-14). The base of the hexagonal lantern is approximately 34' above the ground and stands 13' above the surface of the roof (Figures 6 and 13). The juncture of the four arches form pendentives in each corner. These features and the dome have been repeatedly painted over the course of time with a series of distinct mural and decorative paintings (Figures 15-23). The southern end of the chapel contains the sanctuary, where the altar is placed, which extends approximately 10'6" outside the square of the main space, and is enclosed by a fan vault which is also decoratively painted.

The interior of the dome was originally prepared to receive mural paintings with the application of two plaster campaigns. The first, leveling coat is a red mortar *enfoscado* that was applied in varying thicknesses and in multiple layers to build up and level the brick masonry (Figures 24-25). There is evidence that woven reed mats were used to line the centering forms used to construct the vaults. A second white plaster *enlucido* was used as a finishing coat and provided the ground for the first mural scheme. An analysis and further characterization of these two plaster layers is discussed in chapter 6. The entire Rosario Chapel was painted including walls, arches, and ceilings. The focus of this

investigation is the dome, pendentives, and to a lesser extent the arches. The Chapel walls were not studied.

4 Description of Wall Paintings

As previously described, the interior of the Rosario Chapel has had its dome, pendentives, arches, and walls repeatedly painted since its construction in the 17th century. The most ornate and elaborate have been executed on the dome and four pendentives. This investigation focuses on these elements providing written descriptions of the design layers, which will also be referred to as campaigns or schemes. In conjunction with documenting the wall paintings in the Rosario Chapel a technical analysis has been prepared in chapter 6.

The Rosario Chapel has a rich history of painting. There are as many as twenty layers of plasters and painted designs have been applied to the chapel ceiling since the 17th century. Many of the layers appear to be simple white lime-washes, but interleafed between them are design campaigns that are either figural or geometric. In this project, six distinct campaigns were identified and designated alphabetically from A-F. Maps 1-5 in Appendix A locate the visible remains of various painting campaigns on the dome and four pendentives. This section attempts to document and describe both the design and techniques used to create these campaigns. On-site investigation and cross-sectional analysis of selected samples were the basis for understanding the Rosario Chapel mural phases. A more in-depth discussion of at the stratigraphic analysis and results is presented in chapter 6.

4.1 Campaign A (Mer Creatures)

Design (Pendentives 1-4):

The first painting campaign appears to have employed similar imagery on each of the four pendentives. The pendentives are outlined by thick black banding that defines the junctions of the architectural elements, (i.e., arch, pendentive, base of the dome) (Map 2, Figures 52 and 59). In this area, the banding measures 3.25”-3.5” in thickness, which is then doubled in areas where the framing device is repeated on an adjacent plane. The bottom edge of the dome is accentuated by a similar black band, thicker in its dimension of approximately 6”.

The figures within the black outlined pendentives have only been partially exposed, concealed by later mural painting campaigns. Each of the four pendentives has a single figure approximately 10 feet in height with a scaly fish-like tail and both arms extended perpendicular to the body. The fishtail is yellow in color outlined in black (Figure 52). This same black brushwork also describes the scales and a three lobed fin at the end of each tail (Figures 53-54). The scales transition in color from yellow ochre, describing the lower portion of the tail, to an earth red color beginning at the lower portion of the figure’s torso. The chest appears to be adorned by a garland of fruit and flowers painted in yellow and red with details outlined in black. The figures hold bouquets of flowers in each hand, which include roses of the same yellow and red with details painted in black (Figures 59-60). The face of one of the four figures has been revealed and is rendered in a ¾ view with curly dark blond hair of yellow and black, large eyes described in black, and round, full cheeks and lips accented with red (Figure

51). Without more of the image being exposed, it is difficult to determine if these figures are intended to be male, female, or androgynous. Each of these mer (*la serena*) figures is surrounded by a stylized water motif of black wave like marks and a faint green-blue wash (Figure 52).

Technique (Pendentives 1-4):

This earliest mural painting appears to have been executed in the *secco* technique, painted on dry plaster. The painting was executed directly on the enlucido, (fine plaster coat), which is off-white in color and course in texture with exposed aggregate speckling the surface.

Black Banding

Incised lines and other marks, made while the plaster was still wet, were evident along the base of the dome and along the edge of some of the pendentive's black framing elements. These incised lines demarcate the width of the thick black band along the base of the dome as well as mark the center points of the vertical joint lines, creating the faux ashlar blocks which appear to move up into the dome. They were probably incised to help guide the layout and over designs (Figure 29). Large brush marks, approximately two inches in width are visible within the black bands which were loosely applied within the boundaries of the incised lines and junctions between architectural elements. The black bands accentuate the architectural forms that delineate the Rosario Chapel.

Mer Figure

The painting within the black banded pendentive shows no evidence of design layout such as incised lines, pouncing or under-drawing. The design was instead outlined in black and painted with loose, free-hand brush work. Color was then applied as flat color fields within theses lines. Details such as scales were applied over the background color wash in an equally loose manner with a scale represented by a single semi-circular stroke, which is adorned by a smaller single stroke circle dotting each individual scale (Figure 53). The forms are graphically strong and generally two dimensional with no attempt to model the form, with the exception of the figure's face which uses both line and color to render a slightly more dimensional ¾ view related to the corner position of the pendentive. In addition the artist has made excellent use of perspective by foreshortening the figure, where size increases as the painting moves from the bottom to the top due to the curvature of the pendentive.

Floral Bouquets

The bouquet of flowers held in each of the figures' hands was created with very loose, gestural brush work applied in layers of yellow and red describing the buds and flowers and black lines and stippled strokes used to create leaves, stems and other vegetal details (Figures 59-60).

Ground/Water Motif

A water motif surrounds the figure. Waves are represented by a series of black concave brush strokes applied over a faint green blue wash (Figure 52).

Design (Dome and Arches):

Dome

A faux ashlar motif decorates the dome, giving the illusion of a stone block dome. This is a simple abstract scheme using thick black lines to create the joints between the blocks and the white of the unpainted *enlucido* to form the blocks themselves (Figure 30). Three horizontal bands are presently exposed, the bottom edge of the dome is defined by a 6" thick black band, and the second band is 5" thick and located 24" above the first. A third band is only partially exposed but lies 22" above the second band, (the thickness is unknown). Vertical lines between the first and second bands are 4 ½" thick and are placed approximately 48" apart. The second tier of vertical lines, between the second and third bands, are 4 ¼" thick and are offset by 24" from the center of the vertical lines from the first tier.

Arches

The faux ashlar motif is continued from the dome to the arches. Thick black lines, measuring 4" wide, trace the intrados and extrados of the arch form with 3" thick joint lines creating faux voussoirs (Figure: 59). The arch elements appear to have an additional gray limewash applied between the black lines used to distinguish the stone

depicted for the arches from that of the dome, (which remains the off-white color of the enlucido) suggesting bichrome masonry.

Technique (Dome and Arches):

Incised lines and other marks, made while the plaster was still wet, are evident along the banding elements throughout the dome. These incised lines demarcate the width of the thick black banding and mark the center points of the vertical joint lines creating the faux ashlar blocks. Large brush marks, approximately two inches in width are visible within the black bands which were loosely applied within the boundaries of the incised lines and junctions between architectural elements.

Iconography of Mer Creatures

Clearly the most striking feature of this campaign is the monumental mer creatures (*la serena*). This unique iconography is difficult to place in an art historical context. In myth, mermaids or sirens were said to have the power to enchant sailors with their songs. They were traditionally seen as symbols of seductive temptations that must be overcome to achieve salvation.[32] In the present case, the mer creatures are used in a highly untraditional manner; they adorn the Chapel of the Virgin of the Rosary, holding bouquets of roses thought to represent the rosary. This likely had local resonance for the maritime, island culture of Puerto Rico, though it does not appear to conform to dominant traditions of European Christian iconography. Mer creature (*la serena*) imagery is found in the ceiling vault paintings of the Cathedral *Santa Maria la Menor* (Figure 26), a

[32] Apostolos-Cappadona, *Dictionary of Christian Art* (New York: Continuum Publishing Company, 1994), 240.

Dominican church in *Santo Domingo* built between 1510-1540, and in the relief escutcheon of the Ponce family in the Sanctuary of Iglesia San José (mid 16thc).[33] While both are examples of mer creatures in 16th century Dominican churches located in the Caribbean, neither are equal in terms of monumental scale nor are they dominate iconographic features.

4.2 Campaign B (Red Marbleizing)

Design:

Campaign B is the same for the dome, pendentives and arches. A very abstract faux marbleizing technique is executed in red on a white ground, representing veined marble (Figure 31). No other decorative motifs were observed in association with this campaign; however there existence cannot be discounted at this time.

Technique:

This design layer appears to have been executed in water soluble paint applied to a white lime wash ground. There is no evidence of incised lines, pouncing or under drawing. The red faux marble veins have been applied using loose, freehand strokes with a soft, long haired brush, approximately ½" in diameter penciling brush. There were no lines defining faux ashlar blocks found during site examination.

[33] http://www.dominicanrepublic.com/thecountry/art_culture.php.

4.3 Campaign C (Trompe l'oeil Coffers/Angels)

Design (Pendentives 1-4):

In Campaign C each of the pendentives are framed by thick light olive green border with a smaller rose colored banding. This outline traces the junctions of the arches which form the valley point of each pendentive. The border measures 7" in width with the rose banding measuring ¾" (Figure 55). The bottom edge of the dome (framing the top of the pendentives), is defined by a faux cornice painted in a monochromatic brown palette ranging in value from dark umber to very pale beige using a series of nine smaller bands with widths between ¾ inch and two inches (Figure 67).

The figures within the light olive green outline are only partially visible, due to over painting as well as loss. Each of the four pendentives has a winged figure approximately five feet in height with one arm extended overhead. This pose gives the illusion that the four figures are supporting the weight of the dome.[34]

Pendentive 1

Only small fragments of this design layer are visible, but what can be seen, are portions of the light olive banding that frames the pendentive, as well as a segment of the figure's wing (Map 2).

[34] Wings are symbolic of divine mission, angels, archangels; seraphim and cherubim are all depicted with them. The four Evangelists, Mathew, Mark, Luke and John are also symbolized by winged creatures.

Pendentive 2

The figure, wearing a simple belted tunic, holds a dynamic pose with the left proper leg bent and drapery falling toward the right side of the body (Map 3). The upper torso and head are completely obscured and the lower half of the painting is now gone, making identification of the subject impossible. There is a large area of loss, down to the original Campaign A, at the valley point of Pendentive 2. A 1 ½' x 2' area, along the upper right edge of the pendentive has been patched with later repair mortar and remains unpainted. In addition there is a large area of loss measuring 2 ½' x 2 ½', which now reveals the brick dome.

Pendentive 3

The subject of this pendentive is a male figure holding a palm frond (Figure 63. He has short cropped hair with head turned in a ¾ view (Map 4 and Figures 61-62). The figure is wearing a simple short sleeved tunic, belted at the waist similar to Pendentive 2 (Figure 64). The collar of this garment has a circular button or fastener at the center of the neckline (Figure 62). A large three foot square area of Pendentive 3 is now lost down to the brick and enfoscado, and the upper right corner has lost all layers except for the first Campaign A (Map 4 and Figure 65).

Pendentive 4

The subject of Pendentive 4 is a wavy haired male figure holding a wreath in his right proper hand (Map 5 and Figures 22-23). He is in a similarly dynamic pose as the

subject in Pendentive 2, with the left proper leg bent and drapery falling toward the right side of the body. In addition, he is wearing the same simple garment as in Pendentives 2 and 3: a short sleeved tunic, belted at the waist with a circular button or fastener at the center of the neckline. Behind the figure's left knee is an architectural feature comprised of a rectangular base topped by an orb.

Technique (Pendentives 1-4):

No evidence of preparatory drawings, pouncing, or incised lines is visible. There is a preparatory ground layer of pink which covers all four pendentives, and the dome. A similar palette is shared by the pendentives and dome, incorporating umber, white and a cooler brown or black, with light olive green and a rosy pink in the border. The central designs read as monochromatic color schemes with recesses in drapery rendered in dark browns and lighter projecting elements painted in whitish beige or grey. The figures read as primarily flat, two dimensional images created by free-hand linear outlines surrounded by a pale olive/grey wash. The only attempt to model forms occurs in the representation of the garments worn by the figures.

Design (Dome):

The dome was painted in a *trompe l'oeil* design of coffers which is largely obscured by over painting or illegible due to loss. Each of the visible faux coffers has been precisely measured, surrounded by a framing element, and further adorned by one of three rosette designs (Figures 32-35). There are three rows of coffers diminishing in size from the base of the dome to the highest point near the oculus. The first tier of trapezoidal coffers begins 18" above the faux cornice and measures approximately 30"

across the base, 38” in height, and 24” along the top. The second row of coffers begins 11” above the first and measures approximately 22” across the base, 24” in height, and 18” along the top. The final tier is placed six inches above the second row and 14” below the opening of the oculus. The dimensions of these elements measures approximately 15” across the base, 16” in height, and 11” the top.

Technique (Dome):

There is no evidence of pouncing or incised lines visible but a lighter under drawing may have been executed in faint washes to place the precisely drawn and carefully measured features decorating the dome. This is the most sophisticated and skillfully painted scheme visible in the Rosario Chapel; with dimensional rendering of the rosettes created by a distinct light source. While the placement and drawing of each coffer/rosette is precise, the brushwork modeling these elements is broad and loose. (Figures 33-35) There is a preparatory ground layer of pink which is also evident on all four pendentives. A similar palette is shared by the pendentives and dome, incorporating umber, white and a cooler brown or black. Both read as monochromatic color schemes with recesses in drapery or coffers rendered in dark browns and lighter projecting elements painted in highlights of whitish beige or gray.

Design (Arches):

Olive green limewash with no penciled joint lines found with exposures. The color appears to relate to the border element used to frame each pendentive.

Technique (Arches):

Overall limewash of green appears to describe the arches.

4.4 Campaign D (Battle of Lepanto/Evangelists)

Campaign D is one of the most fragile and incomplete of all the painting campaigns. What remains in most areas are friable fragments depicting partial figures. The surfaces are greatly disrupted by salts, blistering, and flaking, as seen in figure 36. This layer appears to have used an organic binder as a medium which has failed over time.

Design (Pendentives 1-4):

Pendentive 1

What remains of Campaign D on this pendentive is a mortar repair located on the upper third of this element. Each of the three triangular corners has been lost down to the first mural campaign (A), with islands of loss down to the *enfoscado* and brick construction in the center (Map 2). What is visible today is a single male figure holding a large bird in his left proper hand while the right proper arm rests on a rectangular pillar (Figures 16-17).[35] The figure wears a black cloak over a white robe. A solid field of bright blue surrounds the figure; this same color is carried into the dome and is interrupted by the earlier faux cornice element originally painted in Campaign C. This earlier faux cornice appears to have been utilized in this campaign and was not over-painted during Campaign D.

---

[35] Apostolos-Cappadona, *Dictionary of Christian Art* (New York: Continuum Publishing Company, 1994). "John the Evangelist was identified by an eagle as his gospel was thought to have transcended all others with its philosophical language..." P125

Pendentive 2

There is a large area of loss down to the original mural Campaign A at the valley point of Pendentive 2 (Figure 18). A 1 ½' x 2' area, along the upper right edge of the pendentive has been patched with repair mortar and remains unpainted. In addition there is a large area of loss measuring 2 ½' x 2 ½', which now exposes the brick dome construction. Due to excessive powdering and binder loss, the earlier Campaign C imagery often shows through making both campaigns nearly illegible. What can currently be seen is a faint image of the Virgin Mary, distinguishable with the aid of a 1982 photograph (Figure 19). The Virgin is depicted wearing a large gold crown and veil, a yellow and red under robe draped by a brilliant blue cloak. She holds the child Jesus in her right proper arm, while the left is extended with her hand closed as if she were holding something no longer visible (Figures 56-58). There is also a dark charcoal gray area in the upper left corner which is similar to the border color on Pendentive 4. The bottom edge of the dome, (framing the top of the pendentives), is defined by the faux cornice from Campaign C, which was not over-painted.

Pendentive 3

All that remains of this campaign is a few streaks of powdered pigment, with no visible image and no record of what had been painted. A large 3' square of Pendentive 3 is now lost down to the brick and enfoscado, and the upper right corner has lost all layers except for the very first Campaign A. (See Map: 4) The bottom edge of the dome, (framing the top of the pendentives), is defined by the faux cornice from Campaign C, which was not over-painted.

Pendentive 4

There is a thick light charcoal gray border used as a framing device in Pendentive 4. This element traces the juncture of the arches which forms the valley point of each pendentive. The border measures 10" wide. The bottom edge of the dome, (framing the top of the pendentives), is defined by the faux cornice from Campaign C. There is no evidence of the original imagery; all that remains is the light blue field, which is severely compromised. What is visible is the angel figure from Campaign C, obscured by the light blue paint of Campaign D (Map 5). The light blue paint also extends into the dome.

Design (Dome):

This is the most complex composition in the Rosario Chapel, incorporating a figural narrative thought to depict the 1571 Battle of Lepanto. As mentioned earlier, this is an extremely fragmented campaign making legibility difficult. Much of this layer has been lost, over-painted, or has deteriorated to such an extent that earlier layers are now visually dominant. Six small galley ships can be distinguished, each equipped with multiple oars, and a single mast and sail (Map 1). The ships in the foreground measure approximately ten feet long. The bodies of the ships are painted in two to three thick horizontal bands of color (Figure 47). Above the sails fly flags in either red or blue (Figure 37). A wave motif, created by slashing strokes of blues and white (Figure 38), frames the bottom edge of the dome, providing a visual base.

There are six male figures (mariners), each only partially revealed, dressed in either uniform or armor. Mariner 1 sits low on the north side of the dome looking up towards a now obscured area of greens and yellows; he has short cropped hair, wears a

white ruffled collar, and a dark grey uniform trimmed in gold (Figure 39). Moving counterclockwise, mariners 2 and 3 appear to be in the same galley boat and both are leaning in the same southerly direction (Figure 40). Mariner 2 appears to be wearing a grey suit of armor with a flat brimmed helmet; he is armed with a large spear and sports a curly mustache (Figure 41). The third mariner leans over the bow of the ship wearing a black uniform jacket trimmed in gold; he has longer wavy hair and a moustache (Figure 42). One of the most distinct characters is mariner 4, he stands tall on the aft of the boat and appears to be controlling the rudder (Figure 44). He wears what looks like a dark gray suit of armor his neck is completely covered and a tall helmet protects his head. He is armed with a large, sword with a gold handle sheathed in a brown leather belt. The fifth mariner has only his head exposed with what looks like short-cropped hair, a beard and mustache (Figure 45). Mariner 6 is similarly obscured with only a tall helmet and part of his face exposed (Figure 46). Mariners 4, 5 and 6 all appear to be aboard the same boat (Figure 43). There are a number of vault forms which resemble small enclosures characteristic of ships from this period. They sit higher up on the dome perhaps to place them in the background (Figure 48). The eastern half of the dome is difficult to understand visually, although the palette makes a definite shift moving from blue to ochre and green, (possibly depicting the shores of Lepanto).

Technique:

There is evidence that a light brown under-drawing was used to lay out the composition in the dome. This was applied directly on top of Campaign C, with no preparatory ground separating the layers. The artist has used color rather than lines to

describe the subject of the painting. Figures are represented by pink fields for exposed skin and flat spans of color for garments, large blocks of blue create the sky, red and blue fields represent sails, and horizontal bands of flat color describe the boats. Details are then scumbled or applied in thick impasto for further description of the forms. The composition reads as flat two dimensional images with very little attempt made to model forms. This campaign appears to have used paint with an organic binder, little of which remains. There is an interesting treatment of the water motif at the base of the dome; this has been created with vigorous, slashed brush marks which terminate at the top of the faux cornice element from Campaign C. Campaign D uses the largest color palette including: deep ultramarine blues, turquoise, emerald green, bright lime green, bright chrome yellow color, yellow ochre color, white, black, brown, earth red, olive green, pinks and peaches.

Iconography of the Battle of Lepanto

The Battle of Lepanto was fought on October 17, 1571 between the Christian and Islamic world for dominance over the Mediterranean.[36] It was considered the end of eight centuries of conflict between the Ottoman Empire and that of the Papacy. The battle occurred at the mouth of the gulf of Corinth-Patras and was the last major conflict to use the galley ships powered by oarsman (Figure 28). The Battle of Lepanto was often portrayed in art with the image of the Virgin Mary and attending saints watching over the scene from the heavens (Figure 27). The anniversary of the Battle of Lepanto is celebrated by the Roman Catholic Church as the feast of Our Lady of the Rosary on

[36] Angus Konstam, *Lepanto 1571: The Greatest Naval Battle of the Renaissance* (Westport: Preager Publishers, 2005), 7.

October 7th, the day Christians declared victory in 1571.[37] The depiction of the Battle of Lepanto in the Rosario Chapel of Iglesia San José falls in line with traditions begun in Renaissance Europe.

4.5 Campaign E (Measured Ashlar)

Design:

A faux ashlar motif decorates the dome, giving the illusion of masonry construction. This is a simple scheme using ¼" wide lines to create the joints between blocks. The ground is a white lime wash with thin red penciling used for the joint lines (Figure 49). Campaign E is the same for the dome, pendentives and arches. Much of this layer has been lost. Each block located near the oculus measures 7 ¼" across the top, 12" in height and 10 ¼" along the base. The blocks at the bottom of the dome measure 48" wide and 12" high. This campaign can be dated to at least ca. 1890-1920 based on historic photographs (Figures 7-9).

Technique:

This design layer was executed in water soluble paint applied to a white limewash ground. There are drawn, graphite lines which layout the carefully measured joint lines, each a consistent ¼" width.

[37] Hugh Bicheno, *Cresent and Cross: The Battle of Leponto 1571* (London: Cassell, 2003), 28.

4.6 Campaign F (Free-hand Ashlar)

Design:

A faux ashlar motif decorates the dome, suggesting masonry construction. This is a simple scheme using thin lines to create the joints between blocks. The ground is a white lime wash with thin red pencilling used for the joint lines (Figure 50). Campaign F is the same for the dome, pendentives and arches and appears to have been an attempt to repair losses to Campaign E. Much of this layer has also been lost as well. The layout of the individual blocks follows the dimensions of the previous ashlar campaign.

Technique:

This design layer was executed in water soluble paint applied to a white lime wash ground. There are no lines or guides used to layout the painting in this campaign, instead a free-hand technique was employed. As a result the lines painted in this layer vary in width and are much less precise than that in Campaign E.

5 Literature Survey: Scientific Techniques used in the Analysis of Pigments and Colorants

5.1 Introduction to paint

Paint is primarily comprised of two components: the colorant in the form of pigments, dyes, and lakes, and a binder also referred to as the medium or vehicle. Paint systems are most often classified by the paint medium or their film formation mechanism. These include the following processes of film formation:

1) Solidification by crystal formation.[38] This process includes techniques like fresco, where the curing of the substrate (in this case the carbonation process) creates a crystalline surface which incorporates the pigments.

2) Solidification by solvent loss.[39] This is a process where a resinous film is formed by the evaporation of a solvent and includes paints such as glue distempers.

3) Solidification by cross-linking.[40] This is a film formation process where resin monomers react with a catalyst. While durable, linseed oil used in easel paintings as a medium has posed a particularly difficult conservation problem due to cross-linking.

---

[38] Frank G. Matero, *Paintings and Coatings*, ed. Martin E. Weaver and Frank G. Matero, *In Conserving Buildings: Guide to Techniques and Materials* (New York: John Wiley, 1993).
[39] Ibid.
[40] Ibid.

4) Solidification by coalescence.[41] This process of film formation is created by the evaporation of one phase from another suspended as a dispersion. Casein paints are an example of solidification by coalescence.

The above paint classifications encompass an enormous variety of paints with unique qualities inherent to the pigments, medium and methods of application. Paints have been exploited for thousands of years; they are used in mural paintings for inspirational, illustrative and didactic effect, as well as for traditional design applications that reflect simple color schemes and historic trends associated with class and gender.

5.2 The study of paint

The compositional analysis of paint plays a vital roll in our understanding of artists' or craftsmen techniques and palette, our ability to date architectural finishes or works of art, as well as to providing a knowledge base from which conservation efforts can be planned. The compositional analysis of paint, in conjunction with a condition survey, is the starting point for any intervention whether it is cleaning, consolidation, documentation, or research.

The history of historic paint analysis began with the examination of artists' pigments. The first published works included John Haslam's study of mid- fourteenth century wall paintings in St. Stephen's Chapel, Westminster published in 1800.[42] In 1814 Sir Humphry Davy analyzed pigment samples taken from wall paintings in Pompeii, Rome. Both men carried out chemical analysis using acids and heat, and

[41] Ibid.
[42] Stephen Rees-Jones, "Early Experiments in Pigment Analysis," *Studies in Conservation* 35, no. 2 (1990).

Hasalm was able to identify the oil binder using solvent tests. [43] The preparation of cross-sections in the investigation of paint was conducted in 1914 by Laurie but it wasn't until the mid-twentieth century when Rutherford Gettens of the Fogg Art Museum and George Stout, editor of Technical Studies in the Field of Conservation, truly brought the field of paint analysis in the conservation of works of art to a new level.[44] Their book entitled Painting Materials: A Short Encyclopedia, published in 1942, provided a comprehensive text dedicated to the scientific examination of paint, which remains a seminal work in the field. Joyce Plesters furthered the work of Gettens in Stout in her 1956 article, Cross-Section and Chemical Analysis of Paint Samples published in a 1956 issue of Studies in Conservation. Works by Gettens, Stout and Plesters are commonly referred to in contemporary conservation literature, underscoring the importance of those investigations.

The compositional analysis of paint has been most applied in the field of fine arts conservation, which has informed analytic investigations in the field of architectural conservation. In researching analytic techniques for the compositional analysis of paint, it was necessary to extend the search beyond architectural surface coatings and to incorporate investigations of both mural and easel paintings. It is interesting to note that while architectural paint investigations have borrowed much from fine arts conservation, the reverse is now also occurring. This is especially true with mural painting conservation, where it is now recognized that the painted surface cannot be treated in

---

[43] Rees-Jones, Stephen. "Early Experiments in Pigment Analysis." *Studies in Conservation* 35, no. 2 (1990): 93-100.
[44] Joyce Plesters, "Cross-Sections and Chemical Analysis of Paint Samples," *Studies in Conservation* 2 (1956):110.

isolation. The context, environment, and supporting substrate are of primary importance in understanding decay mechanisms and developing appropriate conservation treatments. The Mora, Mora and Philippot book starts the trend with *Conservation of Wall Paintings* published by the Getty Conservation Institute (1984) which is continued in works such as *Conserving the Painted Past* published by English Heritage (1999) (where a significant number of articles are dedicated to the documentation and conditions assessment of the wall paintings in context trying to understand larger environmental and structural impacts affecting a painted work to be examined.

Finally, analytic investigations are most successful when scientists, conservators, curators and historians work collaboratively. The examination of painted surfaces is a complex process requiring complementary techniques, a scientist or conservator must develop appropriate research questions aided by the historical research of paint technology, material availability, as well as having extensive knowledge of the analytical techniques and tools available to answer those questions. This chapter highlights analytic techniques predominately used in the field today for the identification of paints, while also mentioning more obscure or specialized methods.

5.3 Pigments and their sources

Pigments and treated colorants (i.e. lakes and dyes) are the components in paint that gives it its color and opacity or hiding power. They are used in a powder form and suspended in a medium or vehicle as discrete particles.[45] Pigments are derived from a variety of sources ranging from inorganic minerals and ores to organic earths and highly

[45] Matero, *Paintings and Coatings*. P216

colored plant matter.[46] Pigments are classified by color, chemical composition, and source.

The literature discussing pigments uses organic or inorganic composition as one means of classification, with subheadings of natural or synthetic. Natural inorganic pigments are also referred to as Earth pigments and are found in minerals, ores and sedimentary deposits in the earths crust. They are complex mineral mixtures including azurite, hematite, limonite, and cinnabar whose chemical compounds include elements such as iron, copper, mercury, and lead. Carbonaceous organic pigments like Van Dyke Brown also fall into the earth pigment category. Theses pigments are highly stabile as well as being some of earliest in use.[47] Mineral pigments, such as those derived from azurite and lapis lazuli may be further specified as natural minerals with characteristic physical form and constant chemical behavior.[48]

Organic pigments are those composed of carbon with oxygen, hydrogen, nitrogen, sulfur, and other elements derived from plant material. [49] Some of these pigments include lamp black, madder, and indigo. Organic pigments were synthesized as the understanding of pigment chemistry improved in the late nineteenth century, spurred on by the high cost of many naturally occurring pigments. Coal tar derivatives such as mauve and alizarin proved more stable than natural organic colorants and at a much

---

[46] Rutherford J. Gettens, and George L. Stout., *Painting Materials: A Short Encyclopedia* (New York: Dover Publications, Inc., 1942; reprint, 1966). P143
[47] Ibid. P131
[48] Ibid. P131
[49] Ibid. P134

lower cost. Soluble organic dyes, when used in paint, were precipitated into inert lake pigments.

5.4 Pigments and their chemical properties

Pigments differ with respect to their chemical properties due to the fact that they are comprised of a wide variety of chemical compounds. Gettens names some common inorganic coloring materials as oxides, sulphides, carbonates, chromates, sulphates, phosphates and silicates of the heavy metals. There are few metallo-organic compounds which are form pigments like Emerald Green as well as pigments comprised of pure elements such as carbon and gold.

Ideally, pigments should be inert to strong acids, alkyds and heat; they should be resistant to photochemical reactions when exposed to light. This is not always the case, and has resulted in the discontinued use of certain pigments, pigment combinations, or use with certain media. The desire to understand the chemical properties of pigments has produced a large body of research which has identified chemical compounds that form pigments, and created techniques for analysis (the latter of which will be discussed in a later section of this paper).

5.5 Pigment and their physical properties

Physical properties are characteristics that are innate to a material. The most important physical property of a pigment is its color. The color of a pigment is produced by that material's interaction with light, and more specifically, the way in which it

absorbs the component colors of white light.[50] A material's color characteristics, such as hue and purity, rely not only on color absorption but also depend on the size, shape, and texture of pigment grains. The property of color is described by its refractive index, or light bending power as light passes through a pigment grain. The refractive index of a pigment is often proportional to its hiding power. There are also characteristics related to the shape and size of a pigment. For example, mineral pigments are often sharp and angular and traditionally larger in grain size. This sharp angularity is caused by the cleavage properties of minerals.[51] Earth pigments are generally small and rounded, though vary greatly in size and shape; in short they are non-uniform. Pigments also have particular physical properties related to density and their ability to be dispersed and wet in media, all of which play important roles in a pigment's function in a paint system.

5.6 Reasons for conducting pigment analysis

Nineteenth century analysis of pigments was carried out with the intention of synthesizing a new color or more cost effective product. Scientists, conservators and historians have continued interest in this for a number of reasons. Pigment analysis can be used to establish the date of a layer or campaign, as well as to identify authenticity. Identification of pigments can aid in the selection of colorant to be used in a historic interior or guide a conservator's choice of material when in-painting is required to re-establish visual integrity of a degraded surface. Understanding and identifying materials is necessary for planning appropriate conservation interventions.

---

[50] Ibid. P143
[51] Ibid. P143

5.7 Research questions

What we want to know about pigments in a sample will influence the scope of an investigation. Research could include the identification of a pigment, discerning whether or not it is natural or synthetic, organic or inorganic. In the case of fugitive colorants or discolored media, the purpose may be to understand the original color of a paint system. The following section outlines techniques that may be employed in answering these questions. Each method of laboratory analysis will outline the basic principles of the technology: the type of sample appropriate for testing as well as the limitations associated with each. These methods all require the removal of a sample from the object being tested, and are performed only after in-situ investigations have been completed.

5.8 Techniques of analysis

Cross-sections

The start of a laboratory investigation of samples is best when moving from the macro to micro scale. Perhaps the best way to orient and understand exactly what needs to be considered for testing is through examination of a sample by cross-section. This process begins with the most appropriate and representative samples of the painted surface with inclusion of the substrate. The samples are then embedded in a clear resin which is cut, polished and mounted on glass slides. There are a number of articles dedicated to the subject of embedding samples for cross-section analysis, including works by Michele Derrick, et al., and Jia-Sun Tsang. [52]

[52] Jia-sun and Cunningham Tsang, Roland H., "Some Improvements in the Study of Cross Sections," *Journal of the American Institute for Conservation* 30 (1991).

Cross-sections are opaque samples which are observed in reflected light under relatively low magnifications (30x to 150x).[53] One can gather information from this technique such as: the sequence of paint layers, the color and texture of those layers, layer thickness, pigment particle size, and pigment binder ratio of a system. [54] Cross-section analysis allows one to observe physical and optical phenomena related to individual layers and their superimposition, including their manipulation and aging. Cross-sections also provide a safe platform away from the actual painting or surface to conduct micro-chemical tests. After observations have been made using reflected light, testing of a cross section may continue using UV Fluorescence, SEM-EDS, or by teasing pigment particles from the mounted cross section for further examination by polarized light microscopy, or any number of techniques to be discussed later. Sample examination by cross-section is a first step in understanding what a sample is comprised of as well as establishing a testing regime.

Light Microscopy

Optical microscopy techniques include reflected light used with opaque samples such as those prepared as cross sections or it may be used in combination with transmitted light for pigment dispersions. Normal as well as polarized and ultraviolet light microscopy is used for the study pf cross-sections and dispersions.

---

[53] Plesters, "Cross-Sections and Chemical Analysis of Paint Samples." P113

[54] Holchleitner, B., et. al. "Analysis of Paint Layers by Light Microscopy, Scanning Electron Microscopy and Synchrotron Induced X-Ray Diffraction." Paper presented at the Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage, Antwerp, Belgium, 2-6 June 2002.

Polarized Light Microscopy

The Polarized Light Microscope (PLM) is both a magnification device as well as an analytical instrument. The microscope has polarized lenses that absorb light in all directions accept one; this forming a plane of polarization. [55] PLM is a method of narrowing down the possibilities of an unknown, and is described as a quick and cost effective method of analysis for conservators.[56] An appendix entitled 'Terminology and Procedure Used in the Systematic Examination of Pigment Particles with Polarizing Microscope' from (*Artists' Pigments* edited by Robert Feller), offers an excellent outline for investigation. Polarized microscopy exploits a pigment's refractive indices in order to help identify an unknown. The morphology of a pigment particle, including homogeneity, shape, size, surface character, and crystal form, are among the first in the sequence of observations that should be made in an investigation. When a precise measurement of a particle size is desired, a calibrated micrometer ocular may be used. Physical properties of a pigment, such as particle size and shape can help determine the source of a pigment, and decipher subtle differences between natural and synthetic versions of a pigment. For example, natural and synthetic ultramarine will produce the same results from micro-chemical testing; it is only after observation under a microscope that one may distinguish between the two.

---

[55] Eugene. Farrell, *Techniques in Paint Analysis.*, ed. Moss. Roger W, *Paint in America,the Colors of Historic Buildings* (New York: John Wiley and Sons, INC. , 1994).P188

[56] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Robert L. Feller, 3 vols., vol. 1 (New York: National Gallery of Art, 1987). P 285.

Additional investigation of optical properties include: color, pleochrisom, refractive index, birefringence, extinction and interference. Recommended ancillary tests include micro-chemical tests and dispersion staining.[57]

Micro-chemical Tests

Micro-chemical testing coupled with polarized light microscopy are the most common means of paint analysis in architectural conservation, providing sufficient information for determining most pigments and color of an original paint scheme. The previously mentioned publications by Gettens, Stout, and Plesters are often referred to as standards in micro-chemical testing. These references describe tests methods as well as the expected reactions, and have extensive tables grouped by color subdivided by specific pigments. Walter McCrone provides flow charts for chemical testing which helps simplify the process for the conservator.[58] Micro-chemical testing alone will not provide accurate identification of a pigment but rather aid in the process when used in conjunction with PLM[59]. This method of analysis is destructive which must be considered if samples are limited.

Ultraviolet Fluorescence

UV light may be used in pigment analysis and is especially valuable in distinguishing between various white pigments. A sample when exposed to UV radiation may emit visible light. When this occurs during irradiation, it is described as

---

[57] O. P. Agrawal, "Conservation of Wall Paintings in India," *Conservation of architectural surfaces: stones and wall covering* (1993).
[58] *Microscopy for Conservators: Reference Manuel.* (Chicago: McCrone Research Institute).
[59] Andrea M Gilmore, *Analyzing Paint Samples, Investigation and Interpretation.*, ed. Moss. Roger W., *Paint in America,the Colors of Historic Buildings* (New York: John Wiley and Sons, INC., 1994).

fluorescence; if it continues after exposure to UV light it is called phosphorescence.[60] UV lamps or microscopes may be used depending on a conservator's preference. In the study of white pigments, specific colors of visible light are emitted depending on the pigments. For example, carbonate white will result in a rose or bluish white color, zinc produces a bright yellow light, and lead appears a more subdued yellowish white.[61] However, the binding media of the paint system can cause interference and skew results. In short, this is a quick test that leaves a lot of room for error and must be conducted in collaboration with other tests.

Scanning Electron Microscopy and Energy Dispersive Spectroscopy

Scanning Electron Microscopy (SEM) is an imaging technique that magnifies a sample up to 50,000x; 1,000x is more common in conservation. At this magnification, one is able to characterize the surface of a material, detect elemental differences across a sample, and measuring small features. This is a technique used to more precisely describe the morphological features of a pigment, and is most effective in the absence of organic binding media.[62] The output one receives is a magnified image of the sample, at a much higher resolution than is offered by a light microscope.

SEM uses a modified microscope, in which an electron magnet focuses electromagnetic radiation on a sample placed in a vacuum chamber. When energy

---

[60] Marie L. Carden, "Use of Ultraviolet Light as an Aid to Pigment Identification," *APT bulletin* XXIII, no. 9 (1991).
[61] Ibid.
[62] A.R.; Jones Burnstock, C.G.; and Ball, A.D, "Morphology of the Blue Artist's Pigment Smalt Using Scanning Electron Microscopy." (paper presented at the 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage: 2-6 June 2002, Congress Centre Elzenveld, Antwerp, Belgium: proceedings. Grieken, R. van; Janssens, K.; Van't dack, L.; and Meersman, G., Editors. University of Antwerp Antwerp, 2002).

bombards the sample, photons and electron signals are emitted. There are a number of detectors used but the Primary Backscatter and Secondary Electron detectors are most common in conservation.

Samples must be prepared with a conductive coating, most often carbon. Gold or palladium coatings may be more desirable for pure imaging due to their greater conductivity. Samples must be securely attached to the puck with either carbon tape or paint to eliminate charging, which will disrupt analysis. Cross-sections may be examined using SEM but this requires a highly polished sample that will also be coated with carbon, gold or palladium.

SEM is often used in combination with EDS, which identifies the elemental composition of a sample in a scanning electron microscope, heavier than boron. This technique measures emitted X-rays and generates fluorescence from atoms in its path. EDS output is in the form of a peaked spectra or X-ray mapping.

EDS in combination with SEM is a powerful tool and is often mentioned in conservation literature, especially in regards to wall painting conservation. SEM-EDS is very good in detecting inorganic material, but for lighter elements other techniques such as Fourier Transform Infrared Spectroscopy (FTIR) must be considered.

X-Ray Diffraction

X-Ray Diffraction (XRD) is used to identify single-phase, (i.e. minerals, ceramics) or multi-phase material, (i.e. microcrystalline mixtures like stone). In addition it may be used to identify the structure of clay minerals.

Principle of XRD: Crystalline materials diffract light based on the spacing between different atoms in that crystal. Interaction with X-rays will result in secondary diffracted beams which relate to the interplanar spacing in crystalline sample according to Bragg's Law.[63]

Braggs Law: $n\lambda=2d \sin\theta$

Where n is an integer

λ is the wavelength of X-rays

d is the interplanar spacing generating the diffraction

θ is the diffraction angle

Data is presented in a series of peaks which are analyzed to determine phases in material.

[63] Conolly, James. Introduction to X-Ray Diffraction, (2005). epswww.unm.edu/**xrd**/**xrd**class/01-XRD-Intro.pdf

This technique is used to identify crystallography of a material as well as identify minerals and chemical compounds. Advanced XRD analysis may be used to quantify phases in a multi-phase sample as well as to determine crystal size and shape. An advanced study of Maya Blue pigment was conducted by Edwin Littmann in 'Maya Blue, A New Perspective'. In this study, the author relied on micro-chemical spot testing and XRD to try and determine the absorption of the organic indigo colorant into a specific clay mineral base of attapulgite.[64] This study was unable to distinguish between attapulgite and montmorillonite, and further testing strategies suggested that the glycolation of the sample prior to XRD might provide better results. XRD is an advanced technique requiring an experienced practitioner to achieve accurate test results and interpretation.

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR in the study of pigments can be particularly useful for identifying organics that are missed using techniques such as EDS and XRD. FTIR is able to recognize inorganic compounds containing complex anions (such as carbonates, sulfates, silicates), but it is unable to identify simple anions (such as oxides and sulfides).[65] Like EDS, FTIR analysis is based on a sample's interaction with radiation; the difference is in the type of light. IR techniques work with the infrared light and peaked spectra are created by a compound's absorption of IR radiation; Fourier Transform is a mathematical translation of the data. The absorption bands of spectra represent functional groups. Spectra can be equated to a fingerprint of a compound in that they are unique to each compound. The

[64] Edwin R. Littmann, "Maya Blue, a New Perpective," *American Antiquity* 45, no. 1 (1980).
[65] Michele . Derrick, *Infrared Spectroscopy in Conservation Science*, *Scientific Tools for Conservation* (Los Angeles: The Getty Conservation Institute, 1999).

difficulty with this technique is that rarely can one provide pure samples for analysis. A complex sample will produce spectra that are very difficult to interpret and only an experienced scientist can filter results with any success. There is a data base of IR spectra related to art and cultural material that can aid in the process of interpretation called IRUG (Infrared and Raman Users Group). The most common application of FTIR in paint analysis is for the identification of binding media.

Raman Spectroscopy and Particle Induced X-Ray Emission, (PIXE)

Raman Spectroscopy and Particle Induced X-Ray Emission (PIXE) are two techniques which are comparable to FTIR and EDS in their analytic abilities with one key difference: these methods may be used in-situ. If sampling is not an option, Raman and PIXE technologies provide an excellent method for spectral and x-ray emissions analysis. The drawback is that the results may be less accurate, harder to obtain, and less sensitive. Sample preparation required by laboratory methods allows a conservator to choose the best possible sample for a particular technique, and this provides cleaner, more accurate results. Each pigment can be identified by a unique Raman spectrum, which is then compared to known spectra.

Raman spectroscopy is a spectral analysis of light scattered from a sample being bombarded by a monochromatic (LASER) light beam.[66] Spectral intensity is reported as a function of the Raman frequency shift, (difference between frequencies of the incident and scattered light), this gives information about the molecular vibration frequencies of

[66] V. Hayez, "Study of the Composition of the Pigments Used in the Christ "Maiestas Domini" Painting of the Ename Church by Means of Micro Raman Spectroscopy." (paper presented at the Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage, Antwerp, Belgium, 2-6 June 2002 2002).

he sample which is then used to identify molecular composition.[67] One can change the excitation frequency for a broader range of detection, resulting in more accurate pigment identification. For example red laser light (Kr+ laser at 647.1 nm) is used to collect spectra from warm colors and green laser light (Ar+ with wavelengths of 514.5-488 nm) is best for analyzing cool colored pigments.[68] Difficulties occur with this method from undesired broadband fluorescence.

PIXE identifies the elemental composition of a sample similar to EDS. The sample is bombarded with x-rays which are refracted off the sample and have characteristic emmitance energies. Elements lighter than sodium can not be detected, and thus this technique is not useful for the identification of organic compounds. The external beam set up option allows for in-situ analysis where no sample is required. In the literature, if in-situ results were not sufficient, a lab component was conducted using techniques such as SEM-EDS.

5.9 Conclusion

One clear conclusion that can be drawn from the literature surveyed regarding the compositional analysis of paint is that no single technique will provide all the answers, and a comprehensive study will employ multiple methods to arrive at the desired informatione. Additionally, sample testing regimes are governed by one's research questions. A conservator must clearly outline what information is needed for a particular

[67] Ibid.
[68] Ibid.

project, select appropriate analytic techniques, considering cost and availability of equipment, and proceed accordingly.

In addition much of the literature published since 1995 has focused on in-situ methods (also described as non-destructive methods), which were not elaborated on in this paper. Generally, these methods are similar to those employed in a laboratory setting, though they may be used in the field and do not require destructive sampling. These methods will be more useful in mural or fine arts conservation where sampling proves too detrimental to the work rather than in architectural investigation. Non-destructive methods such as Raman and PIXIE tend to be less accurate and sensitive in their analysis. I have focused on the more traditional laboratory investigations in this thesis, due to their relevance to the field of architectural conservation.

In publications addressing conservation treatment or environmental monitoring of painted surfaces, materials analysis is an initial step of any investigation. Finally, in the field of architectural conservation there is a tendency to rely on micro-chemical testing in conjunction with PLM, due to the information needed for those investigations and because the equipment required is readily available. The exception to this was found in architectural finishes studies performed in Italy. It appears that Italian conservators place architectural resources on a similar level of significance to their fine arts holdings, which has resulted in more in-depth studies of these resources as well as equipment availability for those studies.

6 Materials Analysis

6.1 Research goals

Materials analysis of the mural paintings on the dome of the Rosario Chapel was conducted, in order to identify the physical and chemical components and painting techniques used to create the dome's original and subsequent murals. Included in this study will be an analysis of select campaigns' substrate, binders, and pigments.

6.2 On-Site observations, photography and sampling

After an initial site visit, it became obvious that the Rosario Chapel Dome is comprised of as many as 20 paint layers, three of which have complex figurative murals executed in multiple techniques. The entire interior of the dome has suffered due to constant moisture infiltration/condensation, and salt crystallization, as well as biological growth; these conditions have had a devastating effect. There is prevalent intra-layer delamination, as well as significant detachment of these layers from the substrate. The result is a vulnerable, rapidly deteriorating surface that is difficult to read pictorially. A condition survey has been conducted as part of a separate investigation and will not be included in this study.

To date site documentation related to this particular chapel has been scant, providing very little in terms of supporting historical documentation to draw upon to answer art historical questions about the Rosario Chapel wall paintings. It is the intention

of this investigation to document the mural campaigns providing a record of their evolution, and to place these campaigns in a chronology. This process began with on-site investigations which included photographic documentation, field notes and mapping of all visible wall painting campaigns using field acetates and later transferring the information into Auto CAD and ArcGIS as digital maps.

Photography

Digital color photographs at 6 mega pixel resolution were taken from scaffolding providing an excellent opportunity for recording details of imagery and surface condition. Because the space was minimal and distance from the mural could not be gained, complete coverage was impossible; instead multiple images were taken. Large format rectified color photographs taken by Joseph Elliott in 2004 provided complete images of the dome as well as the four pendentives.

Detailed images included: salt efflorescence, areas of loss revealing construction methods, evidence of painting techniques, areas of biological growth and termite damage, as well as painting details. The goals for photography were to provide documentation and to assist in off-site analysis. Illumination included both frontal and raking light to exaggerate technique and conditions.

Sampling

An important component of the two site visits (October 2005 and January 2006) was to collect appropriate representative samples from the Chapel, including samples of

all visible colors. Samples were collected to provide stratigraphic information of paint layers and substrate mortars.

Complete stratigraphies with all layers intact were very difficult to obtain due to the friability of the materials. Areas where loss had occurred provided a plentiful source for sampling. Many of the attempts to sample elsewhere resulted in complete disintegration of the area with no usable specimen. Lime wash layers were extremely brittle, and substrate mortars, especially the enfoscado layer, readily disaggregated thus influencing the sampling process.

6.3 Substrate analysis

6.3.1 Objectives

One objective of substrate analysis for this project was to determine the constituents of the two types of plasters applied to the dome and pendentives. Two of the most serious conditions affecting the dome are those of loss and detachment of the plaster substrate. Major loss often results from detachment of the *enfoscado* either as intra-layer separation where multiple applications were required to achieve the desired leveling effect, or between the *enfoscado* and the masonry support. An understanding of the plaster composition provides important evidence of intrinsic factors related to failure.

Due to the large volume of the sample required for gravimetric analysis, only two samples were used for this study. Each of the samples had both the *enfoscado* as well as the *enlucido*. These samples were taken from areas of loss. This decision was made due to the delicate condition of the dome's substrate and mural campaigns.

6.3.2 Methodology

The earliest mural campaign, which appears to be executed in the *secco* technique, has a two part substrate consisting of a rough *enfoscado* (red leveling plaster), or in the Rosario Chapel multiple layers, finished with a fine *enlucido* (fine white finish plaster). Analysis of the substrate included: gravimetric analysis through acid digestion, and particle size distribution of aggregate by sieve analysis, morphological characterization of the aggregate portion through microscopal examination, and XRD analysis of fines for both plaster layers.

Four samples were selected for gravimetric and sieve analysis, two from the juncture of Pendentive 3 (samples P3.19.1 and P3.19.2) and the dome and the others from the lower valley point of Pendentive 2 (samples P2.18.C1 and P2.18.C2). The two mortar types (*enlucido* and *enfoscado*) were separated and analyzed. ASTM standards C136-84a, C 144-99 were followed for this process. A sample of the fines fraction for both the *enlucido* and *enfoscado* was analyzed by XRD for characterization with special attention paid to clay and salt content.

6.3.3 Results

Plasters

In general, plasters are comprised of binders, aggregates, water and additives. They function as a system providing both decorative and protective surfaces to a substrate. The binding agent is the component providing set, permeability, and cohesive

and adhesive strength.[69] The aggregate fraction is used to add bulk to the plaster and for shrinkage control. [70] Aggregate also plays an important role in a plaster's appearance contributing to characteristics such as color and texture. Additives, such as brick dust, organic matter, plasticizers and many other compounds, may be included to alter working properties, set time and performance of plasters.[71] Important factors contributing to the performance potential of plasters relating directly to the plaster constituents include: the ratio of binder to aggregate, the type and grading of the aggregate, and the amount and type of binder used.

Visual Observations

Each of the four samples were first examined in gross form and observations were made including layer stratification, color (using the Munsell system, ASTM D1535-97), hardness, and texture (Appendix C).

Gravimetric analysis

The *enfoscado* and *enlucido* layers were separated using a scalpel; the samples were then crushed using a mortar and pestle and weighed. The samples were dried at 110° C in an oven for 24 hours and weighed again. Each sample then underwent acid digestion in a 4M solution of hydrochloric acid, which was constantly agitated, until all acid soluble components had dissolved. The insoluble fraction was separated, levigating and filtering the fine components, while leaving behind the larger aggregate particles.

[69]McKee, Harley J. *Introduction to Early American Masonry, Stone, Brick, Mortar, and Plaster* (Washington: National Trust for Historic Preservation, 1973) 61.
[70] Ibid, 64.
[71] Ashurst, John, and Nicola Ashurst. "Chapter 1: Non-Hydraulic Lime." In *Practical Building Conservation*. Vol. 3, Mortars, Plasters and Renders. Hants, England: Gower Technical Press, 1988.

The aggregate was rinsed with de-ionized water and dried in a 110° C oven for 24 hours. The filter paper was also dried in an oven for 24 hours but at a lower 60° C temperature. The fines and aggregate were weighed again and the acid soluble portion was then determined by subtracting the known weights of the insoluble fractions from the original sample weight (Appendix C). The three fractions: fines, acid soluble fraction, and aggregate are reported as weight % as well as volume %.

Sieve Analysis and Aggregate Characterization

The aggregate portion of each sample underwent sieve analysis, according to ASTM C136-01, and was then characterized using a Leica M Stereomicroscope under normal reflected illumination at a magnification of 30x. The Munsell standard color, sphericity, roundness, and mineralogical components of the aggregate were recorded (Appendix C).

X-Ray Diffraction

X-Ray Diffraction (XRD) was used to analyze the mineralogical composition of the fines portion of the selected sample. The *enfoscado* and *enlucido* were again separated, crushed and then dried for 24 hours in a 110° C oven. Each sample was then sieved and the portion that remained in the pan (fines component) was used for XRD analysis (Appendix C). A control sample of low fired brick dust from Puerto Rico was also analyzed by XRD as a known for comparison (Appendix C).

6.3.4 Discussion

Enfoscado (rough plaster)

The two samples analyzed had very similar characteristics such as color, texture, aggregate type and grading, and binder to aggregate ratio, suggesting that they are both part of the same campaign or at least utilizing similar technologies. In addition, both samples possessed paint from the first campaign (A) placing the plasters as part of the original 17th century dome finishes.

The enfoscado lime plasters have a distinct yellowish red color which can be attributed to both the aggregate as well as the fines (Munsell 5YR 5/8, yellowish red). The majority of the aggregate particles were of clear or milky quartz which have a yellowish hue. The quartz particles were often coated by fine orange-red particulate stain. XRD analysis found the feldspar mineral albite which can be brick-red in color due to hematite staining.[72] In addition to quartzitic sand there are magnetite, brick particles and white irregular blebs of lime possibly poorly mixed calcium carbonate or partially carbonated lumps from the slaking pit. Brick-dust was a common additive to mortars for its hydraulic affect; this property is imparted to the plaster mix when the particle size is less than 300μ.[73] The *enfoscado* has course and fine brick particles acting as both a porous particulate aggregate and hydraulic fines, which also impart a red color to the mortar. The aggregate is well sorted throughout the gross sample although grading of the

---

[72] Sandstrom, Bjorn. Fracture mineralogy. Web publication Dec. 2005 http://72.14.203.104/search?q=cache:yOvBR_csrQ0J:www.skb.se/upload/publications/pdf/P-05-197webb.pdf+Albite+Brick&hl=en&gl=us&ct=clnk&cd=36

[73] Jeanne Marie Teutonico et al. The Smeaton Project: Factors Affecting the Properties of Lime Besed Mortars," *APT Bulletin*, Vol. XXV, No. 3-4, 41.

aggregate is poor with an average of 59% of the particles retained on screen ASTM No. 100 (size 150μ). The sand is sub-angular to angular with no evidence of bioclasts, which is characteristic of pit rather than beach sand.

The XRD analysis of the crushed and sieved *enfoscado*, with particle size less than 75μ, resulted in the following semi-quantitative composition: 52% calcite ($Ca\ CO_3$) attributed to the lime binder, 29.3 % quartz (SiO_2), 4% halite (NaCl) salt conamination, 10.01% albite ($Na\ Al\ SiO_3\ O_8$), and 4.4% yagite ($(Na_3\ K)_3\ Mg_4\ (Al, Mg)_6\ (Si, Al)_{24}\ O_{60}$). Albite is a mineral found in low fired (below 950°C) clayey brick; the low fired brick from Puerto Rico analyzed by XRD had a 21.0% Albite content.[74]

The binder to non-binder ratio of the *enfoscado* plaster was determined to be a very lean 1:7.5 (by volume).[75] The mortar readily disaggregates due to insufficient cohesive strength. The *enfoscado* is failing in part due to its inadequate amount of lime relative to the large volume of poorly graded aggregate and brick dust.

The presence of salts has also degraded the *enfoscado* plaster layer. Salts (as halite) are crystallizing not only on the surface of the dome and pendentives, but in areas of detachment where intra-layer separation is occurring in the plaster. With constant water infiltration, due in part to failing roof drains, missing lantern window panes and damaged impermeable roof membrane, the evaporation front now migrates through the

---

[74] Bhatnagar, J.M. "Physical and mineralogical evaluation of a brick sample from an ancient alter structure in Garhwal Himalayan Region," *Current Science* 85, no. 10 (November 2003), 1478.
[75] Volume % was determined using the density of Albite (2.1 g/cc) for Fines, and the density of Calcium Carbonate (1.92g/cc) for the acid soluble fraction.

interior of the dome rather than on the roof. EDS mapping of a sample from the Cupola illustrates the presence of chloride and sodium ions in two distinctive lifts, the first occurring at the surface of the sample, the second occurring in an area of intra-layer detachment in the plaster (Appendix D). The church's location on a small islet surrounded by the Atlantic Ocean within an active hurricane zone provides an ample source of chloride salts.

Enlucido (finish plaster)

As with the *enfoscado* samples, the two *enlucido* samples analyzed have very similar characteristics in color, texture, aggregate type and grading, and binder to aggregate ratios suggesting that they were both applied as part of the same plaster campaign or using the same technology. In addition, sample 2.18.C.2 had paint from the first campaign (A) placing the plasters as part of the original 17th century dome finishes.

The enlucido is a cream-colored lime plaster with a poorly sorted aggregate and bright white lime blebs. The cream color of the matrix can be attributed to the fines fraction which has a yellowish brown color as compared to the bright white blebs of lime. The overall color of the plaster is affected by the fines as well as the aggregate. The aggregate is composed of milky and clear quartz minerals, brick and charcoal particles, as well as trace purple and green mineral grains with round to angular sphericity and no evidence of bioclasts. The charcoal in the aggregate may be fuel contamination from the lime calcining process. XRD analysis of the crushed and sieved *enlucido*, with particle

size less than 75μ identified 83% calcite ($Ca\ CO_3$) attributed to the lime binder, 11.6 % quartz (SiO_2)(fines from aggregate) and, 5% halite (NaCl), from salt contamination.

Observations of the gross sample displayed perpendicular cracks in the *enlucido*, possibly due to shrinkage during the initial set. The *enlucido* is a fat, binder rich mix with a poorly sorted aggregate. As mentioned earlier, one attribute of the aggregate is to provide shrinkage control, which requires a well sorted and well graded aggregate. Neither is true for the plasters analyzed. The ratio of binder to aggregate after gravimetric analysis is approximately 2 parts binder:1 part aggregate (by volume). The *enlucido* also suffers from the affects of water infiltration and salt crystallization; the XRD results identified 5% of the fines fraction alone to contain chloride salts.

6.4 Characterization of stratigraphies and pigment and colorant analysis

6.4.1 Methodology

Cross Sectional Examination

In order to analyze the stratigraphy of the Rosario mural campaigns, selected samples were embedded in polyester resin (Bioplast), cross-sectioned on a variable speed microsaw (Buehler Isomet), and mounted on glass slides. The remaining samples were examined by additional techniques mentioned later. The cross-sections were examined with a Leica M Stereomicroscope under normal reflected light at 30x to 150x magnification in order to describe: the number and sequence of paint layers, their color and textures, and characteristics such as layer thickness, relative pigment to binder ratio per layer, and surface anomalies such as absence or presence of soiling and fractures.

This provided a baseline understanding and framework for continued examination and analysis.

Energy Dispersive Spectroscopy (EDS)

Energy Dispersive Spectroscopy identifies the elemental composition of a sample in a scanning electron microscope, heavier than boron. This technique measures emitted X-rays and generates fluorescence from atoms in its path. EDS output is in the form of a peaked spectra or X-ray (dot) mapping.

Ten pigment samples and two cross-sections were selected for elemental analysis. Due to the wide range of pigments throughout the six major design campaigns a subset of the group was selected. The criteria for selection included the following:

1) The first campaign (A) is highly significant for its age as well as its unique imagery. It is also considered the layer in the best condition providing the potential for both conservation and future interpretation. All identified pigments were tested. Samples of red, yellow, black, and blue-green were analyzed.

2) To better understand the evolution of the Chapel through its mural phases, specific pigments were chosen based on their potential to possibly date a campaign. Blues, greens, yellows, and whites were selected from layers C and D.

3) In addition, Campaign C is has a distinct pink ground layer as well as brown washes that were also tested, due to their prevalence and consistency throughout the dome and pendentives.

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was employed to identify organic binding media. Like EDS, FTIR analysis is based on a sample's interaction with radiation; the difference is in the type of energy. IR techniques work with infrared light and peaked spectra are created by a compound's absorption of IR radiation, Fourier Transform is a mathematical translation of the data. The absorption bands of the spectra represent functional groups which are used to identify an unknown sample especially when compared to known spectra.

Two samples were selected for FTIR analysis: the first from Campaign A, and the second from Campaign D. Attempts were made to provide pure samples for analysis in order to simplify interpretation of the resulting spectra.

6.4.2 Results

Cross Sectional Examination: 36 samples were selected for cross-sectional examination. A summary spread sheet and cross-section forms including photo-micrographs were prepared describing the number, sequence and color of paint layers (Appendix D).

Energy Dispersive Spectroscopy (EDS): ten pigment samples and two cross-sections were analyzed using EDS. The samples were coated in gold rather than carbon to improve conductivity (Appendix D).

Fourier Transform Infrared Spectroscopy (FTIR): two samples were examined using FTIR (Appendix D).

6.4.3 Discussion

The Painting of the Dome and Pendentives of the Rosario Chapel

The Rosario Chapel is comprised of six mural campaigns as outlined in Chapter 4. Through cross-sectional analysis the number and characteristics of layers used to paint those campaigns can be further explored. Due to the complexity of the mural schemes, a single sample stratigraphy cannot be used to represent the succession of campaigns. Instead, the evolution of the murals and their production must be interpreted through many samples and multiple analytical techniques. The spread sheet in Appendix D documents the layer stratigraphies as well as assigned layers to a particular mural campaign. The following sections describe the painting sequence and characterize pigments and binders for select campaigns of the Rosario Chapel dome and pendentives beginning with the first mural Campaign A, and moving sequentially to Campaign D. Campaigns E and F were not analyzed as photographic documentation provides a means of approximately dating these campaigns.

Campaign A (Mer Creatures)

Binding Media

This design layer has been directly applied to the enlucido substrate, what remains is a dense layer of pigment particles with no visible binder illustrated in samples F3.01 and P1.02.1 (Appendix D).

Sample F2.01 shows the application of paint directly on the *enlucido* plaster substrate, the paint does not penetrate the plaster layer; if this was a true (*buon*) fresco

technique the carbonation process would create a crystalline surface which would incorporate the pigments. Examination of the cross-sections supports field observation regarding the identification of *secco* painting for Campaign A (Appendix D).

EDS analysis of samples from Campaign A found calcium, carbon and oxygen: all atomic constituents of calcium carbonate (Appendix D, Samples P2.13, P2.13.2, P2.15, and P1.02). For further characterization of the binder, FTIR was conducted on a sample for the presence of organic media. FTIR analysis did not detect any organic binder; however the poor condition of the dome which has experienced substantial water infiltration, salt efflorescence, and bio-grown may have degraded any organic media once present (Appendix D, Sample P2.18G). Although an organic binder is usually required for *secco* work, limewater with pigments applied to a partially cured substrate could have been the sole means of producing this mural.

Pigments

Campaign A has a limited palette consisting of black, yellow, red, and green. Each of these colors was applied as pure red, black, yellow, or green paint without extenders or a white pigment base and without mixing with the other colors in that palette.

Black pigment: consisting of mostly black with a few brown particles. They are fine opaque, irregular splintery particles characteristic of charcoal black.[76] EDS analysis confirmed the presence of carbon (Appendix D, Sample P2.13.2). In addition, the sample

[76] Rutherford J. Gettens, and George L. Stout., *Painting Materials: A Short Encyclopedia* (New York: Dover Publications, Inc., 1942; reprint, 1966), 148c.

did not contain the element phosphorous, thereby eliminating bone or ivory black as a potential pigment. Presence of lignite was suggested by FTIR analysis; in addition, brown particles are visible through light microscopy, characteristic of lignite, a carbon black from wood coal (Appendix D, Sample P2.18G).[77] FTIR analysis of the pigment also showed that the majority of the particles scattered the IR light suggesting that most of the particles were carbon/graphitic black. The black pigment therefore appears to be primarily carbon/graphitic black and lignite (also a carbon black). These pigments have been used from pre-history to the present.

Yellow pigment: comprised of yellow particles, which are irregular spherulites characteristic of ochre.[78] EDS analysis confirmed the presences of the iron and oxygen, atomic constituents of Ochre, a hydrous iron oxide ($Fe_2O_3 \cdot H_20$) (Appendix D, Sample P2.13). Indian Yellow was an unlikely consideration from EDS spectra containing carbon, oxygen, and magnesium but was eliminated after microscope analysis of particles which do not share the prismatic, plate shape characteristic of this pigment. The yellow pigment appears to be yellow ochre which has been used since pre-history to the present.

Red pigment: comprised of minute crystal particles, characteristic of iron oxide red (red ochre). EDS analysis confirmed the presences of the iron and oxygen, both atomic constituents of red iron oxide (Fe_2O_3) (Appendix D, Sample P1.02). The red pigment therefore appears to be red ochre which has been used from pre-history to the present.

---

[77] Light Microscopy performed by Dr. Tami Lassiter-Caire.
[78] Gettens, *Painting Materials: A Short Encyclopedia*, 148.

Green Pigment: comprised of fragmented green crystals characteristic of both verdigris and malachite.[79] EDS analysis confirmed the presence of copper, carbon, and oxygen, atomic constituents of verdigris, which is a manufactured copper acetate salt $Cu(CH_3COO)_2 \cdot [Cu(OH)_2]_3 \cdot 2H_2O$ (Appendix D, Sample P2.15). Verdigris has been used since antiquity. Malachite, which is a natural copper carbonate, $CuCO_3 \cdot Cu(OH)_2$, used by Egyptians as eye paint, and in ca. 9th century Chinese paintings; it is still in use today.[80,81] The copper green pigment used is either verdigris or malachite.

In conclusion, the pigments identified in Campaign A are those with a long history of use (from pre-history or antiquity to the present). Although they do not provide a specific means of dating, they do support the 17th c date of these paintings.

The unique iconography of mer creatures (*la serena*) are also difficult to place in an art historical context. The mer creatures are used in a highly untraditional manner to adorn the Chapel of the Virgin of the Rosary. This must have had local resonance for the maritime, island culture of Puerto Rico, though it does not appear to conform to dominant traditions of European Christian iconography. Mer creatures (*la serena*) imagery is found in the ceiling vault paintings of the Cathedral *Santa Maria la Menor,* a Dominican church in *Santo Domingo* built between 1510-1540, and in the relief escutcheon of the Ponce family in the original Sanctuary of Iglesia San José.[82] Both are examples of *mer* creatures in 16th century Dominican churches located in the Caribbean, helping provide

---

[79] Ibid., 148a-b.
[80] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Joyce Plesters, 3 vols., vol. 2 (New York: National Gallery of Art, 1993), 132.
[81] Ibid., 184.
[82] http://www.dominicanrepublic.com/thecountry/art_culture.php.

precedence for the use of this imagery which pre-date the reconstructed Rosario Chapel. It is difficult, however, to use trends in Christian or Caribbean art as a tool for placing the first mural campaign in a greater art historical chronology. What can be inferred through historical research is that Campaign A may have been executed during the extensive remodeling of the Rosario Chapel which occurred between 1635 and 1641.[83]

White Layers / Campaign B (Red Faux Marbleizing)

The dome and pendentives have multiple applications of white paint. These layers vary in thickness and include white lime spheroids as well as aggregate particles. There are as many as 9 and as few as 4 distinct white layers identified during the examination of cross-sections (Appendix D, Sample F3.01 and P1.02.1). These appear to have been used to successively over-paint Campaign A. EDS analysis of cross section NAR1 identified calcium, carbon and oxygen, all atomic constituents of calcium carbonate (as limewash or whiting) (Appendix D, Sample NAR1). Between the multiple white limewash layers mentioned above is Campaign B which appears to be a simple marbleizing, executed in red paint. Examination of cross-sections found minute red crystalline particles, similar to the haematite pigment in Campaign A, with a few black particles. Little binding material is visible and the layer is primarily composed of red particles with extensive salt crystals which are visibly destructive to the paint's cohesion (Appendix D, Sample E2.03).

[83] Cuesta Mendoza, *Historia Eclesiastica Del Puerto Rico Colonial: 1508-1700.*

Campaign C (Trompe l'oeil Coffers/Angels)

Campaign C is a complex multi-layered campaign. In order to understand the cross-sections and the paint application sequence, detailed field observations were vital. As described in Chapter 4.3 the dome and pendentives have a preparatory ground layer of pink which covers all four pendentives, as well as the dome. A similar palette is shared by the pendentives and dome, incorporating umber, white and a cooler brown/ black, with light olive green and a rosy pink in the pendentive banding.

These layers vary in thickness and some samples include white lime spheroids and tinting pigment particles. EDS analysis of cross section NAR1 identified calcium, carbon and oxygen all atomic constituents of calcium carbonate (as limewash or whiting) (Appendix D, Sample NAR1). The layers are dense and generally well adhered to one another with little evidence of intra-layer fractures.

Pink ground: is often applied in two layers, the first is thicker with a pale opaque pink matrix including lime spheroids, and minute red pigment particles, the second has a slightly translucent dark tan-pink matrix with lime spheroids and the same minute red pigment particles. Sample P1.04 illustrates well the two distinct pink layers with tiny red pigment particles (Appendix D, Samples P1.04, E2.01, P2.01.3, P1.02.1, and F3.01).

Brown paint: has a bark brown matrix composed of mostly brown pigment particles, with a few large red pigment particles dispersed throughout the layer. (See

Apendix:C, photomicrograph of sample P1.04) This was applied on top of the pink preparatory ground layers.

Green paint: has a grayish matrix and includes black, ochre, and red pigment particles (Appendix D, Sample P2.07). This paint color was found on the pendentive banding as well as the arches.

Rosy pink paint: has a pink matrix with white lime spheroids, and minute, red pigment particles, it is a more heavily pigmented version of the pink ground layers (Appendix D, Sample P3.21). This has limited application and is only seen in the ½" decorative stripe painted on top of the larger olive green banding framing each pendentive.

White paint: EDS analysis confirmed the presence of calcium, carbon and oxygen all atomic constituents of calcium carbonate (chalk) (Appendix D, Sample G3.08). Only the white paint was selected for EDS analysis due to budget constraints, and for its potential to help date Campaign C. The white pigment appears to be chalk which has been used since pre-history to the present.

In the absence of datable pigments, it is possible to ascribe this campaign stylistically to the late 18th century during the completion of the nave in the 1770's. Large areas of mortar repair in the dome occur before or during this campaign and maybe attributed to the repairs of 1772 and 1776.

Campaign D (Battle of Lepanto/Evangelists)

Binding Media

This design layer was directly applied to the previous campaign with no preparatory ground. The paint layers are very thin (Appendix D, Sample E2.01) and often disrupted by extensive salt crystals which are visibly destructive to the paint's adhesion and cohesion (Appendix D, Sample P1.04). Campaign D is one of the most fragile and disturbed of all the painting campaigns. What remains in most areas is a powdered chalking surface or a brittle blistered layer of crystallized salts and pigments, with little or no binder remaining.

EDS analysis of samples from Campaign D found calcium, carbon and oxygen: all atomic constituents of calcium carbonate (as limewash or whiting) (Appendix D, Samples P 3.17, P 3.11, H4.01, G3.06 and F3.03). For further characterization of the binder, FTIR was conducted on a sample for possible presence of organic media. FTIR analysis did not detect any organic binder (Appendix D, Sample P1.06); although it did confirm the presence of calcium carbonate and gypsum. EDS analysis suggested the use of gypsum as a white pigment as well. The poor condition of the dome which has undergone substantial water infiltration may have degraded any organic media once present. The exact binding media was not determined although it does appear that an organic binder was used and has been lost to deterioration.

Pigments

Campaign D has a palette comprised of red, blue, black, white and two yellows. The pigments are often mixed to achieve variations in hue, and chroma resulting in a

highly colored composition. For example, the green examined by EDS and microscopal analysis of dispersions found that that it is comprised of yellow ochre, chrome yellow and artificial ultramarine blue (Appendix D, Sample P3.17). Color is the primary means of describing the mural unlike Campaign A which has a more linear/graphic painting style, or Campaign B which relies of monochromatic value distinctions to describe the painting.

Yellow pigment: comprised of yellow particles, which are irregular spherulites characteristic of ochre.[84] EDS analysis confirmed the presences of the iron and oxygen, atomic constituents of ochre, a hydrous iron oxide ($Fe_2O_3 \cdot H_20$) (Appendix D, Sample P2.13) Indian yellow was a consideration from EDS spectra containing carbon, oxygen, and magnesium but was eliminated after microscopal analysis of particles indicating that they did not share the prismatic, plate shape characteristic of this pigment. The yellow pigment appears to be yellow ochre, which has been used from pre-history to the present.

Lemon yellow pigment: comprised of fine prism grains characteristic of chrome yellow.[85] EDS analysis confirmed the presences of lead, chrome, and oxygen, all atomic constituents of chrome yellow, a lead chromate ($PbCrO_4$) (Appendix D, Sample F3.03). Crocoite, a rare natural mineral of lead chromate, was first officially described in 1797.[86] In 1800, laboratory synthesis of heavy metal chromates began, but it was not until 1815 that chromates were used as artist's pigments, which are still manufactured today. [87,88] It

[84] Gettens, *Painting Materials: A Short Encyclopedia*, 148.
[85] Ibid., 148a.
[86] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Robert L. Feller, 3 vols., vol. 1 (New York: National Gallery of Art, 1987), 189.
[87] Ibid., 190.
[88] Ibid., 189.

is likely that the lemon yellow colored pigment used in Campaign D is synthetic lead chromate. This would place the painting after 1815.

Blue pigment: comprised of uniform small round grains characteristic of artificial ultramarine blue.[89] EDS analysis confirmed the presences of oxygen, silicon, aluminum, sodium, all atomic constituents of natural and artificial ultramarine (Appendix D, Sample H4.01). FTIR also confirmed the presence of ultramarine (Appendix D, Sample P1.06). The earliest known use of natural ultramarine is in wall paintings of Bāmiyān, Afghanistan (the most famous source of the mineral lapis lazuli), from the sixth or seventh century A.D.[90] The high cost of natural ultramarine and the manufacture of synthetic ultramarine diminished the use of the natural version by the mid 19th century. The first recorded observation of synthetic ultramarine was dated to 1787, when deposits were discovered on the walls of lime kilns.[91] In 1828, Jean Baptist Guimet synthesized ultramarine in the laboratory and developed an affordable manufacturing process; by 1830, Guimet established a factory in France to make artificial ultramarine, which became the dominate alternative to the expensive natural version.[92]

Pigment dispersions of sample H4.01 was compared to known dispersions of both natural and synthetic ultramarine prepared by the McCrone Company. From observations under transmitted light using a Nikon AFX-IIA microscope, the blue pigment particles from Campaign D closely resembled the artificial ultramarine in particle shape and size (Appendix D, Sample H4.01 and the previously mentioned

[89] Gettens, *Painting Materials: A Short Encyclopedia*, 148b.
[90] *Artists' Pigments: A Handbook of Their History and Characteristics*, 39.
[91] Ibid.
[92] Ibid.

knowns). The mural in Campaign D depicts the Battle of Lepanto with the majority of the dome and pendentives composed of blue water or sky, this would have been extraordinarily expensive to execute in natural ultramarine. From microscopal observations, EDS analysis, and the shear volume of blue required to execute this mural it is likely that the blue pigment in Campaign D is synthetic ultramarine. This would place the painting after the 1830 manufacture and availability of synthetic ultramarine.

White pigment: comprised of fine pinnate crystal grains characteristic of gypsum rather than hollow spherulites of calcium carbonate (chalk). [93] EDS analysis confirmed the presence of oxygen, carbon and sulpher, all atomic constituents of gypsum, $CaSo4{\cdot}2H_20$ (Appendix D, Sample G3.06). Chalk is also a potential pigment which is calcium carbonate, $CaCO_3$. The white pigment appears to be gypsum which may have been used in combination with chalk; both have been used since pre-history to the present.

The use of chrome yellow and synthetic ultramarine pigments clearly place this campaign in the early mid 19th c. The pigment dates suggest that the Battle of Lepanto was a mural painted during the extensive renovations made between 1860 and 1863, after the transfer of stewardship of Iglesia San José from the Dominican to the Jesuit order. The church had undergone more than thirty years of neglect prior to this transfer, during which funds for structural repairs and maintenance were denied to the caretaker.[94]

---

[93] Gettens, *Painting Materials: A Short Encyclopedia*, 147.
[94] De Hostos, *Historia De San Juan, Ciudad Murada*.

7 Conclusions and Recommendations

Iglesia San José is a highly significant and unique cultural resource on many levels. The church exists today as a record of almost 500 years of evolution in religious thought, icnonography, and stewardship, as well as a record of Spanish colonialism in the Caribbean and more specifically Puerto Rico. In an effort to gain a complete understanding of the church's progression through time, a series of studies referenced throughout this document have provided important information and insight. The fundamental objective for this study was to provide a technical analysis of the Rosario Chapel murals, the only area within Iglesia San José with a complete, extant stratigraphic history of interior surface finishes. This baseline information provided the opportunity to document and interpret the transformations the Rosario Chapel has undergone since its 17th century construction. This study offers a technical analysis of materials and techniques used to execute the painting campaigns, and are a foundation from which future collaborative study and interpretation may continue.

As outlined in the statement of purpose, the primary objectives of this investigation were:

1) To document existing mural campaigns.

2) To establish a chronology of mural painting through analysis of materials and techniques.

3) To evaluate the conditions of the paintings and to determine possible deterioration mechanisms.

4) To propose recommendations for their conservation and interpretation.

Mural documentation

Previous site documentation of this particular chapel was scant, and provided very little in terms of supporting historical documentation to answer questions about the *Rosario* Chapel wall paintings. This investigation documented the mural campaigns, described their evolution, and placed these layers in a chronology. The photographic documentation and condition survey (produced for a separate report) offers a detailed record of the Chapel as it existed between October 2005 and January 2006. This may be used to monitor conservation interventions and aid in the eventual interpretation of the chapel. Beyond the documentation provided herein, a detailed digital photographic record was made of all dome and pendentive surfaces in January 2006.

Chronology of mural painting

Through the analysis of cross-sections, Campaign A was placed as the original painting phase with direct application to the original 17th century *enlucido* (plaster finish coat). Campaigns B and C would have been painted anytime between 1640 and 1860; this study found no evidence that would attribute a more precise date to these two campaigns. It is reasonable to assume given the quality of design and execution of Campaign C, that is was associated with the completion of the nave in the 1770's. Interpretation of the pigment analysis in Campaign D (The Battle of Lepanto) places it in the mid-19th

century, corresponding to extensive renovations carried out by the Jesuit Order between 1860 and 1863. Photographic images of the Rosario Chapel in 1890 and 1935 place the painting of Campaign E between these dates. Lastly, campaign F was painted between 1935 and 1960. While exact dates are impossible to establish for each of the painting campaigns, analysis was able to help attribute Campaigns A, B and C to the Dominican Order, Campaign D to the Jesuit Order, and Campaigns E and F to the Vincention Order. Topics in religious and aesthetic trends, as well as art/architectural preferences for those time periods, are areas of further research that could provide further insight into the evolution of the Rosario Chapel and its decoration.

Condition and Deterioration Mechanisms

As mentioned earlier, the most distressing condition present on the Rosario Chapel is that of plaster and paint detachment with the potential for total loss. An emergency stabilization project was undertaken between January and March of 2006 to address this imminent threat, the results of which are part of a separate report. While stabilizing certain areas of the dome and pendentives was critical to the persistence of the structure, both understanding the causes for its current condition and remedying those factors are also of critical importance to the preservation of the Rosario Chapel murals.

At present, most of the detachment is occurring within the *enfoscado* (rough plaster) layers. To further understand why this is occurring, mortar analysis was performed. Results indicated that the *enfoscado* is a very lean plaster mix with an insufficient ratio of lime binder (1:7). Although the brick dust present was presumable

added to render the plaster hydraulic, its large quantity has adulterated the strength of the plaster. EDS analysis and on-site observations showed that extensive salt crystallization has occurred between the multiple layers of *enfoscado,* further exacerbating the problem of cohesive and adhesive strength. While the binder lean plaster of the *enfoscado* is an intrinsic problem, which potentially requires a consolidation treatment, it is aggravated by continued water infiltration; this has contributed to threatening mechanisms of deterioration. Chloride salts, water and biological growth have contributed to failing paint layers and plasters. It is vitally important to improve issues of water ingress through appropriate roof restoration. A study of hydraulic brick-dust mortars for use as potential exterior renders is being conducted in a separate report.

Recommendations

The evaluation and assignment of significance for the individual painting campaigns is based on condition and my acknowledged outsider view of the iconography. I am not an expert on theology or the culture and history of Puerto Rico, nor do I represent the views of stakeholders such as the Catholic Archdiocese of Puerto Rico. Therefore, it is my first recommendation that all decisions be made as part of a collaborative and transparent process involving appropriate scholars, conservation practitioners and representatives of the church for the most comprehensive and meaningful interpretation and treatment of the Rosario Chapel murals. The following discussion is intended to help inform that process.

The six identified mural campaigns range in terms of their condition as well as significance. The first mural campaign (A), is the most intact of the 6 campaigns on the

pendentives. The limewashes used to paint over the original mer imagery have served as protective layers. It is more difficult to assess the extant Campaign A murals on the dome due to successive over-painting. Large areas of repair were noted and illustrated in the campaign maps, although further stratigraphic analysis and sampling would need to be performed to in order to determine the location of early repairs that have been painted over with later campaigns. The northwest portions of the dome, as well as Pendentive 3, have suffered most from the effects of water infiltration, affecting all 6 campaigns in these areas.

I believe the mer creature iconography used in Campaign A is the most intriguing and significant imagery in the Rosario Chapel murals. The mer creatures are used in a highly untraditional manner which must have had local resonance for the maritime, island culture of Puerto Rico, a subject warranting further research and interpretation by a Caribbean cultural/religious scholar.

Mer creature imagery is found elsewhere in the Caribbean; in the ceiling vault paintings of the Cathedral *Santa Maria la Menor,* and in the relief escutcheon of the Ponce family in the Sanctuary of Iglesia San José. However, the Rosario Chapel is unique in that mer creatures are represented in monumental scale, and are the dominant iconographic features in the chapel. The mer layer is the most visually legible in the chapel, and has the greatest surface area remaining on the pendentives and potentially the dome. I believe that conservation efforts would be most successful if the dome and pendentives were restored to the first campaign (A). This would allow the chapel to be read as a single scheme rather than the fractured and visually confusing space that exists

today. With this said, one of the features that makes the Rosario Chapel so significant within the church is its stratigraphic history; there is a compelling story to tell based on the over 300 years of alterations that are currently evident. Interpretation of the later campaigns (B-F) could be included in the chapel's interpretation by preserving removed sections of the later mural fragments using *strappo* techniques and placing them on display.

The Rosario Chapel murals are highly significant and warrant a comprehensive strategy for their conservation and interpretation. As mentioned earlier, the most effective method for preparing such a plan requires a collaborative process involving all stakeholders. The interpretation and presentation of the Rosario Chapel have the potential to tell a rich story of religious and cultural ideals brought to the island through Spanish colonialism, subsequently transformed through the unique perspective of Puerto Rican island culture. This study of the mural paintings of the *Capilla de la Virgen del Rosario* offers insight into the chapel's evolution; the next phase of interpretation now lies in the hands of the Archdiocese and the people of Puerto Rico.

Bibliography

Apostolos-Cappadona, Diane. *Dictionary of Christian Art*. New York: Continuum Publishing Company, 1994.

Ashurst, John, and Nicola Ashurst. "Chapter 1: Non-Hydraulic Lime Mortars, Plasters and Renders," *Practical Building Conservation, Vol. 3*. Hants, England: Gower Technical Press, 1988.

Bassegoda Nonell, Juan. *La Ceramica Popular De La Arquitectura Gotica*, *Serie De Historia De La Arquitectura Y Del Urbanismo ; No. 8; Publicaciones De La Universidad Politécnica De Barcelona.* Barcelona: Ediciones de Nuevo Arte Thor, 1978.

Bhatnagar, J.M. "Physical and mineralogical evaluation of a brick sample from an ancient alter structure in Garhwal Himalayan Region," *Current Science* 85, no. 10, November 2003.

Bicheno, Hugh. *Cresent and Cross: The Battle of Lepanto 1571*. London: Cassell, 2003.

Burucúa, José Emilio, et al. *Tarea De Diez Años*. Translated by Ann Write and Kate Clayton. Edited by Gabriela Siracusano. Buenos Aires, Milan: Ediciones Fundación Antorchas, 2000.

Butler, William B. "The Avila Adobe: The Determination of Architectural Change." *Historical Archaeology,* 7 (1973): 30-45.

Cabris, Eric. "Il Restauro Delle Galeries Saint-Hubert a Bruxelles." *Tema: tempo materia architettura*, no. 1 (1999): 20-26.

Carden, Marie L. "Use of Ultraviolet Light as an Aid to Pigment Identification." *APT Bulletin* XXIII, no. 9 (1991): 26-37.

Casarino, Alessandra and Pittaluga, Daniela. "An Analysis of Building Methods: Chemical-Physical and Archaeological Analyses of Micro-Layer Coatings on Medieval Facades in the Centre of Genoa." *Journal of Cultural Heritage* 2, no. 4 (2001): 259-75.

Chand, Hot and Shashi Prabha Swami. *Studies in Art and Archaeological Conservation: Dr. B.B. Lal Commemoration Volume.* Delhi : Agam Kala Prakashan, 2004.

Charola, A.E. et al. "Analysis of the Colour Traces Found on the Cloister of the Jeronimos Monastery in Lisbon." *Internationale Zeitschrift für Bauinstandsetzen* 8, no. 5 (2002): 447-74.

Cosenitino, A. et al. "Characterization of Pictorial Pigments by Raman Spectoscopy." Paper presented at the 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage, Antwerp, Belgium, 2-6 June 2002.

Cremades Gracía, Patricia, et al. "Roman Polychrome Ceiling of La Casa De Los Delfines, Velilla De Ebro (Zaragoza, Spain): Treatment of the Ceiling of La Casa De Los Delfines; Analysis of the Paintings Found on the Ceiling of La Casa De Los Delfines of Velilla De Ebro." *Kausis: revista de la Escuela Taller de Restauración de Pintura Mural de Aragón II* 1, no. 1 (2004): 15-24.

Cuesta Mendoza, Antonio. *Historia Eclesiastica Del Puerto Rico Colonial: 1508-1700.* Translated by Beatrice del Cueto. Rupublica Dominica: Arte y Cine, 1948.

David, A. Rosalie, et al. "Raman Spectroscopic Analysis of Ancient Egyptian Pigments." *Archaeometry* 43, no. 4 (2001): 461-73.

Davila, Auturo "Arzobispado De Santo Tomas De Aquino Y La Cultura Puertorriquena." *San Juan: Boletin de la Academia Puertorriquena de la Historia* XIX, no. 55 (1998).

De Hostos, Adolfo. *Historia De San Juan, Ciudad Murada*. Translated by Beatrice del Cueto. Barcelona: Manuel Pareja, 1966.

del Cueto, Beatrice. "Annotated Chronology of Iglesia San Jose, San Juan, Puerto Rico." (Unpublished report: Pantel, del Cueto & Associates, San Juan, 2005).

Delgado Mercado, Osiris. *Historia General De Las Artes Plasticas En Puerto Rico*. Translated by Beatrice del Cueto, *Iglesia Conventual De Santo Tomas (Hoy De San Jose)*. San Juan: Tomo I, 1994.

Derrick, Michele . *Infrared Spectroscopy in Conservation Science*, *Scientific Tools for Conservation*. Los Angeles: The Getty Conservation Institute, 1999.

Derrick, Michele and Melena Gergen. *Methods in Scientific Examination of Works of Art. Volume 3, Thin-Layer Chromatography Reference Materials Binder.* . Los Angeles: The Getty Conservation Institute, 1994.

Derrick, Michele, Luiz Souza, Tanya Kieslich, Henry Florsheim, and Dusan Stulik. ."Embedding Paint Cross-Section Samples in Polyester Resins: Problems and Solutions. ." *Journal of the American Institute for Conservation* 33 (1994): 171-84.

Eastaugh, Nicholas. "Inside Story: Art and Analysis. Part 2, Sampling." *The Picture Restorer* 10 (1996): 16-17.

Edwards, H.G.M., F. Rull, P. Vandenabeele, E.M. Newton, L. Moens, J. Medina and C. Garcia. "Mediaeval Pigments in the Monastery of San Baudelio, Spain: A Raman Spectroscopic Analysis." *Applied Spectroscopy* 55, no. 1 (2001): 71-76.

"DR: Art and Culture." http://www.dominicanrepublic.com/thecountry/art_culture.php

Farrell, Eugene. "Techniques in Paint Analysis." Edited by Roger W. Moss, *Paint in America,the Colors of Historic Buildings*. New York: John Wiley and Sons, INC., 1994.

Ferro, Maximillian L. "New Directions in Architectural Conservation: The Role of Physical Evidence." *Technology & Conservation*, no. 1 (1976): 14-17.

Froment, Françoise, Claude Coupry, and Juliette Rollier-Hanselmann. "Raman Studies of Medieval Wall Paintings." Paper presented at the Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage, Antwerp, Belgium, 2-6 June 2002.

Gettens, Rutherford J., and George L. Stout. *Painting Materials: A Short Encyclopedia*. New York: Dover Publications, Inc., 1942. Reprint, 1966.

Gilmore, Andrea M. "Analyzing Paint Samples, Investigation and Interpretation." Edited by Moss. Roger W., *Paint in America,the Colors of Historic Buildings*. New York John Wiley and Sons, INC., 1994.

Gowing, Robert. "Investigating Wall Paintings: Seeing Is Believing." *English Heritage Conservation Bulletin*, no. 45 (2004): 30-32.

HABS Collection. Call No. HABS, PR, 7-SAJU,1-20.

Hayez, V., et al. "Study of the Composition of the Pigments Used in the Christ "Maiestas Domini" Painting of the Ename Church by Means of Micro Raman Spectroscopy." Paper presented at the Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage, Antwerp, Belgium, 2-6 June 2002.

Heeren, Ron M.A., Jaap J. Boon, Petria Noble and Jørgen Wadum. "Integrating Imaging FTIR and Secondary Ion Mass Spectrometry for the Analysis of Embedded Paint Cross-Sections." Paper presented at the 12th triennial meeting (ICOM Committee for Conservation), Lyon 1999.

Henderson, Louise. "Liberty Cinema: Architectural Paint Research in Practice." *English Heritage Conservation Bulletin*, no. 42 (2002): 80-81.

Holchleitner, B., et. al. "Analysis of Paint Layers by Light Microscopy, Scanning Electron Microscopy and Synchrotron Induced X-Ray Diffraction." Paper presented at the Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage, Antwerp, Belgium, 2-6 June 2002.

Hradilová, Janka, David Hradil, Petr Bezdicka and Tomáš Grygar. "New Analytical Methods and Approaches in the Analysis of Chromatic Layers." *Sborník z Konzervátorského a Restaurátorského Semináre* (2004): 54-58.

Hřebíčková, Barbora. "The Microscopic Identification of Pigments." *Technologia Artis: Yearbook of the Archives of Historical Art Technology Prague* 4 (1996): 84-92.

Hyman, Marian, Solveig A.Turpin and Michael E.Zolensky. "Pigment Analyses from Panther Cave, Texas." *Rock Art Research* 13, no. 2 (1996): 93-103.

Járo, Márta. "Comparison of the Painting Materials Used for Wall Painting in Four Sites of the Roman Province Pannonia." Paper presented at the Roman wall painting: materials, techniques, analysis and conservation: proceedings of the International Workshop, Fribourg, 7-9 March 1996.

Jonsson, Marita and E. Blaine Cliver. "Coloring Historic Stucco: The Revival of a Past Technique in San Juan, Puerto Rico." *APT Bulletin* 33, no. 4 (2002): 31-36.

Kagan, Judith. "La "Galerie Des Antiques" Du Château De Tanlay." *Monumental: revue scientifique et technique de la Sous-direction des monuments historiques, Direction du patrimoine*, no. 2 (1993): 25-37.

Kappers, Lisette and Jors Molenaar. "De Kleuren Van Huis Sonneveld: Reconstructie Van Een Sfeervol Interieur Uit De Nieuwe Zakelijkheid." *CR: interdisciplinair vakblad voor conservering en restauratie* 2, no. 3 (2001): 38-47.

Katsibiri, Olga, Brian Singer and Jim Devenport. "Some Aspects of the Technique and Materials Used for Mordant Gilding on Byzantine Icons and Wall Paintings." Paper presented at the Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage, Antwerp, Belgium, 2-6 June 2002.

Kelley, Stephen J. "Preserving Our Past for the Future." *ASTM Standardization News* 18, no. 12 (1990): 28-31.

Klockenkaemper, R., A. von Bohlen, L. Moens and W. Devos. "Analytical Characterization of Artists' Pigments Used in Old and Modern Paintings by Total-Reflection X-Ray Fluorescence." *Spectrochimica acta. Part B, Atomic Spectroscopy* 48, no. 2 (1993): 239-46.

Konstam, Angus. *Lepanto 1571: The Greatest Naval Battle of the Renaissance*. Westport: Preager Publishers, 2005.

Littmann, Edwin R. "Maya Blue, a New Perspective." *American Antiquity* 45, no. 1 (1980): 87-100.

Magaloni, Diana, R. Newman, L. Baños, Victor M. Castaño, Renato Pancella and Y. Fruh. "An Analysis of Mayan Painting Techniques at Bonampak, Chiapas, Mexico." Paper presented at the Materials issues in art and archaeology IV, Cancun, Mexico, May 16-21, 1994.

Magar, V. and V. Davila. "Considerations on the Dating of Rock Art from the Sierra De San Francisco, Baja California, Mexico." *Rock Art Research* 21, no. 2 (2004): 129-36.

Mairinger, F. and M. Schreiner. *New Methods of Chemical Analysis-a Tool for the Conservator*, *Science and Technology in the Service of Conservation*. Washington, D.C: IIC Congress, 1982.

Malenka, Sally and Beth A. Price. "The Chinese Reception Hall: Research and Conservation of the Painted Decoration." *Bulletin (Philadelphia Museum of Art)* 92, no. 389-390 (2004): 30-47.

Manzano, E., A. Bueno, A. González-Casado and M. Olmo. "Mortars, Pigments and Binding Media of Wall Paintings in The "Carrera Del Darro" In Granada, Spain." *Journal of Cultural Heritage* 1, no. 1 (2000): 19-28.

Matero, Frank G. "Paintings and Coatings." Edited by Martin E. Weaver and Frank G. Matero, In *Conserving Buildings: Guide to Techniques and Materials*. New York: John Wiley, 1993.

Matteini, Mauro, Rocco Mazzeo and Irina Crina Anca Sandu. "Labs Tech European Survey on Methods and Materials for the Conservation of Cultural Heritage: Results and Perspectives." *Technè: la science au service de l'histoire de l'art et des civilisations* 21 (2005): 126-30.

McKee, Harley J. *Introduction to Early American Masonry, Stone, Brick, Mortar, and Plaster*. Washington: National Trust for Historic Preservation, 1973.

Middendorf, B. "Rilem Tc 167-Com: Investigative Methods for Characterization of Historic Mortars." In *Characterization of Old Mortars with Respect to their Repair*: RILEM, 2005.

Miliani, Costanza, et al. "Study of the Pictorial Technique of an Archaic Mural Painting from the Area of the Hypogeum of C. Genucius Clepsina (Cerveteri).)." *Science and Technology for Cultural Heritage* 12, no. 1-2 (2003): 91-97.

Molinas, Bernardo, et al. "Evolution of the Color and Carbonation Phenomenon in Frescoes." *Arkos: Scienza e Restauro* 5, no. 7 (2004): 36-43.

Mora, P, L. Mora, and P. Philippot. *Conservation of Wall Paintings*. Boston: Butterworths, 1984.

Moreno, Thomas, S. Marvel and Maria Luisa. *La Arqutectura De Templos Parroquiales De Puerto Rico*. Rio Piedras: Universidad de Puerto Rico, 1984.

Myers, Catherine S. "A Discussion of Mural Painting Technique: Constantino Brumidi's Paintings at the United States Capitol." *Postprints (American Institute for Conservation of Historic and Artistic Works. Paintings Specialty Group)* (1996): 14-18.

Perrault, Carole Louise. "Point of View. An Architectural Conservator. 1) Learning through the Lens of the Microscope. 2) Artifacts of the Architectural Conservator: An Approach to Their Care and Use." *CRM* 17, no. 9 (1994): 16-20.

———. "Techniques Employed at the North Atlantic Historic Preservation Center for the Sampling and Analysis of Historic Architectural Paints and Finishes." *APT Bulletin* 10 (1978): 6-46.

Pezzola, Riccardo. "Le Facciate Del Palazzo Municipale Di Morbegno." *Arkos: Scienza e Restauro* 6, no. 9 (2004): 70-73.

Plesters, Joyce. "Cross-Sections and Chemical Analysis of Paint Samples." *Studies in Conservation* 2 (1956): 110-57.

Rees-Jones, Stephen. "Early Experiments in Pigment Analysis." *Studies in Conservation* 35, no. 2 (1990): 93-100.

Rigau, Jorge. "World Monument Fund Nomination." San Juan, 2004.

Roascio, Stefano, Alessandro Zucchiatti, Paolo Prati and Aurora Cagnana. "Study of the Pigments in Medieval Polychrome Architectural Elements Of "Veneto-Byzantine" Style." *Journal of Cultural Heritage* 3, no. 4 (2002): 289-97.

Salam, Abd El, and Safaa A. "Analytical Techniques Used in the Examination of Materials of Wall Paintings from the Ancient Sites of Mustafa Pasha and Anfushi in Alexandria." Paper presented at the 6th International Conference on "Non-Destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage": Rome, May 17th-20th 1999: proceedings. Marabelli, Maurizio and Parisi, Concetto, Editors. Italian Society for Nondestructive Testing, Rome 1999.

Sandstrom, Bjorn. *Fracture mineralogy,* 2005. Web publication http://72.14.203.104/search?q=cache:yOvBR_csrQ0J:www.skb.se/upload/publications/pdf/P-05-197webb.pdf+Albite+Brick&hl=en&gl=us&ct=clnk&cd=36

Schostak, Volker, Wolfgang Fünders, Bernhard Recker, Gerhard Drescher, and Herbert Juling. "Konservierungstechniken Für Die Wandmalerei in Der Kirche in Eilsum/Ostfriesland. Restauratorische Und Naturwissenschaftliche Gesichtspunkte." *Restauro: Zeitschrift für Kunsttechniken, Restaurierung und Museumsfragen* 101, no. 4 (1995): 252-58.

Seldes, Alicia M., et al. "Blue Pigments in South American Painting (1610-1780)." *Journal of the American Institute for Conservation* 28, no. 2 (1999): 100-23.

Tobar, P.Emilio. *San Jose Church La Iglesia De San Jose: Templo Y Museo Del Pueblo Puertorriqueno*. San Juan: Imprenta la Milagrosa, 1963.

Tomkiewicz, Carolyn J. "Spanish Colonial Paintings at the Brooklyn Museum: Some Technical Observations." *Postprints (American Institute for Conservation of Historic and Artistic Works. Paintings Specialty Group)* (1995): 103-14.

Townsend, Joyce H. "Microscopy and Paintings." *Microscopy and Analysis* 39 (1994): 11-13.

Tsang, Jia-sun and Roland H.Cunningham. "Some Improvements in the Study of Cross Sections." *Journal of the American Institute for Conservation* 30 (1991): 163-77.

Teutonico, Jeanne Marie, et al. "The Smeaton Project: Factors Affecting the Properties of Lime Besed Mortars," *APT Bulletin*, Vol. XXV, no. 3-4.

van der Weerd, Jaap; Ron M.A. Heeren and Jaap J. Boon. "Preparation Methods and Accessories for the Infrared Spectroscopic Analysis of Multi-Layer Paint Films." *Studies in Conservation* 49, no. 3 (2004): 193-210.

Wachowiak, Melvin Jr. "Efficient Methods for Embedding Paint and Varnish Samples for Microscopy." *Journal of the American Institute for Conservation* 43, no. 3 (2004): 205-26.

Waddington, Jane. "A Colourful Business." *Context*, no. 41 (1994): 22.

Wainwright, Ian N.M.; Moffatt, Elizabeth A.; Sirois, P. Jane; and Young, Gregory S. *Analysis of Wall Painting Fragments from the Mogao and the Bingling Temple Grottoes.*, *Conservation of Ancient Sites on the Silk Road: Proceedings of an International Conference on the Conservation of Grotto Sites.* . Los Angeles: The Getty Conservation Institute, 1997.

Wallert, Arie and Elston, Maya. "Fragments of Roman Wall Painting in the J. Paul Getty Museum: A Preliminary Technical Investigation." Paper presented at the Roman wall painting: materials, techniques, analysis and conservation: proceedings of the International Workshop, Fribourg 7-9 March 1996., Fribourg, 7-9 March 1996.

Walsh, Valentine and Kieslich, Tanya L. "Cross Sections: Their Preparation and Use. Easy Sections: A More Accessible Way." *Conservation News (United Kingdom Institute for Conservation of Historic and Artistic Works)* 68 (1999): 43-46.

Weaver, Martin. "Preliminary Conservation Study Interim Emergency Report on the Vault of the Sacristy of the Church of San Jose, Old San Juan, Puerto Rico." (Unpublished report, Martin Weaver Conservation Consultant Inc. and UMA Engineering Ltd., 1998).

Web Gallery of Art. "Battle of Lepanto". www.wga.hu/html/v/veronese/z_other/lepanto.html

Welsh, Frank S. "Microchemical Analysis of Old Housepaints with a Case Study of Monticello." *The Microscope* 38, no. 3 (1990): 247-57.

Whittington, Trevellyan V. "Paint Fundamentals." Edited by Guy Weismantel, *Paint Handbook*. New York: McGraw-Hill, Inc., 1981.

FIGURES

Figure 1: South elevation of *Iglesia San José*. The Rosario Chapel features a red dome with white petals. (Source: Pantel y del Cueto& Associates, 2002)

Figure 2: 1625 illustration of San Juan (then Puerto Rico) with detail of *Iglesia San José* in upper left corner. (Source: Supelveda, 1989)

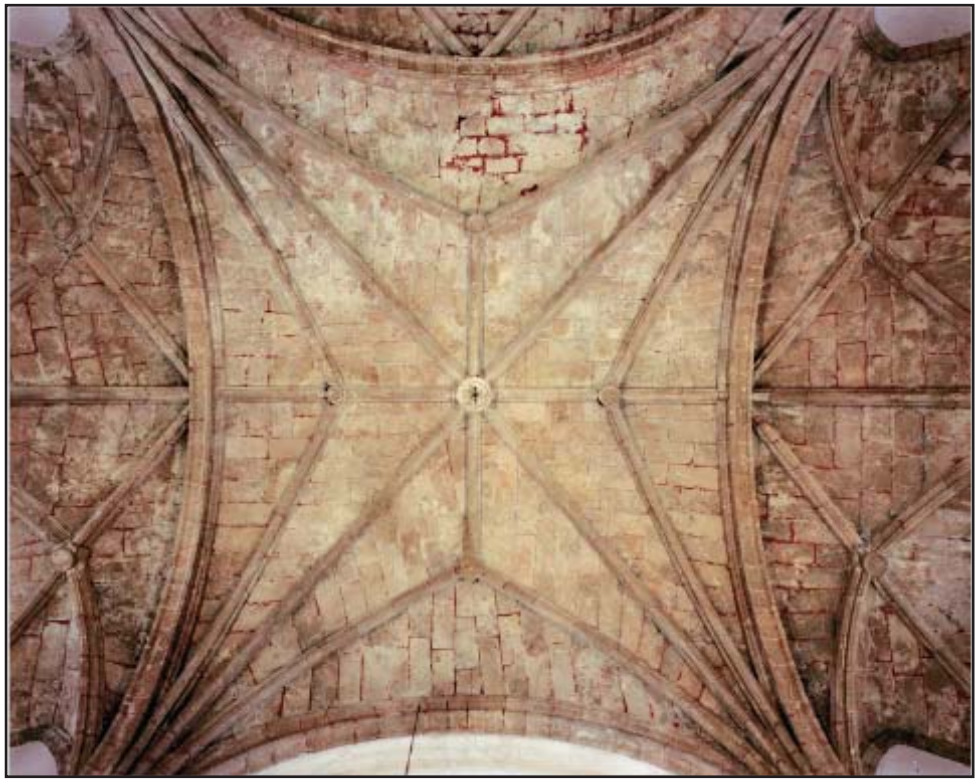


Figure 3: Stelliform groin vaulted ceiling of the Sanctuary.
(Source: Pantel y del Cueto & Associates, 2002)

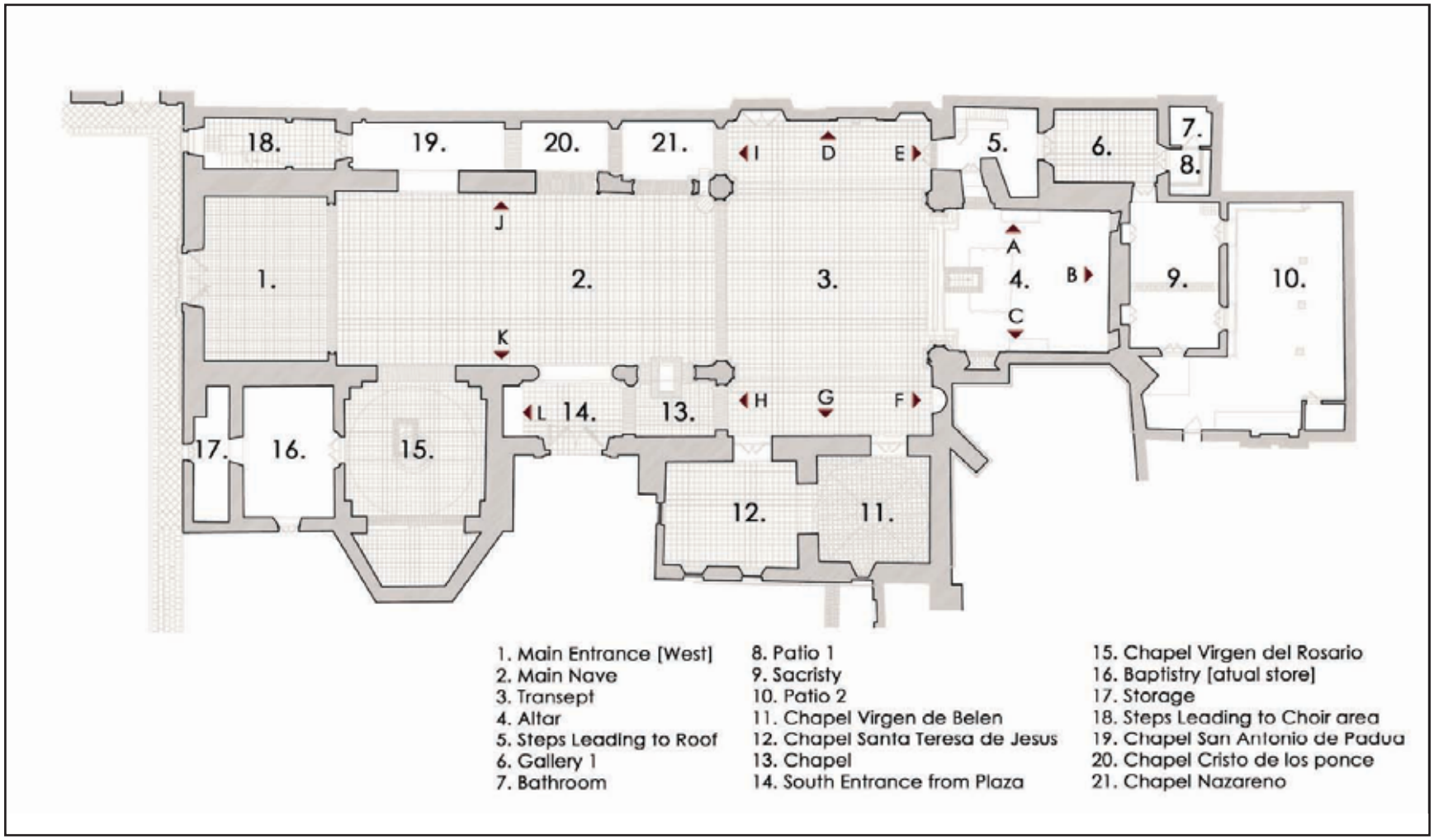


Figure 4: Plan of *Iglesia San José.* (Source: Pantel y del Cueto & Associates)

Figure 5: View of nave barrel vault from the choir loft. Rosario Chapel to the rear right. (Source: C. Silva, 2006)

Figure 6: Rosario Chapel roof with buttress supports. (Source: C. Silva, 2006)

Figure 7: Circa 1890 photograph taken from the Nave looking towards the Transept and Sanctuary.
(Source: Antonio Daubón, private collection)

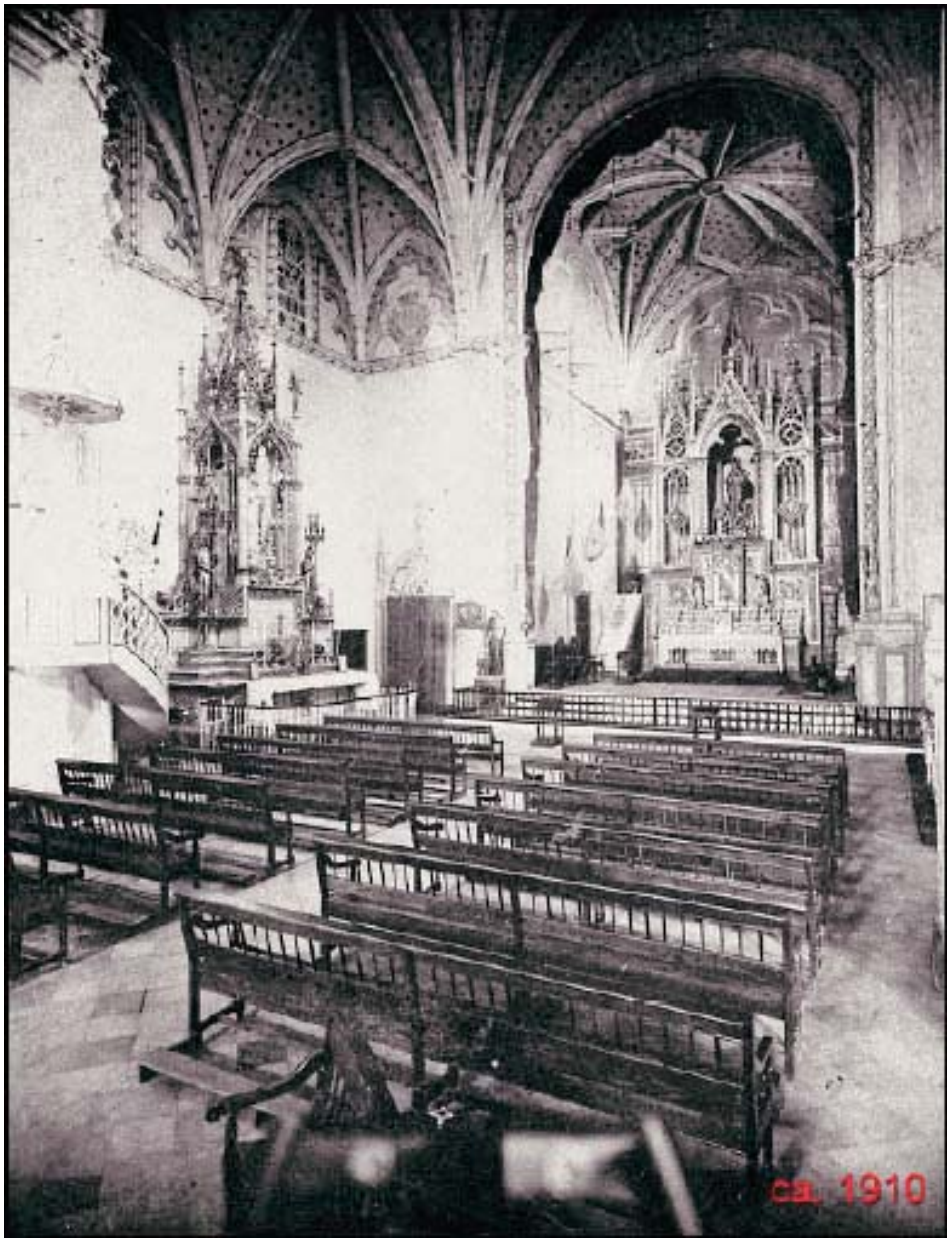


Figure 8: Circa 1910 photograph taken from the transept looking towards the sanctuary. (Source: Antonio Daubón, private collection)

Figure 9: Circa 1935 photograph taken from the sanctuary looking toward the nave. (Source: HABS, PR, 7-SAJU,1-20)

Figure 10: Circa 1980 interior excavation and restoration.
(Source: Pantel y del Cueto & Associates)

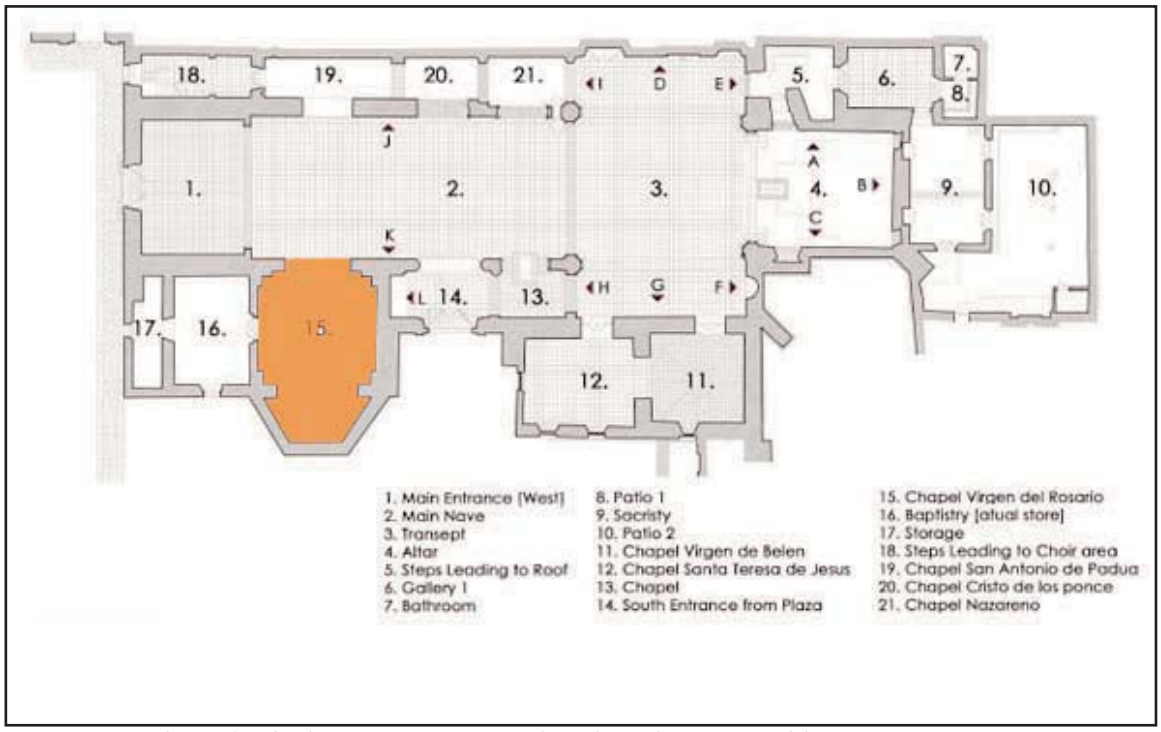


Figure 11: Plan of Iglesia San José, Rosario Chapel annotated in orange.
(Source: Pantel y del Cueto & Associates)

Figure 12: South elevation of Iglesia San José, Rosario Chapel located west (left) of the scaffolding. (Source: C. Silva, 2005)

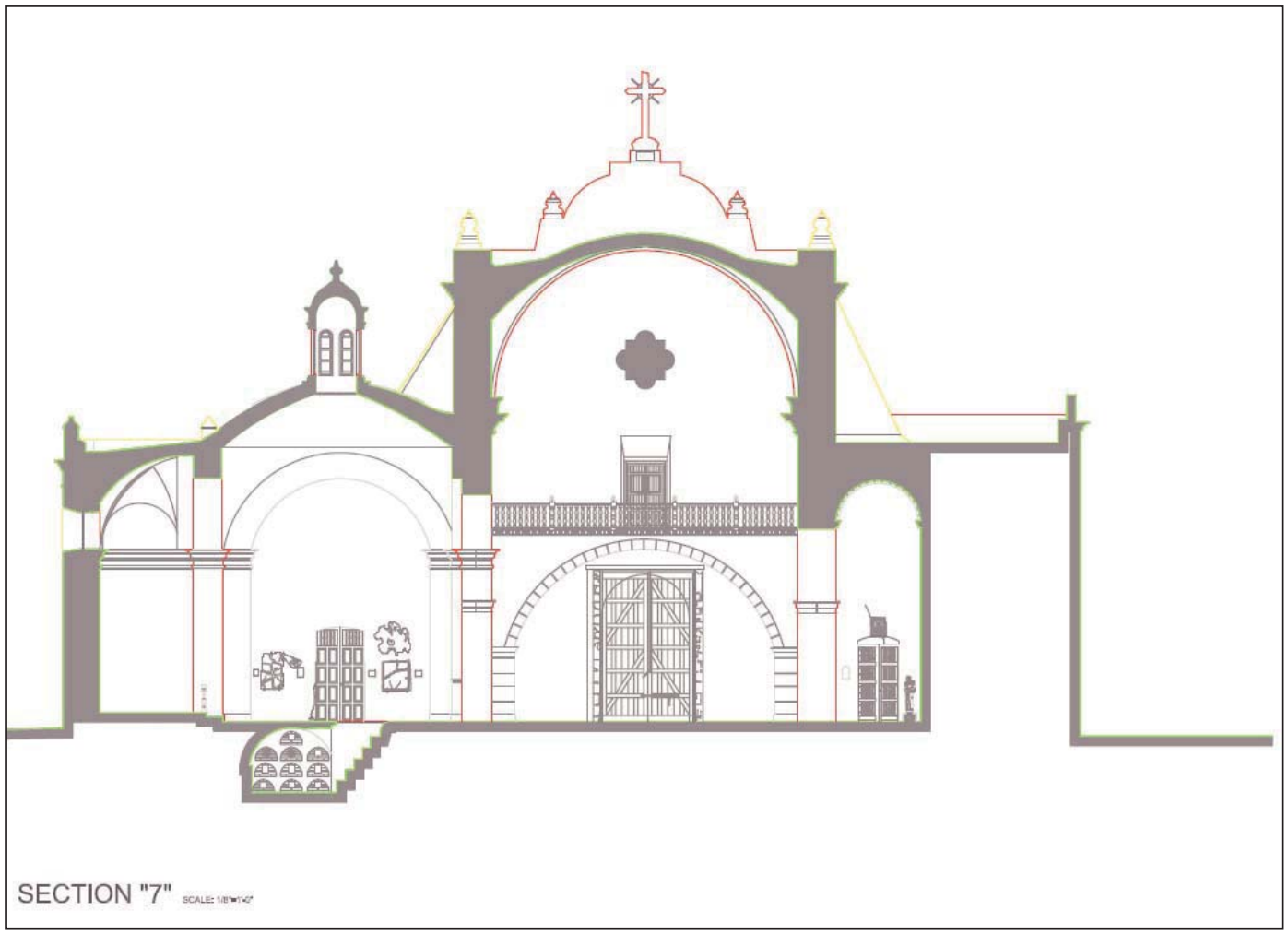


Figure 13: Section of *Iglesia San José*, Rosario Chapel located on the left.
(Source: Pantel y del Cueto & Associates)

Figure 14: Interior of the Rosario Chapel, (left 1981, right 2004). (Source: Pantel y del Cueto & Associates)

Figure 15: Rosario Chapel interior dome. (Source: Joseph Elliott, 2004)

Figure 16: Pendentive 1, southeast corner of Rosario Chapel.
(Source: Joseph Elliott, 2004)

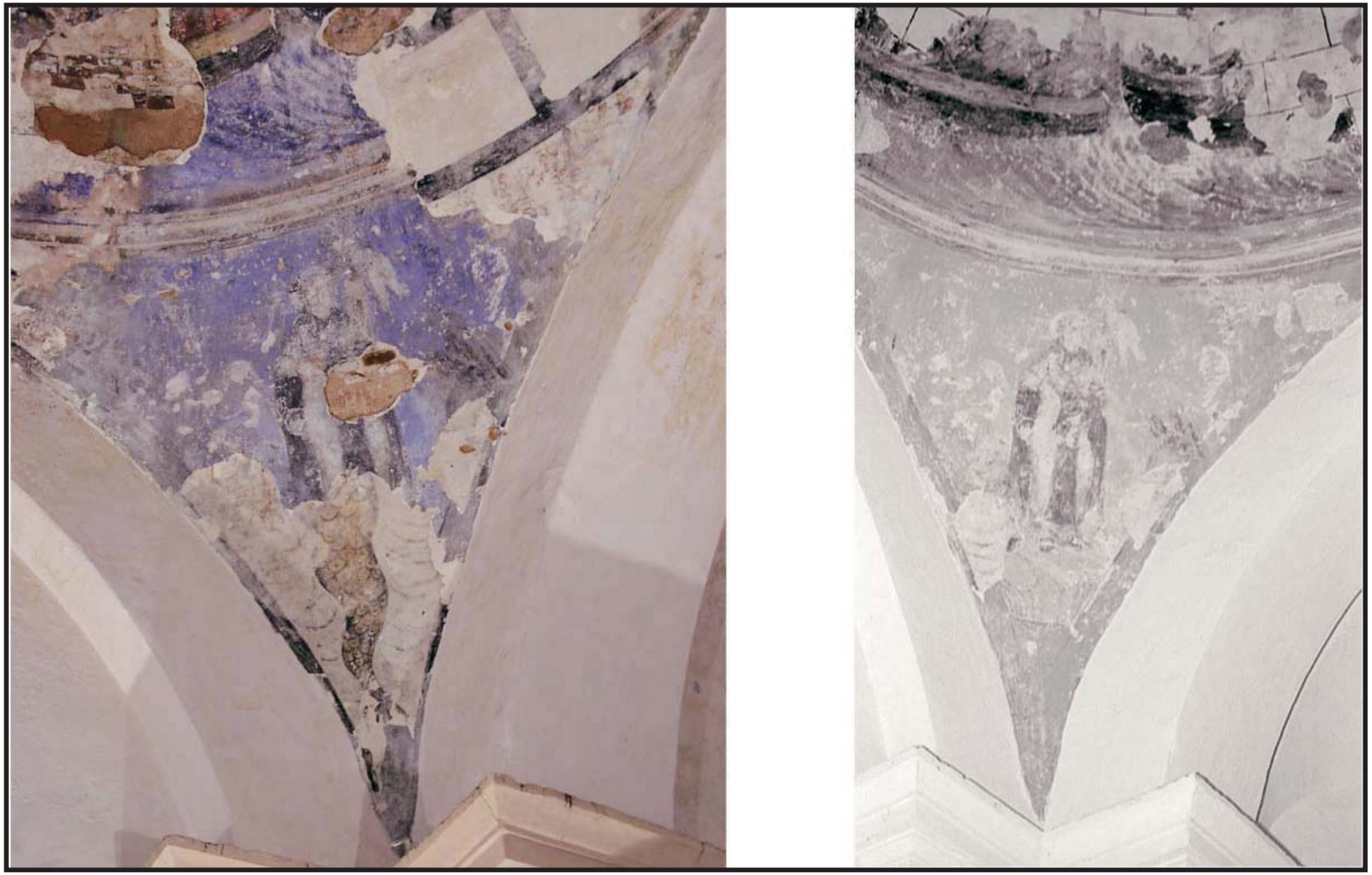


Figure 17: Photographic comparison of Pendentive 1, on the left is a 2004 image and on the right, an image taken in 1981. Note the deterioration in terms of areas of loss and image legibility over a twenty year time span.
(Source: Pantel y del Cueto & Associates)

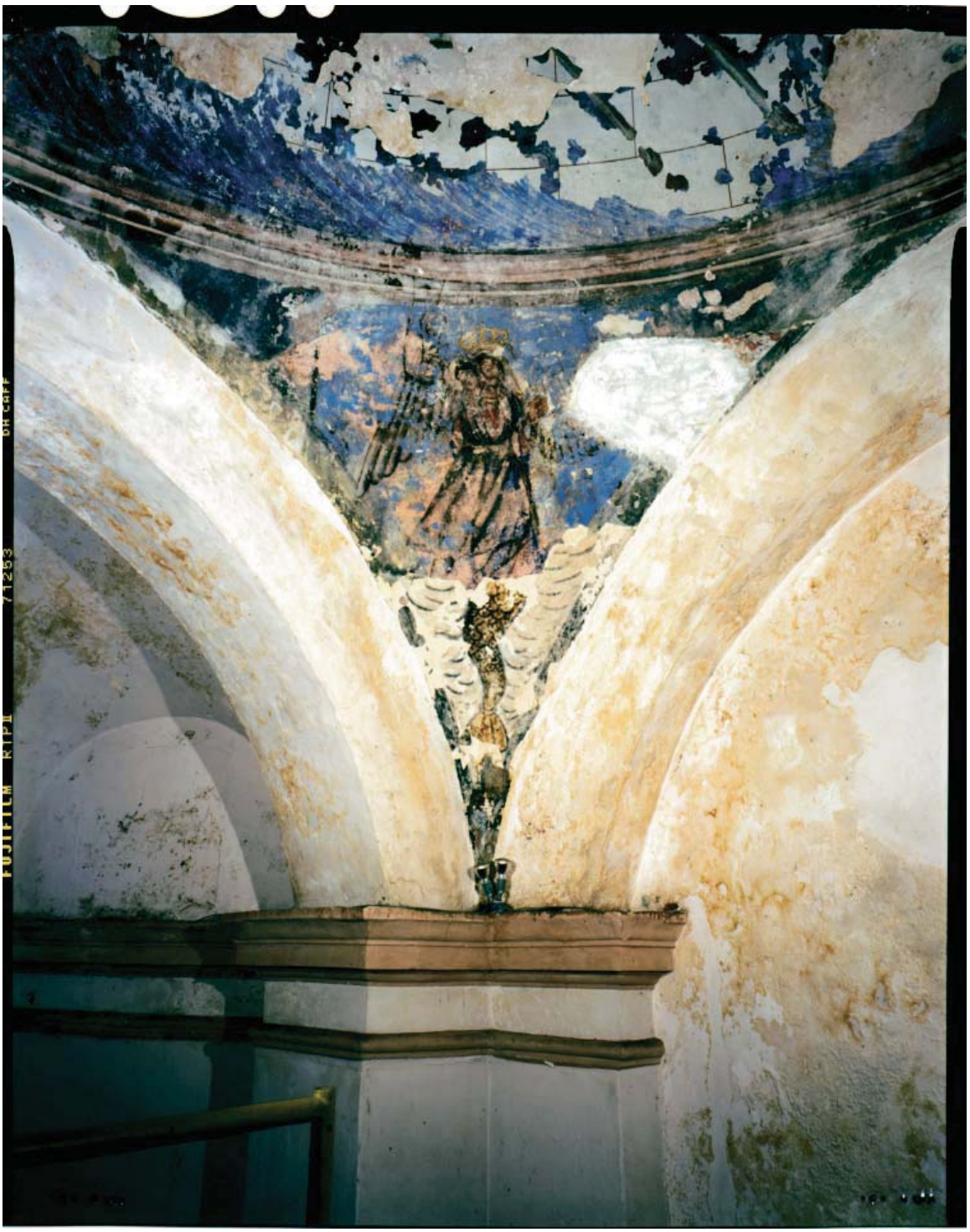


Figure 18: Pendentive 2, southwest corner of Rosario Chapel.
(Source: Joseph Elliott, 2004)

Figure 19: Photographic comparison of Pendentive 2, on the left is a 2004 image and on the right, an image taken in 1981. Note the deterioration in terms of areas of loss and image legibility over a twenty year time span. (Source: Pantel y del Cueto & Associates)

Figure 20: Pendentive 3, northwest corner of Rosario Chapel.
(Source: Joseph Elliott, 2004)

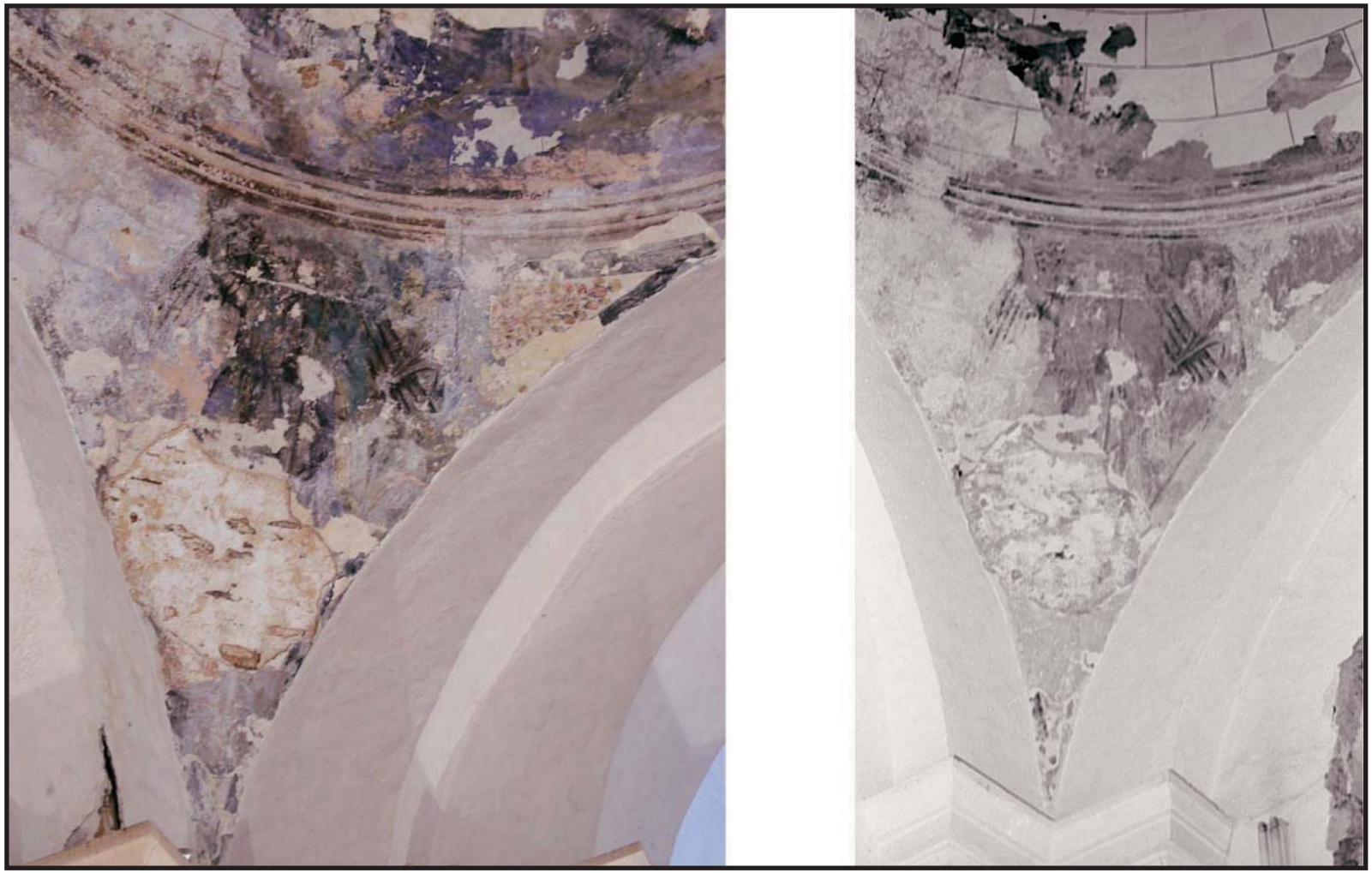


Figure 21: Photographic comparison of Pendentive 3, on the left is a 2004 image and on the right, an image taken in 1981. Note the deterioration in terms of areas of loss and image legibility over a twenty year time span.
(Source: Pantel y del Cueto & Associates)

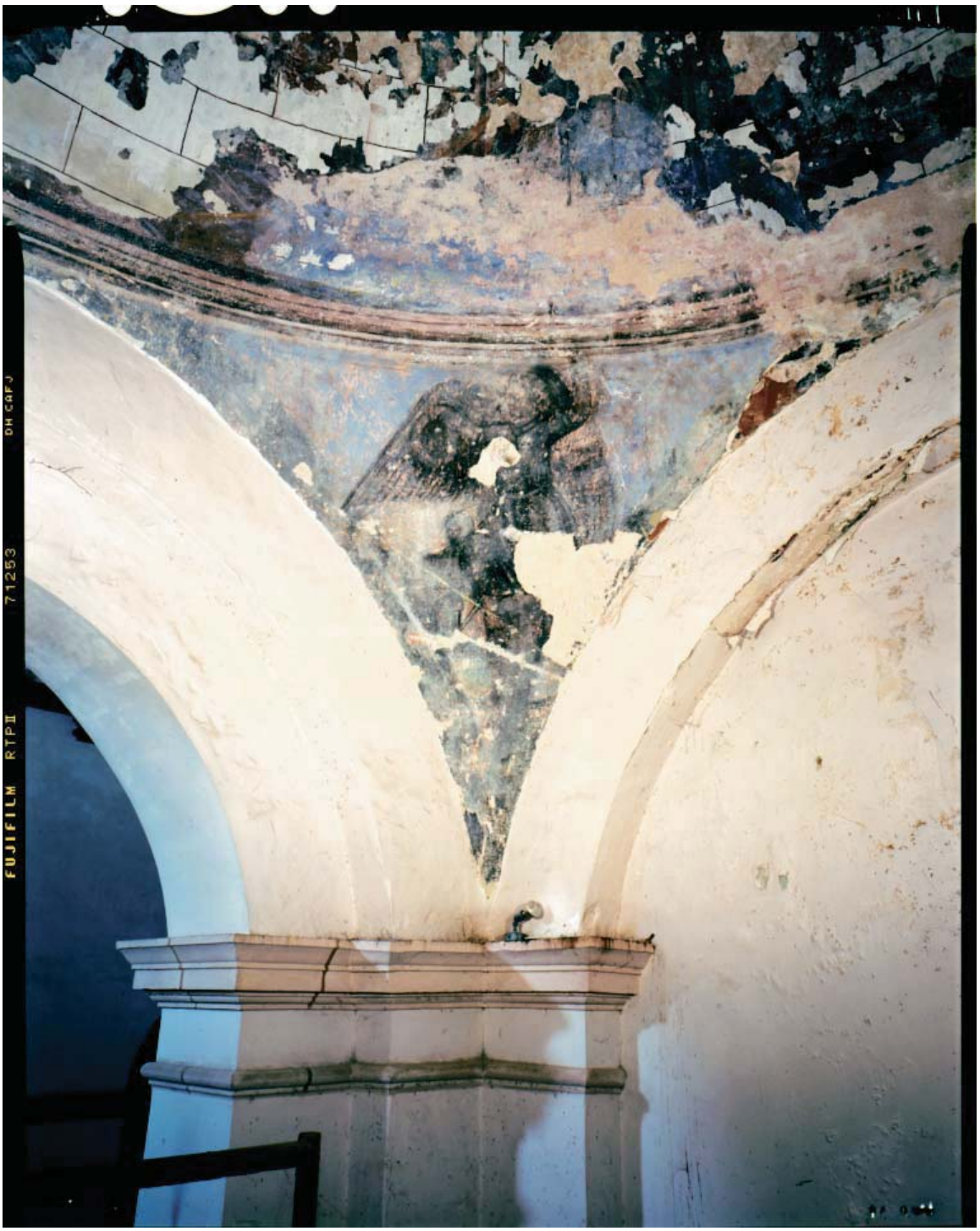


Figure 22: Pendentive 4, northeast corner of Rosario Chapel.
(Source: Joseph Elliott, 2004)

Figure 23: Photographic comparison of Pendentive 4, on the left is a 2004 image and on the right, an image taken in 1981. Note the deterioration in terms of areas of loss and image legibility over a twenty year time span.
(Source: Pantel y del Cueto & Associates)

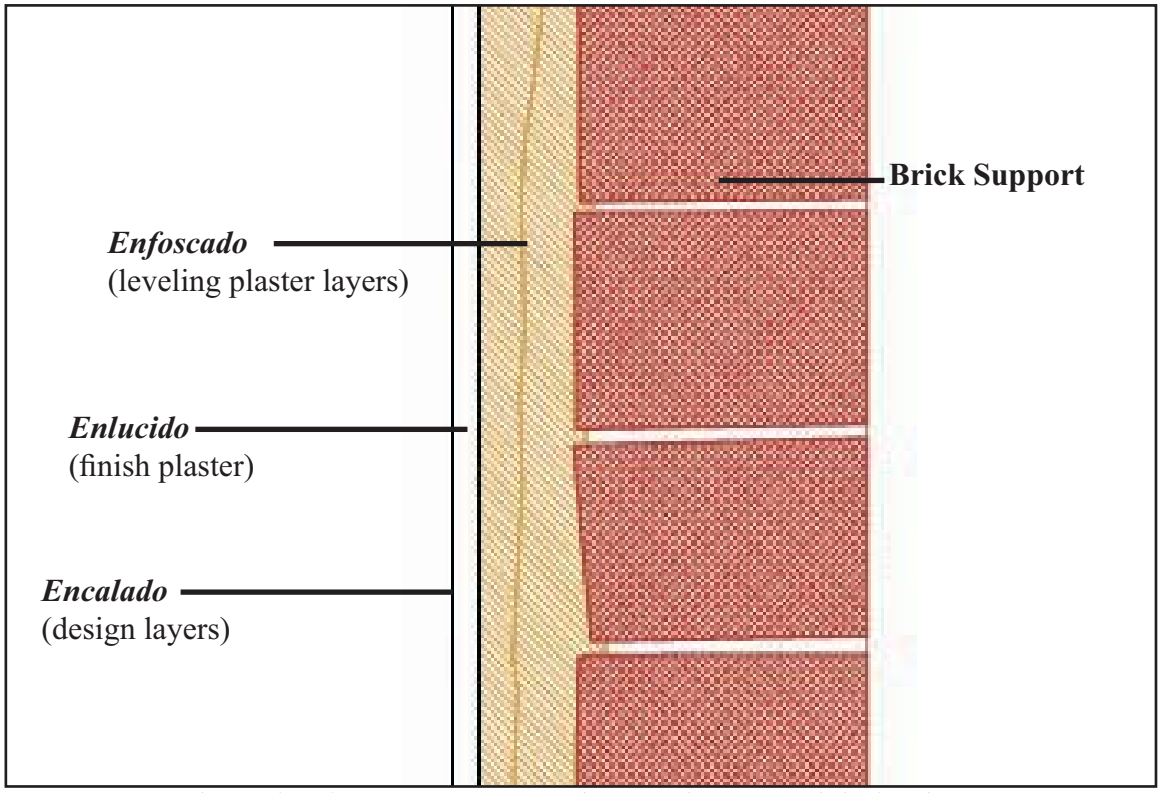


Figure 24: Schematic of masonry support,plaster substrate and design layer sequence composing the Rosario Chapel dome and pendentives.

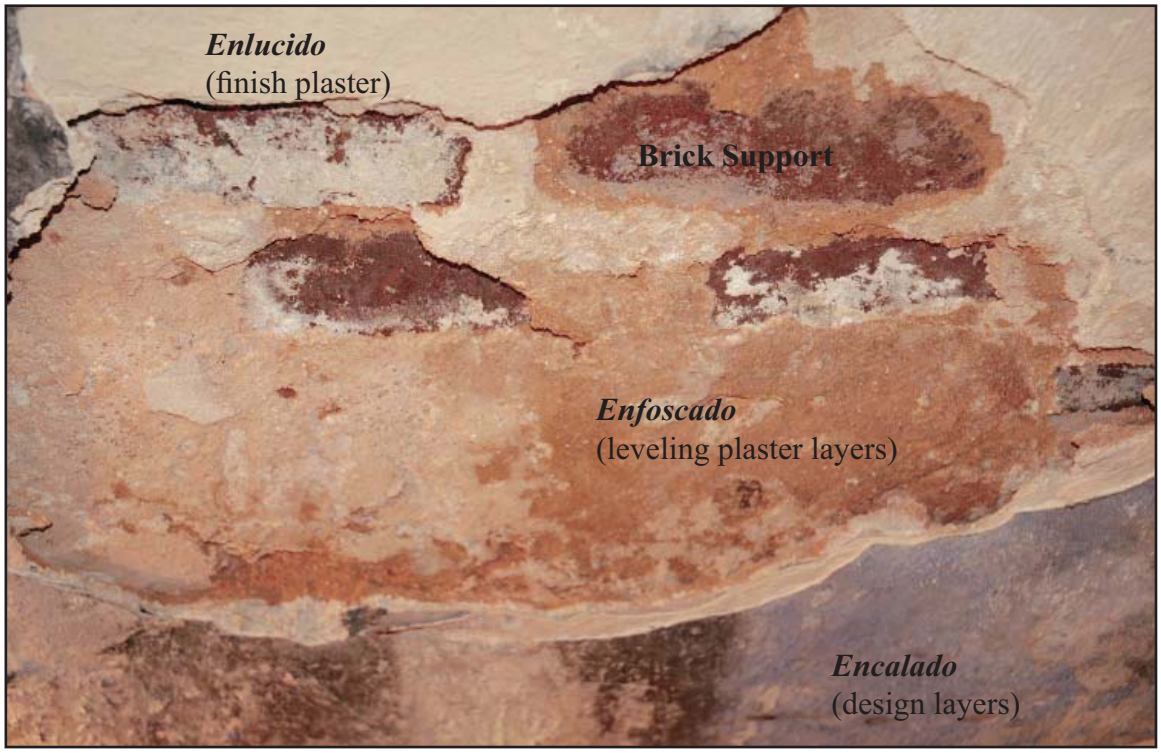


Figure 25: Detail from area of loss on Pendentive 1. (Source: C. Silva, 2006)

Figure 26: Mer-creatures from the Cathedral of Santa Maria la Menor, located in Santo Domingo. Paintings are thought to date from the 16th century. (Source: Pantel y del Cueto & Associates, 2005)

Figure 27: Painting of the Battle of Lepanto, c. 1572, by Paolo Veronese (Oil on canvas, 169 x 137 cm) Gallerie dell'Accademia, Venice. This painting originally placed next to the altar of the Rosary in the church of St. Peter Martyr, Italy. The top of the painting features the Saints Peter, Roch, Justine and Mark who are thought to be urging the Virgin to grant victory to the Christian fleet. The Virgin answered by commanding angels to throw burning arrows at the Turkish armada. (Source: www.wga.hu/html/v/veronese/ z_other/lepanto.html, 2006)

Figure 28: Etching of the Battle of Leponto, 1575, artist unknown, from the private collection of Angus Konstam. This German engraving features a Turkish crew fleeing their galley, after being conquered by the Christians. (source: Kostam, Angus. Leponto 1571, 2005)

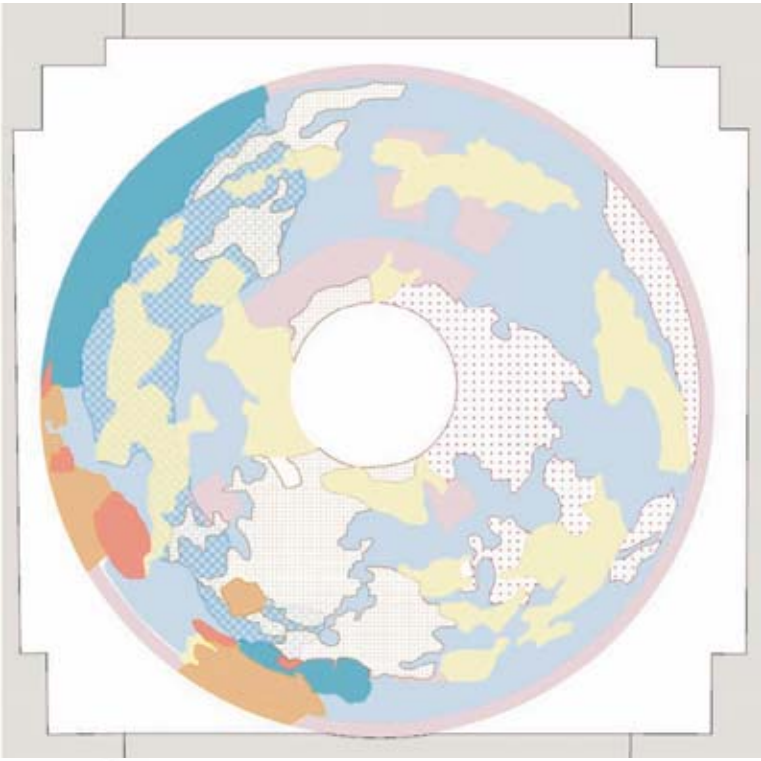
APPENDIX A

Dome and Pendentive Maps
Photographic Details

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL DOME

Extant Mural Campaigns



(Source:Joseph Elliott, 2004)

Campaigns

- Campaign A
- Campaign B
- Campaign C
- Campaign D
- Campaign E
- Campaign F
- Major Loss
- Repair
- Repair-Hidden

Survey completed January 4, 2006

N

A1, Map 1: Painting Campaign Map, Rosario Chapel Dome

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Pendentive 1: Extant Mural Campaigns

(Source:Joseph Elliott, 2004)

Survey completed January 4, 2006

Campaigns

- Campaign A
- Campaign B
- Campaign C
- Campaign D
- Campaign E
- Campaign F
- Major Loss
- Repair
- Repair-Hidden

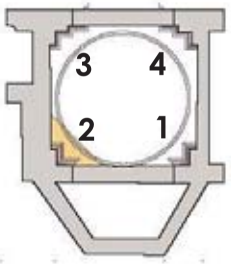
A2, Map 2: Painting Campaign Map, Rosario Chapel, Pendentive 1

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Pendentive 2: Extant Mural Campaigns

(Source:Joseph Elliott, 2004)



Campaigns

- Campaign A
- Campaign B
- Campaign C
- Campaign D
- Campaign E
- Campaign F
- Major Loss
- Repair
- Repair-Hidden

Survey completed January 4, 2006

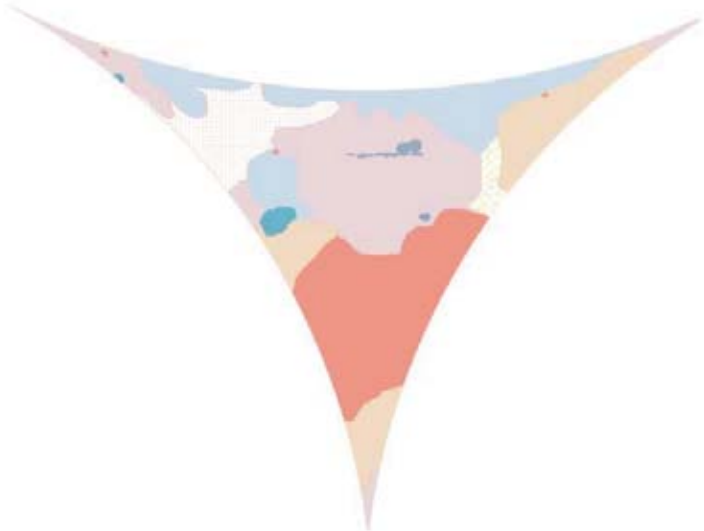
N

A3, Map 3: Painting Campaign Map, Rosario Chapel, Pendentive 2

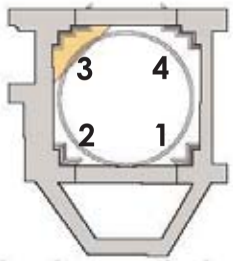
IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Pendentive 3: Extant Mural Campaigns



(Source:Joseph Elliott, 2004)



Campaigns

- Campaign A
- Campaign B
- Campaign C
- Campaign D
- Campaign E
- Campaign F
- Major Loss
- Repair
- Repair-Hidden

Survey completed January 4, 2006

N

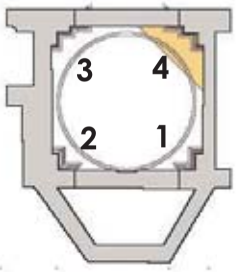
A4, Map 4: Painting Campaign Map, Rosario Chapel, Pendentive 3

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Pendentive 4: Extant Mural Campaigns

(Source:Joseph Elliott, 2004)



Campaigns

Campaign A, Campaign B, Campaign C, Campaign D, Campaign E, Campaign F, Major Loss, Repair, Repair-Hidden

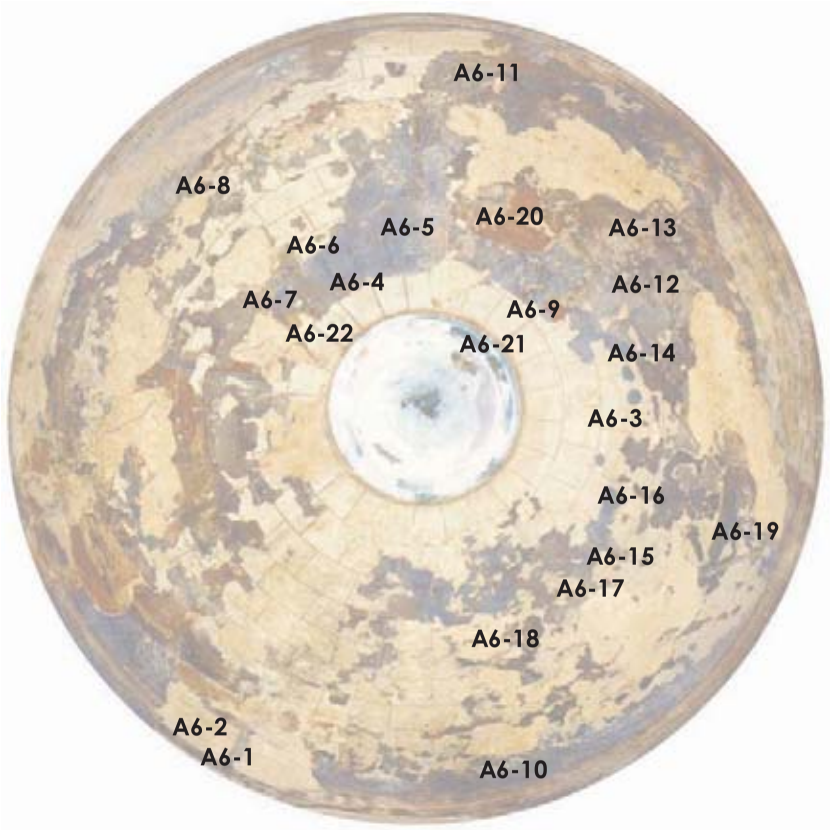
Survey completed January 4, 2006

A5, Map 5: Painting Campaign Map, Rosario Chapel, Pendentive 4

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL DOME

Location of Photographic Details



(Source: Joseph Elliott, 2004)

N

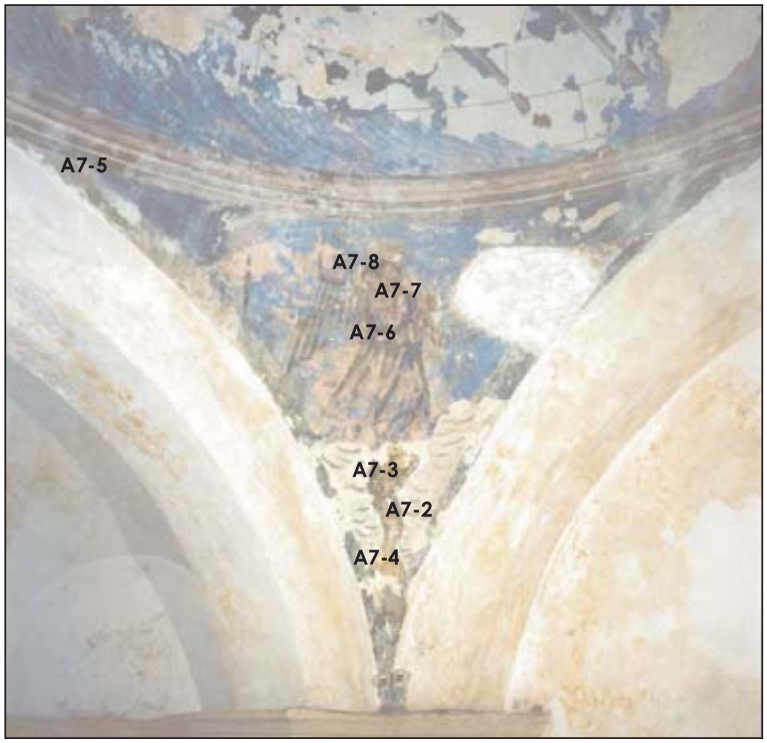
A6, Map 6: Map of Dome with Detail Locations

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Location of Photographic Details

Pendentive 1 (Source:Joseph Elliott, 2004)



Pendentive 2 (Source:Joseph Elliott, 2004)

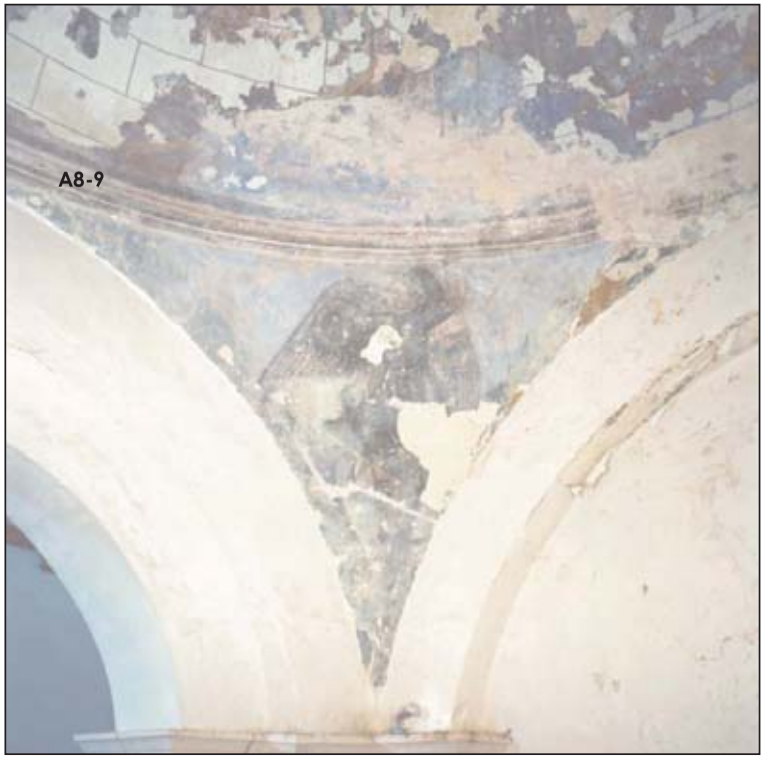
A-7, Map 7: Location of Photographic Details, Pendentives 1 and 2

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Location of Photographic Details

Pendentive 3 (Source: Joseph Elliott, 2004)



Pendentive 4 (Source: Joseph Elliott, 2004)

A-8, Map 8: Location of Photographic Details, Pendentives 3 and 4

Figure 29: Detail (A6-1) Incised lines used to layout painting, Campaign A (Source: C. Silva, 2005)

Figure 30: Detail (A6-2) Ashlar motif evident in the dome, Campaign A (Source: C. Silva, 2006)

Figure 31: Detail (A6-3). Red marbalizing, Campaign B under later limewashes. (Source: C. Silva, 2006)

Figure 32: Detail (A6-4). Faux coffers, Campaign C. (Source: C. Silva, 2006)

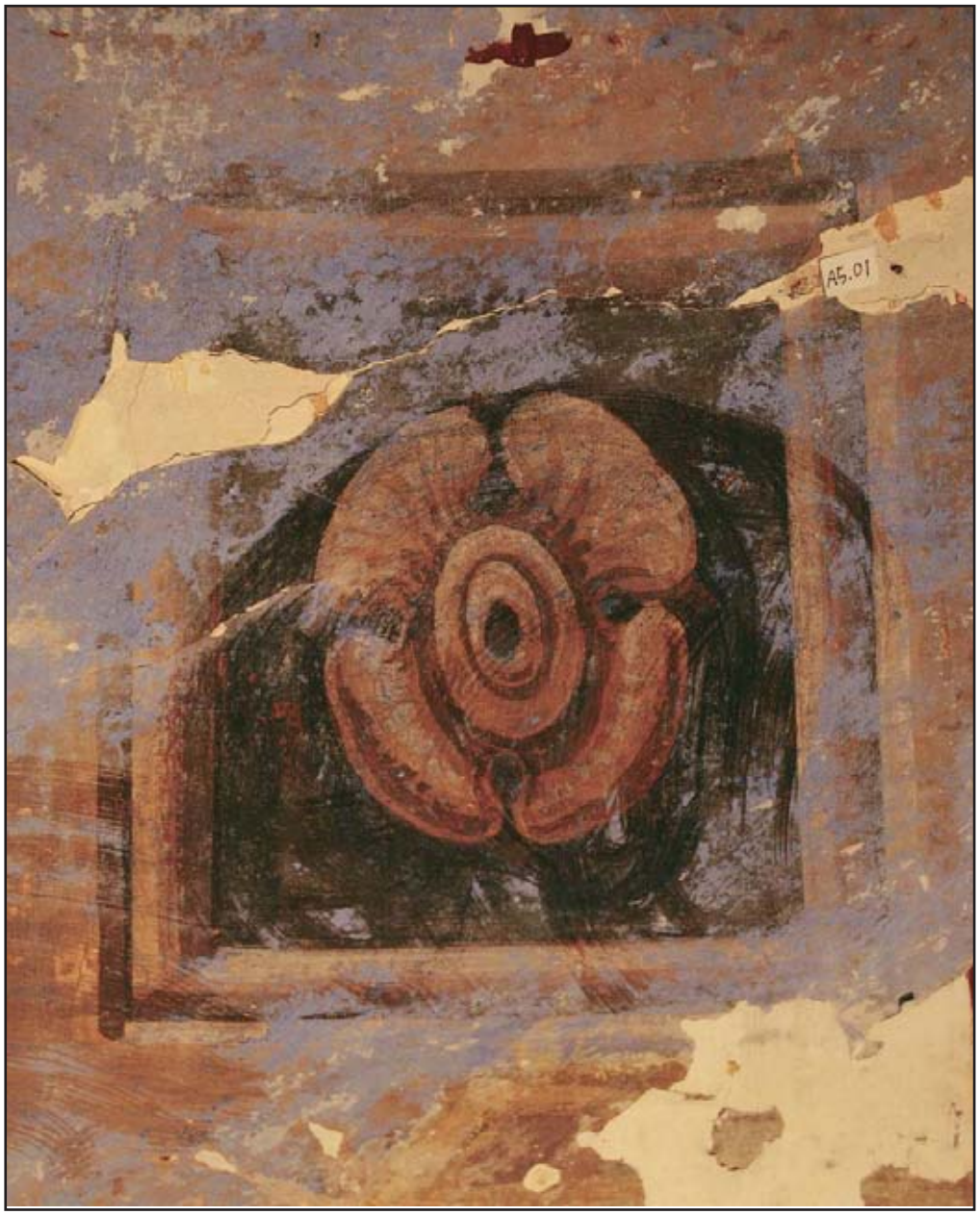


Figure 33: Detail (A6-5) Faux coffer, Campaign C (Source: C. Silva, 2006)

Figure 34: Detail (A6-6) Faux coffer, Campaign C (Source: C. Silva, 2006)

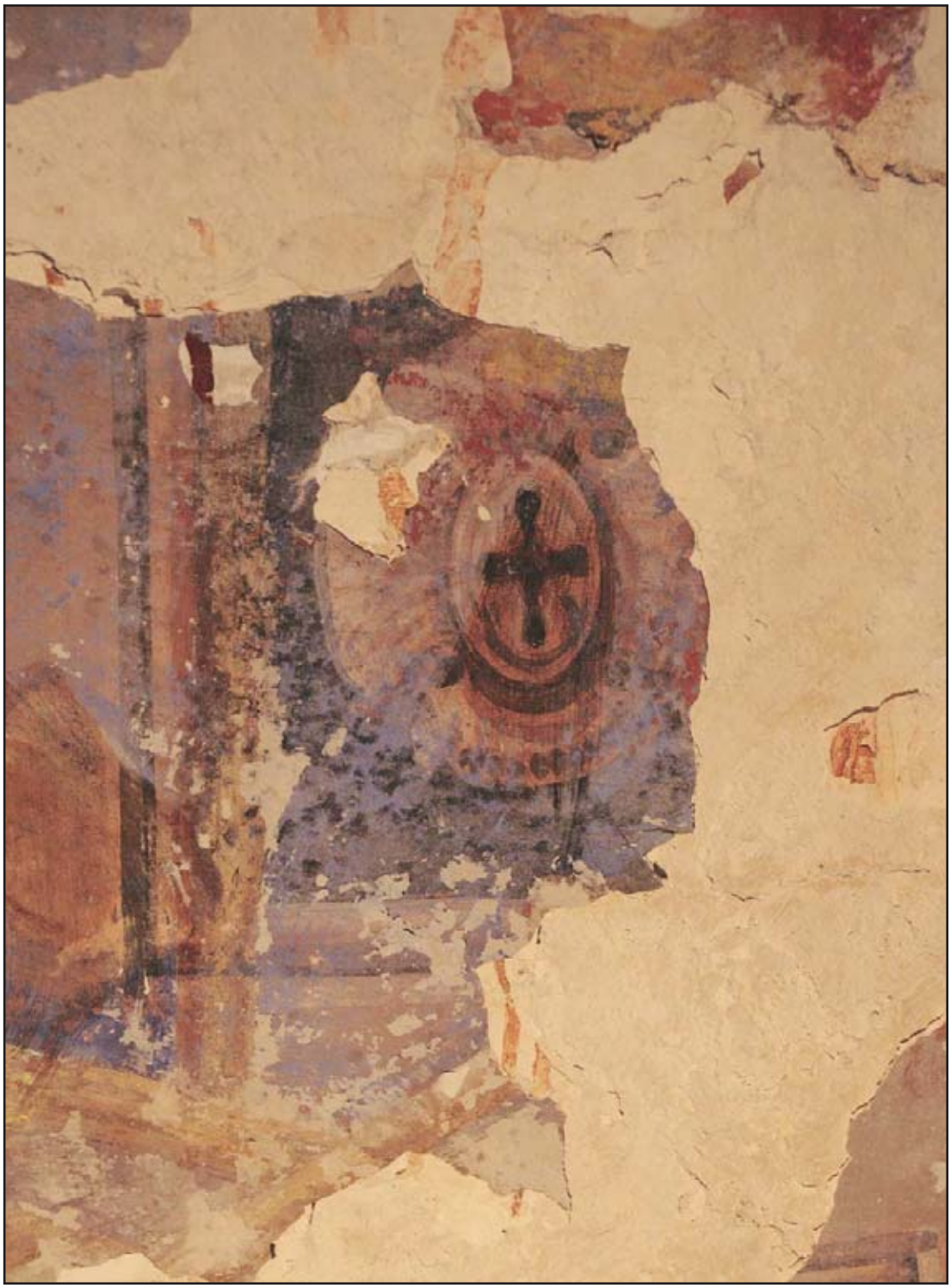


Figure 35: Detail (A6-7) Faux coffer, Campaign C (Source: C. Silva, 2006)

Figure 36: Detail (A6-8) Image of surface conditions: blistering, flaking, and salts. (Source: C. Silva, 2006)

Figure 37: Detail (A6-9) Image of red flag, Campaign D (Source: C. Silva, 2006)

Figure 38: Detail (A6-10) Water motif at the base of the dome, Campaign D (Source: C. Silva, 2006)

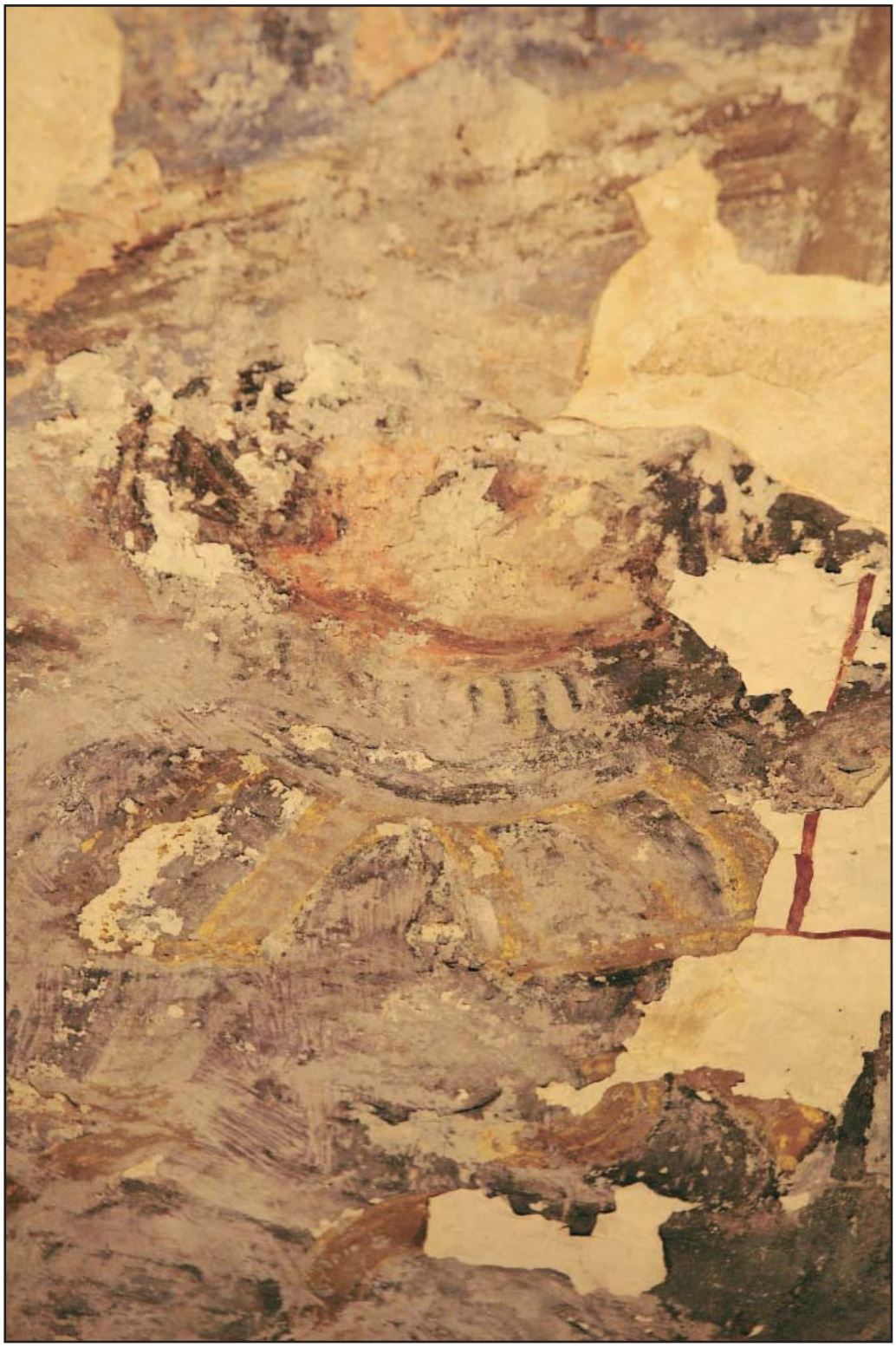


Figure 39: Detail (A6-11). Head of mariner 1, Campaign D
(Source: C. Silva, 2006)

Figure 40: Detail (A6-12) Image of mariners 2 and 3, Campaign D (Source: C. Silva, 2006)

Figure 41: Detail (A6-13) Image of mariner 2, Campaign D
(Source: C. Silva, 2006)

Figure 42: Detail (A6-14) Image of mariner 3, Campaign D (Source: C. Silva, 2006)

Figure 43: Detail (A6-15) Overview of mariners 4,5 and 6, Campaign D (Source: C. Silva, 2006)

Figure 44: Detail (A6-16) Image of mariner 4, Campaign D
(Source: C. Silva, 2006)

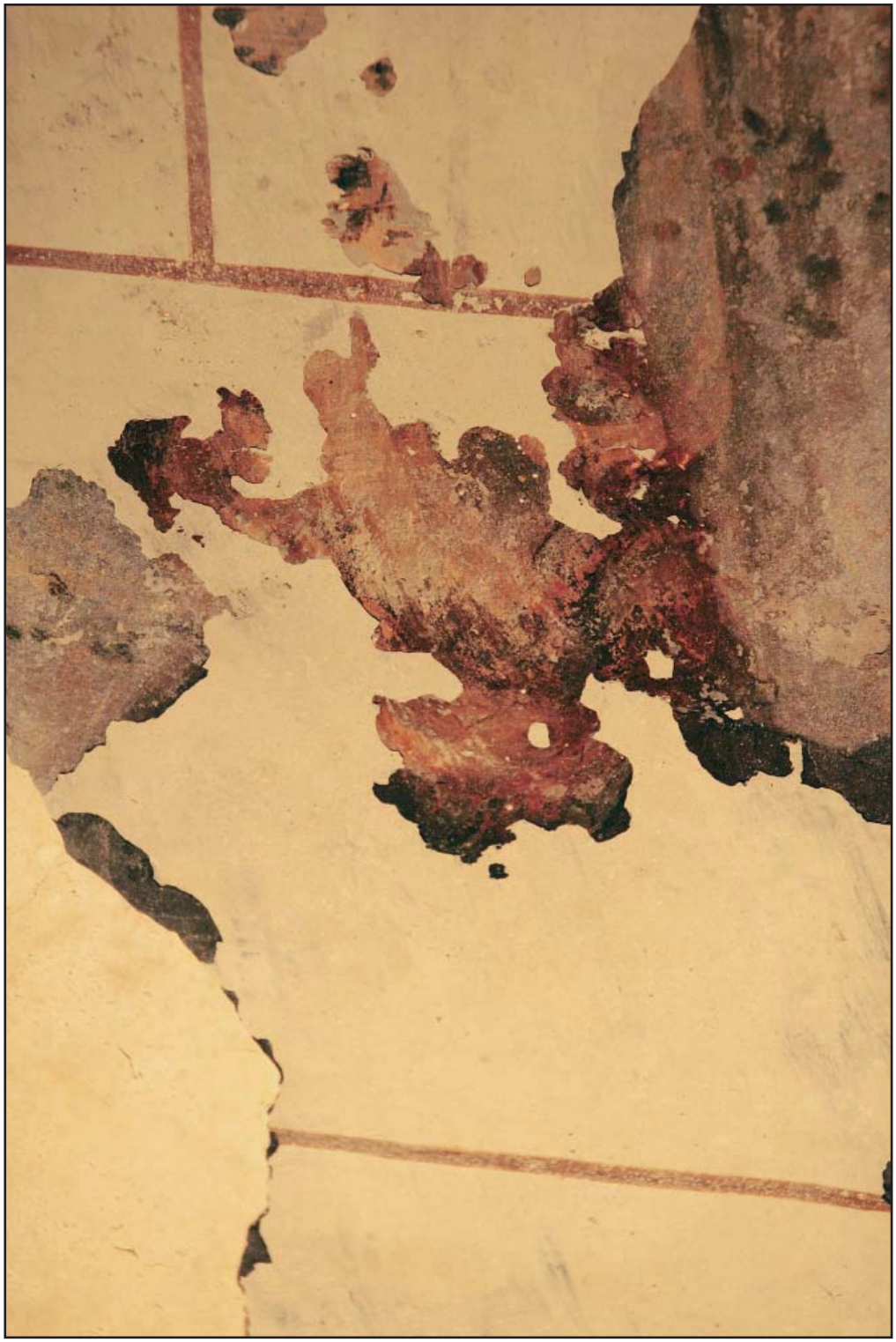


Figure 45: Detail (A6-17) Image of mariner 5, Campaign D
(Source: C. Silva, 2006)

Figure 46: Detail (A6-18) Image of mariner 6, Campaign D
(Source: C. Silva, 2006)

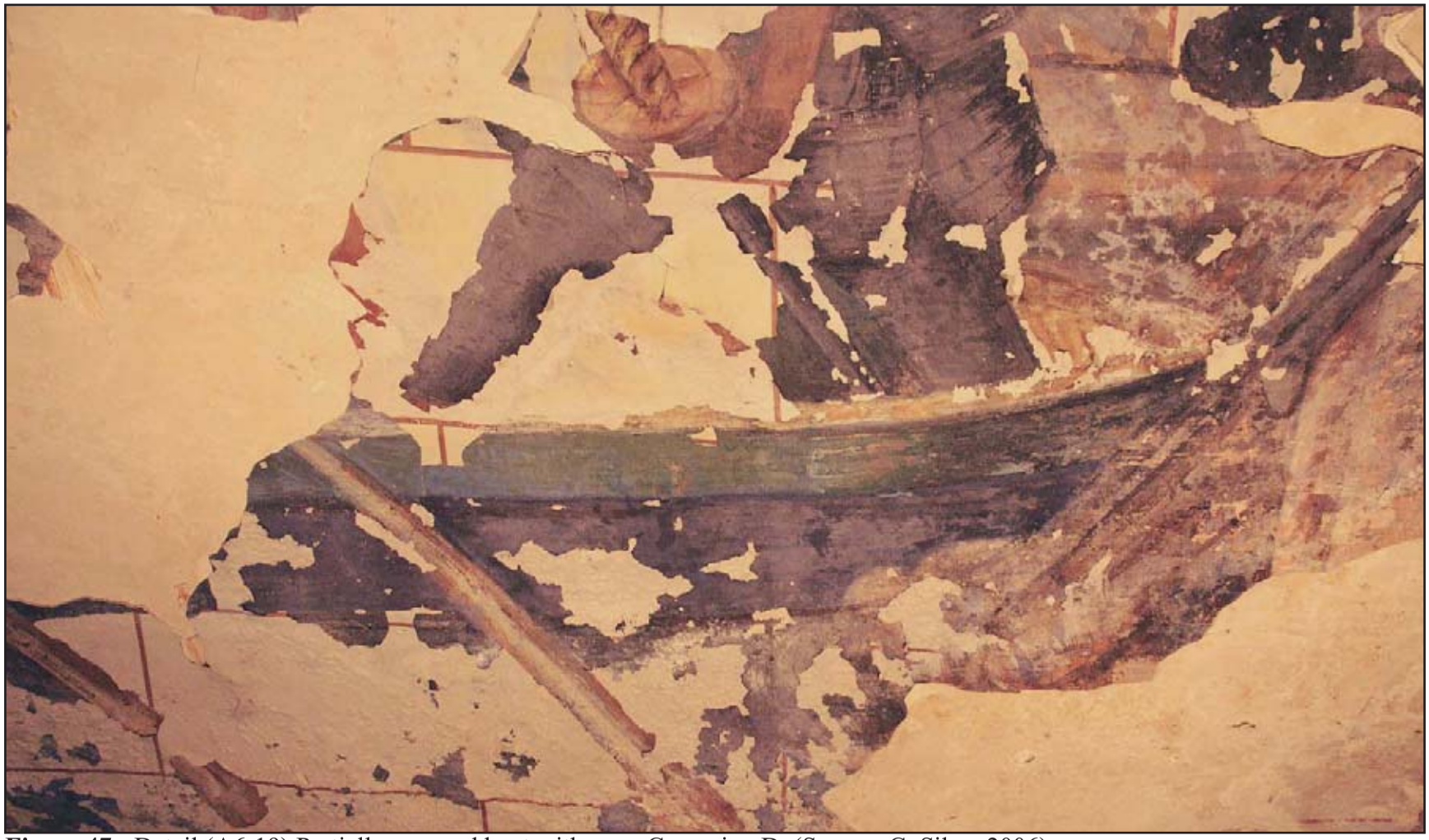


Figure 47: Detail (A6-19) Partially exposed boat with oars, Campaign D (Source: C. Silva, 2006)

Figure 48: Detail (A6-20) Red, vault shaped ship enclosure, Campaign D (Source: C. Silva, 2006) Compare with similar enclosure in Figure 28.

Figure 49: Detail (A6-21) Measured ashlar, ca 1890 Campaign E (Source: C. Silva, 2006)

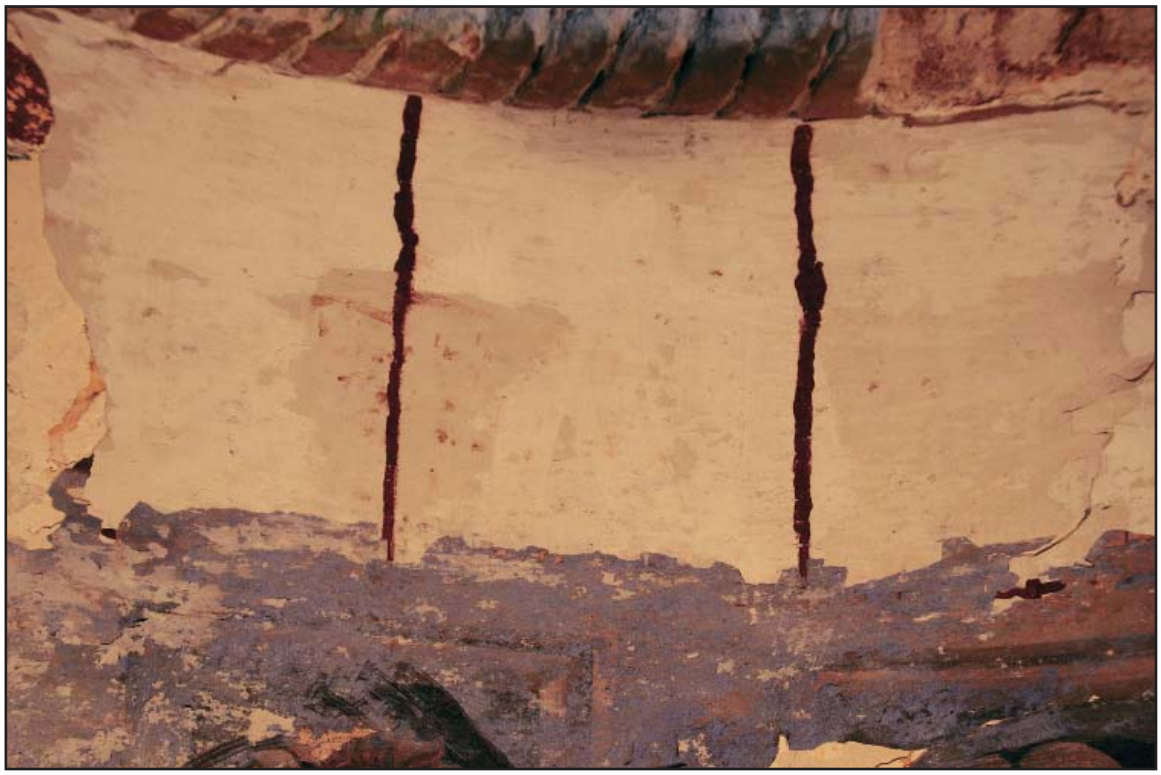


Figure 50: Detail (A6-22) Free-hand ashlar, Campaign F (Source: C. Silva, 2006)

Figure 51: Detail (A7-1) Mer creature's head as it was exposed, Campaign A (Source: C. Silva, 2005)

Figure 52: Detail (A7-2) Mer-figures tail, surrounded by water motif and black banding, Campaign A (Source: C. Silva, 2006)

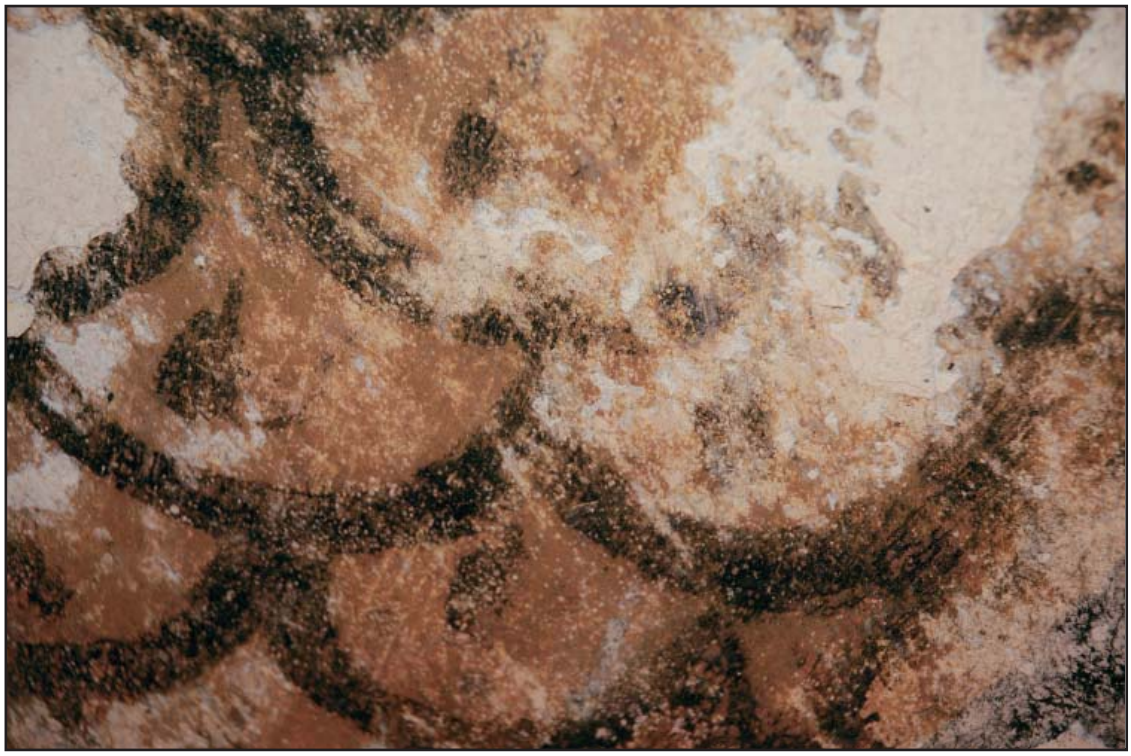


Figure 53: Detail (A7-3) Image of scales on Mer figure's tail, Campaign A (Source: C. Silva, 2006)

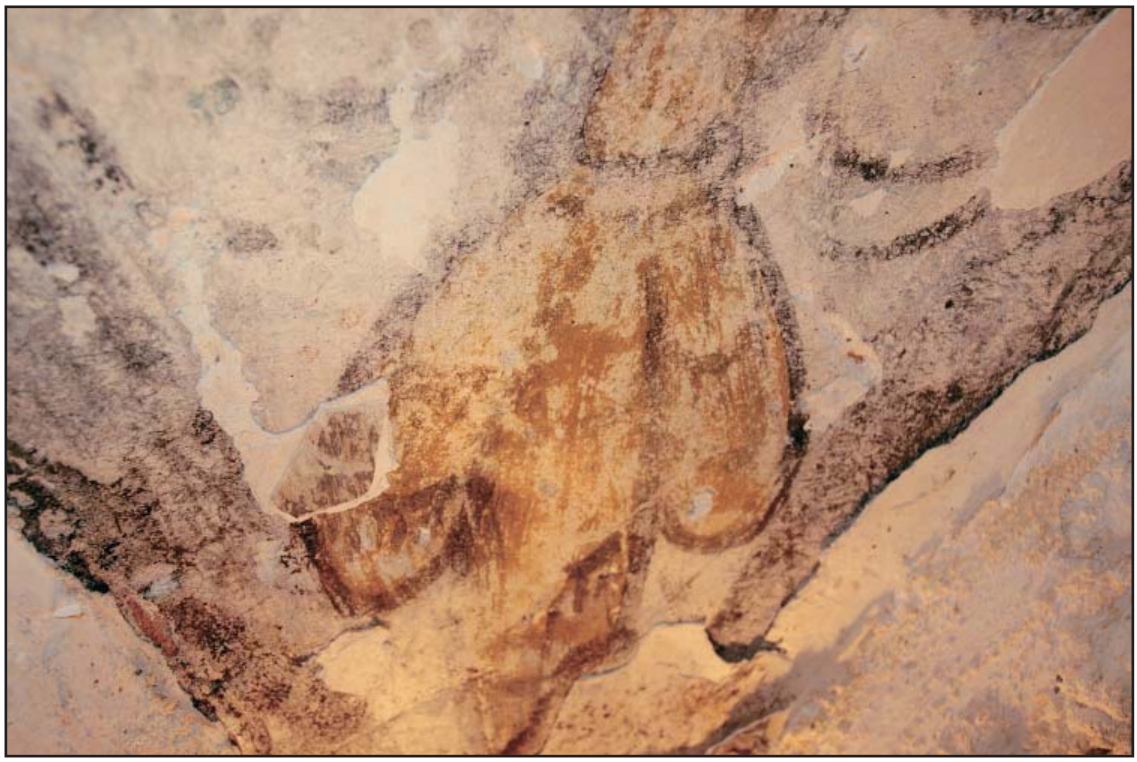


Figure 54: Detail (A7-4) Detail of the bottom of Mer creature'ss tail, Campaign A (Source: C. Silva, 2006)

Figure 55: Detail (A7-5) Olive and rose border, Campaign C (Source: C. Silva, 2006)

Figure 56: Detail (A7-6) Center of Pendentive 2 with repair on upper right (Source: C. Silva, 2006)
Note overlapping figures from Campaign C and D.

Figure 57: Detail (A7-7) Detail of Virgin and child, Campaign D (Source: C. Silva, 2006)

Figure 58: Detail (A-7-8) Detail of the child Jesus, Campaign D
(Source: C. Silva, 2006)

Figure 59: Detail (A8-1). Floral motif with faux voussoirs on the adjacent north arch, Campaign A (Source: C. Silva, 2006)

Figure 60: Detail (A8-2). Detail of a hand holding the floral bouquet, Campaign A (2006)

Figure 61: Detail (A8-3) Center of Pendentive 3, angel figure with loss on lower right, Campaign C (Source: C. Silva, 2006)

Figure 62: Detail (A8-4) Detail of angel figure's face, Campaign C (Source: C. Silva, 2006)

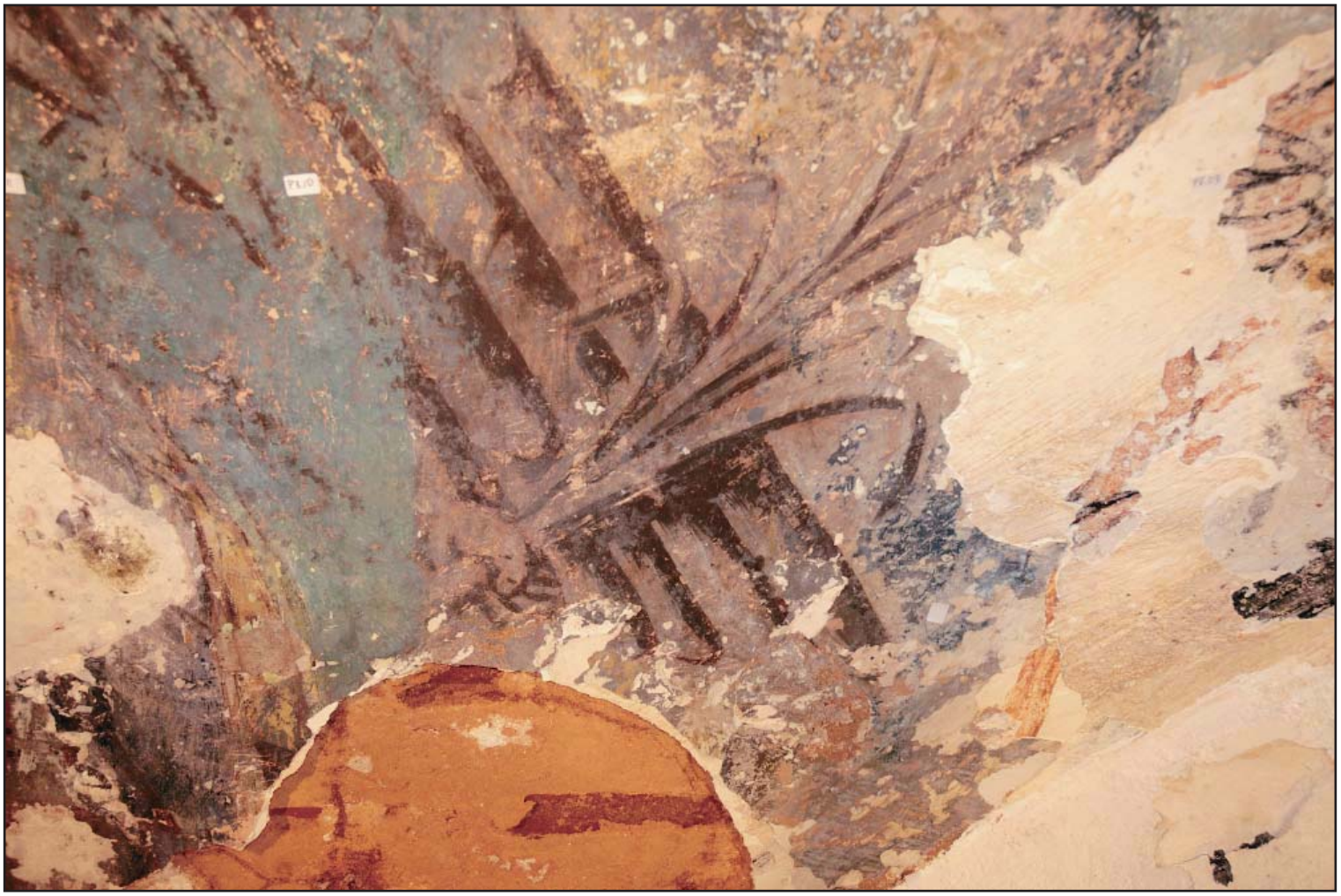


Figure 63: Detail (A8-5) Hand, palm frond, and lower right wing, Campaign C (Source: C. Silva, 2006)
Note the blue-green over-paint from Campaign D.

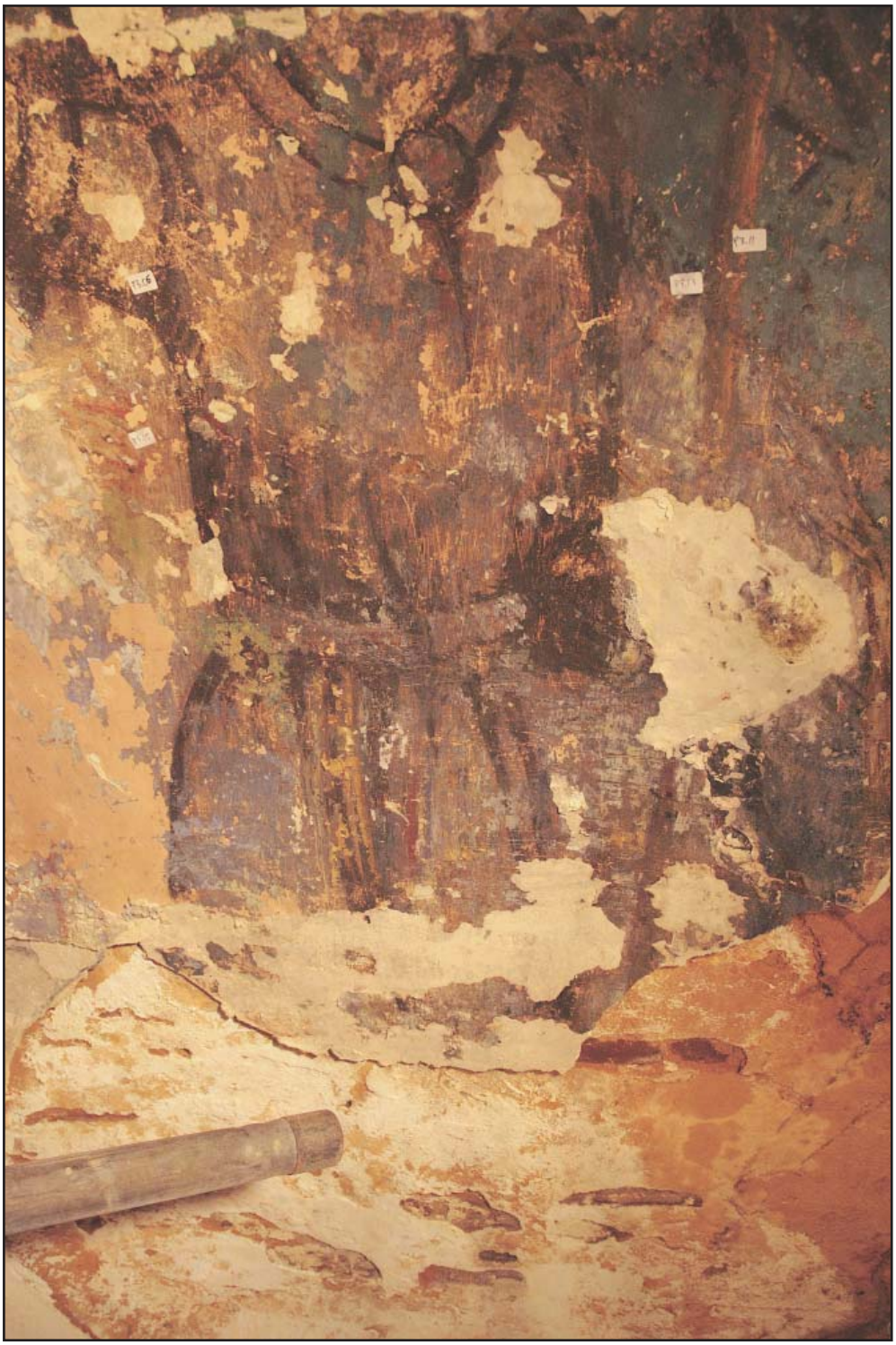


Figure 64: Detail (A8-6) Detail of garment, Campaign C
(Source: C. Silva, 2006)

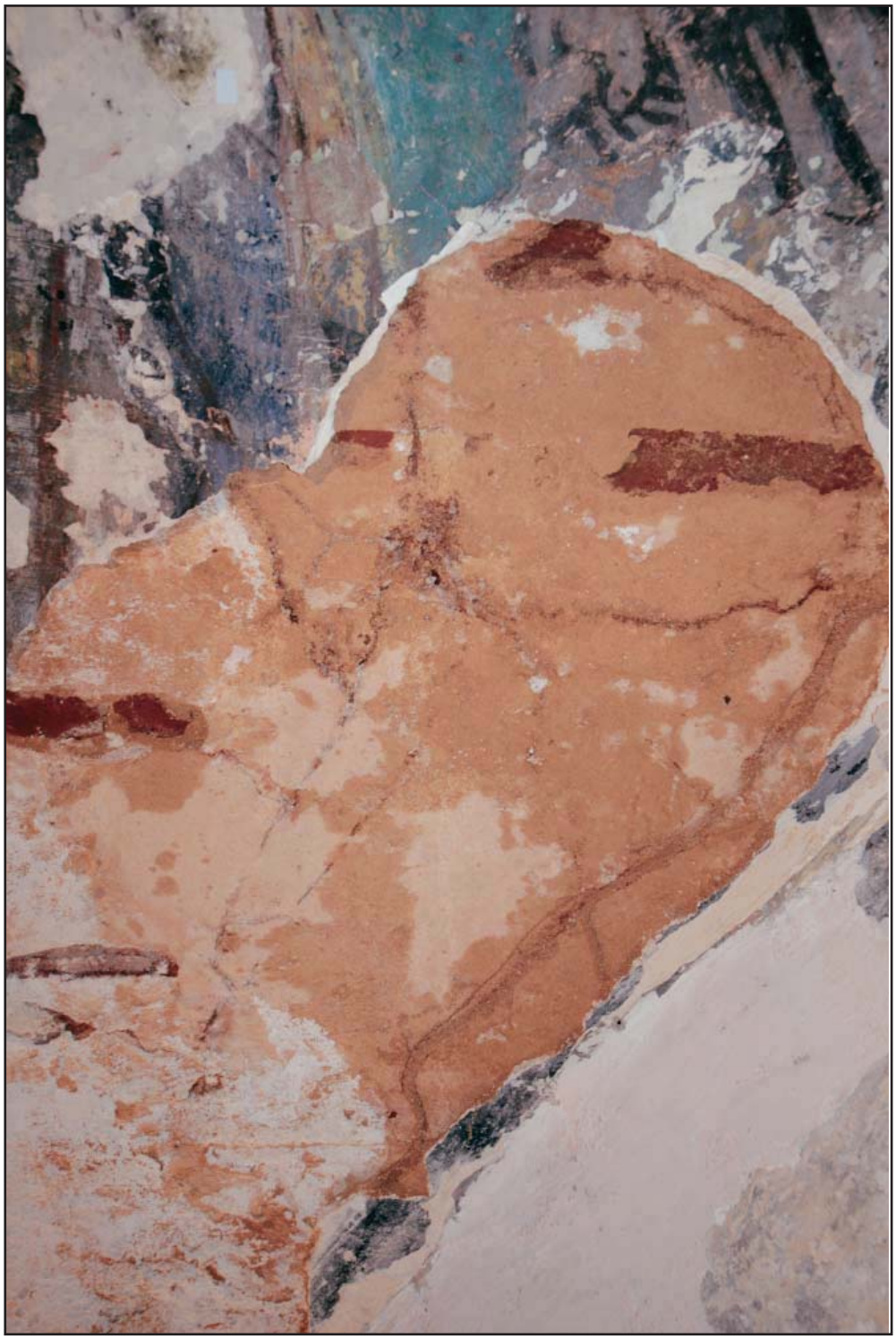


Figure 65: Detail (A8-7) Area of loss with termite tunnels
(Source: C. Silva, 2006)

Figure 66: Detail (A8-8) Image of surface conditions: blistering, flaking, and salts (Source: C. Silva, 2006)

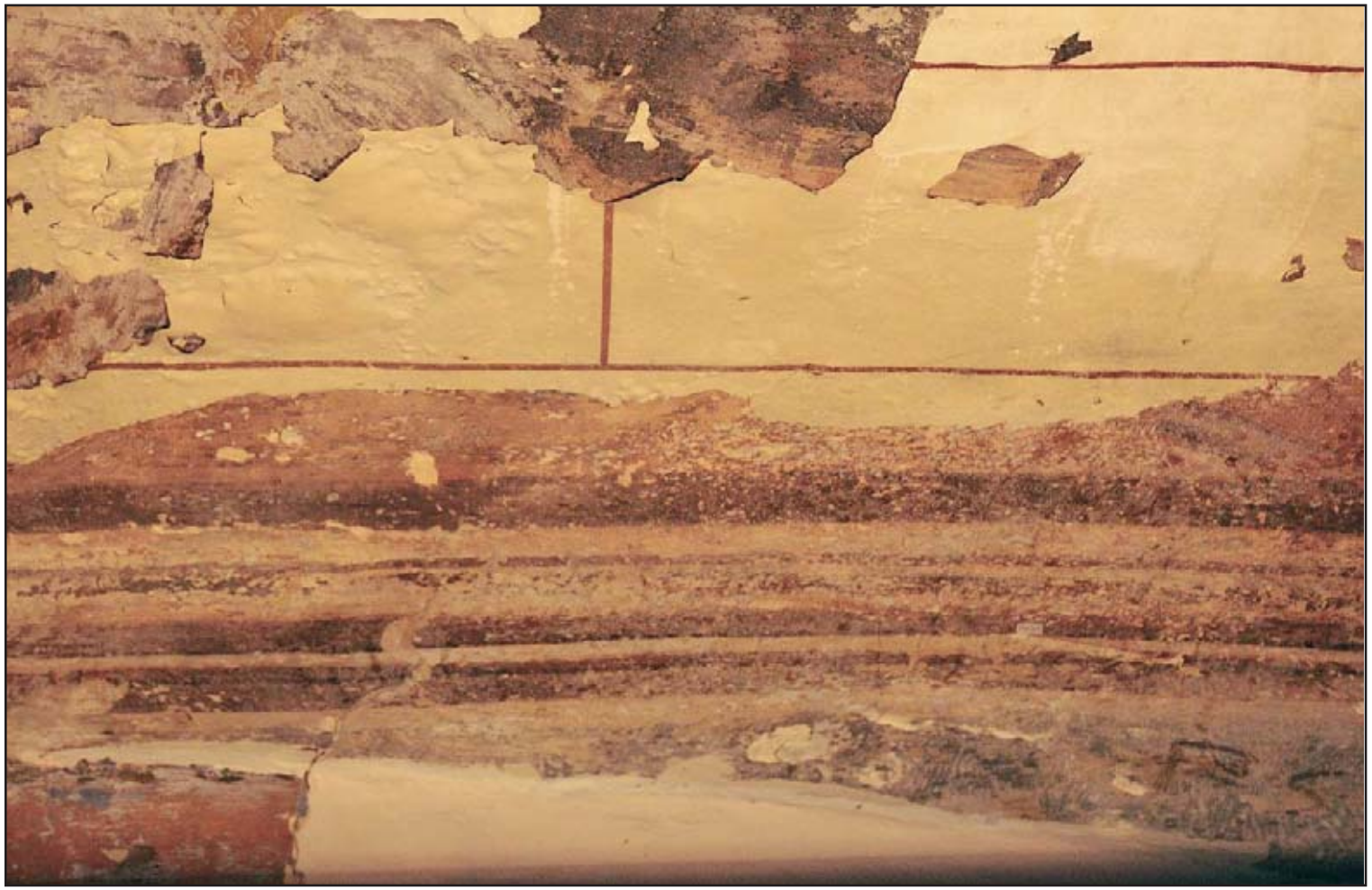


Figure 67: Detail (A8-9) Faux cornice, Campaign C (Source: C. Silva, 2006)

APPENDIX B

Sample Location Maps and Sample Schedule

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL DOME

Sample Locations

(Source: Joseph Elliott, 2004)

N

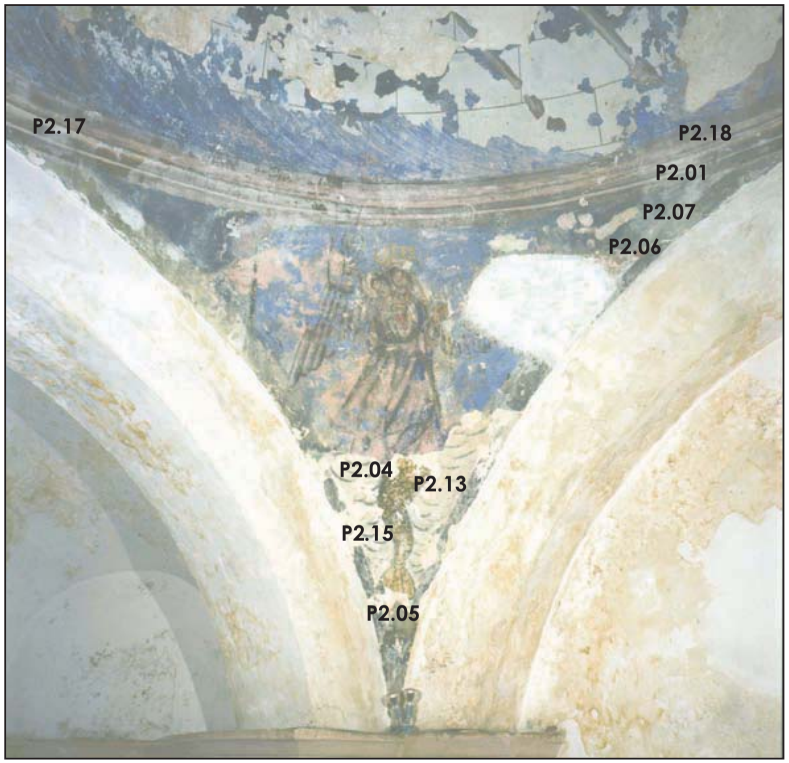
B-1, Map 9: Sample Locations, Dome

IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Sample Locations

Pendentive 1 (Source:Joseph Elliott, 2004)



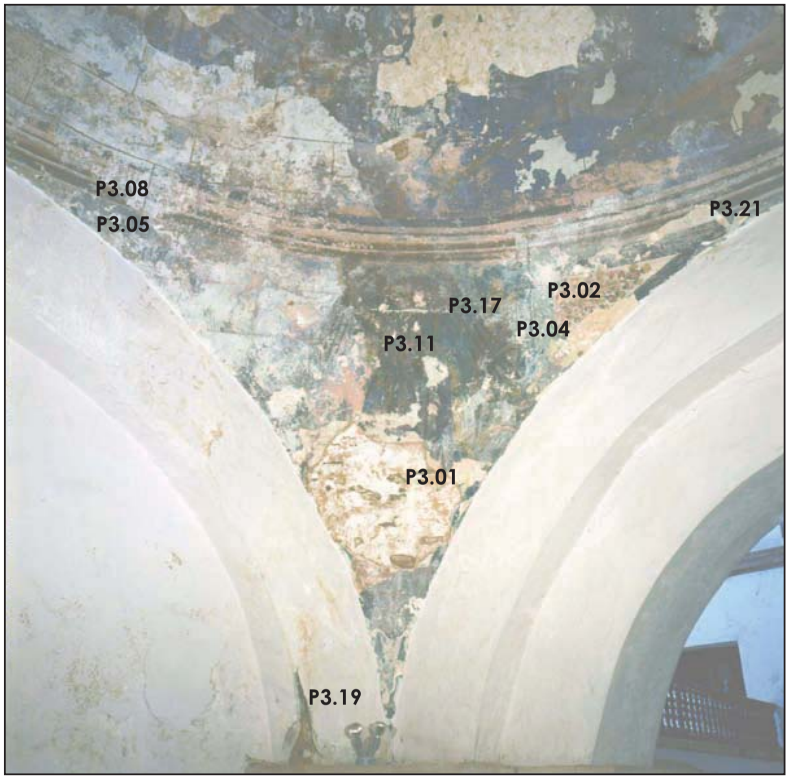
Pendentive 2 (Source:Joseph Elliott, 2004)

B-2, map 10: Sample Locations, Pendentives 1 and 2

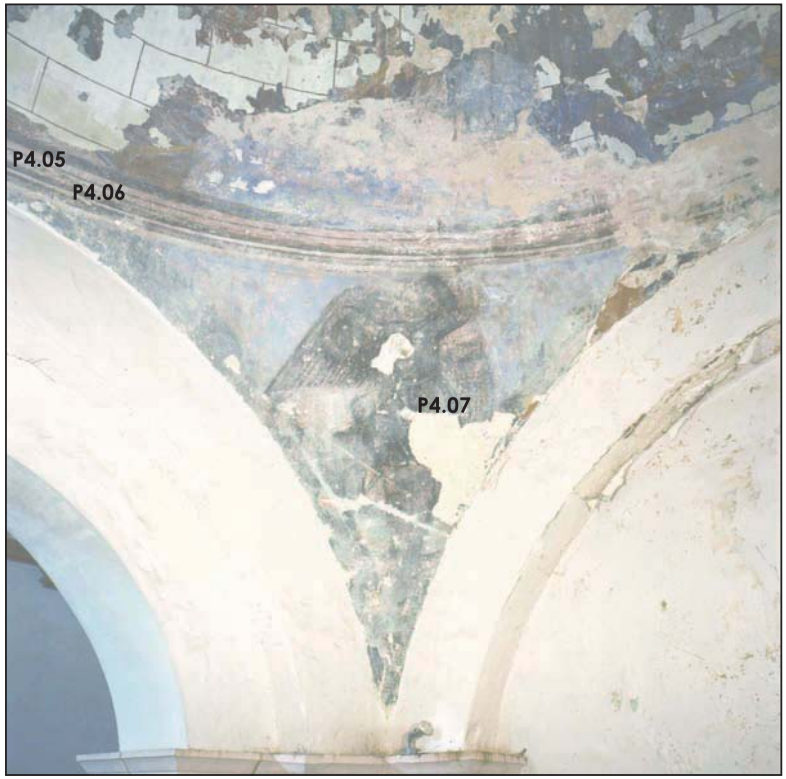
IGLESIA SAN JOSÉ, SAN JUAN PUERTO RICO

ROSARIO CHAPEL PENDENTIVES

Sample Locations



Pendentive 3 (Source: Joseph Elliott, 2004)



Pendentive 4 (Source: Joseph Elliott, 2004)

B-3, Map 11: Sample Locations, Pendentives 3 and 4

Table 1: Master Sample Schedule, Appendix B-4

Samples SAJO_ROSA October 14-16, 2005-December29-January 7, 2006			
Master Sample Schedule			
Sample_Number	**Location**	**Sample_Description**	**Analytical_Techniques**
SAJO-ROSA P1.02	Pendentive 1 -B4	Red Black and Yellow(A) floral motif, multiple limewashes, Pink Ground (C), Blue-gray(D) border, background.	EDS of Red layer(A)
SAJO-ROSA P1.02.1	Pendentive 1 -B4	Red and Black (A) floral motif, multiple limewashes, Pink Ground (C), Blue-gray(D) border, background.	cross-section
SAJO-ROSA P1.02.2	Pendentive 1 -B4	Yellow and Black (A) floral motif, multiple limewashes, Pink Ground (C), Blue-gray(D) border, background.	cross-section
SAJO-ROSA P1.04	Pendentive 1 -B6	Stratigraphy from area where *Mer* face was revealed	cross-section
SAJO-ROSA P1.06	Pendentive 1 -B5	Stratigraphy blue(D), pink and brown(C), lime washes	FTIR, blue(D)
SAJO-ROSA P2.01.1	Pendentive 2-A9	Stratigraphy with floral motif pigment from Mer campaign (A) on underside	cross-section
SAJO-ROSA P2.01.2	Pendentive 2-A9	Stratigraphy with floral motif pigment from Mer campaign (A) on underside	cross-section
SAJO-ROSA P2.01.3	Pendentive 2-A9	Stratigraphy with floral motif pigment from Mer campaign (A) on underside	cross-section

SAJO-ROSA P2.04	Pendentive 2-B4	Blue pigment on pink ground with *Mer* (A) pigments on back	cross-section
SAJO-ROSA P2.05.1	Pendentive 2-E5	Stratigraphy from lower valley of pendentive with multiple design layers, salts, and mold	cross-section
SAJO-ROSA P2.05.2	Pendentive 2-E5	Stratigraphy from lower valley of pendentive with multiple design layers, salts, and mold	cross-section
SAJO-ROSA P2.06	Pendentive 2-B8	Lime wash layer(B) with red faux marbalizing	cross-section
SAJO-ROSA P2.07	Pendentive 2-B8	Upper right corner sample includes green banding associated with (C) ,with pigments from Mer layer (A) on back	cross-section
SAJO-ROSA P2.13	Pendentive 2-C6	Lime wash (B) with yellow and black Mer (A) pigments on back.	EDS of Yellow and Black, layer(A)
SAJO-ROSA P2.15	Pendentive 2-D5	Blue-green from *Mer* layer (A), (very small pigment sample with little evidence remaining on mural)	EDS of Blue-Green, layer(A)
SAJO-ROSA P2.17	Pendentive 2-A1	Brown and white from faux cornice (C) with mer (A)	cross-section
SAJO-ROSA P2.18C	Pendentive 2-A9,A10,B9	Lime wash, Mer layer no pigment, enlucido and enfoscado.	mortar analysis

SAJO-ROSA P2.18G	Pendentive 2-A9,A10,B9	Stratigraghy Black banding from Mer layer, enlucido, enfoscado	FTIR (A)
SAJO-ROSA P3.01.1	Pendentive 3-D6	Design layers, enlucido and enfoscado, loss due to termite damage	cross-section
SAJO-ROSA P3.01.2	Pendentive 3-D6	Design campaigns, enlucido and enfoscado, loss due to termite damage	cross-section
SAJO-ROSA P3.02	Pendentive 3-B8	Stratigraphy including campaigns (D) to (A) on underside	Cross-section
SAJO-ROSA P3.04	Pendentive 3-B8	Lime wash with red marbleizing (B) with pigments from Mer(A) on back	cross-section
SAJO-ROSA P3.05	Pendentive 3-A2	Stratigraphy from right edge of pendentive from edge border including campaigns (D) with blue gray, (C) light green banding, lime washes (B) , black pigment from (A) on underside	cross-section
SAJO-ROSA P3.08	Pendentive 3-A2	White from cornice (C)	EDS of White, layer(C)

SAJO-ROSA P3.11	Pendentive 3-B6	Yellow Ochre pigment (D)	EDS Yellow Ochre, Layer (D)
SAJO-ROSA P3.17	Pendentive 3-B7	Emerald Green pigment (D)	EDS of Green, layer(D)
SAJO-ROSA P3.19	Pendentive 3 (E5-NW arch)	Stratigraphy with lime washes, Mer layer enfoscado and enlucido. Sample from arch area with gray layer over faux vussoirs.	mortar analysis, Thin Section, XRD
SAJO-ROSA P3.21	Pendentive 3-A10	Stratigraphy, Brown faux cornice (C), green with rose border (C), lime washes	Cross-section,EDS-dot mapping of cross-section (ID pink, brown and green from layer(C)
SAJO-ROSA P4.05	Pendentive 4- A1	Umber from faux cornice (C) with olive green on underside	Cross-section
SAJO-ROSA P4.06.1	Pendentive 4- A2	Stratigraphy with red/pink band under the faux cornice and green (C)	Cross-section
SAJO-ROSA P4.06.2	Pendentive 4- A2	Stratigraphy with red/pink band under the faux cornice (C), this green seemed to be part of this layer on other pendentives but may actually correspond to a distinct campaign.	Cross-section

SAJO-ROSA P4.07	Pendentive 4- C6	Stratigraphy including charcoal gray of angel layers (C) to red and black pigments on underside (A)	cross-section
DOME			
SAJO-ROSA A5.01	DOME	Stratigraphy, blue from battle layer, brown from trompe l'oeil coffer, limewashes, lime wash with red marbleizing, enlucido	cross-section
SAJO-ROSA E2.01	DOME	Stratigraphy, top freehand ashlar, grey from figure, pink (C), gray wash layer, lime wash with red marblelizing (B), enlucido	cross-section
SAJO-ROSA E2.03	DOME	Stratigraphy, deep blue from ship, light blue from water (D), pink (C), multiple layers limewashes, enlucido or repair Mortar?	cross-section, EDS-dot mapping of cross-section
SAJO-ROSA E4.01	DOME	Stratigraphy, pencil marked ashlar both red and white paint, (C), limewashes, deep red on bottom (possible A)	cross-section
SAJO-ROSA F2.01	DOME	Stratigraphy Mer (A) black banding, enlucido, enfoscado	cross-section, Pigment dispersion, OM, Micro-Chem tests

SAJO-ROSA F2.02	DOME	Stratigraphy, charcoal paint from bottom of boat, pink trompe layer, multiple limewashes, black pigments from banding (A) on underside	cross-section
SAJO-ROSA F3.01	DOME	Stratigraphy faux cornice (C) limewashes Mer (A) underside	cross-section
SAJO-ROSA F3.03	DOME	Lemon yellow pigment w/ earth red from unidentified form (legs?), layer (D) battle/saint	EDS Lemon Yellow, Layer (D)
SAJO-ROSA G3.01	DOME	red "vault" (D), pink ground(C), lime wash, enlucido, enfoscado	cross-section
SAJO-ROSA G3.02	DOME	Charcoal from battle/saint layer, pink trompe l'oeil layer, gray layer, limewashes, enlucido, enfoscado	cross-section
SAJO-ROSA G3.06	DOME	White from dumbbell shape, layer (D)	EDS of White, layer(D)
SAJO-ROSA H4.01	DOME	Deep blue from water motif, layer (D)	EDS of Blue, layer(D)
SAJO-ROSA H5.01	DOME	Stratigraphy red ashlar joint (top) painted free hand (F), red from flag (D), lime washes one with red marbleizing (B)	cross-section

ARCHES			
SAJO-ROSA N_Ar1		red blue marbleizing green layer, white limewashes, grey limewashes.	cross-section, EDS-dot mapping of cross-section
SAJO-ROSA N_Ar2		grey limewashes, Mer black banding, enlucido, partial enfoscado	cross-section
CUPOLA			
SAJO-ROSA CU_1		aqua blue paint with enlucido	cross-section, EDS-dot mapping of cross-section

APPENDIX C
Substrate Analysis Results

Appendix C-1: Mortar Analysis Sample P2.18C.1

Table 2: Sample Description, Sample P2.18C.1

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**		
Sample Location: **Pendentive 2, (A9-10, B9)**	Date Sampled: **01/04/06**	
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **01/19/06**	
Type/Location: **Red Enfoscado** (rough coat)		Sample No: **P2.18.C1**
General Description: **Red matrix with a well sorted aggregate. Red blebs and white blebs of lime also dispersed throughout the matrix. No evidence of organic matter. Extremely friable, readily disaggregates.**		
Color: **5YR 5/8, yellowish red**	Texture: **80-120 grit (medium)**	
Hardness: 2.5 (Mohs hardness scale)	Gross Weight: **22.76 g**	

Table 3: Sample Components, Sample P2.18C.1

Fines:	Weight: **2.10 g**	Color: **7.5YR 6/6, reddish yellow**	
	Organic Matter: *Animal Hair : Vegetable Fiber : Charcoal : Ash : Wood : Other :* ***Not Applicable***		
Acid Soluble Fraction:	Weight: **5.2 g**		
	Description of Reaction: **Vigorous gas evolution. Complete acid digestion of soluble fraction in 10 hours.**		Filtrate Color: **Dilute lemon yellow color.**
Aggregate:	Weight: **15.46 g**		

Table 4: Sample Assessment, Sample P2.18C.1

	Weight %	Volume % (indirect approximate)*
Fines:	**9.23 %**	**5.51 %**
Acid Soluble Fraction:	**22.84 %**	**13.05%**
Aggregate:	**67.93 %**	**81.44 %**

* Volume % was determined using the density of Albite (2.1 g/cc) for Fines, and the density of Calcium Carbonate (1.92g/cc) for the acid soluble fraction.

Table 5: Morphological Observations, Sample P2.18C.1

ASTM Screen No.	Color (Munsell)	Sphericity	Roundness	Minerological Composition	Mag.
8	N/A	N/A	N/A	N/A	N/A
16	7.5YR 8/2, yellow	Round-Subround	High	Milky Quartz	30x
30	10YR 7/6, reddish yellow	Subround-Angular	Medium	Mostly Clear and Milky Quartz with trace Brick, Magnetite	30x
50	10YR 7/6, reddish yellow	Subangular-Angular	Medium	Mostly Clear and Milky Quartz with trace Brick, Magnetite	30x
100	10YR 7/6, reddish yellow	Subangular-Angular	Medium	Mostly Clear and Milky Quartz with trace Brick, Magnetite	30x
200	10YR 7/6, reddish yellow	Subangular-Angular	Low	Mostly Clear and Milky Quartz with increased Magnetite	30x
Pan	10YR 7/6, reddish yellow	Subangular-Angular	Low	Mostly Clear and Milky Quartz with increased Magnetite	30x

Table 6: Sieve Analysis, Sample P2.18C.1

Screen No.	Screen Size (mm)	M_c (g)	M_2, (g)	M_r, (M_2-M_c) (g)	$\%M_r$ (M_r/M_s)*100%	$\%M_{rt}$ $\sum$ $\%M_r$, (on or above)	$\%M_{pt}$ 100%-M_{rt}%
8	2.36	0.00	0.00	0.00	0.00	0.00	100
16	1.18	0.56	0.59	0.03	0.19	1.26	98.74
30	0.60	0.55	0.74	0.19	1.23	1.42	98.58
50	0.30	0.56	5.68	5.12	33.12	34.54	65.46
100	0.150	0.55	9.18	8.63	55.82	90.36	9.64
200	0.075	0.56	1.64	1.08	6.99	97.35	2.65
Pan	0.001	0.57	0.95	0.38	2.46	99.81	0.19

M_c: Mass of the container. **M_2**: Mass of the container + sample. **M_r**: Mass of the retained sample. **$\%M_r$**: Percent of retained sample per screen. **%Mrt**: Sum of the percent retained sample on or above a given screen. **%Mpt** : Total percentage passing through a given screen.

$$\%\text{Mass Loss, } M_L\ \% = \frac{M_S - \Sigma M_r}{M_S} \times 100\% = 0.19\%$$

Chart 1: Particle Size Distribution, Sample P2.18C.1

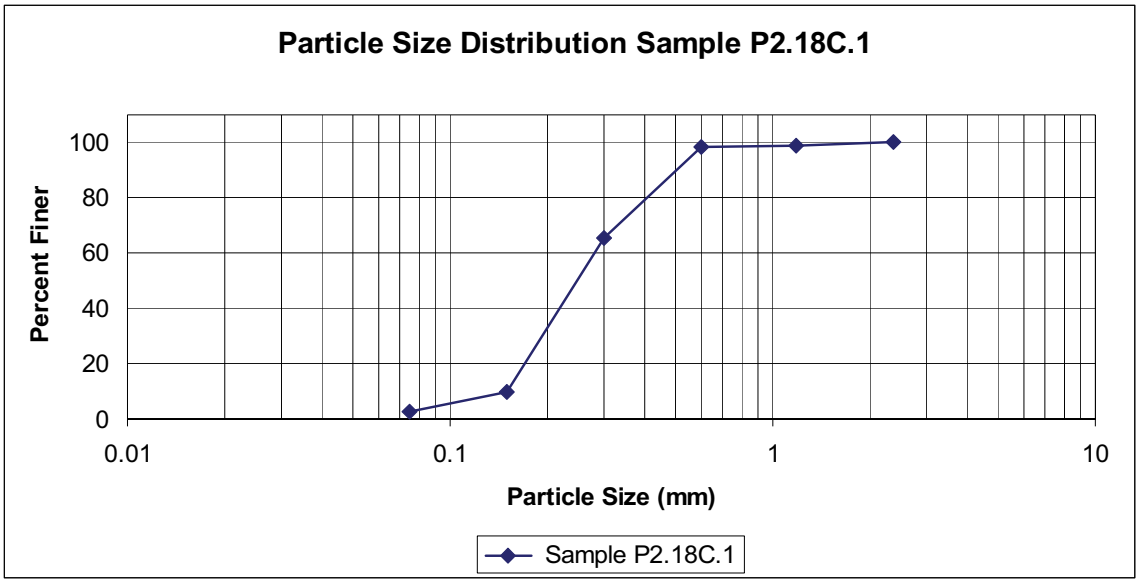


Figure 68: Sample 2.18C.1, *enfoscado* plaster, Appendix C-1

Appendix C-2: Mortar Analysis Sample P2.18C.2

Table 7: Sample Description, Sample P2.18C.2

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Pendentive 2, (A9-10, B9)**	Date Sampled: **01/04/06**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **01/19/06**
Type/Location: **White Enlucido** (finish coat)	Sample No: **P2.18C. 2**
General Description: **Cream matrix with large multi-colored aggregate. Aggregate is not well sorted and there are white blebs of lime visible. No evidence of organic matter. Cracks have formed perpendicular to the surface.**	
Color: **10YR 8/3, very pale brown**	Texture: **course**
Hardness: **3.5** (Mohs hardness scale)	Gross Weight: **20.71 g**

Table 8: Sample Components, Sample P2.18C.2

Fines:	Weight: **0.57 g**	Color: **10YR 5/4, yellowish brown**
	Organic Matter: *Animal Hair : Vegetable Fiber :* ***Charcoal*** *: Ash : Wood : Other : Not Applicable*	
Acid Soluble Fraction:	Weight: **15.46 g**	
	Description of Reaction: **Vigorous gas evolution. Complete acid digestion of soluble fraction in 36 hours.**	Filtrate Color: **Dilute lemon yellow color.**
Aggregate:	Weight: **4.68 g**	

Table 9: Sample Assessment, Sample P2.18C.2

	Weight %	Volume % (indirect approximate)*
Fines:	**2.75 %**	**1.9 %**
Acid Soluble Fraction:	**74.65 %**	**67.6 %**
Aggregate:	**22.60 %**	**30.5 %**

* Volume % was determined using the density of albite (2.1 g/cc) for Fines, and the density of Calcium Carbonate (1.92g/cc) for the acid soluble fraction.

Table 10: Morphological Observations, Sample P2.18C.2

ASTM Screen No.	Color (Munsell)	Sphericity	Roundness	Minerological Composition	Mag.
8	10YR 7/4, vary pale brown	Round-Subround	High	Milky Quartz with trace charcoal, and purple and green grains	30x
16	7.5YR 6/4, light brown	Round-Subround	High	Milky Quartz with trace charcoal, and purple and green grains	30x
30	7.5YR 6/6, brownish yellow	Subround-Angular	Medium	Milky Quartz with trace charcoal,brick and purple and green grains	30x
50	10YR 6/6, reddish yellow	Subround-Subangular	Medium	Milky Quartz with trace charcoal, and purple and green grains	30x
100	10YR 7/6, reddish yellow	Subangular-Angular	Medium	Clear, Milky, and Red Quartz, Mica	30x
200	10YR 7/6, reddish yellow	Subangular-Angular	Low	Clear and Milky Quartz with trace brick	30x
Pan	10YR 7/6, reddish yellow	Subangular-Angular	Low	Clear and Milky Quartz	30x

Table 11: Sieve Analysis, Sample P2.18C.2

Screen No.	Screen Size (mm)	M_c (g)	M_2, (g)	M_r, (M_2-M_c) (g)	$\%M_r$ (M_r/M_s)*100%	$\%M_{rt}$ $\sum$ $\%M_r$, (on or above)	$\%M_{pt}$ 100%-M_{rt}%
8	2.36	0.56	0.81	0.25	5.34	5.34	100
16	1.18	0.57	2.95	2.38	50.85	56.20	43.80
30	0.60	0.57	1.83	1.26	26.92	83.12	16.88
50	0.30	0.57	0.86	0.29	6.20	89.32	10.68
100	0.150	0.58	0.94	0.36	7.69	97.01	2.99
200	0.075	0.56	0.66	0.1	2.14	99.15	0.85
Pan	0.001	0.57	0.59	0.02	0.43	99.57	0.43

M_c: Mass of the container. **M_2**: Mass of the container + sample. **M_r**: Mass of the retained sample. **$\%M_r$**: Percent of retained sample per screen. **%Mrt**: Sum of the percent retained sample on or above a given screen. **%Mpt** : Total percentage passing through a given screen.

$$\%\text{Mass Loss, } \mathbf{M_L}\ \% = \frac{M_S - \Sigma M_r}{M_S} \times 100\% = 0.43\%$$

Chart 2: Particle Size Distribution, Sample P2.18C.2

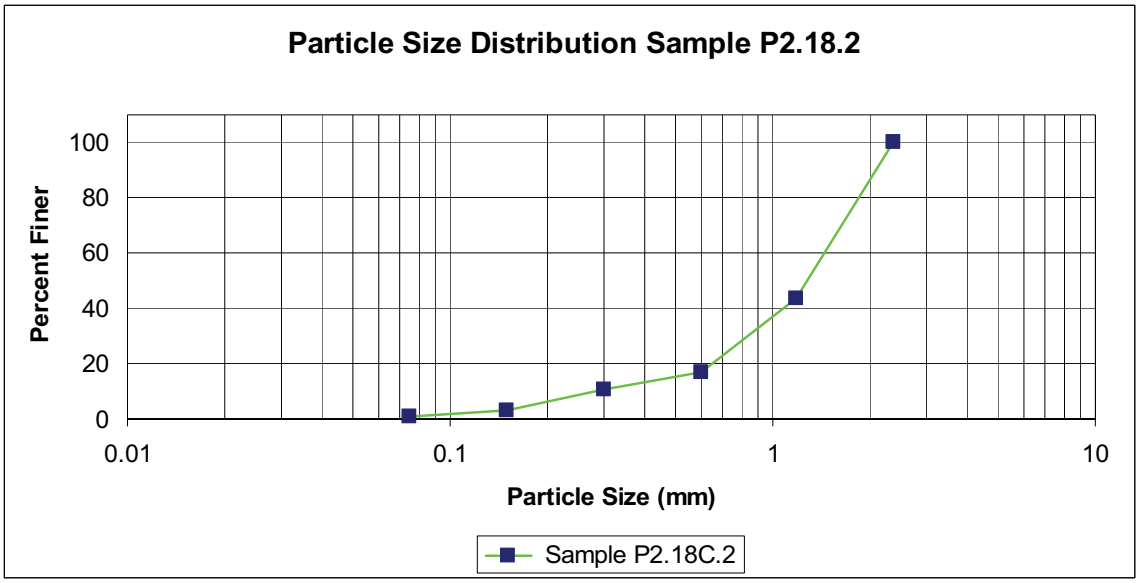


Figure 69: Sample 2.18C.2, *enlucido* plaster

Appendix C-3: Mortar Analysis Sample P3.19.1

Table 12: Sample Description, Sample P3.19

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Pendentive 3, (NW Arch)**	Date Sampled: **01/04/06**
Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Pendentive 3, (NW Arch)**	Date Sampled: **01/04/06**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **01/19/06**
Type/Location: **Red Enfoscado** (rough coat)	Sample No: **P3.19.1**
General Description: **Red matrix with well sorted with aggregate. Red blebs and white blebs of lime also dispersed throughout the matrix. No evidence of organic matter. Extremely friable, readily disaggregates.**	
Color: **5YR 5/8, yellowish red**	Texture: **80-120 grit (medium)**
Hardness: 2.5 (Mohs hardness scale)	Gross Weight: **29.76 g**

Table 13: Sample Components, Sample P3.19.1

Fines:	Weight: **2.7 g**	Color: **7.5YR 6/6, reddish yellow**	
	Organic Matter: *Animal Hair : Vegetable Fiber : Charcoal : Ash : Wood : Other :* ***Not Applicable***		
Acid Soluble Fraction:	Weight: **7.9 g**		
	Description of Reaction: **Vigorous gas evolution. Complete acid digestion of soluble fraction in 10 hours.**		Filtrate Color: **Dilute lemon yellow color.**
Aggregate:	Weight: **22.94 g**		

Table 14: Sample Assessment, Sample P3.19.1

	Weight %	Volume % (indirect approximate)*
Fines:	**8.30 %**	**4.92 %**
Acid Soluble Fraction:	**23.49 %**	**13.41 %**
Aggregate:	**68.21 %**	**81.67 %**

* Volume % was determined using the density of Albite (2.1 g/cc) for Fines, and the density of Calcium Carbonate (1.92g/cc) for the acid soluble fraction.

Table 15: Morphological Observations, Sample P3.19.1

ASTM Screen No.	Color (Munsell)	Sphericity	Roundness	Minerological Composition	Mag.
8	10YR 7/4, vary pale brown	Round-Subround	High	Milky and Red Quartz	30x
16	7.5YR 8/2, yellow	Round-Subround	High	Milky Quartz	30x
30	10YR 7/6, reddish yellow	Subround-Angular	Medium	Mostly Clear and Milky Quartz with trace Brick, Magnetite	30x
50	10YR 7/6, reddish yellow	Subangular-Angular	Medium	Mostly Clear and Milky Quartz with trace Brick, Magnetite	30x
100	10YR 7/6, reddish yellow	Subangular-Angular	Medium	Mostly Clear and Milky Quartz with trace Brick, Magnetite	30x
200	10YR 7/6, reddish yellow	Subangular-Angular	Low	Mostly Clear and Milky Quartz with increased Magnetite	30x
Pan	10YR 7/6, reddish yellow	Subangular-Angular	Low	Mostly Clear and Milky Quartz with increased Magnetite	30x

Table 16: Sieve Analysis, Sample P3.19.1

Screen No.	Screen Size (mm)	M_c (g)	M_2, (g)	M_r, (M_2-M_c) (g)	$\%M_r$ (M_r/M_s)*100%	$\%M_{rt}$ $\sum \%M_r$, (on or above)	$\%M_{pt}$ 100%-M_{rt}%
8	2.36	0.55	0.74	0.19	0.83	0.83	100
16	1.18	0.54	0.72	0.18	0.78	1.61	98.39
30	0.60	0.55	1.06	0.51	2.22	3.84	96.16
50	0.30	0.56	6.09	5.53	24.11	27.94	72.06
100	0.150	7.74	22.2	14.46	63.03	90.98	9.02
200	0.075	0.55	1.75	1.2	5.23	96.21	3.79
Pan	0.001	0.56	1.39	0.83	3.62	99.83	0.17

M_c: Mass of the container. **M_2**: Mass of the container + sample. **M_r**: Mass of the retained sample. **$\%M_r$**: Percent of retained sample per screen. **%Mrt**: Sum of the percent retained sample on or above a given screen. **%Mpt** : Total percentage passing through a given screen.

$$\%\text{Mass Loss, } \mathbf{M_L}\ \% = \frac{M_S - \Sigma M_r}{M_S} \times 100\% = 0.17\%$$

Chart 3: Particle Size Distribution, Sample P3.19.1

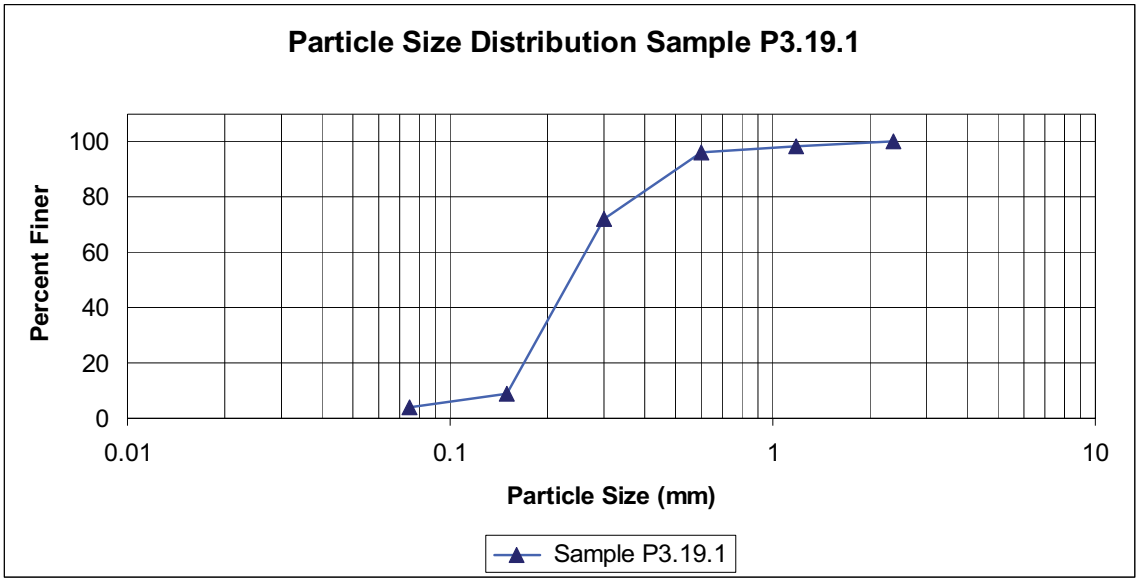


Figure 70: Sample 3.19, red *enfoscado* on the bottom of sample

Appendix C-4: Mortar Analysis Sample P3.19.2

Table 17: Sample Description, Sample P3.19.2

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Pendentive 3, (NW-Arch)**	Date Sampled: **01/04/06**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **01/19/06**
Type/Location: **White Enlucido** (finish coat)	Sample No: **P3.19. 2**
General Description: **Cream matrix with large multi-colored aggregate. Aggregate is not well sorted and there are white blebs of lime visible. No evidence of organic matter. Cracks have formed perpendicular to the surface.**	
Color: **10YR 8/3, very pale brown**	Texture: **course**
Hardness: **3.5** (Mohs hardness scale)	Gross Weight: **29.76 g**

Table 18: Sample Components, Sample P3.19.2

Fines:	Weight: **0.64 g**	Color: **10YR 5/4, yellowish brown**	
	Organic Matter: *Animal Hair : Vegetable Fiber :* ***Charcoal*** *: Ash : Wood : Other : Not Applicable*		
Acid Soluble Fraction:	Weight: **25.42 g**		
	Description of Reaction: **Vigorous gas evolution. Complete acid digestion of soluble fraction in 36 hours.**		Filtrate Color: **Dilute lemon yellow color.**
Aggregate:	Weight: **3.70 g**		

Table 19: Sample Assessment, Sample P3.19.2

	Weight %	Volume % (indirect approximate)*
Fines:	**2.15 %**	**2.3 %**
Acid Soluble Fraction:	**85.42 %**	**59.7%**
Aggregate:	**12.43 %**	**38.01 %**

* Volume % was determined using the density of Albite (2.1 g/cc) for Fines, and the density of Calcium Carbonate (1.92g/cc) for the acid soluble fraction.

Table 20: Morphological Observations, Sample P3.19.2

ASTM Screen No.	Color (Munsell)	Sphericity	Roundness	Minerological Composition	Mag.
8	5YR 5/6, yellowish red	Angular	low	Brick Fragment	30x
16	10YR 8/3, very pale brown	Round-Subround	Medium	Milky Quartz with trace charcoal, and purple and green grains	30x
30	10YR 8/4, very pale brown	Subround-Angular	Medium	Milky Quartz with trace charcoal,brick and purple and green grains	30x
50	10YR 8/4, very pale brown	Subround-Subangular	Medium	Milky Quartz with trace charcoal, and purple and green grains	30x
100	10YR 8/4, very pale brown	Subangular-Angular	Medium	Clear, Milky, and Red Quartz, Mica	30x
200	10YR 6/4, light yellowish brown	Subangular-Angular	Low	Clear and Milky Quartz with trace brick	30x
Pan	10YR 6/4, light yellowish brown	Subangular-Angular	Low	Clear and Milky Quartz	30x

Table 21: Sieve Analysis, Sample P3.19.2

Screen No.	Screen Size (mm)	M_c (g)	M_2, (g)	M_r, (M_2-M_c) (g)	$\%M_r$ (M_r/M_s)*100%	$\%M_{rt}$ $\sum$ $\%M_r$, (on or above)	$\%M_{pt}$ 100%-M_{rt}%
8	2.36	0.55	0.58	0.03	0.81	0.81	100
16	1.18	0.54	1.11	0.57	15.41	16.22	83.78
30	0.60	0.55	1.86	1.31	35.41	51.62	48.38
50	0.30	0.52	1.16	0.64	17.30	68.92	31.08
100	0.150	0.51	1.44	0.93	25.14	94.05	5.95
200	0.075	0.52	0.72	0.2	5.41	99.46	0.54
Pan	0.001	0.54	0.55	0.01	0.27	99.73	0.27

M_c: Mass of the container. **M_2**: Mass of the container + sample. **M_r**: Mass of the retained sample. **$\%M_r$**: Percent of retained sample per screen. **%Mrt**: Sum of the percent retained sample on or above a given screen. **%Mpt** : Total percentage passing through a given screen.

$$\%\text{Mass Loss, } M_L\ \% = \frac{M_S - \Sigma M_r}{M_S} \times 100\% = 0.27\%$$

Chart 4: Particle Size Distribution, Sample P3.19.2

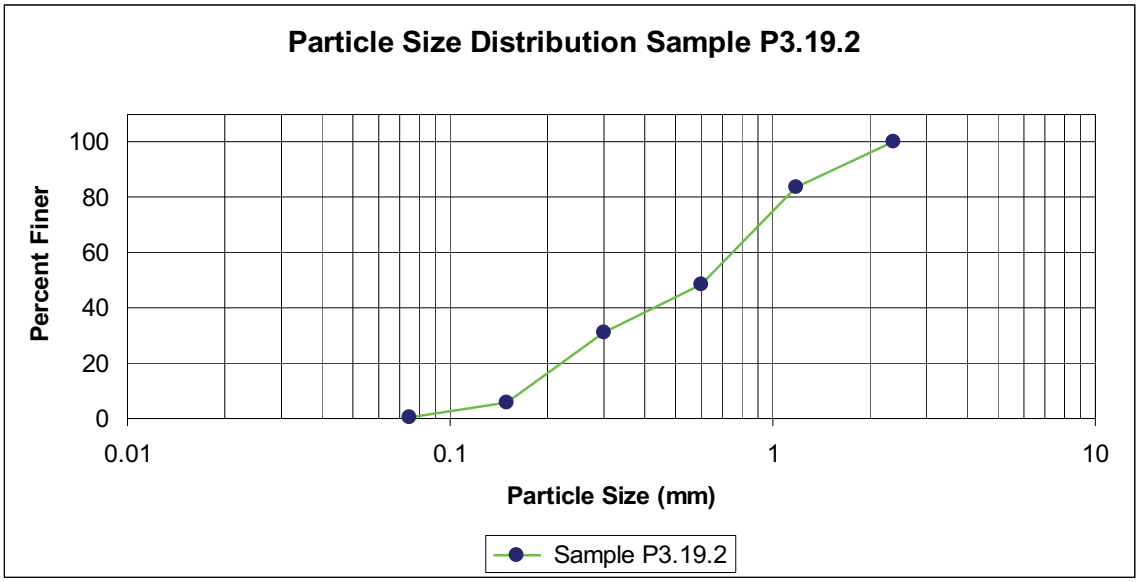
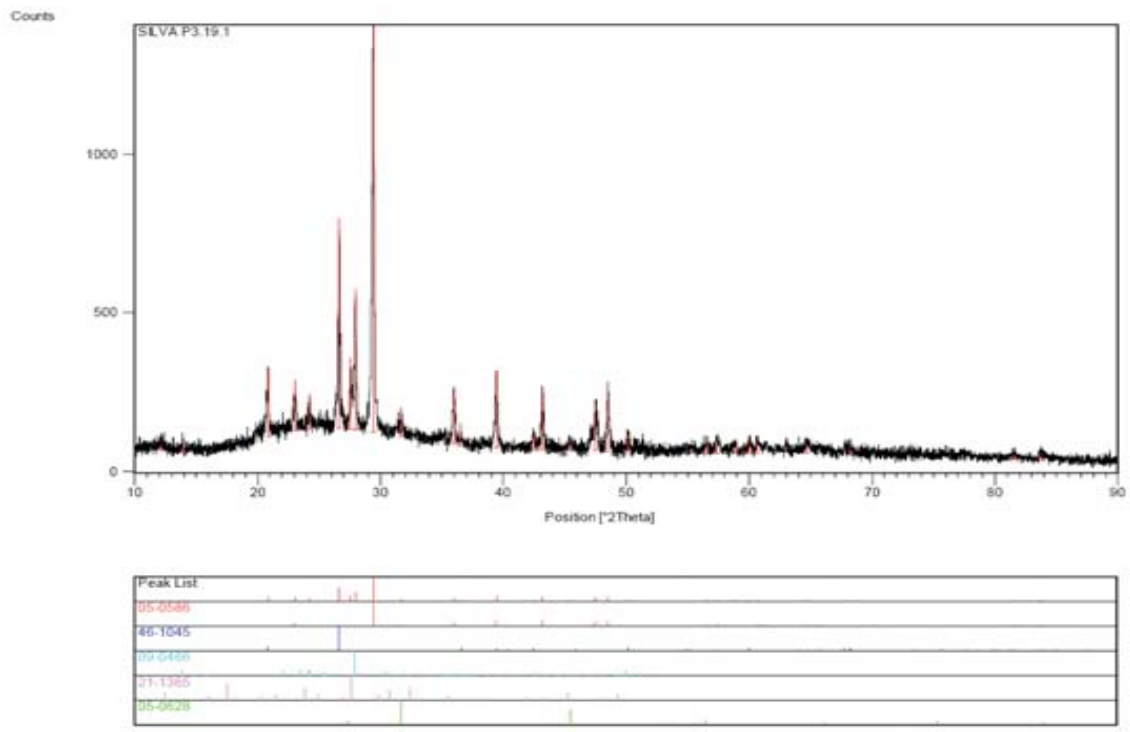


Figure 71: Sample 3.19, white *enlucido* on the top of sample

APPENDIX C-5

Chart 5: XRD Spectra of Fines Fraction, Sample P3.19.1 (enfoscado)

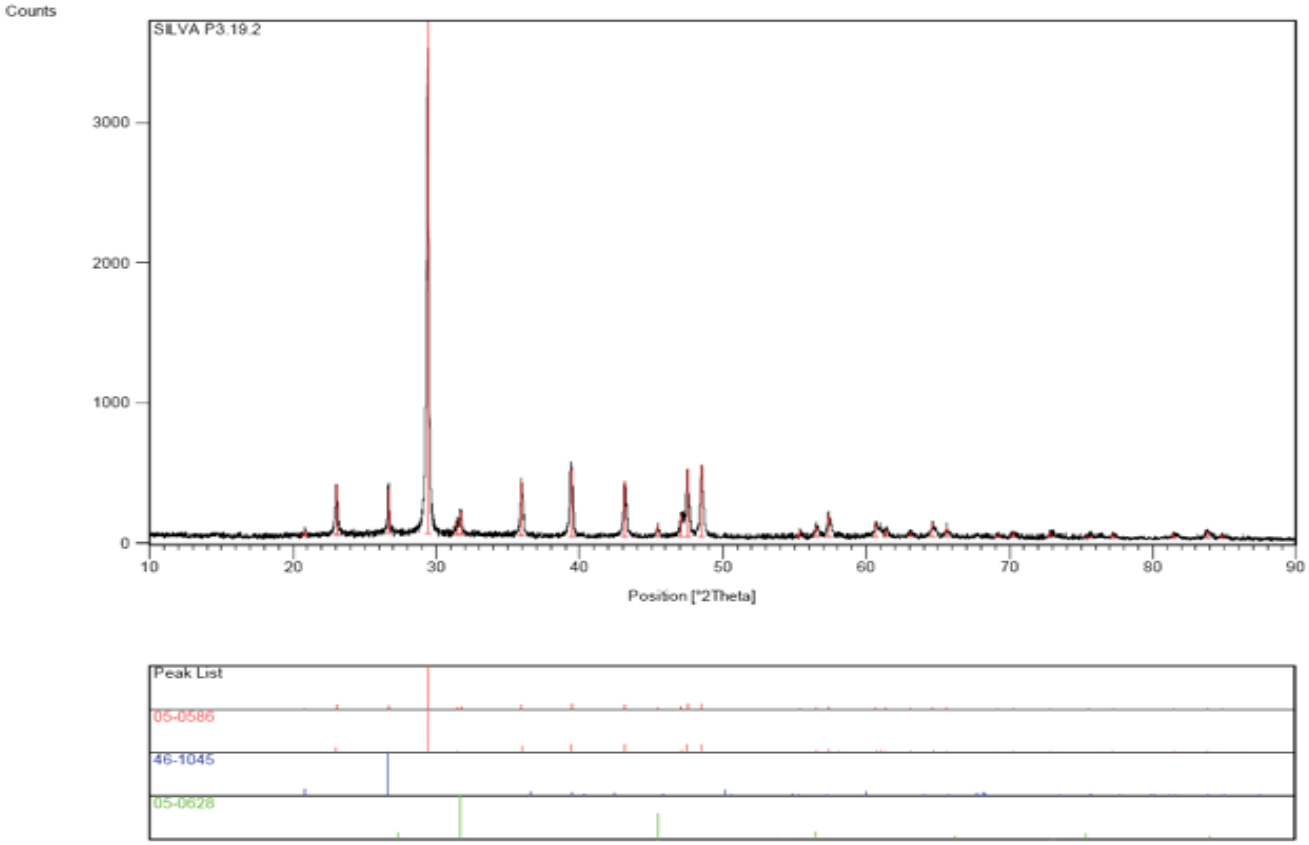
SAMPLE:	**SAJO-ROSA P3.19.1**	**DESCRIPTION: ENFOSCADO**		
Ref. Code	Compound Name	Chemical Formula	Scale Factor	Semi-Quant Composition
05-0586	Calcite, syn	Ca C O3	0.943	52.2%
46-1045	Quartz, syn	Si O2	0.529	29.3%
09-0466	Albite, ordered	Na Al Si3 O8	0.182	10.1%
21-1365	Yagiite	(Na3 , K)3 Mg4 (Al , Mg)6 (Si , Al)24 O60	0.08	4.4%
05-0628	Halite, syn	Na Cl	0.072	4.0%
			1.806	



APPENDIX C-6

Chart 5: XRD Spectra of Fines Fraction, Sample P3.19.2 (enlucido)

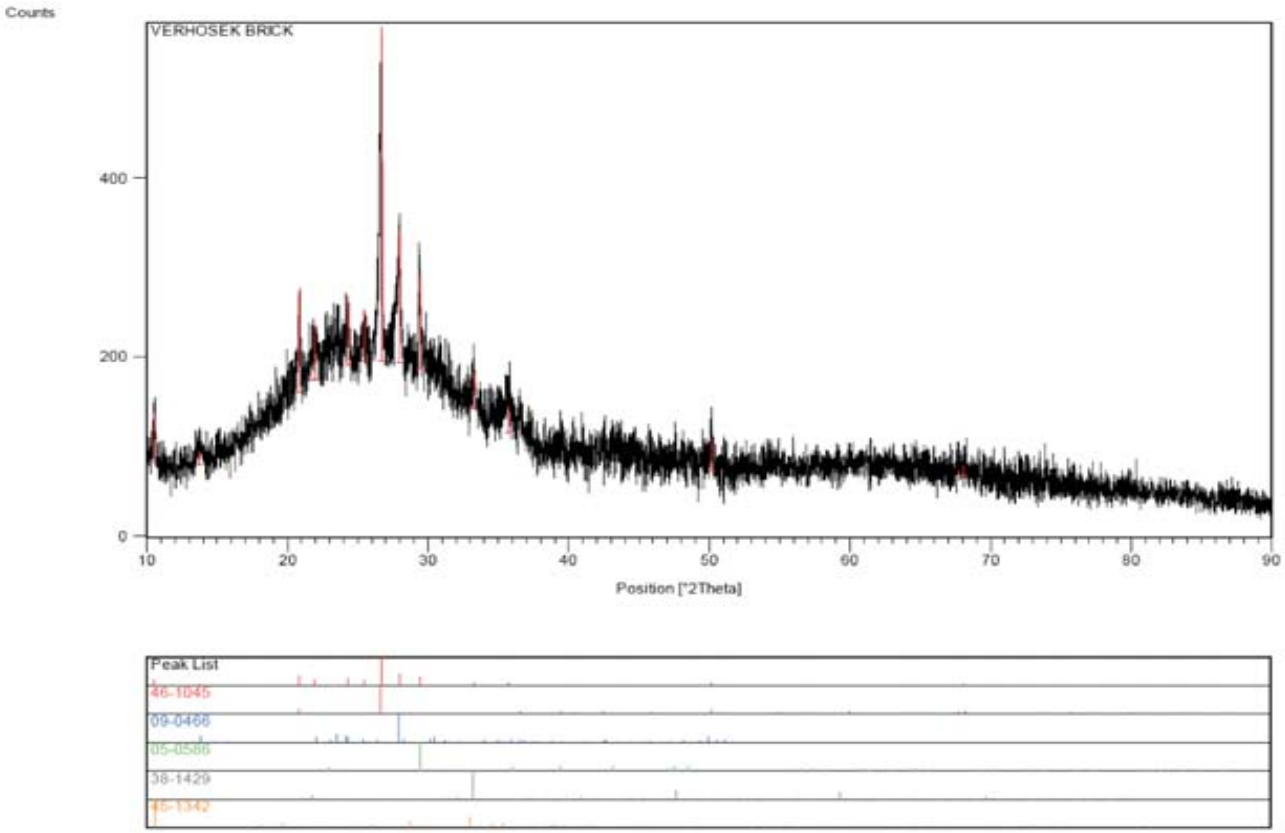
SAMPLE:	**SAJO-ROSA P3.19.2**	**DESCRIPTION: ENLUCIDO**	Scale Factor	Semi-Quant Composition
Ref. Code	Compound Name	Chemical Formula	0.803	
05-0586	Calcite, syn	Ca C O3	0.112	83.4%
46-1045	Quartz, syn	Si O2	0.048	11.6%
05-0628	Halite, syn	Na Cl	0.963	5.0%



Sample Description: Low Fired Brick from Puerto Rico

Ref. Code	Compound Name	Chemical Formula	Scale Factor	Semi-Quant Composition
46-1045	Quartz, syn	Si O2	0.8	49.9%
09-0466	Albite, ordered	Na Al Si3 O8	0.336	21.0%
05-0586	Calcite, syn	Ca C O3	0.161	10.0%
38-1429	tricalcium aluminate	Ca3 Al2 O6	0.205	12.8%
45-1342	Ferroactinolite	(Ca , Na , K)2 Fe5 Si8 O22 (O H)2	0.1	6.2%
			1.602	

Large "hump" is due to amorphous material - most likely SiO_2



APPENDIX D

Pigment/Colorant and Binder Results

Table 22: Comaprative Analysis Matrix of Cross-Section Stratigraphies					
Layer_No	**SAJO-ROSA_ P1.02.1**	**SAJO-ROSA_ P1.02.2**	**SAJO-ROSA_ P1.03**	**SAJO-ROSA_ P1.04**	**SAJO-ROSA_ P2.01.1**
1	Red and Black	Yellow ochre color	Black	creamy white	Light Gray
2	creamy white	cool white	creamy white	creamy white	creamy white
3	creamy white	creamy white	creamy white	creamy white	Light Gray
4	creamy white	creamy white	creamy white	creamy white	cool white
5	cool white	creamy white	cool white	creamy white	creamy white
6	creamy white	cool white	creamy white	creamy white	cool white
7	creamy white	cool white	cool white	creamy white	Red-Orange
8	creamy white	cool white	creamy white	Tan-pink	cool white
9	creamy white	cool white	Tan-pink	Brown	creamy white
10	Tan-pink	Tan-pink	Blue-gray	Black	creamy white
11	Charcoal Gray	Charcoal Gray		Blue	creamy white
12					Gray
13					Tan-pink
14					
15					
16					
17					
18					
19					
Comments	Red and Black (A) floral motif, multiple limewashes, Pink Ground (C), Blue-gray(D) banding, background.	Yellow and Black (A) floral motif, multiple limewashes, Pink Ground (C), Blue-gray(D) banding, background.	Black (A) banding, multiple limewashes, Pink Ground (C), Blue-gray(D) banding, background.	Limewashes, Pink and Brown (C), Black and Blue (D) area surrounding figures head.	Gray layer possible layer A, limewashes, Red marbalizing (B), undetermined gray, pink(C)

Key:	
	Mortar Layer
	Campaign A
	Campaign B
	Campaign C
	Campagin D
	Camapign E
	Campaign F

SAJO-ROSA_ P2.01.2	**SAJO-ROSA_ P2.01.3**	**SAJO-ROSA_ P2.04**	**SAJO-ROSA_ P2.05.1**	**SAJO-ROSA_ P2.05.2**	**SAJO-ROSA_ P2.06**
Red and Black	Black	Black	creamy white	Red	Black
creamy white	creamy white	Gray	creamy white	Gray	creamy white
creamy white	Gray	cool white	creamy white	creamy white	Gray
creamy white	creamy white	creamy white	creamy white	creamy white	creamy white
cool white	creamy white	creamy white	creamy white	creamy white	creamy white
creamy white	creamy white	creamy white	creamy white	creamy white	creamy white
Red-Orange	cool white	creamy white	Light Tan-pink	Light tan-pink	creamy white
creamy white	Red-Orange	Grayish-white	Darker tan-pink	Darker tan-pink	creamy white
cool white	creamy white	Tan-pink	Transpaarnt yellow	Charcoal Gray	cool white
creamy white	creamy white	slightly darker pink	Blue	Yellow-Orange	Red-Orange
Gray	Gray	Blue	Charcoal Gray		
Tan-pink	Tan-pink		Yellow-Orange		
slightly darker pink	slightly darker pink				
Light Gray	Gray				
Red and Black (A) floral motif, multiple limewashes, Red marbalizing (B), Pink Ground (C), light gray(D) banding, background.	Black (A) floral motif, multiple limewashes, Red marbleizing (B), Pink Ground (C), light gray(D) banding, background.	Black (A) banding, Gray, multiple limewashes, Pink Ground (C), blue (D) background.	Multiple limewashes, Pink Ground (C), Protenaceous layer, blue, gray, yellow-orange (D) background.	Multiple limewashes, Pink Ground (C), blue, gray, yellow-orange (D) background.	Black (A) banding, multiple limewashes,Red marbleizing (B).

Key:

- Mortar Layer
- Campaign A
- Campaign B
- Campaign C
- Campagin D
- Camapign E
- Campaign F

SAJO-ROSA_ P2.07	**SAJO-ROSA_ P2.17**	**SAJO-ROSA_ P3.01**	**SAJO-ROSA_ P3.02**	**SAJO-ROSA_ P3.04**	**SAJO-ROSA_ P3.05**
Red and Black	Black	Enfoscado	Yellow and Black	Black and Red	Black
creamy white	cool white	Enlucido	Cool White	Grayish White	Grayish White
cool white	creamy white	Black	creamy white	creamy white	Cool White
creamy white	creamy white	Grayish White	creamy white	Cool White	Black
creamy white	creamy white	creamy white	creamy white	creamy white	Cool White
creamy white	creamy white	creamy white	creamy white	creamy white	creamy white
creamy white	creamy white	Cool White	creamy white	creamy white	Light Gray-green
Gray	creamy white		creamy white	creamy white	Yellow-Beige
Light tan-pink	creamy white		creamy white	creamy white	Gray
Darker tan-pink	creamy white		creamy white	Orange-Red	
Gray-green	Light Gray		creamy white		
	Yellow-Beige		Light Gray		
	Brown		creamy white		
			Tan-pink		
			Yellow-Beige		
			Blue		
Black and red (A) floral motif, multiple limewashes, Pink Grounds and green banding(C).	Black (A) banding, multiple limewashes, light gray and beige ground with brown from faux cornice (C).	Black (A) banding, multiple limewashes.	Yellow and Black (A) floral motif, multiple limewashes, Pink Ground (C), Blue(D) background.	Black and red (A) floral motif, multiple limewashes, Red marbleizing (B).	Black (A) banding, Gray, multiple limewashes, Gray-green banding (C), gray (D) background.

Key:	
	Mortar Layer
	Campaign A
	Campaign B
	Campaign C
	Campagin D
	Camapign E
	Campaign F

SAJO-ROSA_ P3.21	**SAJO-ROSA_ P4.06.1**	**SAJO-ROSA_ P4.06.2**	**SAJO-ROSA_ P4.07**	**SAJO-ROSA_ A5.01**	**SAJO-ROSA_ E2.01**
Cool White	**Repair mortar**	Black	Black and Yellow	Enlucido	Enlucido
creamy white	Gray	**Repair mortar**	creamy white	White	White
creamy white	Tan-pink	Gray	creamy white	White	White
creamy white	Pinkish-Rose	Tan-pink	creamy white	White	White
creamy white			creamy white	White	White
Light Gray			creamy white	White	Light Gray
Tan-pink			creamy white	Black	Light Pink
Black			Light Gray	Yellowish-white	Light Orange Yellow
Pinkish-Rose			Tan-pink	Orange	Dark Blue-Gray
yellow			Yellow	Orange-Brown	Light Gray
Rust			Black-Brown	White	White
Gray				White	Red
				White	
				Red-Orange	
Limewashes, Pink ground, black, rose banding(C). Yellow, Rust and Gray (D) area near bottom edge of dome	gray limewash, pink ground layers (C).	Black banding (A), repair mortar bottom of the dome, gray, Pink (C)	Black and Yellow mer figure (A), Pink ground (C), Yellow, Black-brown angel figure (C).	Red (F) freehand ashlar	Enlucido, Pink light orange Yellow (C), Blue-Gray, light gray (D), White, Red (F) freehand ashlar

Key:	Mortar Layer
	Campaign A
	Campaign B
	Campaign C
	Campagin D
	Camapign E
	Campaign F

SAJO-ROSA_ E2.03	**SAJO-ROSA_ E4.01.1**	**SAJO-ROSA_ E4.01.2**	**SAJO-ROSA_ F2.01**	**SAJO-ROSA_ F2.02**	**SAJO-ROSA_ F3.01**
Repair mortar	White	White	Enfoscado	Black	Black
White	Orange-Red	Orange-Red	Enlucido	creamy white	creamy white
Creamy White	White	White	Black	creamy white	creamy white
Tan-pink	Orange-Red	Orange-Red		creamy white	creamy white
Yellow	White	White		creamy white	creamy white
Charcoal Gray	Light Gray	Light Gray		creamy white	creamy white
Black	Light Pink	Light Pink		creamy white	creamy white
Blue	Pale yellow-green	Pale yellow-green		creamy white	creamy white
	Brownish-Orange	Brownish-Orange		creamy white	creamy white
	Tan-pink	Tan-pink		creamy white	creamy white
	Yellow	Yellow		Pale green-gray	creamy white
	Orange	Orange		Light tan-pink	Light tan-pink
	White	White		Yellow	Pale green-gray
	Orange	Orange		Dark Blue	Cream
					Brown
Repair mortar, Pink, yellow(C), Gray, Black Blue, (D)	area near oculus with red band along the edge.	area near oculus with red band along the edge.	Black from faux ashlar (A)	Black Banding (A), pink background (C), Blue (D)	Black banding base of dome (A), limewashes, Pink, cream , brown from faux cornice (C)

Key:	
	Mortar Layer
	Campaign A
	Campaign B
	Campaign C
	Campagin D
	Camapign E
	Campaign F

SAJO-ROSA_ G3.01	**SAJO-ROSA_ G3.02**	**SAJO-ROSA_ H5.01.1**	**SAJO-ROSA_ H5.01.2**	**SAJO-ROSA_ NAR1**	**SAJO-ROSA_ NAR2**
Enfoscado	Enfoscado	creamy white	creamy white	Black	Enfoscado
REPAIR mortar	**REPAIR mortar**	creamy white	creamy white	creamy white	Enlucido
creamy white	creamy white	creamy white	creamy white	creamy white	Black
creamy white	creamy white	creamy white	creamy white	creamy white	Gray
creamy white	creamy white	Orange-Red	Orange-Red	creamy white	
Light Gray	creamy white	creamy white	creamy white	Light Brown	
Light tan-pink	Orange-Red	Pale gray	Pale gray	creamy white	
Light Pink (C)	creamy white	Light tan-pink	Light tan-pink	creamy white	
Orange	Pale green-gray	Yellow	Yellow	creamy white	
	Light tan-pink	Orange-Red	Orange-Red	creamy white	
	Orange-Brown	White	White	creamy white	
	Dark Gray	Orange-Red	Orange-Red	Pale yellow-green	
		White	White	grayish white	
		Orange-Red	Orange-Red	grayish white	
				grayish white	
				Pale Blue	
				Tan-pink	
				Gray	
				White	
Enfoscado, repair mortar, lime washes, pink(C), Orange (D).	Enfoscado, repair mortar, lime washes, pink(C), Gray (D).	lime washes, pink (C), yellow (D), Orange white (E), orange, white (F)	lime washes, pink (C), yellow (D), Orange white (E), orange, white (F)	Black (A),Pink (C), Gray(D)	Enfoscado, enlucido black with gray (A)

Key:	
	Mortar Layer
	Campaign A
	Campaign B
	Campaign C
	Campagin D
	Camapign E
	Campaign F

SAJO-ROSA_ CU1
Enlucido
creamy white
creamy white
Light Aqua Blue
Light Aqua Blue
Dark Aqua Blue

Key:

Mortar Layer
Campaign A
Campaign B
Campaign C
Campagin D
Camapign E
Campaign F

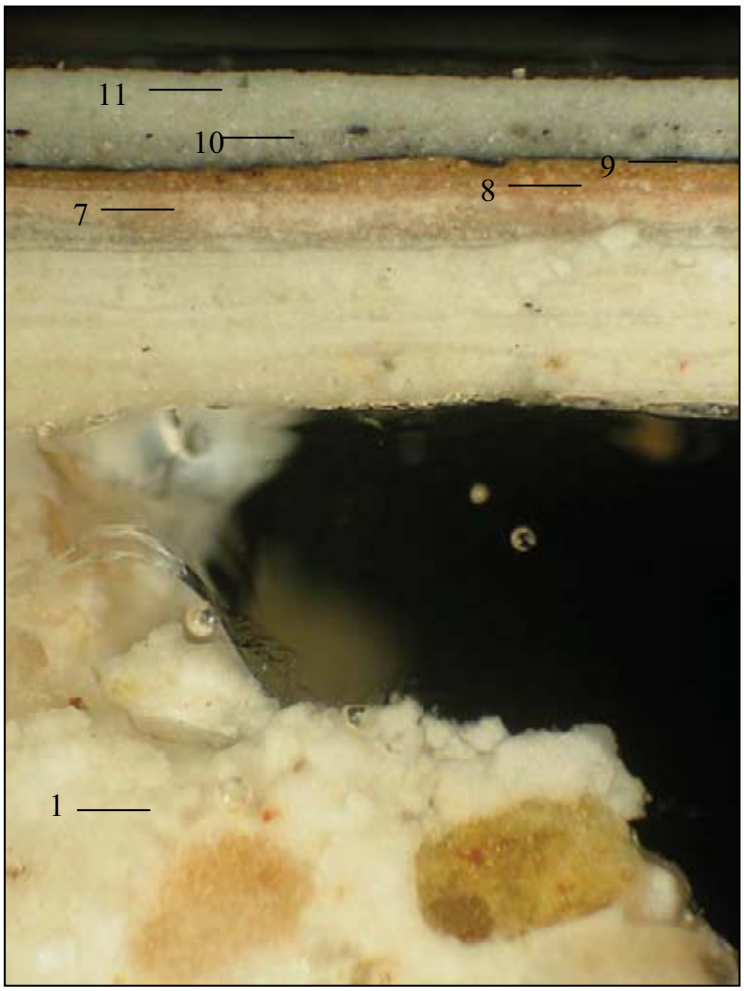
APPENDIX D-2.1: CROSS SECTIONAL ANALYSIS, SAMPLE E2.01

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Dome-E2**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA E2.01**	Type of Illumination: **Reflected**
Substrate: **Enlucido**	Magnification: **125x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS



STRATIGRAPHY
(STARTING FROM SUBSTRATE)

1. Enlucido
2. White
3. White
4. White
5. White
6. Light Gray
7. Light Pink (C)
8. Light Orange Yellow (C)
9. Dark Blue-Gray (D)
10. Light Gray (D)
11. White (F)
12. Red (F)-not in photo

Campaign in parentheses.

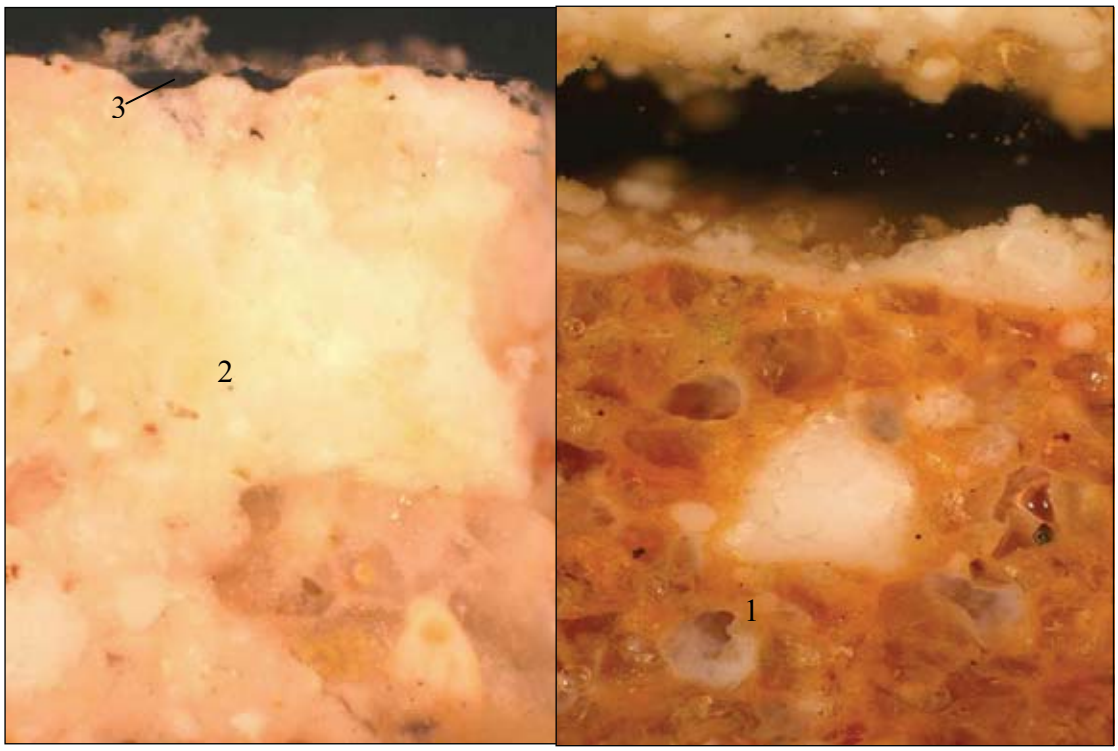
APPENDIX D-2.2: CROSS SECTIONAL ANALYSIS, SAMPLE F2.01

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Dome-F2**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA F2.01**	Type of Illumination: **Reflected**
Substrate: **Enfoscado and Enlucido**	Magnification: **125x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS



Top of sample **Middle of sample**

STRATIGRAPHY (STARTING FROM SUBSTRATE)

1. Enfoscado
2. Enlucido
3. Black (A)

Campaign in parentheses.

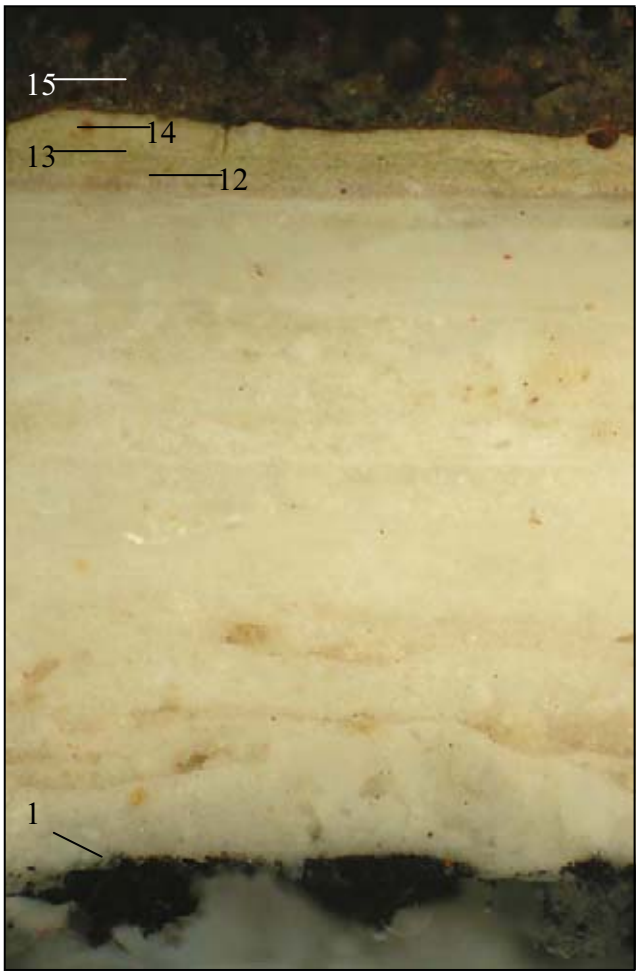
APPENDIX D-2.3: CROSS SECTIONAL ANALYSIS, SAMPLE F3.01

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Dome-F2**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA F3.01**	Type of Illumination: **Reflected**
Substrate:	Magnification: **125x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS



STRATIGRAPHY
(STARTING FROM SUBSTRATE)

1. Black (A)
2. creamy white
3. creamy white
4. creamy white
5. creamy white
6. creamy white
7. creamy white
8. creamy white
9. creamy white
10. creamy white
11. creamy white
12. Pale peachy-pink (C)
13. Pale green-gray (C)
14. Cream (C)
15. Brown (C)

Campaign in parentheses.

APPENDIX D-2.4: CROSS SECTIONAL ANALYSIS, SAMPLE P1.02.1

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Pendentive 1- B4**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA P1.02.1**	Type of Illumination: **Reflected**
Substrate:	Magnification: **125x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS

STRATIGRAPHY
(STARTING FROM SUBSTRATE)
Campaign in parentheses.

1. Yellow Ochre (A)
2. Cool White
3. Creamy White
4. Creamy White
5. Creamy White
6. Cool White
7. Cool White
8. Cool White
9. Cool White
10. Peachy-pink (C)
11. Charcoal Gray (D)

APPENDIX D-2.5: CROSS SECTIONAL ANALYSIS, SAMPLE P1.04

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Pendentive 1- B6**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA P1.04**	Type of Illumination: **Reflected**
Substrate:	Magnification: **150x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS

STRATIGRAPHY
(STARTING FROM SUBSTRATE)

(Campaign in parentheses)

1. creamy white
2. creamy white
3. creamy white
4. creamy white
5. creamy white
6. creamy white
7. creamy white
8. Peachy-pink (C)
9. Darker pink (C)
10. Brown (C)
11. Black (D) -not in image
12. Blue (D)

APPENDIX D-2.6: CROSS SECTIONAL ANALYSIS, SAMPLE P2.01.3

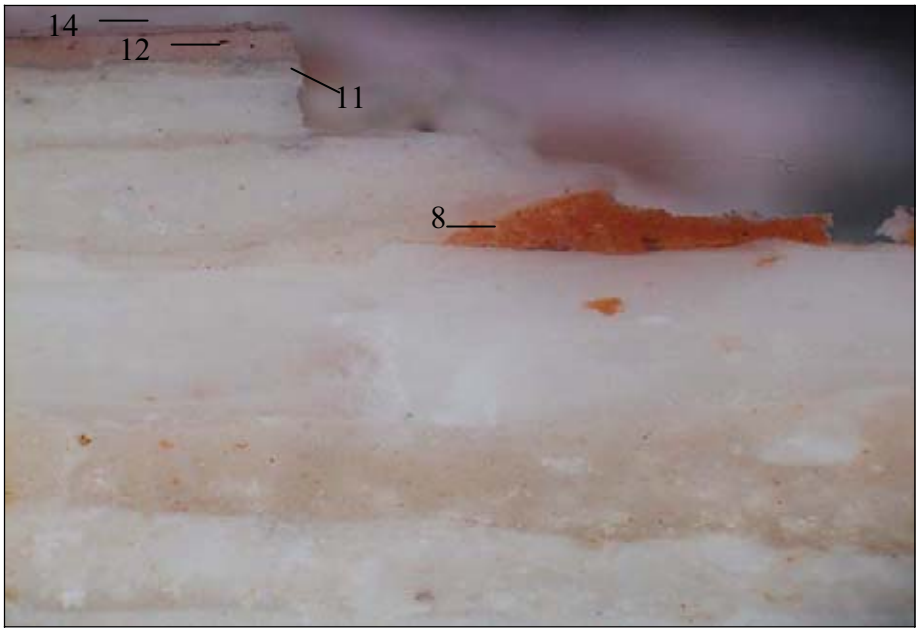
Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan Puerto Rico**	
Sample Location: **Pendentive 2-A9**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA P2.01.3**	Type of Illumination: **Reflected**
Substrate:	Magnification: **200x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS

Photomicrograph of top of sample layers 6-14



STRATIGRAPHY (STARTING FROM SUBSTRATE)

1. Black (A)
2. Creamy White
3. Gray
4. Creamy White
5. Creamy White
6. Creamy White
7. Cool White
8. Red-Orange (B)
9. Creamy White
10. Creamy White
11. Gray
12. Peachy-Pink (C)
13. Slightly Darker Pink (C)
14. Gray(D)

APPENDIX D-2.7: CROSS SECTIONAL ANALYSIS, SAMPLE P2.07

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan, Puerto Rico**	
Sample Location: **Pendentive 2-B8**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA P2.07**	Type of Illumination: **Reflected**
Substrate:	Magnification: **200x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS

Top of sample layers 3-11

STRATIGRAPHY (STARING FROM SUBSTRATE)

1. Red and Black - not in image (A)
2. Creamy White- not in image
3. Cool White
4. Creamy White
5. Creamy White
6. Creamy White
7. Creamy White
8. Gray (C)
9. Peachy-pink (C)
10. Darker peach (C)
11. Gray-green (C)

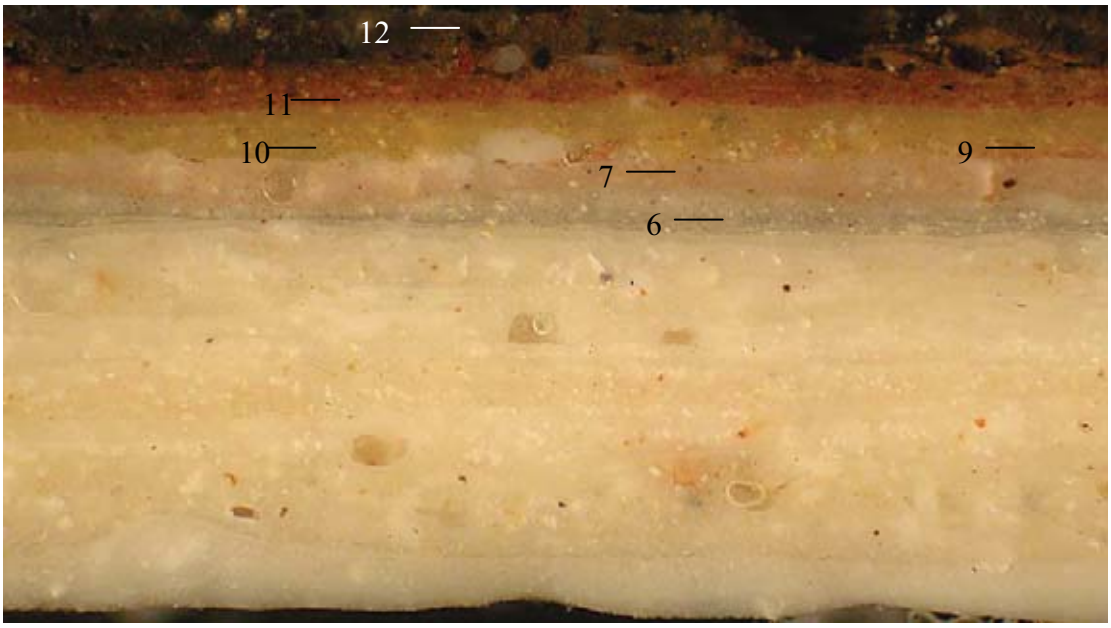
APPENDIX D-2.8: CROSS SECTIONAL ANALYSIS, SAMPLE P3.21

Project Site: ***Capilla de la Virgen del Rosario, Iglesia San José,*** **Old San Juan, Puerto Rico**	
Sample Location: **Pendentive 3-A10**	Date Sampled: **January 2006**
Analysis Performed By: **Cynthia Silva**	Date Analyzed: **March 2006**

DESCRIPTION OF SAMPLE

Sample No: **SAJO-ROSA P3.21**	Type of Illumination: **Reflected**
Substrate:	Magnification: **200x**
Microscope: **Nikon AFX-IIA**	Camera: **Nikon Coolpix 5000 Digital Camera**

COMMENTS



STRATIGRAPHY (STARING FROM SUBSTRATE)

1. Cool White
2. Creamy White
3. Creamy White
4. Creamy White
5. Creamy White
6. Light Gray (C)
7. Peachy-pink (C)
8. Black –not in image (C)
9. Pinkish-Rose (C)
10. Yellow (C)
11. Rust (C)
12. Gray (C)

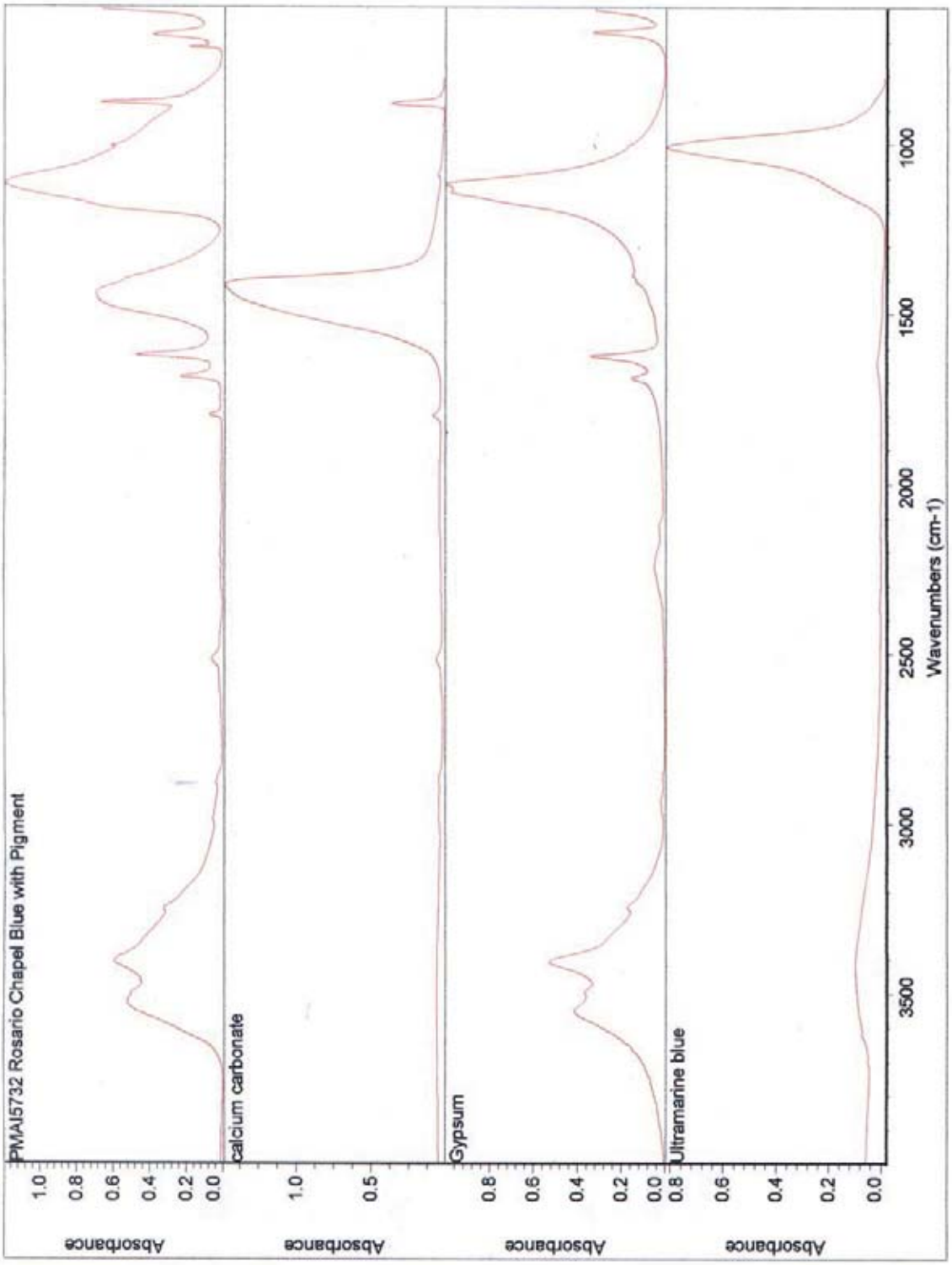


Chart 7: FTIR spectra, sample P1.06, Campaign D blue pigment and binder analysis

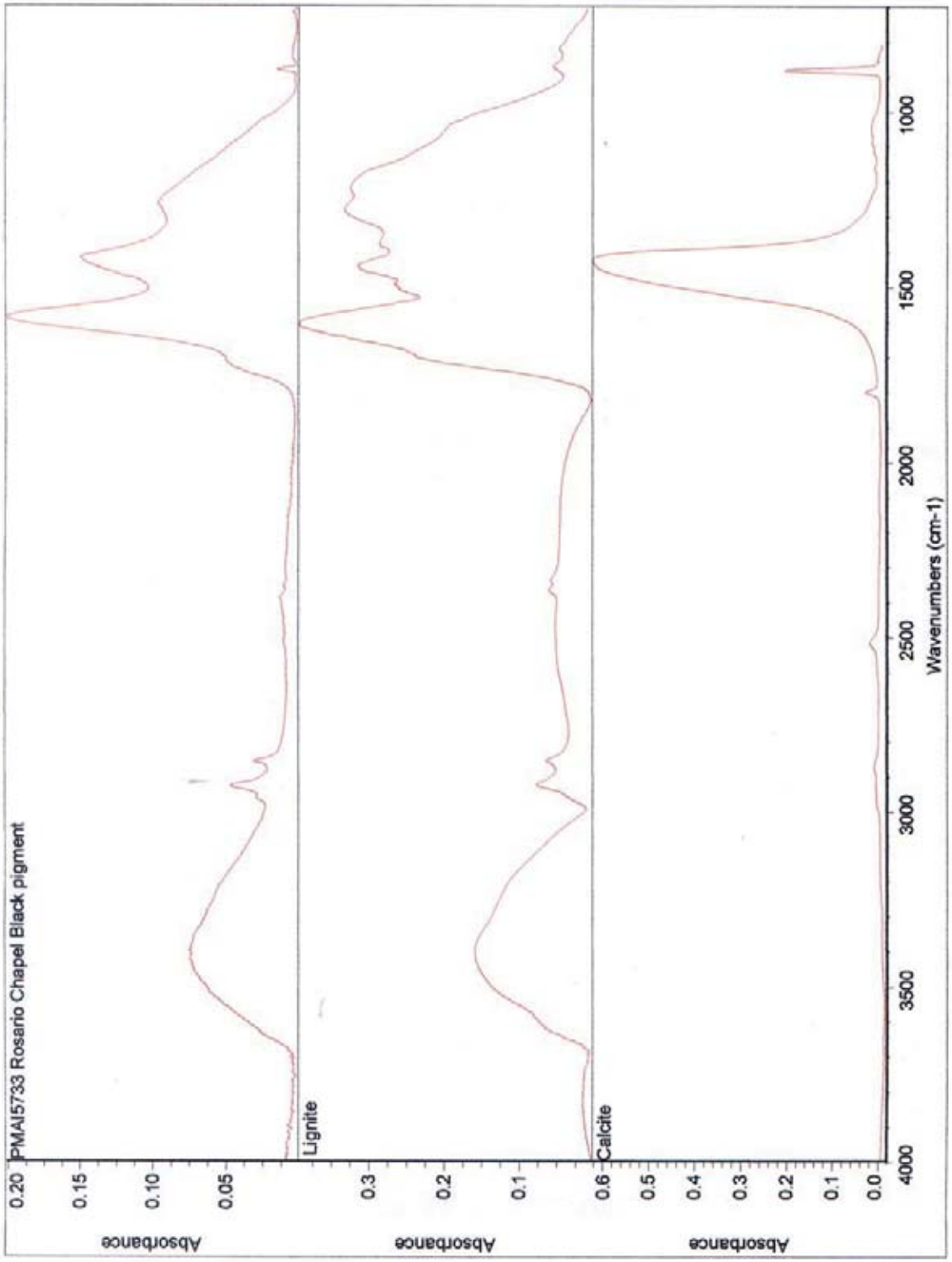
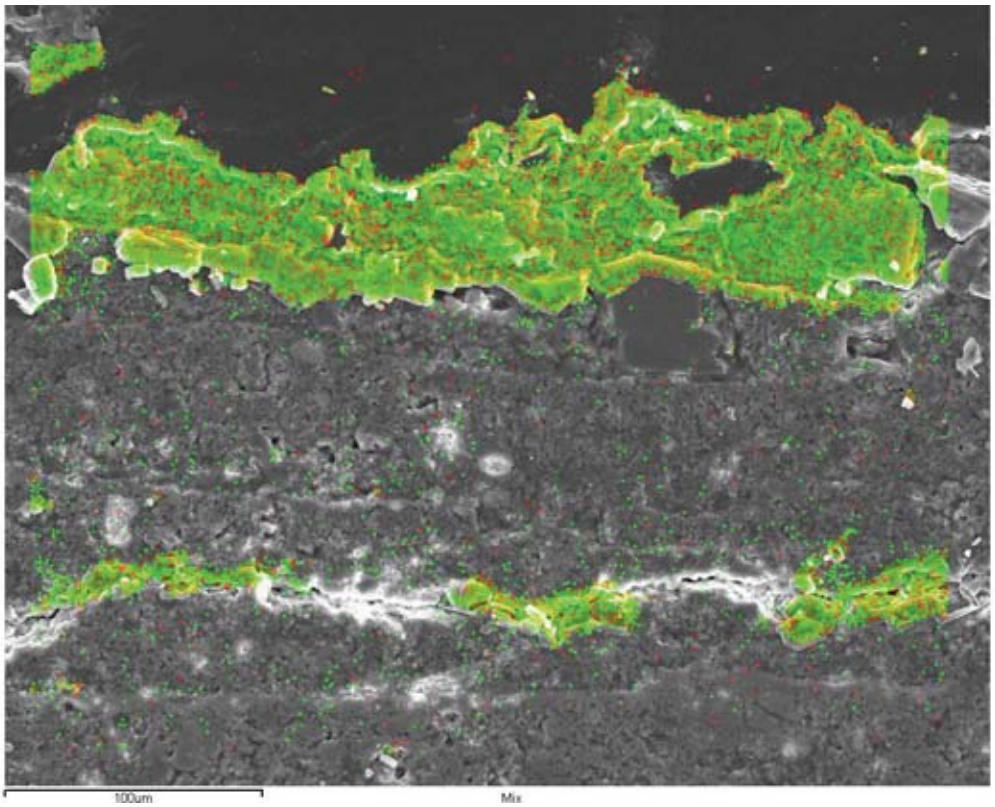


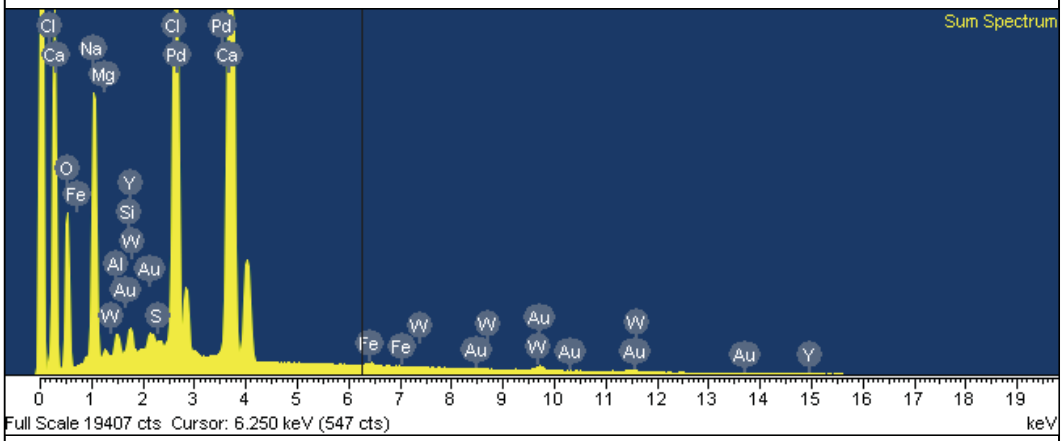
Chart 8: FTIR Spectra, Sample P2.18, Campaign A black pigment and binder analysis

Chart 9: EDS Results, Sample Cu1

Sample ID: CU1
Magnification: 300x

Sample Description: Cross-section from cupola
Working Distance: 17mm



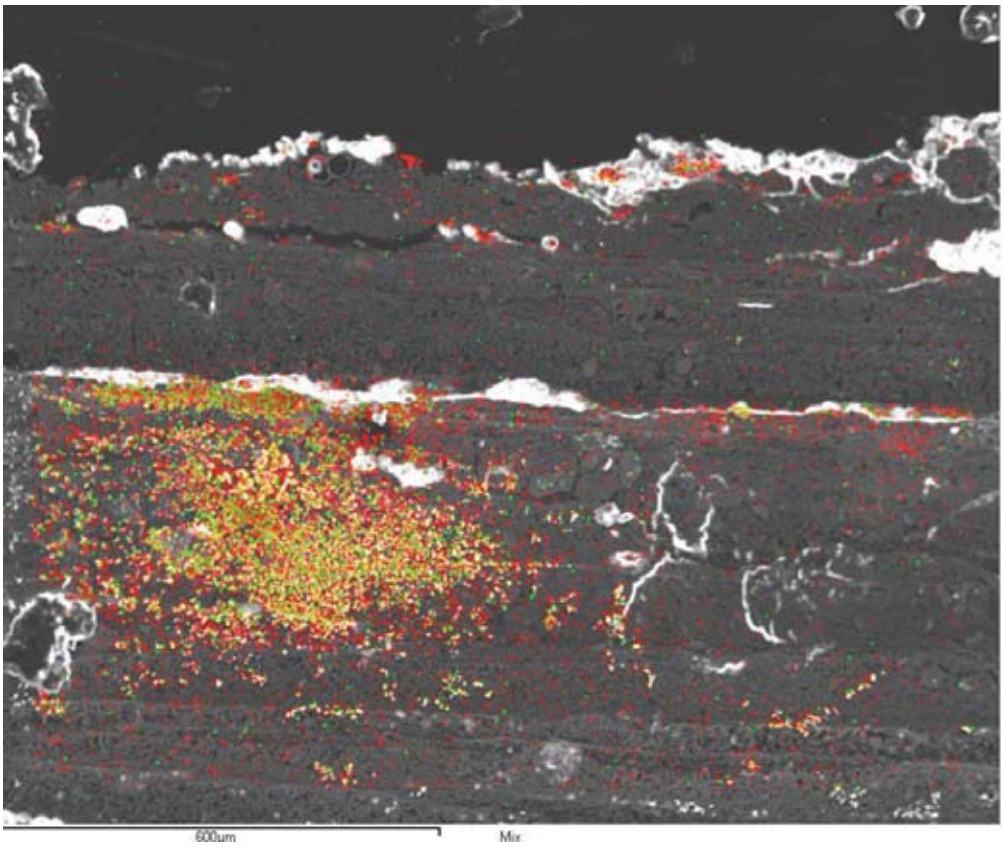


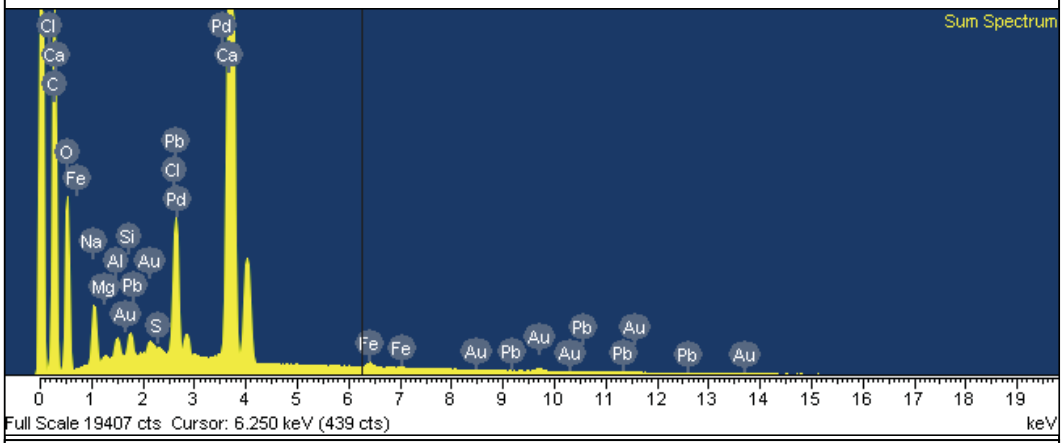
Comments: Electron mapping of Cl (green) and Na (red) indicating the presence of halite (sodium chloride) at detached interfaces.

Chart 10: EDS Results, Sample NAR1

Sample ID: NAR1
Magnification: 85x

Sample Description: Cross-section from the North Arch
Working Distance: 17mm



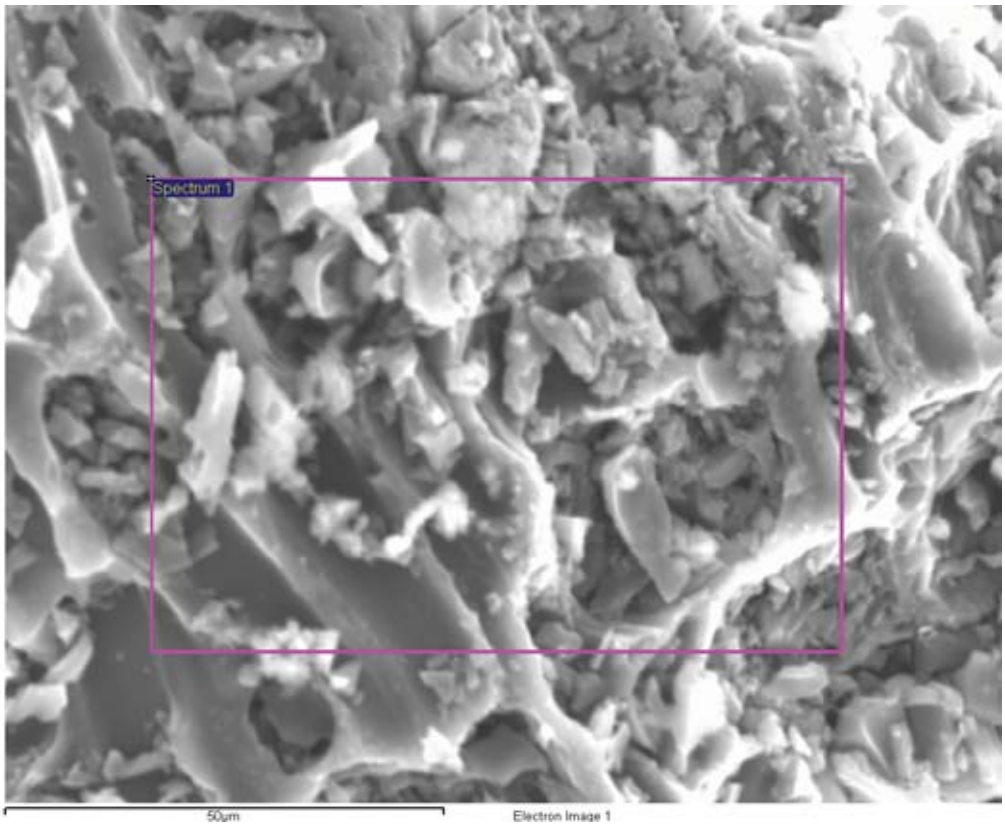


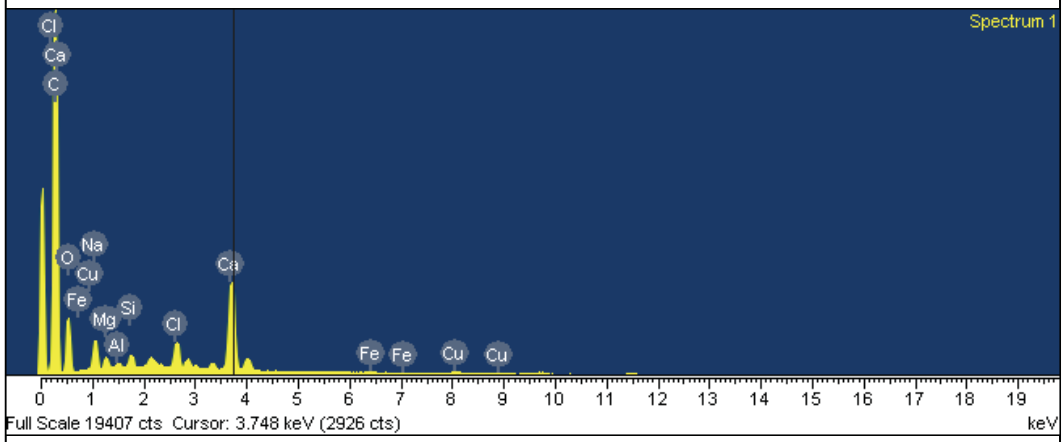
Comments: Electron image of Na (green), Cl (yellow), and Fe (red).

Chart 11: EDS Results, Sample P2.13.2

Sample ID : P2.13 2
Magnification: 1000x

Sample Description: Black. Campaign (A)
Working Distance: 17mm





Comments: Carbon without phosphorous could be graphite or lamp black. Shiny metallic sheen observed in stereomicroscope suggests graphite.

Table 23: Analysis of EDS Results, Sample P2.13.2

Sample ID: P2.13.2

Color: Black

Elements	Possible Pigments	Other
Calcium, Ca		Calcite, enlucido or pigment whiting
Carbon, C	Carbon Black	Calcite, enlucido or pigment whiting
Oxygen		Calcite,Clays, enlucido or pigment whiting
Silicon, Si		Quartz ,Clays
Aluminum, Al		Clays
Magnesium, Mg		Clays
Sodium, Na		Salts
Iron, Fe		Clays, sample contamination
Chloride, Cl		Salts
Potassium, K		Sample contamination
Titanium, Ti		Sample contamination, Pollution
Copper, Cu		Sample contamination

Comments: Sample did not contain phosphorous eliminating bone and ivory black. Brown particles are visible through light microscopy, characteristic of Lignite a carbon black from wood coal as well as Jet.[1] Presence of calcite suggests contamination from lime-rich enlucido rather than whiting as a pigment given its pure black color.

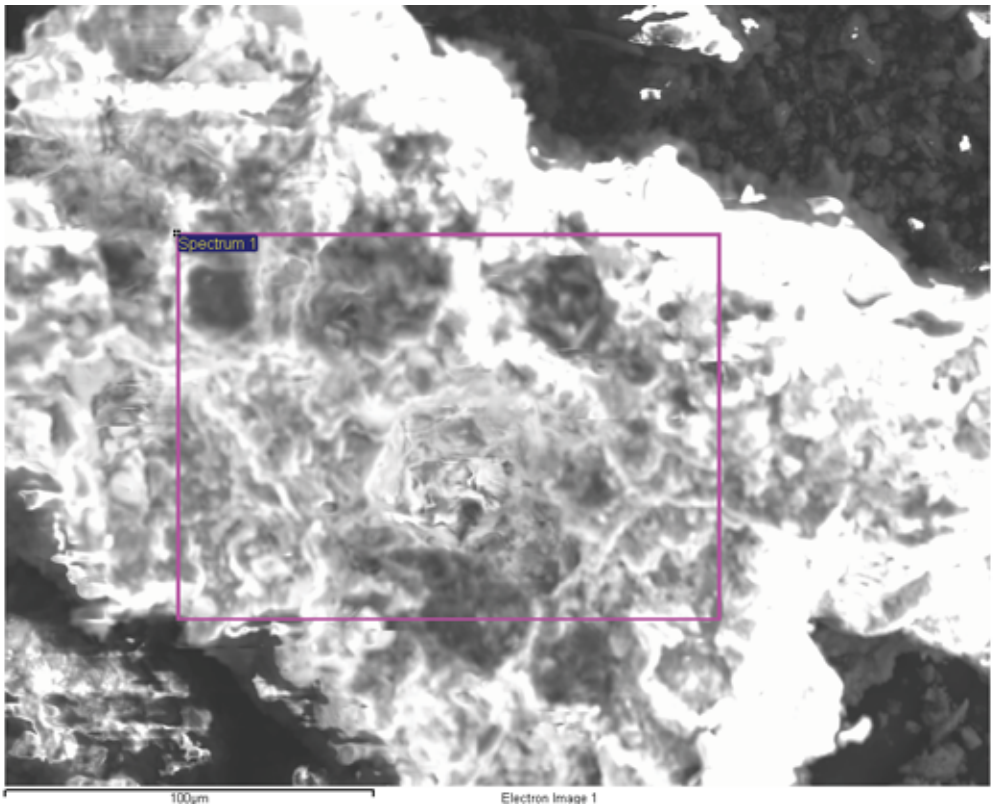
Conclusion: Carbon Black (prehistoric-present)

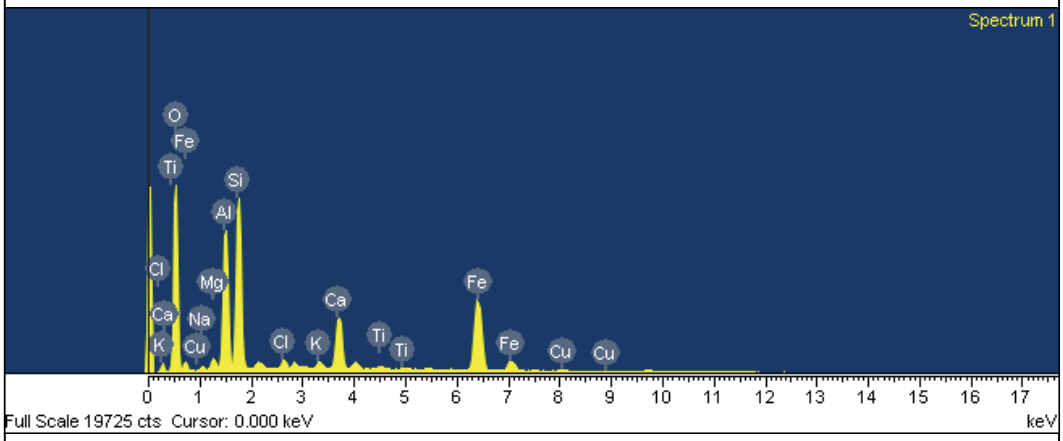
[1] Light Microscopy performed by Dr. Tami Lassiter-Caire.

Chart 12: EDS Results, Sample P2.13

Sample ID: P2.13
Magnification: 430x

Description: Yellow, campaign (A)
Working Distance: 17mm





Comments: Presence of iron indicates possibility of ochre (iron oxide) pigment.

Table 24: Analysis of EDS Results, Sample P2.13

Sample ID: P2.13

Color: Yellow Ochre

Elements	Possible Pigments	Other
Calcium, Ca		Calcite, enlucido or pigment whiting
Carbon, C	Indian Yellow	Calcite, enlucido or pigment whiting
Oxygen	Yellow Ochre, Indian Yellow	Calcite,Clays, enlucido or pigment whiting
Silicon, Si		Quartz ,Clays
Aluminum, Al		Clays
Magnesium, Mg	Indian Yellow	Clays
Sodium, Na		Salts
Iron, Fe	Yellow Ochre	
Chloride, Cl		Salts
Potassium, K		Sample contamination
Titanium, Ti		Sample contamination, Pollution
Copper, Cu		Sample contamination

Conclusions:

Yellow Ochre: Iron Oxide, $Fe_2O_3 \cdot H20$ (prehistoric-present)
Indian Yellow, $C_{19}H_{16}O_{11}Mg \cdot 5\ H_2O$ (15th C-1908) - Most poplar in India, although the pigment was used in Europe. The pigment is a magnesium salt which is colored yellow by cow's urine.[2]

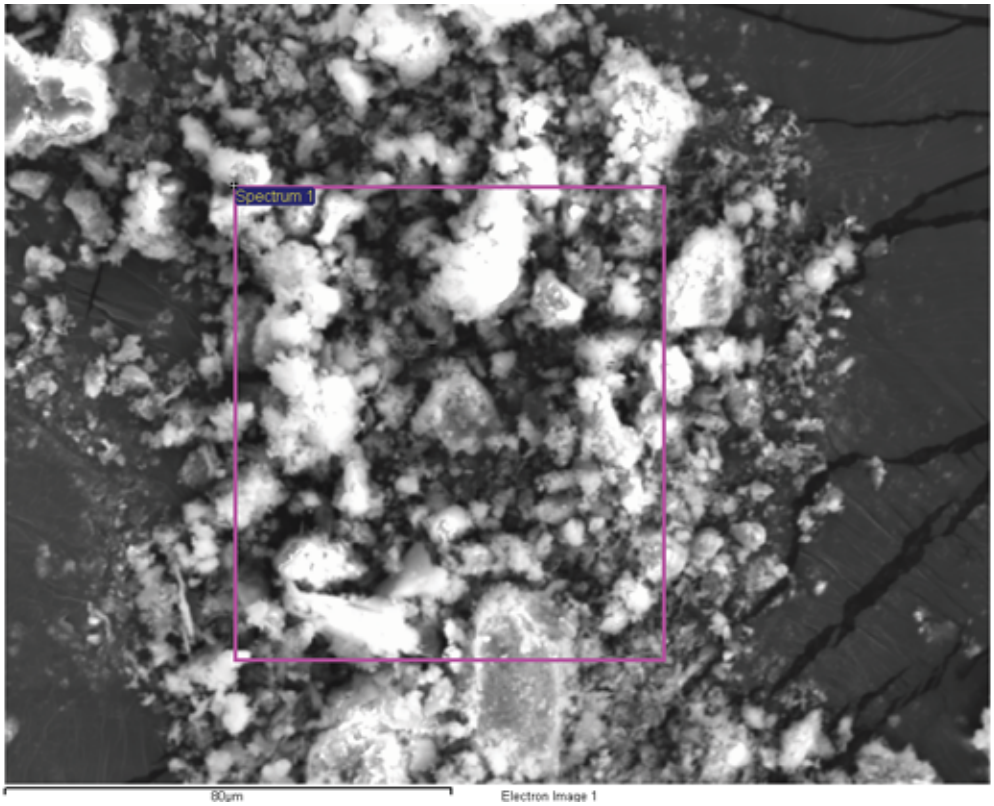
Presence of calcite suggests contamination from lime-rich enlucido rather than whiting as a pigment given its pure yellow color.

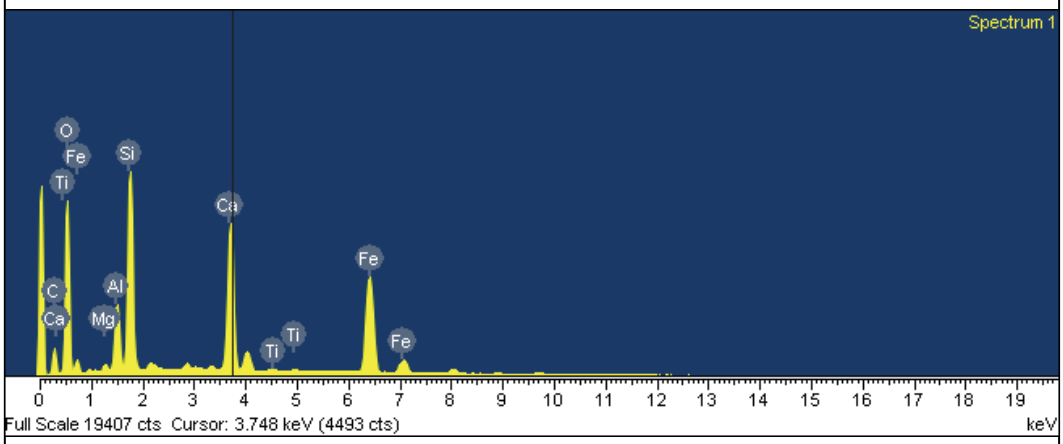
[2] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Robert L. Feller, 3 vols., vol. 1 (New York: National Gallery of Art, 1987).

Chart 13: EDS Results, Sample P1.02

Sample ID: P1.02
Magnification: 650x

Sample Description: Red, Campaign (A)
Working Distance: 17mm





Comments: Presence of iron indicates possible red ochre, (iron oxide) pigment.

Table 25: Analysis of EDS Results, Sample P1.02

Sample ID: P1.02

Color: Red

Elements	Possible Pigments	Other
Calcium, Ca		Calcite, enlucido or pigment whiting
Carbon, C		Calcite, enlucido or pigment whiting
Oxygen, O	Iron Oxide	Calcite,Clays, enlucido or pigment whiting
Silicon, Si		Quartz ,Clays
Aluminum, Al		Clays
Magnesium, Mg		Clays
Iron, Fe	Iron Oxide	
Titanium, Ti		Sample contamination

Conclusions:

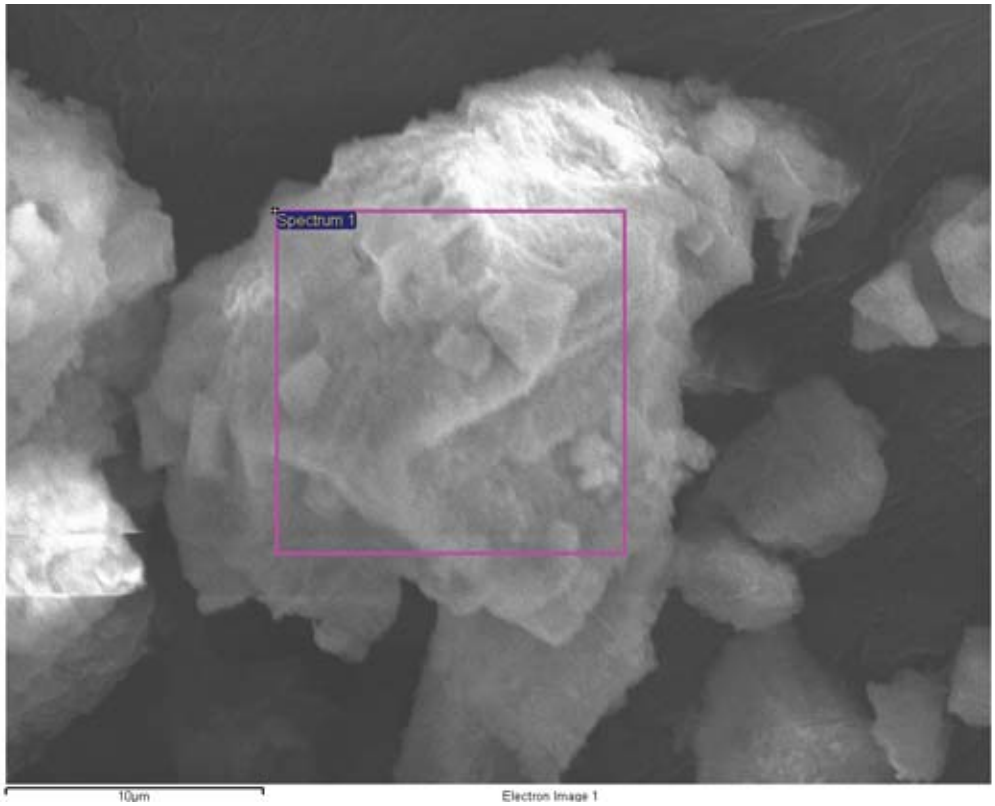
Red Ochre: Iron Oxide, Fe_2O_3 (prehistoric-present)

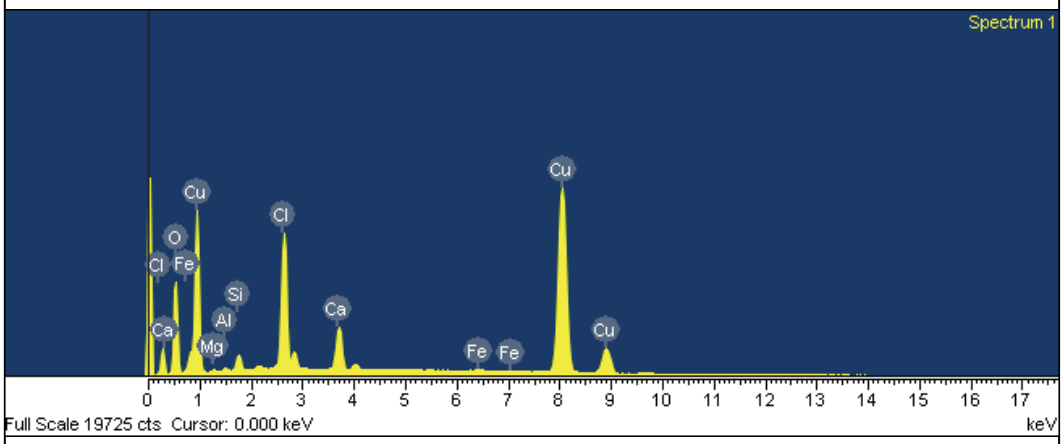
Presence of calcite suggests contamination from lime-rich enlucido rather than whiting as a pigment given its pure red color.

Chart 14: EDS Results, Sample P2.15

Sample ID: P2.15
Magnification: 3000x

Smple Description: Green, campaign (A)
Working Distance: 17mm





Comments: Copper without arsenic, or cobalt indicates possible verdigris.
Chloride salts present.

Table 26: Analysis of EDS Results, Sample P2.15

Sample ID: SAJO-ROSA P2.15

Color: Green

Elements	Possible Pigments	Other
Calcium, Ca		Calcite, enlucido or pigment whiting
Carbon, C		Calcite, enlucido or pigment whiting
Oxygen, O	Verdigris, Malachite	Calcite,Clays, enlucido or pigment whiting
Silicon, Si		Quartz ,Clays
Aluminum, Al		Clays
Magnesium, Mg		Clays
Copper, Cu	Verdigris, Malachite	
Iron, Fe		Sample contamination
Chlorine, Cl		Salts

Conclusions:

Verdigris: Copper acetate, $Cu(CH_3COO)_2 *[Cu(OH)_2]_3*2H_2O$. Used since antiquity.[3]
Malachite: Copper carbonate, $CuCO_3 * Cu(OH)_2$. Used by Egyptians as eye paint, and in ca. 9th Century Chinese paintings. (still in use)[4]

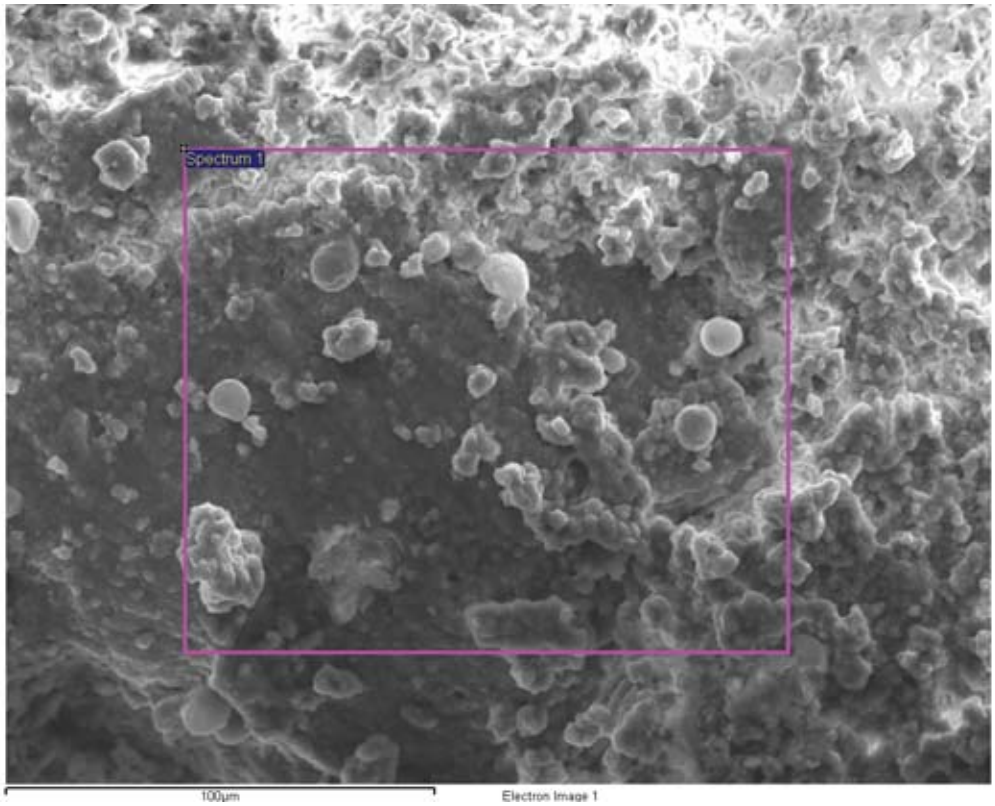
Presence of calcite suggests contamination from lime-rich enlucido rather than whiting as a pigment given its pure green color.

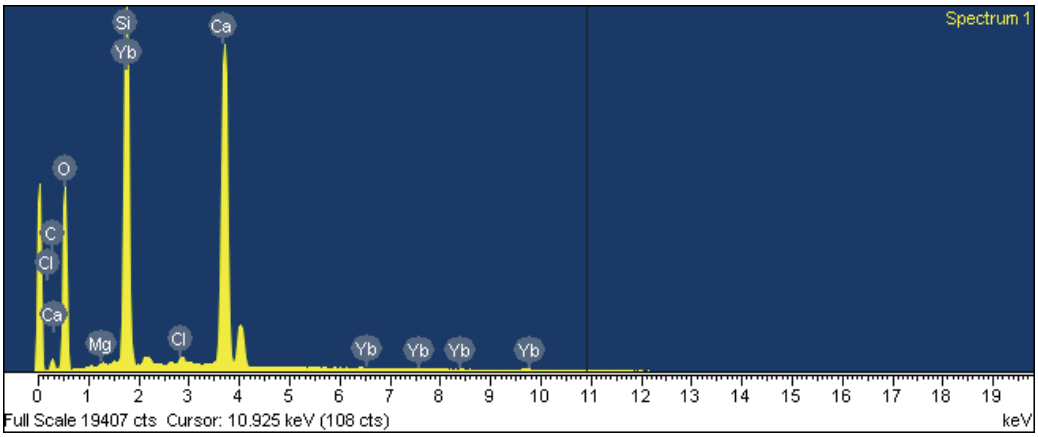
[3] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Joyce Plesters, 3 vols., vol. 2 (New York: National Gallery of Art, 1993), 132.
[4] Ibid., 184.

Chart 15: EDS Results, Sample G3.08

Sample ID: G3.08
Magnification: 500x

Sample Description: White, campaign (C)
Working Distance: 17mm





Comments: Possible Chalk, (calcium carbonate), Talc, (Mg, Si, O), or Diatomaceous Earth, (Si and O). Chloride salts.

Table 27: Analysis of EDS Results, Sample G3.08

Sample ID: SAJO-ROSA G3.08
Sample Description: White, Campaign C
Color:
White

Elements	Possible Pigments	White	Other
Calcium, Ca	Chalk	Chalk	Calcite
Carbon, C	Chalk	Chalk	Calcite
Oxygen	Chalk	Chalk	Calcite
Silicon, Si			Quartz aggregate, Clay
Magnesium, Mg			Clays
Chloride, Cl			Salts
Ytterbium, Yb			Rare element, probably a false match

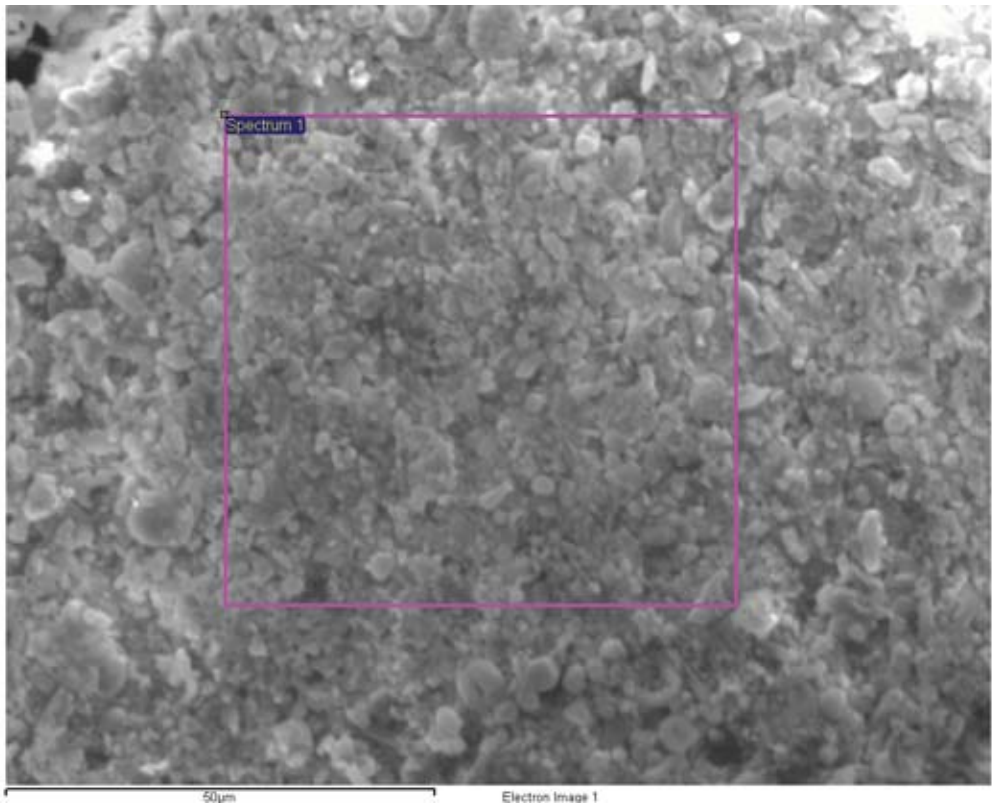
Conclusions:

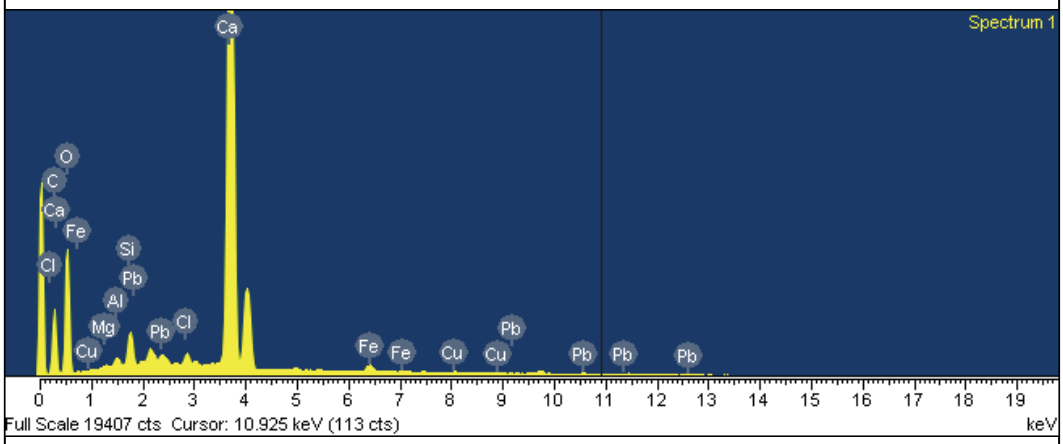
Chalk/Whiting/Earth White: Ca Co_3
Source: Calcite, Marble, Limestone. Shells, Coral
History of use: Antiquity

Chart 16: EDS Results, Sample P3.11

Sample ID: P3.11
Magnification: 1000x

Description: Yellow Ochre color, campaign (D)
Working Distance: 17mm





Comments: Iron indicating possible yellow ochre, (iron oxide) pigment.

Table 28: Analysis of EDS Results, Sample P3.11

Sample ID: SAJO-ROSA P3.11
Sample Description: Yellow Ochre Color, Campaign D
Color: Yellow Ochre

Elements	Possible Pigments	White	Other
Calcium, Ca		Chalk	Calcite
Carbon, C	Indian Yellow	Chalk	Calcite
Oxygen	Yellow Ochre, Indian Yellow	Chalk	Calcite,Clays
Silicon, Si			Quartz ,Clays
Aluminum, Al			Clays
Magnesium, Mg	Indian Yellow		Clays
Iron, Fe	Yellow Ochre		
Chloride, Cl			Salts
Lead, Pb			Sample contamination
Copper, Cu			Sample contamination

Conclusions:

Yellow Ochre: Iron Oxide, Fe_2O_3 + H20 (prehistoric-present)

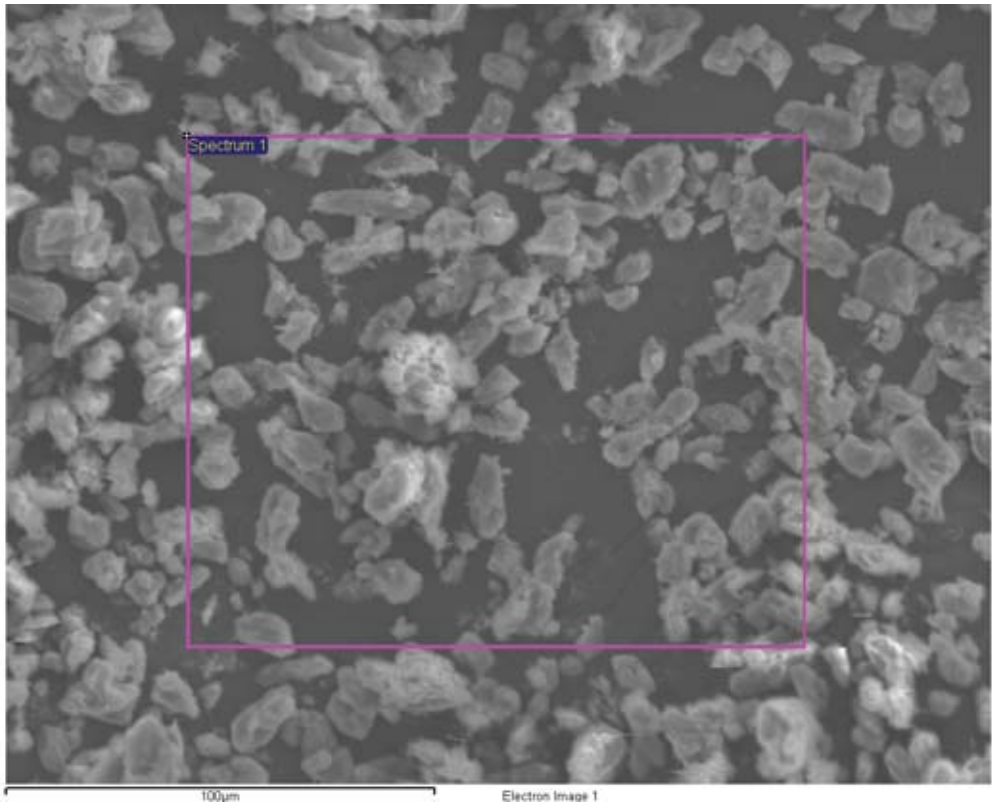
Indian Yellow, $C_{19}H_{16}O_{11}Mg \cdot 5\ H_2O$ (15th C-1908) - Most poplar in India, although the pigment was used in Europe. The pigment is a magnesium salt which is colored yellow by cow's urine.[5]

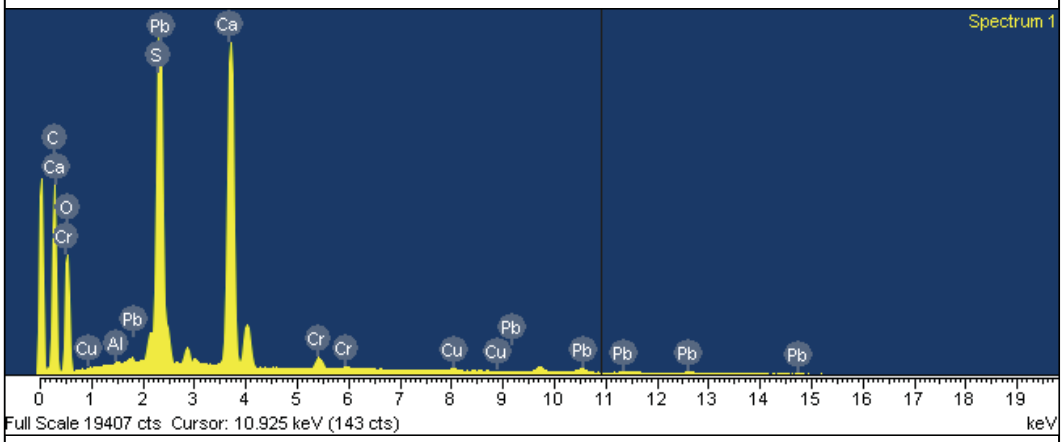
[5] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Robert L. Feller, 3 vols., vol. 1 (New York: National Gallery of Art, 1987).

Chart 17: EDS Results, Sample F3.03

Sample ID: F3.03
Magnification: 500x

Sample Description: lemon yellow color, Campaign (D)
Working Distance: 17mm





Comments: Lead and Chrome indicate possible Chrome Yellow, ($PbCrO_4$).

Table 29: Analysis of EDS Results, Sample F3.03

Sample ID: SAJO-ROSA F3.03
Sample Description: Lemon Yellow, Campaign D
Color: Yellow

Elements	Possible Pigments	White	Other
Calcium, Ca		Chalk, Gypsum	Calcite, Gypsum
Carbon, C		Chalk	Calcite
Oxygen	Chrome Yellow	Chalk, Gypsum	Calcite,Gypsum, Clays
Sulfer, S	Chrome Yellow	Gypsum	Gypsum
Aluminum, Al			Clays
Chromium, Cr	Chrome Yellow		
Lead, Pb	Chrome Yellow		
Copper, Cu			Sample contamination

Conclusions:

Chrome Yellow: Lead Chromate, $PbCrO_4$.

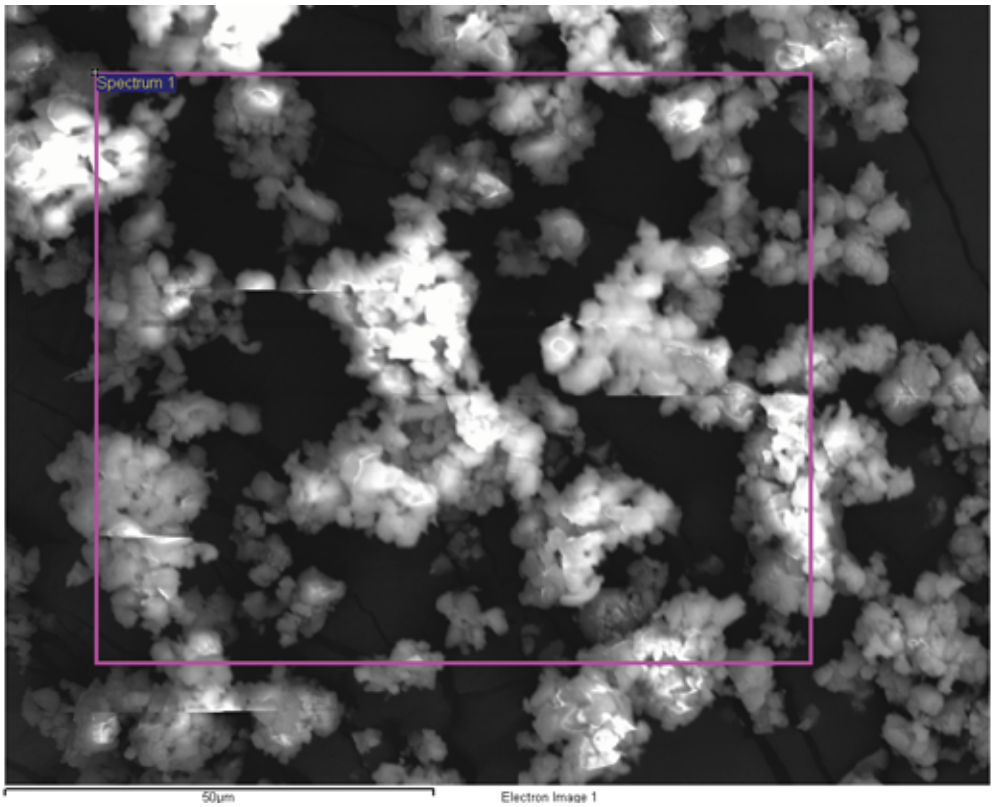
History of Use: Crocoite, a rare natural mineral, was discovered in 1797.[6] In 1800, laboratory synthesis of heavy metal chromates began.[7] 1815, is the earliest record of chromate's use as an artist's pigment, which is still manufactured today. [8]

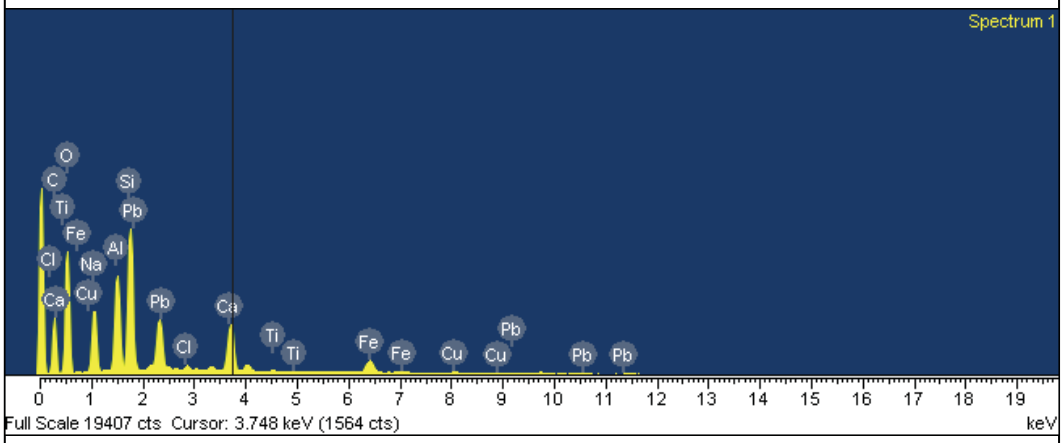
[6] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Robert L. Feller, 3 vols., vol. 1 (New York: National Gallery of Art, 1987), 189.
[7] Ibid., 190.
[8] Ibid., 189.

Chart 18: EDS Results, Sample H4.01

Sample ID: H4.01
Magnification: 1000x

Sample Description: Deep blue, Campaign (D)
Working Distance 17 mm





Comments: Potential pigments include **Ultramarine artificial**, ($Na_{6\_10}Al_6Si_6O_{2\_4}$). **Ultramarine natural**, ($3Na_2 * 3Al_2O_3 * 6SiO_2 * 2Na_2$).Possible stray irradiation from adjacent sample picking up copper.

Table 30: Analysis of EDS Results, Sample H4.01

Sample ID: SAJO-ROSA H4.01
Sample Description: Blue, Campaign D
Color: Deep Blue

Elements	Possible Pigments	White	Other
Calcium, Ca		Chalk	Calcite
Carbon, C		Chalk	Calcite
Oxygen	Ultramarine	Chalk	Calcite, Clays
Silicon, Si	Ultramarine		Quartz ,Clays
Aluminum, Al	Ultramarine		Clays
Sodium, Na	Ultramarine		Salts
Chloride, CL			Salts
Iron, Fe			Sample contamination
Lead, Pb			Sample contamination
Titanium, Ti			Sample contamination
Copper, Cu			Sample contamination

Comments: FTIR confirms Ultramarine Blue pigment

Conclusions:

Ultramarine Blue, Natural: $3Na_2O*3Al_2O_3*6SiO_4*2Na_2S$
Source: Mineral Lapis Lazuli

History of use: Earliest known use of pigment is in wall paintings located in Afghanistan, sixth or seventh century A.D.[9] High cost and the manufacture of synthetic Ultramarine diminished use of natural version by the mid 19th Century.

Ultramarine Blue, Artificial: $Na_{6\_10}Al_6Si_6O_{24}S_{2\_4}$

History of use: First recorded observation 1787 when deposits were discovered on the walls of lime kilns, 1828 Jean Baptist Guimet synthesized Ultramarine and developed an affordable manufacturing process. In 1830, Guimet established a factory to make artificial Ultramarine.[10]

[9] *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Joyce Plesters, 3 vols., vol. 2 (New York: National Gallery of Art, 1993), 39.
[10] Ibid.

PIGMENT DISPERSIONS

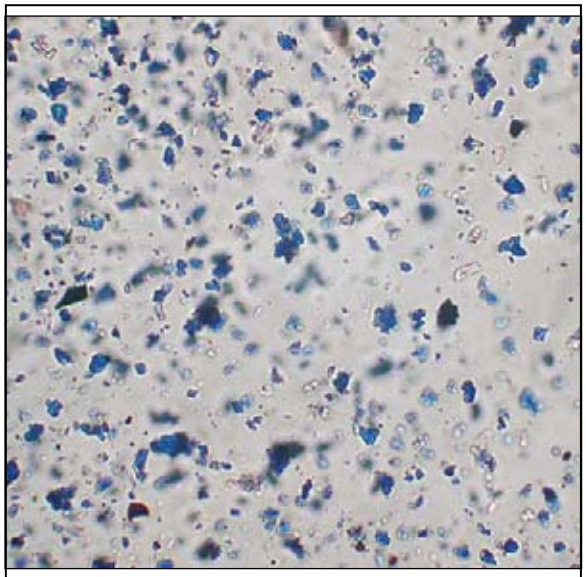


Figure 72: Pigment Dispersion, Sample H4.01. Pigment identified as Ultramarine through EDS analysis (plane polarized light, 600x)

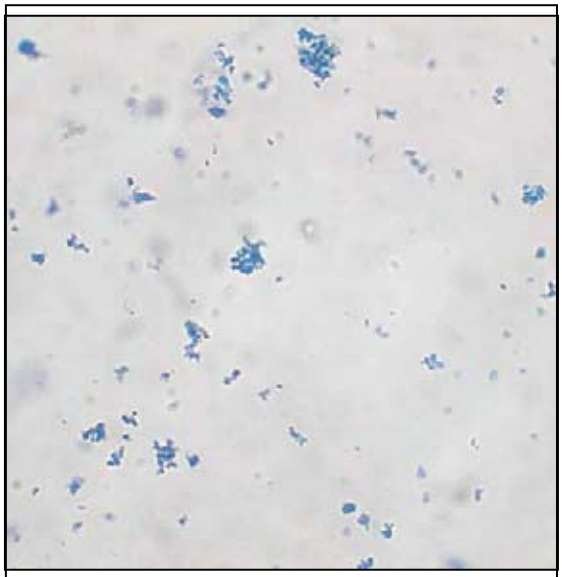


Figure 73: Pigment Dispersion, Synthetic Ultramarine, McCrone Slide Collection. (plane polarized light, 600x)

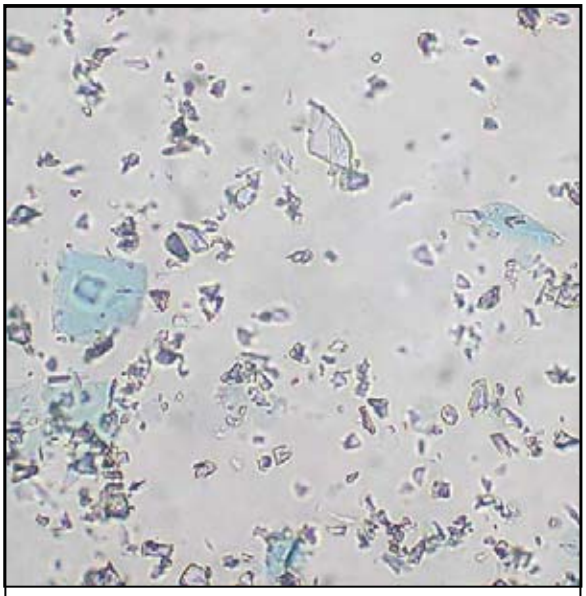
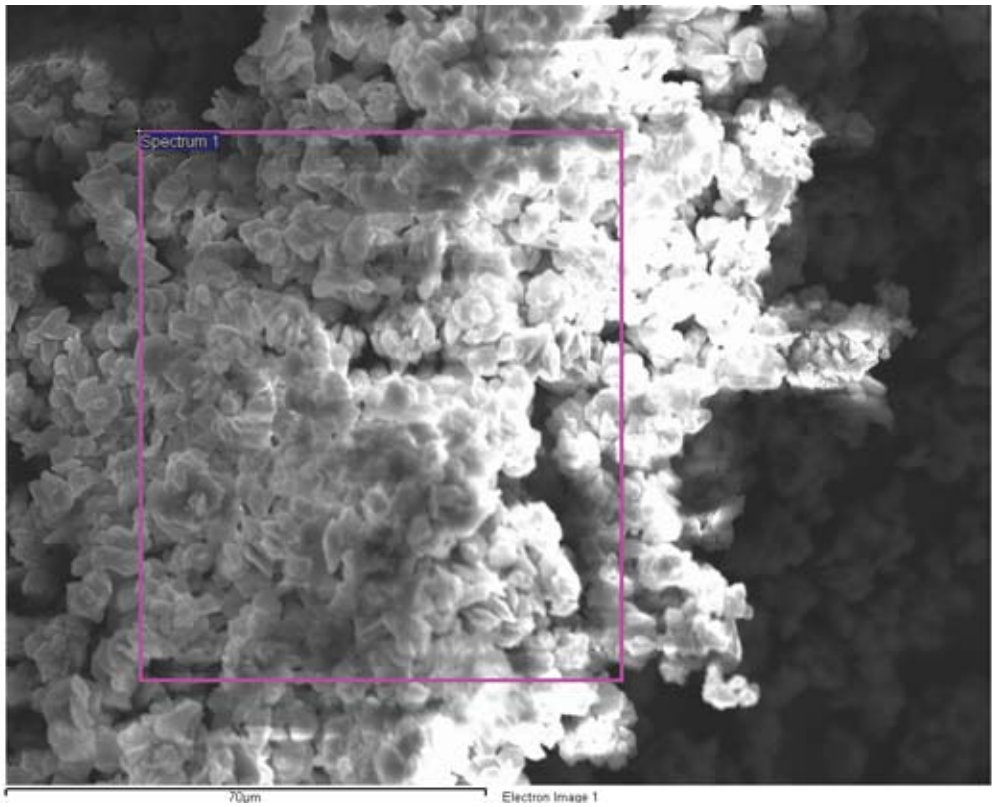


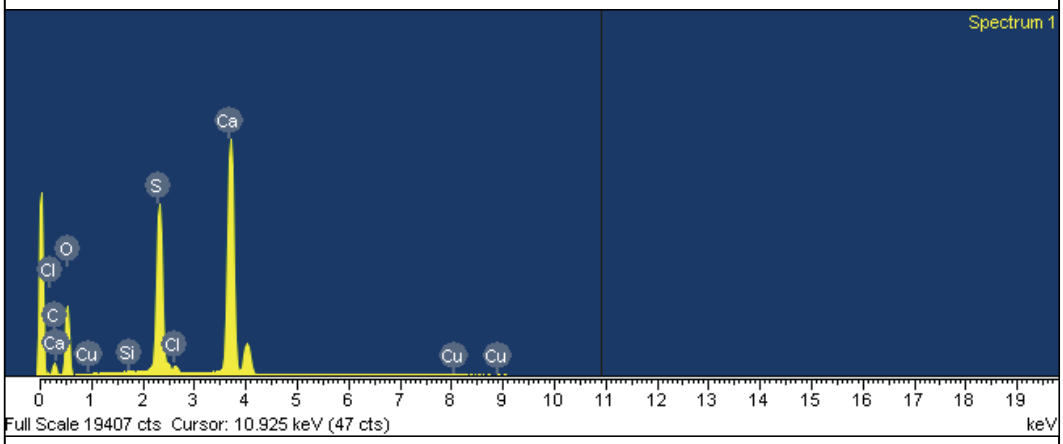
Figure 74: Pigment Dispersion, Lapis Lazuli, Forbes Collection. (plane polarized light, 600x)

Chart 19: EDS Results, Sample G3.06

Sample ID: G3.06
Magnification: 800x

Description: White, campaign (D)
Working Distance: 17mm





Comments: Ca and S possible Gypsum as white. Chloride salts. Calcium Carbonate, part of binding media.

Table 31: Analysis of EDS Results, Sample G3.06

Sample ID: SAJO-ROSA G3.06
Sample Description: White, Campaign D
Color: White

Elements	Possible Pigments	White	Other
Calcium, Ca	Gypsum, Chalk	Gypsum, Chalk	Calcite, Gypsum
Carbon, C	Chalk	Chalk	Calcite
Sulfer, S	Gypsum	Gypsum	Gypsum
Oxygen	Gypsum, Chalk	Gypsum, Chalk	Calcite, Gypsum
Silicon, Si			Quartz aggregate
Copper, Cu			Sample contamination
Chloride, Cl			Salts

Conclusions:

Chalk/Whiting/Earth White: Calcium Carbonate, Ca Co3
History of use: Antiquity

Gypsum: Calcium Sulphate, CaSo4
History of use: Antiquity

INDEX