# ASSESSING THE DETERIORATION OF PENNSYLVANIA MARBLE IN WILLIAM STRICKLAND'S MECHANICS' BANK

Alberto Calderón-González

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## 1. Introduction

In the early nineteenth century Philadelphia was the second-largest city in the United States and a quickly developing metropolis, its growth supported by the creation of countless new institutions – both public and private – to serve its diversifying needs. One among these was the Mechanics' Bank, which catered to the needs of Philadelphia's burgeoning yet rapidly transforming social class of mechanics, or craftsmen. Built in 1837 on a two-lot parcel of land on Third Street, the Bank's building was the last major structure erected in the city by William Strickland, one of the country's leading architects.<sup>1</sup> Strickland's design made the most of the limited space to create a dignified design that represented the Mechanics' aspirations through the use of the Greek Revival, in the Corinthian order, as a style; and of Pennsylvania marble as a building material (Fig. 1).

Pennsylvania marble, quarried in the vicinity of Philadelphia, is a moderately metamorphosed and polishable calcareous stone, quarried in both gray (also called blue) and white varieties. During the first half of the nineteenth century it was highly popular in the Philadelphia area as a high-end building stone, with Greek Revival architects such as Strickland as its leading proponents. Structures ranging from federal institutions to hundreds of stoops and grave markers were carved out of the versatile, attractive stone. However, Pennsylvania marble was eventually discovered to be highly susceptible to weathering, especially in the increasingly industrial and polluted Philadelphia of the late nineteenth and early twentieth centuries; and eventually fell out of favor, being abandoned altogether as a building stone when the quarries closed in 1934.<sup>2</sup>

<sup>&</sup>lt;sup>1</sup> Jackson, 22.

<sup>&</sup>lt;sup>2</sup> Kimmel, 3-5.

As an obsolete material that is, nonetheless, a fundamental part of Philadelphia and America's historic fabric, issues surrounding the conservation of Pennsylvania marble have been at the forefront for a long time. Much of this work has focused on major publiclyowned buildings, such as the Independence National Historical Park sites of the Second Bank of the United States and Philadelphia Merchants' Exchange.<sup>3</sup> The Mechanics' Bank building, with a continuous history of private ownership to the present day, presents many similarities to these buildings in design, construction, and deterioration; but also many distinct conditions, some of which arise from its history of frequent changes in use and scant, poorly documented, and sometimes misguided maintenance.

Knowledge gained from the study of the Mechanics' Bank building not only helps understand the nature and state of its deterioration with a view to informing future maintenance and conservation. It also seeks to improve the general understanding of Pennsylvania marble as a building stone by contributing to the existing corpus of research; and, in doing so, to test and nuance previous hypotheses on the microstructure of the marble and its relationship to observed macroscopic conditions.<sup>4</sup>

<sup>&</sup>lt;sup>3</sup> See "Sources on Pennsylvania Marble" in Bibliography

<sup>&</sup>lt;sup>4</sup> As put forward in Kimmel, 19-20.



Figure 1: The Mechanics' Bank building in late 2017.

## 2. Literature Review

The need for documenting the Mechanics' Bank prior to the study of its marble façade is justified by its limited discussion in published sources. Hamlin, a useful source for contextualizing the American Greek Revival and an admirer of Strickland, makes no mention of it whatsoever. Jackson's brief biography of Strickland only lists the name of the building, while Gilchrist's more detailed work initially overlooks it, dismissing its mention in other sources as a mistake; this is corrected in her later addendum, which acknowledges the Bank to be her "most glaring omission [...] in Philadelphia" and, as well as including a photograph, notes (inaccurately) the inscription with the date, architect, and builder.<sup>5</sup> Only Webster and Peterson, in their catalog of Philadelphia historic buildings, give any additional information and sources, though they misidentify the building material as granite.<sup>6</sup>

In order to carry out a diagnostic of the façade's deterioration it is first necessary to understand the characteristics and behavior of Pennsylvania marble. Kemp gives a general characterization of marble as a building stone and of its behavior and deterioration, while Kimmel's thesis was the first to observe the microstructure, composition, and behavior of Pennsylvania marble, showing how it differs from other types of marble and how these differences inform its behavior. Kimmel's findings are based on samples from the Second Bank of the United States, which will be compared and contrasted with findings from the Mechanics' Bank. Steiger, Charola, and Sterflinger give a detailed overview of the microstructural and physicochemical causes of stone deterioration. Other authors have discussed processes that affect marble specifically, such as the effect of solar radiation on thermal expansion and salt crystallization (Sáez-Pérez and Rodríguez-Gordillo; Yavuz and

<sup>&</sup>lt;sup>5</sup> Jackson, 13; Gilchrist (1950), 49; and Gilchrist (1954), 2, 14, 16.

<sup>&</sup>lt;sup>6</sup> Webster and Peterson, 84.

Topal); acid rain and air pollution, with an emphasis on sulfur oxide gases (Meierding); and bacterial activity (Savvides et al.). No sources found so far discuss the effect of painting and paint-stripping on stone, which has been a significant episode in the Bank's maintenance history.

A methodology for the condition surveying of stone including a discussion of testing procedures can be found in Siedel and Siegesmund. The key to effective condition surveying of stone is a thorough, causality-free condition glossary. While Anson-Cartwright's Icomos-ISCS glossary is the most widely accepted and comprehensive guide for characterizing stone deterioration patterns, the glossary completed for Matero et al.'s 2003 surveying of the Second Bank of the United States is more strictly causality-free and is specifically tailored towards Pennsylvania marble. For ease of comparisons with other buildings, this is the glossary that, with the necessary adjustments, will be used as a model for condition surveying. Nesse is a good introduction to polarized light microscopy (PLM) for petrographic analysis; analysis of marble and calcareous stones is discussed in Vernon, useful for identifying the properties of individual grains; and Ingham; which includes an illustrated catalog of rock microstructures. The latter also discusses the petrographic analysis of sedimentary rocks, their book has been useful for identifying features related to incomplete metamorphism.

Among the buildings whose issues are comparable to those of the Mechanics' National Bank, the two most useful comparisons – sharing its architect, material, and location in Center City Philadelphia and having attracted a substantial corpus of research – are the Second Bank of the United States and the Merchants' Exchange. As well as Kimmel and

<sup>&</sup>lt;sup>7</sup> Ingham, 137-162.

Matero et al, research on the Second Bank includes Aphale's thesis interpreting the conditions found in the condition survey; Bernberg's thesis on predictive analysis of stone decay; Ryan-Biggs' report on non-destructive evaluation (which focuses on radar technologies that were not available for this project) and a thesis on treatment testing (Glavan). Similarly, the corpus on the Merchants' Exchange includes Kottke's thesis on laser scanning for condition surveying and, again, reports on treatment testing including McBratney's thesis on the treatment of Pennsylvania marble and the 2008 request for proposal for the conservation of the Carrara marble capitals, very similar to those on the Mechanics' Bank. Among these, the papers on treatment testing are not immediately relevant to the scope of this thesis; however, they would be very useful as a reference should a treatment plan ever be prepared for the façade of the Mechanics' Bank.

## 3. Methodology

The first step in the study of the Mechanics' Bank's marble façade was its documentation to obtain drawings that would serve as a base on which to map any subsequent research. This was followed by an in-situ evaluation that comprised visual condition surveying, nondestructive testing, and sample-taking. Subsequently, the conditions recorded were mapped and samples were analyzed and tested in the laboratory. Interpretation of the data gathered through these evaluation methods eventually made it possible to propose deterioration hypotheses and establish comparisons with other Pennsylvania marble buildings.

#### 3.1. Documentation

Archival research was the first step in the documentation process. Historical records and graphic documents have provided valuable insights into the Bank's history and historical condition. However, as of this thesis, no historic measured drawings of the building; no written records of its construction; and no measured drawings whatsoever of its façade have surfaced. Therefore, completing sufficiently detailed and accurate measured drawings of the façade and understanding its assembly through visual observation became a necessary preliminary step to any further research work.

The façade was measured using a Nikon total station facilitated by the Department of Historic Preservation of the University of Pennsylvania. A total station is a device that locates points in three-dimensional space in reference to a point of origin. Two sets of points were taken: one on January 24, 2018 containing 502 points; and one on January 26 containing 410 points. Due to their different points of origin, both surveys were matched to each other utilizing three reference points and the matching was confirmed through tape measurements of horizontal dimensions. The three-dimensional point cloud obtained from these surveys was processed through AutoCAD software to create a set of two-dimensional drawings for the façade comprising as many views as necessary to represent its multiple surfaces. Local rectified photographs were used in areas where the density of information obtained from total station points was insufficient (Appendix 1). The following criteria were followed to create the drawings:

- In cases of intentional alterations to the façade from the original state, the current state was represented (e.g. the fluting of the antae, which was removed in the twentieth century, was not represented).
- In cases of material deterioration, including dimensional loss or displacement, the state prior to damage was represented, since variations from this state would be represented in the conditions survey (e.g. the capitals are shown complete even though many volutes are missing).
- Minor furnishings and hardware attached to the stone (e.g. railings, planters, or banners) were not represented, since they impair visibility of the stone surfaces and would be shown in the conditions survey.

In addition to the façade plans, a hand-drawn assembly section was produced to help understand the building's construction. This was based on visual surveying of interior and exterior spaces; the attic, the basement, and several partially removed window frames on the second floor provided especially useful information. Magnetometric scanning was performed in addition to this to determine the location of metallic anchors (see Section 3.3.1.).

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## 3.2. Condition Surveying

The spatial location of deterioration conditions in relation to the building and to each other is fundamental to understanding their nature and establishing hypotheses for their origin. Therefore, a detailed conditions survey based on visual observations and mapped to the base drawings was necessarily a central part of this thesis.

The key to a useful conditions survey is a clear, unambiguous catalog of identified conditions to be mapped on the building. To facilitate an unbiased assessment of the causes behind deterioration, it is of paramount importance that the catalog be descriptive, unambiguous, and causality-free.<sup>8</sup>

Two previously published condition catalogs were considered for this survey. The catalog developed for the 2003 condition survey of the Second Bank of the United States was designed specifically for Pennsylvania marble, explicitly striving to be causality-free.<sup>9</sup> Its main disadvantage is the lack of hierarchy or grouping of conditions; another drawback is the lack of a distinct separation between differential soiling and deep crusts, grouped together as "encrustation". The second, the ICOMOS-ISCS Illustrated Glossary on Stone Deterioration Patterns, provides a much more extensive set of organized categories of deterioration.<sup>10</sup> While these are more specific than the Second Bank categories, telling them apart requires testing or determination of causation, which makes them useful for describing hypothetical or fully researched conditions but impractical, and even potentially misleading, for a prediagnostic condition survey. This, together with the possibility of easily comparing both Pennsylvania marble surveys, justify the choice of the Second Bank condition catalog as a reference for this thesis.

<sup>&</sup>lt;sup>8</sup> Matero et al, 23.

<sup>&</sup>lt;sup>9</sup> Ibid., 78-107.

<sup>&</sup>lt;sup>10</sup> Anson-Cartwright, 7ff.

A preliminary visual survey sought to detect the presence of the conditions from the catalog in the Mechanics' Bank. Some of the conditions present in the Second Bank were not found in the Mechanics' Bank and were therefore removed from the catalog. These include efflorescence as well as treatments – such as bird repellent, treatment coatings, sealant repairs, and stone replacement – of which there is no history in the latter. Conversely, the condition "paint coatings" was added to the catalog, since it is substantially different from the Second Bank condition of "previous treatment coatings" and of high importance to the Mechanics' Bank's overall state (Table 1; Appendix 2).

Condition	Second Bank	Mechanics' Bank	
Orientation of Foliation Planes	Х	Х	
Mineral Inclusions	Х	Х	
Network Cracking	Х	Х	
Moderate Cracking	Х	Х	
Major Cracking	Х	Х	
Friability / Flaking	Х	Х	
Differential Erosion	Х	Х	
Contour Scaling / Exfoliation	Х	Х	
Incipient Spalling	Х	Х	
Dimensional Loss	Х	Х	
Deformation / Displacement	Х	Х	
Open Joints	Х	Х	
Deteriorated Mortar Joint	Х	Х	
Efflorescence	Х		
Metallic Staining	Х	Х	
Encrustation	Х	Х	
Microflora	Х	Х	
Chemical Bird Repellent Treatments	Х		
Sealant Repair	Х		
Repointing	Х	Х	
Stone Dutchman	Х		
Filled Cracks	Х	Х	
Tooling Marks	Х	Х	
Composite Repairs	Х	Х	
Stone Replacement	Х		
Previous Treatment Coatings	Х		
Paint Coatings		Х	
Stone Redressing	Х	Х	
Defective Mechanical Features	Х	Х	
Condition Unique	Х	Х	
Historic Conditions	Х	[Not on drawings]	

Table 1: Comparison of Second Bank and Mechanics' Bank condition catalogs.

Since scaffolding beyond an owner-provided small ladder was not available, direct close-up visual observation of the entire marble surface was not a viable option for the condition survey. Direct visual observation was performed to a height of ca. 10' above access level (ca. 15' above street level) and was complemented at higher locations by photographic surveying based on stone-by-stone photographs taken with a telephoto lens. Conditions were mapped on the measured drawings in AutoCAD software using orthorectified photographs of each individual stone (Appendix 3). Stitching of the images to create a photographic elevation would have been unusually time-consuming due to the multiple façade planes and was discarded since it did not add any useful information.

## 3.3. Non-Destructive Testing (NDT)

In-situ testing of building materials is an important part of the research process, since it makes it possible to test multiple locations on the building in their real context and can provide a high amount of information for little material damage.<sup>11</sup> The tests that were performed on the building can be considered non-destructive testing (NDT) due to their very low to nonexistent impact on the fabric. Three different in-situ testing procedures were performed on the façade: magnetometric scanning, percussive sounding, and Rilem absorption testing (Table 2).

<sup>&</sup>lt;sup>11</sup> Siedel and Siegesmund, 372.

Type of action	Procedure	Purpose	Impact		
	Sweep handheld metal	Locate and map hidden metallic			
Magnatamatric	detector over surface.	pins and anchors. Deteriorating			
Magnetometric	Detector will buzz in	metallic anchors are a common	None		
scanning	presence of ferrous	cause of cracks, sometimes			
	metals.	hidden, and staining.			
	Lightly tap stone with	Locate cracks parallel to surface			
Doreuccivo	metal hammer. Areas with	causing incipient spalls or			
reicussive	distinctive sound may	exfoliation. Many stones are	None		
sounding	indicate exfoliation or	face-oriented and can crack in			
	incipient spalling.	ways not visible externally.			
Dilam	Attach measured tube to	Determine permeability of	Reversible		
Kilein	stone surface with putty.	stone. Permeability is often	short-term		
absorption	Fill with water and time	related to microscopic	soaking of		
lest	speed of absorption.	deterioration of stone.	stone		
Table 2: Non-destructive testing procedures.					

# 3.3.1. Magnetometric Scanning

Magnetometric scanning involves swiping a handheld metal detector over the stone surfaces. The detector will buzz when in the proximity of a metallic (not necessarily ferrous) element. The detector responds to metals located inside the material to several inches in depth, which makes it possible to locate pins, anchors, or flashing sheets embedded in the wall and not outwardly visible. The detector was swept over all wall joints in the pronaos wall, pilasters and columns to a height of 10' above access level; the stair cheek walls; and the floor of the pronaos (Appendix 4).

The main limitation of magnetometric scanning is that it gives false positives in the presence of visible metallic elements, which in the Mechanics' Bank include electric wiring tubes and steel planters. No information could be obtained in the vicinity of these elements.

# 3.3.2. Percussive Sounding

Percussive sounding of surface materials involves hitting the material with a mallet to gain information about its cohesion and attachment according to the sound it emits. In the case of stone, this makes it possible to locate cracks and incipient spalls occurring parallel to the surface, which often cannot be detected visually and may in time cause accelerated weathering or even spalling of large areas of stone surface. This is most useful in cases where the stone was installed face-oriented, as is the case for much of the Mechanics' Bank. Typically, stone is tested using a metallic hammer, which produces a distinctive ringing sound when applied to undamaged stone.

Percussive sounding was performed over the pronaos walls and the pilasters to a height of 10' above access level. Soft blows were dealt with a steel hammer in rows approx. 6" apart all over the surface of the stone. Three different sounds were identified: a ringing sound corresponding to undamaged stone; a dull sound corresponding to stone with loss of cohesion, e.g. through microcracking parallel to the surface that often resolves in contour scaling; and a hollow sound corresponding to loosely attached parts indicating incipient spalls (Appendix 4).

# 3.3.3. Rilem Absorption Test

The Rilem absorption test (also known as Karsten tube) is a simple non-destructive test that gives a rough in-situ measure of the water absorptivity of a material. The latter, which depends on its content of interconnected open pores, is fundamental for understanding the weathering of a material, since access of water into the microstructure is a main cause for a wide range of deterioration conditions.<sup>12</sup>

To perform the test, a measured tube graduated in cubic centimeters is attached with putty to the stone surface (straight tubes are available for horizontal surfaces, and angled tubes for vertical ones) and water is poured into the tube, measuring the amount of water

<sup>&</sup>lt;sup>12</sup> Siedel and Siegesmund, 389-392.

absorbed at certain time intervals to obtain an absorption curve. While many factors affect the accuracy of the test, it is an inexpensive way to obtain a good rough comparison between the absorption rates of different materials or different locations.

Seven tests were performed on the Bank (Table 3; Appendix 4). Deionized water was used to avoid introducing salts into the building. The volume of water absorbed was measured at 15 second intervals for the first minute; 30 second intervals for the following 3 minutes; and 1 minute intervals subsequently.

ID	Location	Type of marble	Condition	Orientation
RT01	South anta wall	Blue	Sound	Vertical
RT02	South pilaster interior	Blue	Contour scaling	Vertical
RT03	South door jamb	White	Sound	Vertical
RT04	South door jamb	White	Friable	Vertical
RT05	Pronaos wall	Blue	Contour scaling	Vertical
RT06	Steps	Blue	Sound	Horizontal
RT07	South column base	Cream	Sound	Horizontal

Table 3: Rilem testing locations.

# 3.4. Sample Testing

Observation and testing of material samples in the laboratory is complementary to in-situ testing. Since it is destructive by nature, the amount of material that can be sampled is much less, and the locations more limited, than for in-situ testing. On the other hand, laboratory testing of samples allows for in-depth observations that make it possible to determine the chemical composition and microstructure of the material more accurately. Samples from the Mechanics' Bank were collected and subjected to macroscopic observations, soluble salt testing, and microscopic analysis including both stereomicroscopy and polarized light microscopy (PLM).

#### *3.4.1. Sample Collection*

Six marble samples (SS01-06) were taken in different locations. These were selected to include the maximum possible variety of situations: white vs. blue marble, exposed vs. protected surfaces, and sound vs. disaggregated or deteriorated stone. Two mortar samples (MS01-02) were taken to represent the two types of mortar identified at the time; in addition, sample SS04 contained mortar attached to the marble. Two samples of paint (PS01-02) were taken corresponding to the two identified colors of paint coating (Table 4, Appendix 5).

Samples were collected with the authorization and under the supervision of the building's owners. To minimize the impact on the building, samples were taken from areas of low visibility and, wherever possible, taking advantage of preexisting cracking and deterioration. Samples were removed by hand, with a scalpel, or using a hammer and chisel. Due to access limitations, all the samples were taken within 10' of access level (15' above street level). Therefore, no sampling of the capitals was possible even though they were suspected to be a different type of marble from the rest of the building.

ID	Туре	Location	Condition	<b>Representative of</b>	Notes
SS01	Stone	Corner of panel, south wall	Small, sound fragment	Blue marble in cleaned areas, sound condition	Already detached (mechanical spall)
SS02	Stone	Column drum, north column	Small, friable flakes	Blue marble, friable	From area of high erosion and friability
SS03	Stone	Base of north pilaster at alley	Small, sound fragment	Blue marble in uncleaned areas, sound condition	From area with major but old dimensional loss. Area never painted or cleaned
SS04	Stone, mortar	South door jamb	Large, friable fragment w/ mortar	White and blue marble with mortar joint, poor condition	Already detached.
SS05	Stone	Edge of panel, north anta (at crack)	Large, sound fragment	Blue marble in cleaned areas, sound condition	From tip of crack/ incipient spall
SS06	Stone	Pilaster panel, south pilaster (at crack)	Medium, friable fragment	Blue marble in cleaned areas, poor condition	From tip of crack/ incipient spall
MS01	Mortar	South pilaster, vertical joint to anta panels	Large, sound fragment	Repair mortar	Already detached
MS02	Mortar	North pilaster, vertical joint	Small flakes	Original mortar	Already detached from one side of joint as joint opened
PS01	Paint	North pilaster, vertical joint	Small flakes	Blue paint	From inside of joint as main surface was stripped of paint
PS02	Paint	Column shaft, south column	Small flakes	Cream paint	Flaked off easily

Table 4: Location of collected samples.

# 3.4.2. Salt Testing

Salt testing is a chemical analysis performed to detect the presence of soluble salts in a material.<sup>13</sup> Soluble salts in marble can have different origins, including biological excrement (nitrates) and pollution (sulfates). Salts accumulate in intergranular cracks and, through their crystallization and hygroscopicity, contribute to the disaggregation of the material. In addition, pollution can transform the calcium carbonate in the marble into calcium sulfate

<sup>&</sup>lt;sup>13</sup> Siedel and Siegesmund, 397.

(gypsum crust) increasing its solubility and reducing its resistance to erosion. Detection of soluble salts can indicate the presence of these conditions, even to small extents.

Salt testing was performed for all stone samples. Fragments of the samples were ground and mixed with 50ml of deionized water, then stirred for 10min. Salt testing strips were subsequently introduced in the solution to determine the presence of soluble salts. These are strips of paper coated with chemical reagents that change their color in the presence of a certain ion. Three types of strip were used: the MQuant Chloride Test, which detects Cl<sup>-</sup> (chloride) ions in concentrations of 500 -  $\geq$  3000 mg/l; the MQuant Nitrate test, which detects NO<sub>3</sub><sup>-</sup> (nitrate) ions in concentrations of 10 – 500 mg/l and the non-quantified presence of NO<sub>2</sub><sup>-</sup> (nitrite) ions; and the MQuant Sulfate Test, which detects SO<sub>4</sub><sup>2-</sup> (sulfate) ions in concentrations of 200 – 1600 mg/l.

#### 3.4.3. Visible and Fluorescent Light Microscopy

The primary tool used for analyzing the microstructure and composition of sampled materials was microscopic analysis. Three types of microscopic analysis were used: visible light, fluorescent light, and polarized light microscopy (see Section 3.4.3).

Visible light microscopy observes samples under natural or artificial visible light. Two microscopes were used: a Leica MZ16 Stereomicroscope and an Olympus CX31 Compound Microscope. Both of these use reflected light, since samples are opaque, and operate at low magnifications (1x to 11.5x). The stereomicroscope is useful for analyzing unprepared samples since it provides a three-dimensional view of the sample surface; both microscopes can be used for analyzing cross-sections.

Fluorescent light microscopy takes advantage of autofluorescence; that is, the property that certain materials have of being excited by ultraviolet radiation (excitation

light) and subsequently emitting light in a distinct frequency of the visible spectrum (emission light). Since this is a property of many organic materials such as binders, it is especially useful to analyze cross-sections of finish materials such as paint coatings; the different emission colors of each paint binder can reveal differences between layers that are not obvious to the naked eye, and can help identify the type of binder used. For fluorescent light microscopy the Olympus CX31 Compound Microscope was used with a blue-violet UV light source (Nikon Super High Pressure Mercury Power Supply HB-10101AF). Visible and fluorescent light microscopy were most useful for the preliminary observation of unprepared stone samples, and for the analysis of cross-sections of paint coatings and mortar pointings.

For the analysis of paint coatings, a cross-section was first obtained by casting the sample in a cube of clear bioplastic. The cube was then sliced using a Buchler Isomet 1000 Precision Saw; polished; and mounted on a glass slide. The samples (PS01 and PS02) were then analyzed and photographed using the compound microscope in both visible light and ultraviolet configurations, noting features such as number of layers; penetration into the substrate; soiling; and possible composition of the layers.

Mortar cross-sections were obtained in the same way as paint samples and then analyzed and photographed at low magnification under the stereomicroscope. The main goal of this was to observe the relationship between the historic layers of pointing mortar; only sample SS04 was analyzed since it seemed to have the highest number of layers. To analyze the microstructure of the mortars, petrographic analysis under polarized light was used instead (see Section 3.4.3).

# 3.4.4. Polarized Light Microscopy (PLM)

Polarized light microscopy is a form of microscopy used for the analysis of crystalline materials, taking advantage of the refraction of light by crystals. It is a form of transmitted light microscopy: in it, a thin section of the sample is mounted with a light source under it. A polarizer placed underneath the sample filters the light from the source so that it will only vibrate in one plane. A second, removable polarizer (analyzer) placed above the sample at a right angle to the lower polarizer filters light at a perpendicular plane to the former; thus, absent any refraction, all light from the source is blocked altogether. Samples can be observed using only the lower polarizer (plane polarized light, PPL) or both (cross polarized light, XPL). By comparing both images, it is possible to identify the composition of a sample based on its crystalline structure: for instance, isotropic crystals do not refract light and are transparent in PPL but opaque in XPL, while anisotropic crystals create distinctive sets of interference colors and patterns. Since interference colors in XPL are dependent on the thickness of the sample, for a correct analysis all thin sections must be cut to an exact thickness of 30µm.<sup>14</sup>

PLM analysis was used to gain insight into the microstructure and composition of the stone and mortars. Samples SS03, SS04 and SS05 were selected as being representative of as many types of marble and mortar and as many conditions as possible; they were prepared into thin sections by National Petrographic Services, Inc. of Rosenberg, TX. The thin sections were then analyzed under PPL and XPL using an Olympus CX31 polarizing microscope.

For the marble samples, the granular structure; changes to the structure by deterioration such as weathering, crusts or cracking; accessory minerals; and salt growth at

<sup>&</sup>lt;sup>14</sup> Nesse, 14-24, 37-52.

cracks were noted. For the mortar, the composition and structure of both binder and aggregate were noted (Appendix 6).

#### 4. Background

## 4.1. Historical Background

Over time, the Mechanics' Bank building has undergone numerous changes in ownership and use (Fig. 2). This complex history has left its mark in the form of physical transformations of its fabric. The longest and most impactful periods of ownership corresponded to the Mechanics' Bank, its original owner, from 1837 to 1904; and the Norwegian Seamen's Church, from 1930 to 1982.

The Mechanics' Bank was one of the first financial institutions designed to serve the needs of Philadelphia's mechanic class. Incorporated as a society in 1810, it received its first charter in 1814.<sup>15</sup> The bank initially occupied a previously existing brick building that had been a hat factory. After a burglary in 1833 made clear that the building was inadequate to its purpose, the Bank's directors authorized construction of a new, dedicated building in 1836. George Handy and Claude Brasion donated two adjacent lots on 22 and 24 South Third Street on which the Bank commissioned architect William Strickland with erecting a building. By November 1837 construction had been completed and the Bank moved to its new premises.<sup>16</sup>

William Strickland (Navesink, NJ, 1788 – Nashville, TN, 1854) was at this time one of the highest regarded architects and engineers in Philadelphia. A disciple of Benjamin Latrobe, he had made a name for himself erecting public and commercial buildings; the most noteworthy of these were in the Greek Revival style and often, especially in Philadelphia, clad in Pennsylvania marble.<sup>17</sup> It was a banking building –the Second Bank

<sup>&</sup>lt;sup>15</sup> "Banks and Trust Companies", Philadelphia Historical Commission.

<sup>&</sup>lt;sup>16</sup> "Original and Subsequent Owners", Philadelphia Historical Commission.

<sup>&</sup>lt;sup>17</sup> Hamlin, 74-78.



Figure 2: Timeline of the Mechanics' Bank building, 1814-2018. Two periods of long-time ownership are clear (1837-1904 and 1930-1982) with frequent changes of ownership in the intermediate periods.



Figure 3: One of the earliest photographs of the building while still owned by the Mechanics' Bank (1899).

Source: Official Office Building Directory, 471.

of the United States (1818-24)– that established Strickland's reputation; and by the time of the Mechanics' Bank commission he was already responsible for some of the principal financial and commercial structures in Philadelphia. These included the Philadelphia Mint (1829-33, demolished), the Merchants' Exchange (1832-34) and the Philadelphia Bank (1837, demolished).<sup>18</sup> Strickland's take on Greek Revival borrowed heavily from Stuart and Revett's *Antiquities of Athens* for details, yet it combined them into a distinctive language (Fig. 3). Critics such as Talbot Hamlin have praised Strickland's designs for their graceful solutions, even when applied to modest buildings such as the Providence Athenaeum (1836-38).<sup>19</sup> Although not discussed by Hamlin, the Mechanics' Bank, contemporaneous with the Athenaeum and of a similar scale, is arguably as good an example of this grace as any of Strickland-s buildings.

The Bank belongs to a type of narrow-lot temple bank building popular during the early- to mid-nineteenth century in the Philadelphia area and elsewhere.<sup>20</sup> Primarily a brick structure, it originally consisted of a two-story banking room lit by a skylight, since the narrow lot precluded side windows; and three smaller offices arranged symmetrically at the back.<sup>21</sup> A basement underneath contained the bank vaults. The façade was laid out in the Corinthian order as a distyle in antis. This, the oldest of the Greek temple forms, consists of two central columns flanked by cheek walls terminating in pilasters (*antae*), forming a portico (*pronaos*) that faces only forward and can therefore be easily adapted to a building sandwiched between other structures.<sup>22</sup> This façade was executed in Pennsylvania marble

<sup>&</sup>lt;sup>18</sup> Gilchrist (1950), 81-94.

<sup>&</sup>lt;sup>19</sup> Hamlin, 57.

<sup>&</sup>lt;sup>20</sup> E.g. T.U. Walter's Bank of Chester County (West Chester, PA, 1836) or the Philadelphia Savings Fund ( 306 Walnut St., Philadelphia, PA).

<sup>&</sup>lt;sup>21</sup> Hexamer

<sup>&</sup>lt;sup>22</sup> Cyril M. Harris, Dictionary of Architecture and Construction, Fourth ed. (New York: McGraw-Hill, 2005), 317.

by Struthers and Son. John Struthers was the leading Philadelphia marble mason at the time and a close collaborator of Strickland in many of his Philadelphia projects.<sup>23</sup> The façade stands out for its slender proportions and the quality of its architectural detailing, closely related to Strickland and Struthers's earlier work for the Merchants' Exchange only a few blocks away on Third Street. The most distinguished example of this are the very elaborate Corinthian capitals with hollowed-out carving, following the model of the Choragic Monument of Lysicrates in Athens as publicized by Stuart and Revett, which differs significantly in its details from the more common Roman Corinthian.<sup>24</sup> The capitals in these two Philadelphia buildings arguably constitute the high point of early-nineteenth-century American architectural ornament; in the Merchants' Exchange they were carved of Carrara marble by Italian masons.<sup>25</sup>

The building was occupied by the Mechanics' Bank, after 1864 called the Mechanics' National Bank, until 1904.<sup>26</sup> In 1874, its interior was altered by James E. Windrim, who added a back extension but retained the double-story banking room (Fig. 4).<sup>27</sup> The Mechanics' National Bank ceased operations in 1904 and sold the building to a private individual named Stanley Francis; over the next twenty-six years, it underwent a succession of owners, including the Citizens' Bank and the State Bank of Philadelphia; the longest occupation was by the N.Z. Graves Company, a paint distributor that owned it from 1907 to 1919.<sup>28</sup> In 1929, the Norwegian Seamen's Church, a religious institution that provided services to Norwegian and other Scandinavian mariners, expressed interest in acquiring the

 <sup>&</sup>lt;sup>23</sup> Roger W. Moss, "Struthers, John (1786 - 1851)," Philadelphia Architects and Buildings, accessed May 22, 2018, https://www.philadelphiabuildings.org/pab/app/ar\_display.cfm/127005.

<sup>&</sup>lt;sup>24</sup> James Stuart and Nicholas Revett, *The Antiquities of Athens* (London, 1762), Plate 14.

<sup>&</sup>lt;sup>25</sup> Hall, Matero, and Hinchman, 2.

<sup>&</sup>lt;sup>26</sup> "Banks and Trust Companies", Philadelphia Historical Commission.

<sup>&</sup>lt;sup>27</sup> Webster and Peterson, 84.

<sup>&</sup>lt;sup>28</sup> "Original and Subsequent Owners", Philadelphia Historical Commission.

building, which it did in 1930.<sup>29</sup> Within the year, the church had commissioned Edwards and Green of Camden, NJ with a project to refurbish the building and divide the interior into two floors. A chapel occupied most of the first floor, while a reading room was installed in the second. "Other minor alterations" were effected including roof repairs, new electrical and heating systems, and the installation of stained glass throughout the first floor windows.<sup>30</sup> Campaigns of repairs and improvements continued through the 1940s and 1950s: the south façade was refinished in 1954 in response to the demolition of the adjacent building. An air conditioning system was installed in 1961.<sup>31</sup>

During the church's ownership, the building started to attract attention as an architectural landmark. On June 26, 1956 the newly formed Philadelphia Historical Commission placed it on the Philadelphia Register of Historic Places.<sup>32</sup> Inspired by the development of Independence National Historical Park, in 1963 the Seamen's Church inquired about clearing the area between the building and Market Street to create a square, following the example of nearby Christ Church – ostensibly without success.<sup>33</sup> In 1970, the building was placed on the Pennsylvania Register of Historic Sites and Landmarks, later absorbed by the National Register of Historic Places.<sup>34</sup>

As port activity in Philadelphia declined, the Seamen's Church sold the building at auction in 1982 for \$ 230,000; between this year and 2006, the building's owners were multiple, often sharing stakes in its ownership.<sup>35</sup>

<sup>&</sup>lt;sup>29</sup> "Minutes, May 15, 1929", Seamen's Church Institute Records.

<sup>&</sup>lt;sup>30</sup> "Minutes, 1930-1932", Seamen's Church Institute Records.

<sup>&</sup>lt;sup>31</sup> "Minutes, October 27, 1954", Seamen's Church Institute Records; and Building Permits.

<sup>&</sup>lt;sup>32</sup> "Mechanics National Bank," Philadelphia Architects and Buildings, accessed May 22, 2018, https://www.philadelphiabuildings.org/pab/app/pj\_display.cfm/16164.

<sup>&</sup>lt;sup>33</sup> Tinius Olsen to Philadelphia Historical Commission, March 21, 1963. Philadelphia Historical Commission.

<sup>&</sup>lt;sup>34</sup> Webster and Peterson, 84.

<sup>&</sup>lt;sup>35</sup> Register of Deeds.



Figure 4: Early depictions of the Mechanics' Bank building are rare. Top to bottom: Hexamer Atlas (1860), Dreer Manuscript (first known elevation, 1870-80) and Sanborn Atlas (1916) showing rear addition by Windrim.

The first venue to occupy the building after the Seamen's Church was the well-known underground nightclub Revival (1982-1996), followed by a variety of commercial and entertainment venues including Coyote Ugly, Jake and Oliver (c. 1997-2003), and Foggy Goggle (2004). Many of the church's furnishings, such as the stained glass windows and carved wooden pews, were retained; the most significant alteration during this period was the painting of the façade in 2004, stripped away the following year.<sup>36</sup>

In 2006, Darren and Jason Hill acquired the Bank building for WebLinc Co., a developer of e-commerce platforms.<sup>37</sup> WebLinc utilizes the second floor as its headquarters and the center of its Philadelphia urban campus; it also operates a bar and restaurant on the first floor which, in an homage to the building's history, carries the name of National Mechanics.<sup>38</sup>

#### 4.2. Characterization of Pennsylvania Marble

The main material used for the façade of the Mechanics' Bank is Pennsylvania marble in its different varieties. True marble is a metamorphic stone formed through the recrystallization of rocks containing the carbonates calcite, CaCO<sub>3</sub>, and dolomite, CaMg(CO<sub>3</sub>)<sub>2</sub>. In its pure state, marble is white; if it shows coloring, this is due to accessory minerals. <sup>39</sup> This definition notwithstanding, the word "marble" as a building material has been applied to any calcareous stone that will take polishing; and, in some cases, even to non-calcareous stones.<sup>40</sup>

<sup>&</sup>lt;sup>36</sup> Karen Robinson to Philadelphia Historical Commission, October 12, 2004. Philadelphia Historical Commission.

<sup>&</sup>lt;sup>37</sup> Deed 51485134, Register of Deeds.

<sup>&</sup>lt;sup>38</sup> "About Us," National Mechanics, accessed May 22, 2018, http://www.nationalmechanics.com/about/.

<sup>&</sup>lt;sup>39</sup> Kemp, 217-218.

<sup>&</sup>lt;sup>40</sup> Kimmel, 2.

Marble was used extensively in the early-nineteenth-century United States as a construction stone owing both to the discovery of sources in the country and to a conscious wish to emulate Classical models under the then popular Greek Revival style.<sup>41</sup> Pennsylvania marble was quarried in the Marble Hall (Plymouth Meeting) and King of Prussia quarries in Montgomery County, just upstream of the Schuylkill River from Philadelphia, in three varieties: white, gray ("blue") and white with gray banding.<sup>42</sup> In the early nineteenth century, driven by architects such as Benjamin Latrobe and William Strickland, it became the premier building stone in the city. It fell into disuse around the middle of the century as its poor weathering became evident in the increasingly polluted atmosphere of Industrial Revolution Philadelphia; while Victorian taste dictated more colorful materials such as brownstone. By the time marble became a desirable building stone again at the end of the century, better-performing marbles from regions such as Vermont and Georgia had become more readily available through improved transportation.<sup>43</sup> As the geological features of the King of Prussia and Marble Hall quarries made marble increasingly difficult to extract, both would eventually close before 1934. Pennsylvania marble is no longer quarried today.<sup>44</sup>

The most complete characterization of Pennsylvania marble to date is based on samples taken from the Second Bank of the United States and studied by Jocelyn Kimmel, who established that the marble's microstructure was the primary factor in the variability of its deterioration at the Second Bank. The behavior of marble depends on properties such

<sup>&</sup>lt;sup>41</sup> Matero et al, 1.

<sup>&</sup>lt;sup>42</sup> Kimmel, 3.

<sup>&</sup>lt;sup>43</sup> Matero et al, 1.

<sup>&</sup>lt;sup>44</sup> Kimmel, 4.
as the size, roundness and interlocking of the grains; the stone's isotropy; and the presence of accessory minerals.

As determined by Kimmel, Pennsylvania marble is a weakly metamorphosed calcitic marble (or, conversely, a highly metamorphosed limestone) with blue dolomitic banding and mineral inclusions of graphite, mica and quartz. Unlike fully metamorphosed marble, which is isotropic, Pennsylvania marble has a marked foliation with weak bonding between layers, making its behavior highly anisotropic and the orientation of installation, therefore, a critical factor in its performance. This, together with the abundance of accessory mineral inclusions, makes Pennsylvania marble highly vulnerable to surface weathering.<sup>45</sup>

Kimmel studied three varieties of Pennsylvania marble present at the Second Bank: dark and fine-grained, white and medium-grained, and white and fine-grained. The darker marble had the most interlocked grains and, therefore, the lowest porosity; and, counterintuitively, presented the least accessory minerals. The white marbles presented higher porosity due to more rounded grains and a higher proportion of mineral inclusions, especially for the fine-grained marble. This explains the higher susceptibility of the white marbles to salts, disaggregation, and spalling.<sup>46</sup>

<sup>&</sup>lt;sup>45</sup> Kimmel, 19.

<sup>&</sup>lt;sup>46</sup> Kimmel, 7-20.

#### 5. Findings

In order to comprehend the behavior of a structure it is important to understand its nature and performance across time, from its construction to the present day; and across scales, from the microscopic to the macroscopic. Since each of these factors influences all the other, no thorough knowledge can be gained without understanding all of them. Therefore, instead of organizing the findings by method of research – these are described extensively in Chapter 3 – I have organized them according to these parameters, starting with the macroscopic and the original state and finishing with the microscopic and the current state. Section 5.1 describes the façade's assembly, both in its original intent and in its alterations throughout time. Section 5.2 takes a look at the macroscopic deterioration patterns of the façade surfaces. Finally, Section 5.3 takes a close look at the construction materials (marble as well as mortars and paint coating) with an emphasis on their microstructure.

### 5.1. Façade Assembly

The building's Third Street façade is the only part built of Pennsylvania marble and by far its most significant exterior feature. Other building elevations are clad in stucco or show exposed brick and, not visible from the street, were never designed to be a part of the building's image; only the south façade was refinished and repainted as the adjacent building was demolished in 1954.<sup>47</sup>

#### 5.1.1. Construction

The façade (Fig. 5) is a brick structure clad in semi-load-bearing Pennsylvania marble panels; the two columns and architrave above them are composed of solid, fully load-

<sup>&</sup>lt;sup>47</sup> "Minutes, October 27, 1954", Seamen's Church Institute Records; and Building Permits.

bearing marble units. The four capitals are also solid units, and (although it was not possible to take samples to confirm this) their intricate detailing suggests that they may have been carved of a different (statuary) marble, as was the case for the very similar Carrara marble capitals of the Merchants' Exchange. Marble units in visible areas, especially the pronaos walls, are large face-oriented ashlar cut to regular dimension with very thin (ca. 1mm) white mortar joints. In areas further away from view, such as the pediment, units are cut to different sizes – a common, economical practice to take advantage of irregular quarry blocks.<sup>48</sup> At the steps' cheek walls, protected from view by other buildings, units are mismatched in size and shape, possibly the result of squaring quarry leftovers. The typical assembly of the façade, as observed through missing window frame panels, consists of a brick wall ca. 2' deep clad in ca. 6" thick marble panels. Marble units for moldings and carved areas may be substantially thicker; for instance, the front panels of the antae can be as thick as 10". Magnetometric scanning revealed these panels to be attached to the structure by metal anchors, likely wrought iron (See Appendix 4). Anchors are present at most but not all of the horizontal joints, typically one in the center of each unit, and are not present at the vertical joints. The column drums, three for each column, are held together by what may be a cross-shaped anchor to prevent rotation. Metal flashing is present at least at the second joint in each pilaster, possibly to protect the building from water infiltration along the long vertical joints in this area.

The building rests on a basement spanned by a segmental 1' brick barrel vault. This vault is supported by foundation walls made of Pennsylvania marble rubble. A further marble rubble foundation wall runs underneath the pronaos façade. The foundation

<sup>&</sup>lt;sup>48</sup> Miguel Sobrino González, *La Piedra como Motivo para la Arquitectura*, vol. 8-52-01, Cuadernos Del Instituto Juan de Herrera (Madrid: Instituto Juan de Herrera, 2002), 11.



Figure 5: Section through façade showing building assembly. The building's marble-clad brick walls, held together by iron cramps, rest on a vaulted foundation. Second floor added 1930.

underneath the columns and antae could not be examined, since physical removal of material would be necessary for its observation; it may be a parallel and similarly constructed wall, or piers functioning as individual footings. For the same reason, it was not possible to determine the type of foundation underneath the portico and the steps; the floor slabs may be resting directly on the ground, or may be set on brick arches or vaults (there is precedent for this in Strickland's Second Bank building). Due to their displacement, it is likely that at least the lower two or three steps are set on the ground directly.

The building is covered by a low-pitch front-gabled roof, with purlins running from the pediment to the back gable supported by two intermediate queen-post trusses that frame the central skylight. Much of the roof frame seems to be original. The floor of the attic consists of front-to-back joists running uninterrupted over the pronaos wall and supporting a lath-and-plaster ceiling both inside and outside.

As the Norwegian Seamen's Church refurbished the building in 1930-32, a floor frame with joists running parallel to the façade was installed.<sup>49</sup> Some interior features still show evidence of the building's original appearance or the 1872 alterations; these include the oversized crown molding in the second floor or the pink marble floor visible underneath the twentieth-century first-floor floorboards. The sash windows on the first floor (excluding the glass) and pivot windows on the second floor may also be original.

# 5.1.2. Historical Evolution

The earliest photographic image showing the façade of the Mechanics' Bank is a view from 1898, taken sixty-one years after construction and six years before the end of the Bank's

<sup>&</sup>lt;sup>49</sup> Building Permits.

operations.<sup>50</sup> Photographs from 1898-1901 show the building in what appears to be a good state of conservation (Fig. 6). The façade marble seems to be exposed, with all the joints clearly visible; fluting is present not only on the columns, but also on the front of the antae pilasters (since disappeared); and the detailed capitals seem to be mostly complete, with the exception of the more exposed volutes at the corners of the building. The façade is fitted with signs showing the name of the bank both on the antae and over the entrance, and ornate Empire-style cast iron lamps on the cheek walls of the steps. There is a good chance that these may have been original to the building, since they are very similar (the shaft, specifically, is identical) to those installed in 1832 at the Franklin Institute, now the Philadelphia History Museum.<sup>51</sup> All doors and windows are fitted with striped awnings, and the second-floor windows have flagpoles attached to their sills.

No further photographs are known until 1950, when one appears in Gilchrist's Additions;<sup>52</sup> this photograph, and the clearer view in the 1957 Historical American Buildings Survey file<sup>53</sup>, shows evidence of the progress of deterioration as well as rehabilitation and restoration campaigns carried out by the Seamen's Church. Three main interventions by the Church affected the façade. The first one took place in 1930-32 when Edwards and Green rehabilitated the building; its extent on the façade is unclear. The second happened in 1947-48 after an inspection of the building showed substantial

<sup>&</sup>lt;sup>50</sup> Engelhardt, 177.

<sup>&</sup>lt;sup>51</sup> Cindy Little, "Imagine Making Your Way Down Seventh Street...," Philadelphia History Museum, October 25, 2016, accessed May 22, 2018, http://www.philadelphiahistory.org/blog/imagine-making-your-way-down-seventh-street-to-a-program-at-15-south-7th-street/.

<sup>&</sup>lt;sup>52</sup> Gilchrist (1954), 14.

<sup>&</sup>lt;sup>53</sup> "EAST (FRONT) ELEVATION", HABS.

deficiencies.<sup>54</sup> The final one, executed by contractor Robert Gerling in 1955, included the repointing and eventually the "waterproofing" (likely painting) of the marble façade.<sup>55</sup>

The 1957 photograph after these campaigns shows, most significantly, the fluting on the antae removed; and the capitals encased in metal cages for pigeon proofing and safety (probably in 1948, see 5.1.3). Beneath the cages, the capitals show much more extensive deterioration than in 1901, with only three of the eight visible volutes remaining intact; deterioration is also visible at the spalled edges of the pediment moldings. A closer look at the façade, especially the antae, suggests it was painted white – and, indeed, white paint residues on the building show ghosts of the capital cages, confirming painting campaigns during this period (in 1947 or 1955, see Section 5.3.4). The transformation of the building into a church meant that most of the exterior furnishings of the Bank were gradually removed. Circa 1932 the awnings were taken down, stained glass was fitted on the first-floor windows, and new and larger flagpoles were installed at their previous location on the window sills. Discreet bilingual English and Norwegian signage on the antae occupied after 1945 the place where the larger bank signs had been; grilles on the windows were removed in 1949; and new, simpler lamps on the cheek walls replaced the original ones in 1950.<sup>56</sup> In 1957 railings were added to the steps.<sup>57</sup>

By 1977, the Church had once again rearranged the façade's fixtures. Four new, large flagpoles were installed in 1958 on collars attached to the marble columns, reinforced with guy-wires anchored at a lower point.<sup>58</sup> The church's signage was also replaced at a later

<sup>&</sup>lt;sup>54</sup> "Minutes, May 6, 1948", Seamen's Church Institute Records.

<sup>&</sup>lt;sup>55</sup> "Minutes, January 26, 1955", Seamen's Church Institute Records.

<sup>&</sup>lt;sup>56</sup> "Minutes, September 17, 1945; February 21, 1949; and February 22, 1950", Seamen's Church Institute Records.

<sup>&</sup>lt;sup>57</sup> "Minutes, October 2, 1957", Seamen's Church Institute Records.

<sup>&</sup>lt;sup>58</sup> "Minutes, October 8, 1958", Seamen's Church Institute Records.



Figure 6: The façade underwent successive transformations throughout the twentieth century. Left to right and top to bottom: 1901 (King), 1957 (HABS), 2004 (PRHP), and 2018.

date, though in a similar size and shape to the older one, and a historical marker plaque was added on the left anta. The photograph included in the 1982 auction pamphlet confirms these arrangements.<sup>59</sup>

No good-quality photographs have been found of the 1982-1996 period. However, a set of 1997 photographs shows the removal of the cages enclosing the capitals, as well as of the church's lamps, signage, and flagpoles.<sup>60</sup> New hanging signage and lamps were attached, respectively, to the front of the antae and columns; with promotional banners hanging above them. Electrical wiring was installed along the façade to supply the lamps on the columns and smaller spot lamps on the back wall.

In 2004, the tenants running the bar "Foggy Goggle", believing themselves to have their landlord's authorization, painted the building in a "Biloxi blue" color, which they understood to be "historic" since they had seen it in a catalog of "historic" colors.<sup>61</sup> Photographs show that the antae and back wall of the façade were painted blue. In addition to the painting, two large, billowing banners with the name of the bar were attached to poles on the antae. The Philadelphia Historical Commission noticed this and promptly ordered that the paint be stripped, which was undertaken in 2005, imperfectly, through chemical methods.<sup>62</sup>

Since 2006, few alterations have been made to the façade. Repairs to the columns were performed in 2007 using Jahn M120 Marble Repair Mortar.<sup>63</sup> The most significant recent changes, however, have been the removal of the banners on the antae and

<sup>&</sup>lt;sup>59</sup> "Trustee's Auction", Philadelphia Historical Commission.

<sup>&</sup>lt;sup>60</sup> Laura M. Spina to David Cohen, May 14, 1997. Philadelphia Historical Commission.

<sup>&</sup>lt;sup>61</sup> Karen Robinson to Philadelphia Historical Commission, October 12, 2004. Philadelphia Historical Commission.

<sup>&</sup>lt;sup>62</sup> "Application for Building Permit, August 5, 2005". Philadelphia Historical Commission.

<sup>&</sup>lt;sup>63</sup> Jonathan E. Farnham to Nathan Flanigan, April 16, 2007. Philadelphia Historical Commission.

subsequent installation of new, similar banners; and the addition of cor-ten steel planters with torches on top of the steps' cheek walls. In the last sixty years, material loss at the capitals and cornices has continued; while the loss at the cornices has been much smaller than between 1901 and 1957, the capitals have continued to deteriorate to the point where there is only one complete volute left overall (see Sections 5.2.6 and 5.2.7).

### 5.2. Deterioration Patterns

According to the visual conditions survey performed as part of this thesis (see Section 3.2 and Appendices 2, 3) the building displays a complex system of conditions including deterioration patterns and intentional transformations. A majority of the stone's surface presents one or several conditions, though not all of these are equally threatening to the building: the most prevalent condition is the presence of paint coatings, which are remainders from the twentieth- and twenty-first-century painting campaigns. Due to the complexity of the building's shape; to the different assembly systems in different areas; and to historically uneven degrees of intervention, few general conclusions can be extracted that apply to the whole building. Instead, the description of the stone's conditions has been organized by architectural element: the steps, the pronaos floor, and the pronaos walls; the pilasters, the columns, and the capitals; and, finally, the entablature crowning the façade all present different deterioration systems.

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5.2.1. Steps



Figure 7: Location of steps within the Mechanics' Bank façade.

The steps present by far the highest degree of displacement of stone units anywhere in the building (Fig. 8). The central steps, furthest from the cheek walls, show inward and downward movement; the three lower steps also present outward tilting. This seems to suggest a subsidence of the foundation structure and has caused wide open joints between the stones, some of which have been repointed with a mortar that is already separating.

The stone units at the steps are installed with horizontal bedding, so that the treads are face-oriented and the risers edge-oriented horizontal. Although there is differential erosion and some minor spalling at the step edges connected to pedestrian traffic and the hauling of heavy goods such as bar supplies (more pronounced at the center of the steps), in general there are few surface conditions, with no instances of friability or contour scaling. Microcracking and some moderate cracking following the foliation planes is, however, present at the risers. A few moderate, vertically oriented structural cracks are also visible under the columns; these seem to be related to differences in the foundation structure between the columns and elsewhere around them. Some soiling accumulation is present on the risers in a pattern that suggests differential washing.

In 1950, a car crash against the southern end of the steps caused significant spalling at and around the south end of the third step, part of which was repaired with mortar.<sup>64</sup> Later installation (c. 1997-2004 according to photographs) of a fire hydrant at the south corner of the steps exacerbated conditions in this area by causing additional cracking. Two metal handrails were installed on the steps in 1957, each anchored at three points into large holes infilled with repair mortar.<sup>65</sup> These attachments have caused moderate cracking of the stone and metallic staining.

The cheek walls on both sides of the steps are composed of vertically installed panels, mostly edge-oriented horizontal, and a coping also with horizontal bedding. These units, especially the vertical panels, present substantial microcracking and some moderate cracking following the foliation planes; this is concentrated at the outer edges of the walls, especially on south-facing elevations. Encrusted soiling is also present on the side elevations of these cheek walls, both north and south; it is especially exacerbated on the north elevation of the north wall, permanently protected since it faces the alley. Uniquely in the building, parts of the north elevations show microflora growth.

The 1950 crash affected the south cheek wall's south elevation as well as the steps. The areas affected have been infilled with repair mortar. After 2006 two cor-ten steel planters were installed atop the cheek walls. Rainfall washing large amounts of iron oxides from the cor-ten steel has caused staining both on the cheek walls and on the adjacent areas of the steps.

<sup>&</sup>lt;sup>64</sup> "Minutes, February 22, 1950", Seamen's Church Institute Records.

<sup>&</sup>lt;sup>65</sup> "Minutes, October 2, 1957", Seamen's Church Institute Records.



Figure 8: Conditions at steps, left-right and top-down: SE corner with effects of car crash and metallic staining; open joints, structural cracks and differential washing below south column; aerial view of displaced steps.

# 5.2.2. Pronaos Floor



Figure 9: Location of pronaos floor within the Mechanics' Bank façade.

The pronaos floor is composed of large face-oriented blue marble slabs with horizontal bedding. The edge of the floor towards the steps shares many of the steps' conditions, such as differential erosion at edges, and the central slab is tilted outwards since it rests on the subsiding central section of the steps.

Most of the floor shows few conditions outside of weak, generalized erosion due to human transit and small corner and edge spalls. Differential erosion is more pronounced in the north half of the floor but not severe; the trajectory of the doors can also be identified by an erosion pattern. More serious surface conditions such as contour scaling and friability are generally absent.

A major cross-shaped crack with shearing displacement at the northwesternmost stone slab, prolonged as moderate cracks into the two adjacent stones (Fig. 10), is consistent with an as yet undocumented impact or point load episode. One of the quarters into which the crack divided the stone has been infilled with repair mortar. One of the slabs between the columns is divided by two parallel cracks – one of them infilled - into three separate parts; this stone also shows evidence of former metallic features in the form of drill holes. These features have not been identified, nor is their connection with the cracking clear; the cracking could also be connected to the displacement of the steps. Apart from these two cases there is little cracking of the floor slabs.

Encrusted soiling is present at the protected corners between the back wall and the antae (especially behind the pilasters) and at the corners of the door surround. This soiling is more prevalent on the southern side. Some metallic staining can also be found at the southern side; some of it may be intrinsic, while other parts can clearly be connected to the use of a movable steel smoking pole.

The 1957 metal handrails have their top anchoring point near the edge of the floor and present here the same conditions as at the steps.



Figure 10: Conditions at floor, left-right and top-down: cracking and displacement at center, with holes for metal attachments; soiling and metallic staining at south wall; cross-shaped crack (mortar repair at bottom left).

#### 5.2.3. Pronaos Walls



Figure 11: Location of pronaos wall within the Mechanics' Bank façade.

The pronaos walls include both the back wall of the pronaos and the interior surface of the antae behind the pilasters. These are clad in large, regular units of Pennsylvania blue marble with few inclusions, approximately 6" thick and face-oriented with the exception of the edge-oriented horizontal lintel above the central window . Being a protected, flat area with few outstanding reliefs or edges, there is little dimensional loss or major structural cracking visible throughout; microcracking, associated with foliation planes, appears only at the one edge-oriented unit. Some structural movements, much less pronounced than at the steps and floor, are evident from open joints and a small number of structural cracks above the door on both sides, exacerbated by very thin mortar joints and hard repointing (Fig. 12).

Surface conditions, however, are evident throughout the wall. These include pervasive contour scaling and differential erosion associated with a face-oriented installation; and flaking on a few, localized stone units. These conditions seem to have little connection to the location and orientation of the stones, although units in the upper courses tend to show larger areas with preserved tooling marks indicating intact surfaces. The geology of each individual unit seems to play a larger role on the prevalence of these conditions, especially for friability; however, they also seem to be more common in the vicinity of joints and, especially, window openings. Percussive sounding of the first three courses revealed these conditions to be mostly superficial, with only one recorded instance of hidden spalling at the north anta wall.

In 2004 the whole wall was painted blue; it had previously been painted white. Chemical stripping followed in 2005. Most of the walls show little to no evidence of paint residue; the exception to this are the two top courses (three at the north anta wall) where cleaning seems to have been imperfect or nonexistent. On some of these units the amount of remaining paint is so large that cleaning does not seem to have been attempted at all; if this is the case, areas with loss of paint indicate surface loss in the last thirteen years and are a proof that surface deterioration processes are ongoing.

An electrical conduit connecting lighting fixtures runs along the entire wall above the first floor windows. This does not seem to have a damaging effect on the façade beyond visual impact; what little metallic staining is present on the façade units seems to be intrinsic. Soiling on the façade necessarily postdates the 2005 stripping; it is concentrated at the base, where it accumulates at the same protected areas described for the floor; on the north and south antae as streaks running down from the capitals suggesting bird excrement; and – to a much lesser extent – at the window sills indicating differential washing. Some graffiti, both painted and incised, is present at the lower south corner of the back wall.

The door surround is built of thin, long Pennsylvania white marble units, where the jambs are edge-oriented vertical and the lintel is face-oriented. The jambs show substantial differential erosion with loss of detail and friability at the edges. The long vertical joints

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between them and the back wall have historically opened, and continued to do so after repointing with hard cement mortar; as a result, the mortar has pulled the friable marble away from the jamb in large flakes that can be detached by hand, especially at the south jamb. The lintel, being face-oriented, shows surface friability instead. Two anchor holes at the lintel suggests metallic ornament at the corners, since disappeared; metallic staining, however, follows the path of the electrical conduit mentioned above, which rests directly on the lintel. Some encrusted soiling is present at the south jamb.



Figure 12: Conditions at pronaos walls, left-right and top-down: contour scaling and repointing; top of north anta with paint coating; open joints, soiling and electrical conduit; mortar causing marble flaking at south jamb.

## 5.2.4. Pilasters



Figure 13: Location of pilasters within the Mechanics' Bank façade.

The two pilasters capping the antae at the corners of the building are composed each of three courses of long, vertical stone units, plus a small base. Each course consists of three units, their depths ranging from 4" to 10", wrapped around the brick core. Front-facing units are face-oriented and originally showed fluting which was tooled back at some point between 1930 and 1950. Side-facing units are face-oriented on the exterior north elevation; edge-oriented vertical on the exterior south elevation; and a mixture of both on the interior elevations.

A small amount of structural movement seems to have caused cracking and incipient spalling at the lower unit of the north pilaster's south elevation; as well as the opening of the joints between the pilasters and the anta walls, which have been partially repointed (Fig. 14).

The long and minimally staggered vertical joints between the front and side stone units have, over time, become avenues for the circulation of water. This has caused severe differential erosion of the units with dimensional loss and opening of the joint. Where the units are edge-oriented vertical, this has been especially exacerbated causing friability, micro- and moderate cracking, and spalling at these joints as well as at the joint with the anta walls. Face-oriented units at the top course of the inward elevations and the two top courses of the front elevations present severe friability.

The front and inward sides of the pilasters were painted blue in 2004 and subsequently cleaned; they show little remaining evidence of paint. In contrast, the outward elevations to the alleys retain large amounts of white paint from the mid-century painting campaigns. The main metallic elements attached today are the alley gates, the National Mechanics banners and two electrical conduits continuing those at the back wall. While many metallic elements were attached over time to the front of the pilasters, most of these have been removed and patched and have left little metallic staining. Some staining from the now removed capital cages is present at the top of the pilasters.

Most encrustation on the inward and front elevations is connected to deterioration conditions. Encrusted soiling is present at the protected areas at the bottom of the south alley elevation and throughout the north alley elevation, the most protected area of the building. North alley units also present very large spalls at their back which are old and ostensibly unassociated with any other condition. It is unclear how these originated and, since they are located at some of the least visible marble surfaces in the building, they may have been deliberate.

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Figure 14: Conditions at pilasters, left-right and top-down: structural spalling (north inward); spalling and erosion (south inward); paint residue and severe friability (south); soiling and large spalling (north at alley).

## 5.2.5. Columns



Figure 15: Location of columns within the Mechanics' Bank façade.

The two columns are each composed of three solid drums plus a base. Most of the drums present vertical bedding, excluding the top south drum with diagonal beds. Among the rest, all the drums are face-oriented when seen from the front excluding the middle north, which is edge-oriented.

The column bases have horizontal bedding and present some microcracking associated with the bedding as well as significant erosion with loss of detail; but little friability. This pattern is concentrated especially in exposed areas facing east and southeast (Fig. 16). Metallic staining is also pervasive on exposed areas, but its cause is not clear; it may have been caused by metallic elements higher up that have since been removed, such as the capital cages. The more protected areas facing west and northwest show less influence of these conditions, but have a substantial amount of encrusted soiling. The south base shows structural cracking connected to the movement of the floor slabs.

Conditions at the column drums are affected by their orientation, their position in the column, and the direction of the foliation planes. Loss of detail through differential erosion

of the fluting is most prevalent in the more exposed southeast orientation; this is more significant at the lower drums, where it is accompanied by friability. Dimensional loss by spalling also tends to be more frequent in more exposed areas but depends more on foliation orientation, as it is more prevalent where the foliation planes are perpendicular to the relief of the fluting. Thus, the two bottom drums and top north drum (and, much less so, the middle south drum) show dimensional loss primarily on their east elevation and secondarily on their west elevation; and the middle north drum shows dimensional loss on its south elevation. Especially at the north column, this dimensional loss has been repaired with mortars at several points in time. The top south drum, with diagonal bedding, shows little dimensional loss but substantial cracking along foliation planes at the top end with possible incipient spalling.

The columns were twice painted white and much of this paint coating is still present throughout. A middle band with loss of paint coating is related to the former presence of flagpoles attached to a ring. Along the interior elevation of each column rises a vertical electrical conduit connecting to the pronaos wall; encrusted soiling is prevalent around these but there is little evidence of metallic staining. The latter is more prevalent at the top of the columns on the exposed areas, where it can be associated with the now removed capital cages.



Figure 16: Conditions at columns, left-right and top-down: microcracking, erosion and staining (north base); electric conduit (south); spalling of fluting and repair (north); diagonal cracking and incipient spalling (south).

#### 5.2.6 Capitals



Figure 17: Location of capitals within the Mechanics' Bank façade.

The four capitals seem to be made of a different type of marble from the rest of the building, although this could not be confirmed; they present no clear evidence of foliation. Each capital, including the abacus, is made of one single block of marble. Many elements – most notably the volutes, fleurons, and tips of the acanthus leaves – were originally carved in very high relief with large amounts of openwork.

Most of the more fragile elements have been lost to spalling throughout all the capitals. This includes the tips of practically all acanthus leaves; the tips of most of the openwork volutes, with only one intact and one damaged volute left (at the two south capitals); and the fleurons, only one of which is preserved at the south pilaster capital (Fig. 18). Friable areas and encrustation are present in the vicinity of the spalled areas and, especially, above the volutes and at and between the helices. This suggests the transformation of the marble into gypsum as a possible cause of the dimensional loss, though it does not confirm it. Generally speaking, the exposed elevations (facing east) show the greatest amount of deterioration, while the protected areas (facing west at the column capitals and north at the south pilaster capital) show the lowest amount. Among the exposed areas, those at the pilaster capitals show the largest amount of deterioration, including cracking and incipient spalling at the lower corners of the south unit that is not present at the other capitals. The abaci show differential erosion with loss of detail at the originally sharp tips, and soiling at the lower part of the scotia molding. The southwest tip of the abacus at the southern column capital has spalled together with the volute underneath.

The capitals were in generally good condition as late as the beginning of the twentieth century (Fig. 20), when only the tips of the outermost volutes, probably affected by water discharge from the pediment, had spalled; damage progressed to the central area in the first half of the twentieth century, but even by 1957 there were several volutes intact and the sharp tips of the acanthus leaves were preserved. Only in the second half of the twentieth century did dimensional loss become pervasive throughout all the capitals.

The capitals were painted white in the mid-twentieth century. Large amounts of this paint coating, deteriorating in many places, are still present, especially at the west elevations. The tips of the larger acanthus leaves and the abaci form ledges that, in protected areas, become a prime location for the nesting of birds; metal spikes have been attached in these areas of all capitals but the southernmost to prevent this from happening.

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Figure 18: Conditions at capitals, left-right and top-down: friability and spalling (south pilaster); abacus spalling (north column); intact leaf tips and metal spikes (south column); only intact volute and fleuron (south pilaster).

# 5.2.7. Entablature



Figure 19: Location of entablature within the Mechanics' Bank façade.



Figure 20: Evolution of dimensional loss at entablature and capitals (Sources: King, HABS). The former seems to have stabilized after 1957. Spalling of capitals began at building's corners and generalized in the last fifty years.

The entablature is composed of a combination of relatively shallow cladding units which are face-oriented (frieze and tympanum); narrow, deeper courses that are edge-oriented horizontal or following the slope of the unit (moldings and cornices); and solid units (architrave) which are a combination of both, an edge-oriented unit being used for the central span and face-oriented units elsewhere.

Overall, the entablature has large areas of remaining white paint coating; many units are painted almost entirely, which makes it difficult to identify surface conditions. Only four rectangular areas above the capitals, corresponding to the cages installed in the mid twentieth century, are completely unpainted. The interior and lower surfaces of the architrave are in fairly good condition, excepting encrustation at the most protected areas; in many sections it is possible to identify tooling marks. At the front elevation, the faceoriented units at the sides exhibit substantial contour scaling causing loss of detail at the edges of the fasciae (Fig. 21). The edge-oriented unit, instead, shows much less deterioration. The frieze, while composed of face-oriented units, also shows little damage.

The course of dentils below the cornice shows soiling encrustation and differential erosion which are much more pronounced near the corners than at the center of the course. Overall, however, there is little loss of detail. Many nooks between the dentils have been occupied by insect nests.

Above this course, the cornice underside also shows insect nests as well as encrusted soiling in a band parallel to the edge. The cornice sill shows a crust throughout that has only been washed away at the edge (to a larger extent in the center where it is less protected) to give way to contour scaling. The large cornice overhang with a drop perpendicular to the direction of the foliation planes has spalled for more than two thirds of its length; and is close to spalling in other areas where cracks and microcracking are visible, especially at the north end where it is seemingly kept in place by a loop of wire. Before 1901 the cornice overhang was essentially intact; the vast majority of the spalling happened between 1901 and 1957, with only minor losses at the center occurring since (Fig. X). The raking cornice above the pediment presents similar issues of insect nesting and encrustation; while present dimensional loss is much more limited, the large amount of microcracking along the foliation planes warns that this may become an issue in the future.

The face-oriented units at the pediment tympanum show few visible conditions. There is localized contour scaling and soiling at protected corners and in the vicinity of the sill. The central unit, however, shows diagonal cracking with some shearing movement of unclear origin.



Figure 21: Conditions at entablature, left-right and top-down: encrustation and contour scaling at pediment; paint coating and insect nests at dentils and cornice; contour scaling at architrave and spalling at cornice.

#### 5.3. Façade Materials

The main façade material is marble in several varieties, most notably Pennsylvania Blue; this is the primary focus of this research. Materials that are directly applied to the marble as part of construction or repair campaigns have a significant influence on the marble's behavior and can affect its microstructure or its performance as an assembly, which makes their study almost equally important; in the Mechanics' Bank, this includes pointing mortars; repair mortars; and paint coating. On the other hand, materials that largely form their own assembly within the façade – such as metal fittings, window assembles, and the lath-and-plaster ceiling – have a more indirect effect on marble behavior and have been considered outside the scope of materials analysis.

# 5.3.1. Marble

Three marbles were likely used on the façade, of which two have been confirmed. The vast majority of the façade was built using the blue variety of Pennsylvania marble; this includes the steps, pronaos walls, antae, pilasters, columns, and entablature – even though paint coatings mostly conceal this for the two latter. The door surround was built using white Pennsylvania marble. Due to the intricacy of their detail (difficult to carve in the foliated Pennsylvania marble) and the historical precedent of Carrara marble having been used for the capitals of the Merchants' Exchange, the four capitals are assumed to have been carved of a statuary marble of better quality than Pennsylvania marble. This could not be confirmed as their location made it impossible to take samples.

Rilem absorption testing revealed significant differences between the blue and white marbles, and especially between cohesive and friable marble (Fig. 22, Table 5). Cohesive blue marble showed the flattest absorption curves and lowest absorption rates at plateau, followed by cohesive white marble, which showed a similarly low absorption rate but a steeper initial curve. Loss of cohesion in marble, which involves the separation of grains forming cracks that act as interconnected pores, predictably increased absorption rates dramatically. The increase was high for white marble but much more so for blue. This suggests that initial loss of cohesion can create an avenue for water infiltration and, therefore, accelerate the rate of deterioration.

The data presented two peculiarities. One is that marble at the floor had much lower absorption rates than marble at other locations. This can be attributed to a choice of better marble for the floor (and, indeed, marble at the floor shows less deterioration conditions associated to microstructure than elsewhere) but also to a saturated pore structure since the marble may not have dried as thoroughly from rain events in the days preceding the testing. This dependence on environmental conditions and impossibility of a thorough controlled drying is a general limitation of Rilem testing as compared to laboratory absorption tests, which could not be performed due to sample size limitations.

The second peculiarity is the much smaller variation under loss of cohesion for white marble as compared to blue. An explanation behind this may be that the white units were smaller and more irregular with the more and less cohesive areas closer together, and therefore external factors affected absorption rates.

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RILEM ABSORPTION TEST RESULTS and average absorption rates at plateau (cm<sup>3</sup>/min)

Figure 22: Rilem absorption curves at different test locations. In sound condition, the marble used on the floor has the slowest absorption rate, and white marble has a faster absorption rate than blue. Loss of cohesion causes a dramatic increase in absorption rates.

Marble	Absorption rate (cm <sup>3</sup> /min)	
type	Cohesive	Friable
Blue	0.08~0.16	13.6~18
White	0.14	1.33

Table 5: Absorption rates according to type of marble.

Testing of soluble salts for all the marble samples revealed a small presence of sulfate ions throughout and minimal to non-existent presence of other ions (Tables 6, 7). This is consistent with the observed lack of efflorescence throughout the building. No significant differences were observed between types of marble (SS04, white, vs. all other samples, blue) or exposure; the only significant differences were by condition.

The only sample that showed both friability and encrustation, SS02, yielded the highest concentration by far of sulfates (SO<sub>4</sub><sup>2-</sup>); this indicates a transformation of the
calcium carbonate CaCO<sub>3</sub> into calcium sulfate dihydrate CaSO<sub>4</sub>  $\cdot$  2H<sub>2</sub>O (gypsum) typically caused by the effect of atmospheric pollutants on the marble.<sup>66</sup> Samples that showed either only encrusted soiling (SSO3) or only friability (SSO4, SSO6) yielded low concentrations of sulfates, suggesting that these types of deterioration are not primarily related to the formation of gypsum crusts.

Common sources of nitrites (NO<sub>2</sub>-) and nitrates (NO<sub>3</sub>-) in marble structures are fertilizers, animal excrement (esp. bird guano) and urine.<sup>67</sup> A typical source of chlorides (Cl-) are deicing salts poured on floors during winter. Only Sample SSO2 yielded low amounts of nitrates, and only sample SSO5 seemed to yield trace amounts (<<0.2mg/g) of chlorides. No samples were taken from the floor and steps, where presence of both urine and deicing salts has been observed; it is expected that samples in those areas would yield higher amounts of chlorides, nitrites, and nitrates.

Sample weight in John aq. Solution (ing/1)	
(g) $Cl^{-} NO_2^{-} NO_3^{-} SO_4^{2-} Cl^{-} NO_2^{-} NO_3^{-} SO_4^{2-}$	2-
<b>SS01</b> 6.60 400~800 3.03~6	5.06
SS02 1.03 2.3~10 >1600 0.11~0.49 >77.0	67
<b>SS03</b> 1.84 400~800 10.87~2	21.74
<b>SS04</b> 2.21 400~800 9.05~1	8.10
<b>SS05</b> 1.56 <<5 400~800 <<0.2 12.82~2	25.64
<b>SS06</b> 7.36 800~1200 5.43~8	3.15

Table 6: Salt concentrations in marble samples.

<sup>&</sup>lt;sup>66</sup> Kemp, 222.

<sup>&</sup>lt;sup>67</sup> Siedel and Siegesmund, 374.

Marble	SO <sub>4<sup>2</sup></sub> concentration (mg/g)				
type	Cohesive	Friable, no crust	Friable, crust		
Blue	3.03~25.64	5.43~8.15	>77.67		
White	n/a	9.05~18.10	n/a		
Marhle		$N\Omega_{2}$ concentration (mg/	ˈm]		
type	Cohesive	Friable no crust	5J Friable crust		
Blue	-	-	0.11~0.49		
White	n/a	-	n/a		
Markla		Cl. concentration (mg/s	a		
Marble	CI-concentration (mg/g)				
type	Cohesive	Friable, no crust	Friable, crust		
Blue	<<0.2				
White	n/a	- n/a			

n/a -Table 7: Salt contents according to type of marble.

PLM analysis was performed on three samples of blue marble (SS03, SS05, and SS04(b)) and one sample of white marble (SS04(w)). All samples show a holocrystalline stone composed primarily of calcite or dolomite crystals, with a small to moderate proportion of accessory minerals and no evidence of binder; textures ranging from granoblastic to foliated; and subhedral to anhedral grains (Table 8). This indicates that, while the stone's metamorphism is not thorough, there is little reason to call Pennsylvania marble a sedimentary rock. The composition of the Pennsylvania marble groundmass has previously been shown through X-ray diffraction to be a combination of calcium and magnesium silicates (indistinguishable in PLM), making this a dolomitic marble.<sup>68</sup>

<sup>68</sup> Kimmel, 14.

	BLUE MARBLE			WHITE MARBLE
	SS03	SS04(b)	SS05	SS04(w)
		Macroscopic sample	1	
Location	Foot of N pilaster	Back wall at door	North anta wall	Door surround
Sample condition	Cohesive, soiled	-	Cohesive to friable, clean to soiled	Friable, clean
Stone unit condition	Cohesive	Contour scaling	Mostly cohesive	Microcracks and flaking
Soluble salt content	SO4 <sup>2-</sup> (low)	n/a	SO4 <sup>2-</sup> (low) Cl <sup>-</sup> (trace)	SO4 <sup>2-</sup> (low)
	Polari	zed light microscopy	(PLM)	
Crystallinity	Holocrystalline	Holocrystalline	Holocrystalline	Holocrystalline
Grain size	Medium	Medium	Small to medium	Medium to large
Grain shape	Subl to anhedral, equant to subelongate	Anhedral, subequant to elongate	Subhedral and some anhedral, equant to elongate	Subhedral, equant to subelongate
Grain boundary	Irregular, few triple junctions	Irregular, few triple junctions	Less irregular, some triple junctions	Less irregular, some triple junctions
Texture	Granoblastic	Foliated	Granoblastic to foliated	Granoblastic to foliated
Groundmass	Calcite/dolomite	Calcite/dolomite	Calcite/dolomite	Calcite/dolomite
Accessory minerals	Feldspar (orthoclase, microcline): Large, fairly abundant. Unidentified (weath. feldspar?): Very large, infrequent	<i>Micaceous laths</i> (pr. muscovite): Small, abundant <i>Quartz:</i> Small, infrequent	<i>Micaceous laths</i> (pr. muscovite): Small, infrequent <i>Quartz:</i> Very small, very infrequent	Micaceous laths (pr. muscovite): Small, abundant Quartz: Small, infrequent Feldspar (orthoclase): Large, infrequent Unidentif. opaque (graphite?): Very small, very infreq.
Deterioration	Cracking (intergr.): None Cracking (intragr.): None Surface soiling: Moderate Crystal weathering: Shallow Gypsum crust: None Other: None	<i>Cracking (intergr.):</i> Large, parallel to foliation planes <i>Cracking (intragr.):</i> Small <i>Surface soiling:</i> n/a <i>Crystal weathering:</i> n/a <i>Gypsum crust:</i> n/a <i>Other:</i> Growth of lenticular crystals at cracks (soluble salts: gypsum?).	<i>Cracking (intergr.):</i> Medium, parallel to foliation planes, at surface <i>Cracking (intragr.):</i> Small, at surface <i>Surface soiling:</i> Little <i>Crystal weathering:</i> Shallow <i>Gypsum crust:</i> None <i>Other:</i> Growth of crystals at cracks (soluble salts: gypsum?).	<i>Cracking (intergr.):</i> Large, parallel to foliation planes <i>Cracking (intragr.):</i> Large, parallel to cleavage <i>Surface soiling:</i> None <i>Crystal weathering:</i> At spall <i>Other:</i> Splitting of mica laths at cracks. Growth of lenticular crystals at cracks (soluble salts: gypsum?).

Table 8: Characterization of samples studied under PLM.



Figure 23: Sample SS03 under PPL and XPL (40x). Note microcline feldspar crystal at top left.

Blue samples presented a significant degree of variation. Sample SS03 showed the least amount of foliation, with a granoblastic texture; and the most irregular grain boundaries, with few triple junctions (Fig. 23). It had the largest amount of accessory minerals by volume, consisting of large orthoclase and microcline crystals and a few large, weathered crystals that may also be feldspar. The macroscopically visible crust on the sample was determined to be only a thin soiling layer, with shallow weathering of the outermost crystals and no gypsum crust formation (Fig. 24). No cracks, either inter- or intragranular, were present.



Figure 24: Surface weathering and soiling in SS03. XPL (100x).



Figure 25: Sample SS04(b) under PPL and XPL (40x). Note cracking and small quartz and mica crystals.

Sample SS04(b) presented a foliated texture, with a clear orientation of the more elongate but equally irregularly bounded grains (Fig. 25). Possibly because the sample size was very small, no evidence of feldspar was found; instead, small but relatively abundant micaceous laths, probably muscovite, were found lodged between the calcite grains, as well as a few rounded grains of quartz that likely formed before the crystallization of the calcite (Fig. 26). Intergranular cracking was clearly visible, connected to the macroscopic contour scaling and probably exacerbated by the mechanical tension caused by the cement mortar; little intragranular cracking was present. Some lenticular crystals at the cracks, too small to be clearly identified, suggest crystallization of soluble salts.



Figure 26: Detail of micaceous laths both intact and split at crack in SS04(b). XPL (200x).



Figure 27: Sample SS05 under PPL and XPL (40x). Note cracking with lenticular growth and small mica laths.

Sample SS05's texture was intermediate between that of SS03 and SS04(b), showing less foliation. The grain boundaries were less irregular with a larger proportion of triple junctions; on the other hand, differences in grain size were more pronounced (Fig. 27). The same accessory minerals were present as in SS04(b) (micaceous laths and quartz grains) though in substantially smaller proportions. The macroscopically visible crust on the sample was determined to be only a thin soiling layer, with shallow weathering of the outermost crystals and no gypsum crust formation. Intergranular cracking (and some very incipient intragranular cracking along cleavage planes) was present to a depth of a few millimeters, and absent further into the stone. Like in SS04, lenticular crystals at the cracks suggest crystallization of soluble salts which, considering the detection of sulfates by salt testing, are likely to be gypsum (Fig. 28).



Figure 28: Crystal growth at intergranular crack and cleavage plane in SS05. XPL (200x).



Figure 29: Sample SS04(w) under PPL and XPL (40x). Note large cracks, both inter- and intragranular; and split micaceous lath at top left.

The white marble sample tested, SS04(w), showed like SS05 a granoblastic to foliated texture and less irregular crystals with a noticeable proportion of triple junctions (Fig. 29). However, there was less difference in grain sizes and the grains where somewhat larger than in any of the blue samples. Although SS03 may have a larger total content of accessory minerals due to the large feldspar crystals, SS04(w) showed the greatest diversity of accessory minerals. As well as some feldspar crystals it presented abundant micaceous laths; a few small, rounded grains of quartz; and a few small opaque grains which may be graphite. The sample was macroscopically the most deteriorated, with advanced friability; PLM confirmed this, showing large cracks parallel to the foliation planes as well as intragranular cracking along the grain cleavage planes (Fig. 30). Micaceous laths at the cracks were splitting and showed growth of lenticular crystals, likely to be gypsum (Fig. 31).



Figure 30: Cracking of calcite along cleavage planes in SS04(w). XPL (100x).



Figure 31: Quartz grain and splitting micaceous lath with growth of salt crystals in SS04(w). XPL (200x).

### 5.3.2. Pointing Mortars

Three mortar campaigns have been identified in the façade: all of them are visible in a section through the joint between the back wall and the door surround at SS04 (Table 9, Fig. 32). The first pointing campaign (M01) can still be identified in many areas of the building, though it has weathered away in others. It forms recessed white-colored joints barely 2 mm thick; the difficulty of repointing such thin joints suggests it is the original 1837 campaign. Petrographic analysis shows it is a lime mortar, probably non-hydraulic; due to the thinness of the joint very little aggregate was used. Where the joints opened, M01 either broke in half (at angle joints) or separated cleanly sticking to one side (at flush joints).

Two repointing campaigns, both of them partial, followed M01. Since repointing of the building was discussed both in 1941 and – specifically for the façade – in 1955, it is

probable that these two campaigns correspond to these dates.<sup>69</sup> According to this, campaign M02 took place in 1941. Parts of the building were repointed, especially where the joints had opened the most (such as between the pilasters and the antae wall, and between the door surround and the back wall). The pointing was raised, overflowing the joints, and was made as flush as possible at flush joints and concave at angles. According to the petrographic analysis, a light gray Portland cement mortar was used with an approximate binder-aggregate ratio of 1:1 and an aggregate of large, mostly sub-rounded grains of quartz and feldspar. Where joints opened, M02, due to its rigidity, did not crack completely and tended to stay in one piece and separate from the marble.

Campaign M03 took place in 1955. It was applied in similar places as M02, often on top of the former as joints continued to open. A darker gray Portland cement mortar with an approximate binder-aggregate ratio of 1:2, its aggregate is composed of small, well-sorted, mostly sub-angular grains of quartz. Either because it was a more rigid mortar or because of the deterioration of the stone, in some areas this mortar glued both marble units together, causing one of them to break apart as the joint continued to move. This happened especially at the joint between the friable white marble door surround and the blue marble back wall.

<sup>&</sup>lt;sup>69</sup> "Minutes, May 22, 1945; and January 26, 1955", Seamen's Church Institute Records.

Mortar	Date	Samples	Binder	Aggregate	BiAg. ratio	Thin Section (XPL, 40x)
M01	1837	SS04, MS02	Lime (non- hydraulic), carbonated	Small subangular particles	Mostly binder	
M02	1941	SS04, MS01	Portland cement (mechanical cracking)	Large, well- graded, sub- rounded to sub-angular quartz and feldspar grains	~1:1	
M03	1955	SS04, MS01	Portland cement	Small, well- sorted, sub- angular to angular quartz grains	~1:2	

Table 9: Types of pointing mortar.



Figure 32: Section of Sample PS4 (1.25x) showing successive repointing campaigns. As movement caused the original mortar to crack, two increasingly more rigid and mechanically stronger ("harder") mortars were substituted resulting in cracking of the marble itself.

## 5.3.3. Repair Mortars

Repair mortars, both recent and older, are present on the building's façade in limited amounts; they seem to have always been the preferred option for dimensional loss repairs, with no evidence of stone Dutchmen throughout the building. Most mortar repairs are at the steps and floor and on the columns.

No samples were taken of repair mortars, and therefore no microscopic analysis was performed. Older mortars, which are contemporaneous with paint campaigns on the columns (see Section 5.3.4) since they are covered with them, seem to match the stone's color more closely; newer mortars have been used since the acquisition of the building by its current owners in 2006, and are lighter in color.

The product used for newer mortar repairs was Jahn M120 marble repair mortar. This is a single-component cementitious mortar for stone repairs distributed by Cathedral Stone in standard or custom-made colors. It is vapor-permeable and mineral-based, containing no latex or acrylic bonding agents; and is applied by mixing with water.<sup>70</sup>

## 5.3.4. Paint Finishes

A substantial amount of paint coating remains on the building in varying degrees of deterioration. This includes cream paint on the entablature, pilasters (outside), columns, and capitals; and blue paint on the upper two courses of the pronaos walls, as well as some residue in other parts of the pronaos wall and the inside and front of the pilasters.

Photomicrographs of the cream layers on the south column (Fig. 33) show that two layers, L01 and L02, were applied successively. Both show visible pigment grains in a white binder with yellowish-green fluorescence that suggests an oxidized drying oil as a binder,

<sup>&</sup>lt;sup>70</sup> Jonathan E. Farnham to Nathan Flanigan, April 16, 2007. Philadelphia Historical Commission.

such as a linseed oil. Penetration into the substrate is nonexistent. The small amount of soiling between both layers suggest they were applied in relatively close sequence; the most likely hypothesis is that L01 was applied during the 1947 repairs campaign, and L02 could correspond to the "waterproofing" described in 1955, simultaneous with the M03 pointing campaign.<sup>71</sup> A heavy layer of soiling on top of L02, in some places easy to mistake for a third paint layer, suggests L02 has been exposed to the elements for a long time. Observation of the architrave above the capitals reveals the ghosts of the wire cages installed in the mid twentieth century – yet the capitals, which would have been inside these cages, are painted. This increases the likelihood of two campaigns, one occurring before and one after the installation of the cages, and confirms the probable installation of the latter in 1948. This date would also explain the homogeneous appearance of the stone on photographs taken between 1957 (and for some parts 1950) and 1982.

The photomicrographs of the blue paint show the residue left inside a joint at the north pilaster. Only one layer of paint, L03, is visible showing no visible pigment grains and no autofluorescence, which is consistent with modern acrylic paints. Very little soiling is perceptible, but there is substantial penetration into the substrate, which indicates that the marble had lost its intragranular cohesion before the paint was applied. L03 is well documented to have been the outcome of a painting campaign in 2004. The commercial name of the paint used, Biloxi blue, is used by many suppliers; this makes it difficult to determine the exact product used. Since the sample is from an open joint, the direct application of the paint on the stone here is not representative of the whole surface, and in many places it would have been applied over the cream paint.

<sup>&</sup>lt;sup>71</sup> "Minutes, May 6, 1948; and January 26, 19", Seamen's Church Institute Records.



Figure 33: Sample PS2-02 above (4x, visible and blue-violet UV light) shows two layers of cream paint. Sample PS1-01 below (4x, visible light, UV not shown since no fluorescence detected) shows one layer of blue paint.

The 2005 paint stripping was performed using an agent with the commercial name Peel-Away 7.<sup>72</sup> This product, distributed by Dumond Chemicals, is a solvent-based paint remover consisting of an acid-free (pH 6) and methylene chloride-free light brown paste applied as a poultice. Its active ingredients are benzyl alcohol (20-40%); 1-Methyl-2-pyrrolidone (10-20%); and alpha-(4-nonylphenyl)-omega-hydroxy-poly(oxy-1,2- ethanediyl) branched (<2%); it also contains 10-20% dibasic ester and water.<sup>73</sup> Its application involves pressurewashing or scraping the surface and then applying the product (on a dried surface) and covering with laminated paper for up to 48 hours. The poultice is then removed by scraping or low-pressure washing.<sup>74</sup>

The stripping \ applied to the building was incomplete; it seems to have been applied only to the areas painted blue (where it eliminated both the blue paint and, where present. the underlying white paint), excepting the upper courses which were either imperfectly cleaned, or not cleaned at all.

Table 10 and Fig. 34 show the most likely progress of paint and stripping campaigns on each of the building's elements.

<sup>&</sup>lt;sup>72</sup> "Application for Building Permit, August 5, 2005". Philadelphia Historical Commission.

<sup>&</sup>lt;sup>73</sup> Dumond. Peel Away 7: Safety Data Sheet. 2015.

<sup>&</sup>lt;sup>74</sup> Dumond, *Peel Away 7 – Solvent Based Paint Remover: Tech Data Sheet* (West Chester, PA, 2017).

Layer	L01	L02	L03	S01
Color	Light cream	Light cream	Electric blue ("Biloxi")	[Stripping]
Date	1947	1955	2004	2005
Building element				
Base and steps	-	-	-	-
Pilasters (exterior)	Yes	Yes	-	-
Pilasters (interior, front)	Yes	Yes	Yes	Yes (all layers)
Pronaos walls	-	Yes	Yes	Yes (exc. top courses)
Columns	Yes	Yes	-	-
Capitals	Yes	-	-	-
Entablature	-	Yes (exc. under cages)	-	-

Table 10: Paint and stripping campaigns.





### 6. Discussion

The previous chapter analyzed the condition of the Mechanics' Bank marble façade, from its assembly to its microstructure. This chapter will build on these findings to shed some light on the origins of the deterioration patterns found; and to compare them with previous research carried out on the Pennsylvania marble on the Second Bank of the United States and the Philadelphia Merchants' Exchange.

# 6.1. Contributing Factors to Deterioration

It is beyond the scope of this paper to provide a conclusive diagnostic of the causes of marble deterioration. Such undertaking would require the elaboration of cogent deterioration hypotheses and their modeling and monitoring, tasks that could be a thesis unto themselves. However, it is pertinent to set forth some of the factors that are likely to have contributed to the deterioration of the building to a greater or lesser extent. These factors can be divided into those external to the structure (such as the environment and occupants) and those internal. The latter can be divided into macrostructural factors, related to the building's construction; and microstructural factors, related to the marble itself.

### 6.1.1. External Factors

External factors causing the deterioration of the marble are related to five primary agents: thermal energy from the sun, moisture sources, atmospheric gases, biological growth, and anthropogenic causes. Either isolated or in association, these factors contribute to material loss either through the formation of cracks leading to micro- or macroscopic material separation; or through the conversion of marble into other substances, usually watersoluble.

Due to the high and anisotropic thermal expansion coefficient of calcite, marbles tend to form microcracks when subject to thermal cycles which, under direct insolation, can happen daily due to significant day/night temperature differences, especially in summer. This formation of microcracks can be an entry point for other agents increasing deterioration.<sup>75</sup> More calcitic and more isotropic marbles are more susceptible to this effect.<sup>76</sup> The foliated, somewhat dolomitic marble at the Mechanics' Bank is not affected by this effect in the extreme; however, the effect is noticeable in areas such as the south-facing elevation of the step cheek walls, which show microcracking parallel to foliation planes; and in the column drums, where dimensional loss and friability are more frequent on exposed south- and southeast-facing areas.

Moisture sources include the building's interior, groundwater, and precipitation. Due to vapor pressure diffusion and stack effect, moisture can flow outward through a building's porous walls, especially at the top, and evaporate at the surface causing deterioration. This may have contributed to surface damage; however, marble's low porosity limits its effect, and the lack of significant differences in deterioration between the back wall and the anta walls, or between the top and the bottom of the walls, make this unlikely to be the primary deterioration agent. Groundwater rises by capillarity from the ground through the walls, also evaporating on their surface; the lack of moisture at the basement wall under the façade suggests this is not a significant factor.

<sup>&</sup>lt;sup>75</sup> Sáez-Pérez and Rodríguez-Gordillo, 153.

<sup>&</sup>lt;sup>76</sup> Steiger, Charola, and Sterflinger, 230.

Precipitation is another important source of moisture. Rainwater can dissolve the calcite in the marble in a small amount that is somewhat exacerbated with the presence of carbon dioxide, and more so with the presence of sulfate or nitrate ions (acid rain).<sup>77</sup> However, the effect of these seems to be limited, as Meierding observed little correlation between the impact of acid rain and marble deterioration trends.<sup>78</sup> Rain has more importance as an agent of differential washing, dissolving gypsum crusts formed on the marble surface; this can be seen most clearly at the pediment sill, where the black gypsum crust has been washed away in the more exposed areas. Predominant wind patterns in Philadelphia cause rain to be more damaging to east-oriented façades.<sup>79</sup>

The effect of pollutant gases in the atmosphere, especially sulfur dioxide (SO<sub>2</sub>), was observed by Meierding to have a greater impact on the durability of marble than acid rain.<sup>80</sup> Sulfur dioxide, in the presence of water, reacts with the calcium carbonate and turns it into water-soluble calcium sulfate (gypsum) that is easily washed away. This causes an erosion that is stronger in areas with present or past abundance of coal gases, especially former industrial areas; according to Meierding's data, the erosion rate in Philadelphia's Old City would be close to 1mm/100yrs, or about 2mm in the Bank's lifespan on average (Fig. 35). The concentration of atmospheric SO<sub>2</sub> in Philadelphia peaked between c. 1930 and 1950; this was immediately prior to the restoration campaigns where it was decided to paint the façade, while photographs predating this peak show little apparent deterioration of the stone (Fig. 36).

<sup>&</sup>lt;sup>77</sup> Kemp, 222.

<sup>&</sup>lt;sup>78</sup> Meierding, 577.

<sup>&</sup>lt;sup>79</sup> Hall, Matero, and Hinchman, 126.

<sup>&</sup>lt;sup>80</sup> Meierding, 577.



Figure 35: Dimensional loss rates for marble tombstones in the Philadelphia area (mm/100yr); red dot shows

Mechanics' Bank. A correlation with SO2 pollution is visible. Adapted from Meierding, 578.



Figure 36: SO<sub>2</sub> concentration in Philadelphia, 1880-1980, and appearance of the building. Photographs from c. 1900 show little deterioration; paint campaigns in 1947 and 1955 probably responded to quick deterioration c.

1930-50. SO<sub>2</sub> data from Meierding, 584.

Biological growth of algae and fungi on marble takes place mostly in areas with relatively constant moisture levels.<sup>81</sup> In the Mechanics' Bank this is limited to the north side of the south cheek wall, and has little effect on the building as a whole. Bacteria can also cause the formation of benign (non-soluble) yellow oxalate crusts on marble; on the Mechanics' Bank only the capitals show small occurrences of this.<sup>82</sup>

Last but not least, human action affects the weathering of the marble. Some of the human-caused patterns attested in the Mechanics' Bank include vandalism (graffiti); accidental damage by vehicles; and surface erosion at the floor related to circulation patterns. Less obviously, the application of deicing salts on the steps and floors can cause saline solutions to leach into the stone and crystallize inside intergranular joints, exacerbating cracking.<sup>83</sup> Although the low porosity of the marble seems to be somewhat of a safeguard against this, the effect is worth taking into account, particularly in already deteriorated areas. Finally, traffic along Third Street produces vibrations, which have been shown to have a measurable effect on stone deterioration especially on smaller or loose units that resonate with them.<sup>84</sup> Vibrations may be linked to small dimensional loss at corners in the vicinity of narrow joints.

## 6.1.2. Internal Factors: Building Assembly

The way the marble is installed also affects its behavior. As discussed in Section 5.2., the installation orientation of the marble units is directly connected to deterioration patterns; most importantly, face-oriented installation reduces mechanical cracking of units but

<sup>&</sup>lt;sup>81</sup> Steiger, Charola, and Sterflinger, 291ff.

<sup>&</sup>lt;sup>82</sup> Steiger, Charola, and Sterflinger, 259.

<sup>&</sup>lt;sup>83</sup> Steiger, Charola, and Sterflinger, 266.

<sup>&</sup>lt;sup>84</sup> Steiger, Charola, and Sterflinger, 228.

facilitates contour scaling and may enable hidden spalling parallel to the surface, though very few instances of this have been identified.

The façade is composed of two main layers: a likely more porous inner brick layer, and an outer marble layer with relatively low porosity. The very narrow joints in this layer are the easiest routes for evaporation, which may explain the deterioration of such a large proportion of the original mortar; the repointing of these with impermeable cement mortars can divert evaporation through the stone, accelerating its surface deterioration. In any case, the low porosity of the outer layer can cause condensation between the brick and the marble, potentially leading to deterioration of the brick, biogrowth, and rusting of the stone anchors; although no compelling evidence has been found suggesting this is happening, this is an issue that should be taken into consideration.

The narrow joints also limit the stone units' options for movement. As the building settles this can cause the units to rest on each other directly, resulting in point loads that lead to small corner and edge spalls. Cement repointing mortar glues the units together and, having a greater mechanical strength than the marble, can cause the units to break rather than separate; this is especially significant where the marble already presents loss of cohesion, such as at the door surround.

Corrosion of the metal anchors can cause them to expand, prying cracks in the stone units. These would typically be parallel to the surface, causing the spalling of large fragments of stone; and would be difficult to detect before the stone's failure. It must be said, however, that in the parts of the building tested through percussive sounding this did not seem to be an issue. External metallic features corrode causing metallic staining that is difficult, though not impossible, to remove. The most severe example of this is the quick and thorough staining of the cheek walls at the steps after the installation of cor-ten steel planters on top of them. These, which serve no structural purpose, should be removed as soon as possible and replaced by non-corroding elements to limit the damage.

It is difficult to assess the effect that being painted for almost sixty years had on the façade's behavior. On one hand, if evaporation through the stone is a major factor in stone deterioration, an impermeable paint could have caused moisture accumulation at the surface leading to salt growth and crack formation, which would have revealed a fragile surface that would have deteriorated quickly after cleaning. On the other hand, the paint would have protected the stone from external factors such as rain and sulfur gases, though not from the effects of thermal cycling. The effect of paint removal is once again difficult to gauge, though the composition of the removal agent does not suggest that it would either dissolve the minerals in the marble or induce salts into the microstructure. Areas where the blue paint was not removed show loss of painted surface through contour scaling, suggesting this has been an active process in the last fourteen years.

# 6.1.3. Internal Factors: Stone Microstructure

The condition surveys show many changes in deterioration pattern not easily connected to location on the building. In these cases, microstructural differences are the most likely candidate for explaining differences in deterioration. The samples subject to petrographic analysis revealed significant differences in microstructure and composition even within stones of a similar appearance, which can explain some of the less obvious patterns.

The intrinsic formation of cracks in the stone, acting as capillary pores, is the most significant factor contributing to deterioration. Cracks become avenues for water infiltration: while sound Pennsylvania marble has very low porosity due to good interlocking of the grains, porosity increases dramatically in samples showing friability or contour scaling. Water absorption causes the crystallization of soluble salts, mostly sulfates, leading to rapid microcrack growth.<sup>85</sup> Therefore, factors conditioning the formation of microstructural cracks are a significant indicator of stone durability. Three main factors have been identified as having an effect:

- Degree of foliation. Stones with a more marked orientation of the grains along foliation planes (e.g. SS04(b)) tend to form microcracks easily along those planes.<sup>86</sup>
- 2. Interlocking of grains. Portions of the stone that undergo more thorough metamorphism tend to have larger grains with smoother boundaries terminating in triple junctions (e.g. SS04(w)). These boundaries separate more easily than less metamorphosed, more irregular boundaries (e.g. SS03); in addition, the random orientation of the crystals increases the effect of anisotropic thermal expansion.<sup>87</sup> As a result, more thoroughly metamorphosed areas are counterintuitively less durable than moderately metamorphosed ones.
- 3. Presence of accessory minerals at grain boundaries. Large crystals of accessory minerals such as feldspars interlock with the calcite grains and have no observable effect on the stone's performance (e.g. SS03). However, small crystals of quartz and mica laths tend to act as wedges between the grains facilitating crack formation (e.g. SS04(w)). Mica seems to have an especially significant effect, since its microstructure of weakly-bonded thin layers tends to attract water particles as well as facilitate the accumulation of salts. This causes it to separate easily, prying the cracks open.<sup>88</sup>

<sup>&</sup>lt;sup>85</sup> Steiger, Charola, and Sterflinger, 229.

<sup>&</sup>lt;sup>86</sup> Yavuz and Topal, 39.

<sup>&</sup>lt;sup>87</sup> Steiger, Charola, and Sterflinger, 230.

<sup>&</sup>lt;sup>88</sup> Steiger, Charola, and Sterflinger, 262.

In light of these circumstances, the large-grained white marble used for the door surround appears to be less durable than the blue marble in general. However, there is large variation within the blue marble; some areas are not much different from the white marble, and can be even less durable due to marked foliation; while other areas can be much more durable.

### 6.2. Comparison with Other Pennsylvania Marble Structures

## 6.2.1. General Deterioration Patterns

The only other Pennsylvania marble building with a full published condition survey is the Second Bank of the United States, a much larger building constructed by Strickland earlier in his career.<sup>89</sup> The Second Bank has four stone-clad façades, with two Doric porticoes facing north and south and two plain elevations facing east and west. White Pennsylvania marble, both fine and medium-grained, was used for the north and south façades, while blue marble was used for the side elevations;<sup>90</sup> it is possible that Strickland and Struthers' shift to blue marble for most of the façade at the Mechanics' Bank (and the Merchants' Exchange) was motivated by their realizing the white marble's poorer performance. The stone layout at the Second Bank is somewhat more irregular than at the Merchants' Exchange, but the construction and assembly systems do not seem to have changed radically.

A greater difference can be observed regarding the orientation of the stone; while stones at the Second Bank show little consistency in their haphazard orientation with a predominance of diagonal and face-oriented units, most of the units at the Mechanics' Bank are either face-oriented or edge-oriented according to their longest direction; less than 10% of the units are inconsistent with this and very few units, only one of them major, have

<sup>&</sup>lt;sup>89</sup> Matero et al., and Aphale.

<sup>&</sup>lt;sup>90</sup> Aphale, 8-9.

diagonal bedding. This greatly reduces the amount of spalling associated with cracking along foliation planes. In both buildings face-oriented installation is associated with contour scaling, whereas edge-oriented installation is more related to differential erosion patterns.

As regards deterioration patterns, although the Second Bank shows a similar amount of deterioration for all orientations, a greater amount of repairs on the north and south elevations indicates that this was not the case in the past; and seems to confirm that a greater impact of insolation and acid rain on north and east elevations does affect the rate of deterioration.<sup>91</sup> On the Second Bank, the least deteriorated large surfaces were the protected north and south pronaos walls, showing mostly contour scaling (predominant on the north) and friability (predominant on the south);<sup>92</sup> although on the Mechanics' Bank the conditions at the pronaos walls are similar, their rate of deterioration is greater suggesting that processes like paint coating may have had a significant effect. On both buildings, the columns, due to their shape with thin, raised fluting, show the greatest amount of spalling either incipient or resolved, though the mostly vertical stone orientation greatly reduces the amount of structurally compromising large diagonal spalls at the Mechanics' Bank compared to the Second Bank.<sup>93</sup>

Some minor conditions differed between both buildings, though it is significant that neither of them showed substantial amounts of efflorescence. Most evidently, the Mechanics' Bank was painted over time, while the Second Bank was not but was subjected to treatment coatings. Metallic staining is mostly iron at the Mechanics' Bank and mostly copper at the Second Bank, reflecting the use of different metals for construction elements. Some of the stones at the Second Bank's cheek walls showed deformation which may have

<sup>&</sup>lt;sup>91</sup> Aphale, 108.

<sup>&</sup>lt;sup>92</sup> Aphale, 103.

<sup>&</sup>lt;sup>93</sup> Aphale, 108.

been caused by their large size, thin proportions and exposed nature; this is not an issue anywhere in the Mechanics' Bank.

### 6.2.2. Deterioration of the Capitals

The 2008 request for proposals for the capitals of the Merchants' Exchange describes very similar conditions to those affecting the Mechanics' Bank capitals, making a good case for both having been carved of the same material.<sup>94</sup> In the Merchants' Exchange, Lysicrates capitals like those in the Mechanics' Bank were found both on the east and the west façade. The east façade presented more severe deterioration patterns that resembled more closely those found on the Mechanics' Bank, also east-facing; like on the latter, exposed areas showed more severe deterioration. The reasons cited included greater insolation and the effect of wind-driven, predominantly east-facing acid rain.<sup>95</sup>

Capitals at the Merchants' Exchange presented dimensional loss at the same locations as at the Mechanics' Bank, caused by disaggregation of the core stone abetted by the formation of a heavy gypsum crust. Soiling patterns at crevices were also very similar.<sup>96</sup> While Mechanics' Bank capitals did not present copper staining and those at the Merchants' Exchange had no paint coating residue on them, the main deterioration patterns remain the same. Damage, however, is more thorough at the Mechanics' Bank, where, in some cases, all instances of certain details have been lost.

<sup>&</sup>lt;sup>94</sup> Hall, Matero, and Hinchman, 4-5, 33.

<sup>&</sup>lt;sup>95</sup> Hall, Matero, and Hinchman, 4.

<sup>&</sup>lt;sup>96</sup> Hall, Matero, and Hinchman, 33.

## 6.2.3. Marble Microstructure

Jocelyn Kimmel's study of Pennsylvania marble at the Second Bank of the United States identified three main varieties: a blue, interlocked marble with a small amount of quartz and mica as accessory minerals; a white, larger-grained, more porous marble with some amounts of mica as accessory mineral, less durable than the former; and a white, finegrained, even more porous marble with quartz, mica, and orthoclase grains as accessory minerals. From this, she established that the blue marble was more durable than the white ones; and that accessory crystals of orthoclase, quartz, and especially mica were the main causes of crack formation, as were differences in porosity and grain interlocking.<sup>97</sup>

The samples studied in this thesis confirm porosity differences and degree of grain interlocking as affecting the durability of the marble; and add type of texture (degree of foliation) as a factor. PLM images of developing cracks confirm the role of the accessory minerals mica and quartz in the deterioration of the marble; but nuance the connection between the amount of accessory minerals and durability, since large crystals of feldspar seem to have little effect on the stone's performance.

The white marble used in the Mechanics' Bank seems to correspond roughly to Kimmel's medium-grained white marble, though it has a larger variety and amount of accessory minerals. While Kimmel's assertion that blue marble is more durable than white marble seems to hold generally true, a significant range of microstructures and compositions – associated to a significant range in durability – has been found in blue marble, encompassing most of the accessory minerals found by Kimmel in white marble only. It is thus necessary to reject the idea that blue marble lacks the accessory minerals present in white marble and is therefore always more durable.

<sup>&</sup>lt;sup>97</sup> Kimmel, 19-20.

### 7. Conclusions

The Mechanics' Bank is a Philadelphia landmark and, in spite of its small size, one of the finest structures built in the city in the early nineteenth century, with some of the most accomplished architectural carvings of its time anywhere in the United States. For both its architecture and its eventful history it is deserving of greater attention than it has received until now.

The building's marble façade, its most prominent feature, is unfortunately in a poor condition, with some elements being in a dire situation caused by the influence of weather and pollution; lack of continued maintenance; and episodic, misguided interventions. Although much of the deterioration seems to have peaked during the second quarter of the twentieth century, there is sufficient evidence that deterioration processes are active and need to be attended to.

Some of these deterioration processes require urgent attention, either because they compromise the building's safety or functionality; or because they can cause irreversible damage affecting its legibility as a piece of heritage. The former include the displacement of the steps; the rapid deterioration of the pilaster panels along their joints which could eventually cause their failure; the diagonal cracking of the top unit of the south column, which can lead to large spalls; and the incipient spalling of the cornice overhangs at the pediment. Among the latter, the capitals show very advanced detail loss, exacerbated in the last fifty years, with some features having been lost completely or almost completely; continued deterioration of these true masterpieces of architectural sculpture would be an irreparable loss.

Other conditions are not as distressing, but their prevention is easy for a great reduction in the damage inflicted on the building. Chief among these is the metallic staining

of the cheek walls at the steps, which can easily be stopped by replacing the cor-ten planters with non-rusting features.

Research on the origins of the façade's deterioration has shown it to be mostly related to weathering processes common to Pennsylvania marble, most significantly sulfur oxide gases and thermal cycling. The microstructure of the marble plays a significant role; especially the interlocking of the grains, degree of foliation, and presence of microscopic mineral inclusions at the grain boundaries such as muscovite laths. A contribution of this thesis has been to show that blue Pennsylvania marble presents a broader range in its microstructure and accessory mineral content than previously known, explaining the variability of its behavior.

# 7.1. Recommendations for Future Research

Further research would be useful for a better understanding of the façade's deterioration processes that would help in its conservation. Continuation of testing complemented with monitoring and modeling would make it possible to measure the real impact of the proposed deterioration mechanisms on the stone's performance. Specifically, thermal imaging of the façade accompanied by moisture transport modeling of the wall section would enable a better understanding of the behavior between the layers of brick and marble at the walls. Temperature monitoring at local points and insolation modeling would improve the understanding of the mechanisms of thermal cycling.

To understand the rate and evolution of recent surface loss at the façade, it would be useful to put together an archive of detail photographs of the past fifteen years for comparing the stone's condition over time, especially in blue-painted areas where it is easier to see changes. Three-dimensional scanning and modeling would make it possible to quantify the rates of surface loss.

The documented presence of deicing salts and displacement at the steps should be explored in more depth. Probes should be made to understand the underlying structure and its degree of deterioration. Salt testing of samples from the steps is recommended to assess the absorption of salts from deicing.

It was not possible to sample and analyze the capitals in detail due to their location on the building; therefore, many hypotheses about them have been left untested. Analysis of marble samples from the capitals would make it possible to confirm their building material and compare it with the Merchants' Exchange; and to understand the true degree of their deterioration.

While not all of these actions are strictly necessary for conserving the façade of the Mechanics' Bank, they would all bring about useful knowledge of its condition and its evolution. After almost two hundred years of comings and goings, changes in use, damage, and repair, the building surely deserves it.
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# **APPENDICES**

# **Appendix 1: Measured Drawings**



Aoi Ground Plan

# | Mechanics' National Bank

22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

### AOI - EXTERIOR

Author: Alberto Calderón-González

(n)

loft





Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37

A02 - PRONAOS INTERIOR

Author: Alberto Calderón-González

loft

# **Appendix 2: Condition Catalog**

Conditions Glossary (I)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Orientation of foliation planes

Definition: The foliation planes of stone determine a pattern of orientation. If the planes are perpendicular to the surface the orientation is edge-oriented horizontal (a), vertical (b) or diagonal (c). If they are parallel to the surface of the stone, the orientation is face-oriented (d).





Condition: Mineral inclusions

Definition: Inclusions of different minerals different from the base in color and texture may be present in the stone as veins or phenocrysts. These are at least 1/2 inch in width, noticeably different from the foliation pattern, and appear raised in relief or weathered out.



Condition: Network cracking

Definition: A network of intersecting thin surface cracks, associated with mineral inclusions or foliation patterns.







Conditions Glossary (2)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Moderate cracking

Definition: Cracks between  $1/16^{\circ}$  and  $1/8^{\circ}$  (1.6 to 3.2 mm) wide, regardless of cause. They may be structural (a) or along foliation planes (b).



Graphic:

Graphic:

Condition: Major cracking

Definition: Cracks above 1/8" wide, regardless of cause. Usually associated to displacement (a) or incipient spalling (b).





Condition: Friability/Flaking

Definition: Surfaces with disaggregation of grains (a) or shallow stone flakes (b) that crumble on touch.





Conditions Glossary (3)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Differential erosion

Definition: Weathering of the surface perceptible by coarse texture (a), or depth differences above 1/4" at foliation planes and inclusions (b), or loss of detail (c)





Condition: Contour scaling/exfoliation

Definition: Stepped irregular surface loss greater than  ${\sf I}/8"$  in depth, forming a characteristic pattern associated with the foliation planes



Graphic:

### Condition: Incipient spalling

Definition: Discontinuity in the stone that causes partial separation without loss of the stone element. Detectable by sounding and typically associated with foliation planes.

### Graphic:





Conditions Glossary (4)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Dimensional loss

Definition: Loss of stone elements at least 2sq in in area, and  $\ensuremath{\mathrm{I}/2^{*}}$  deep. May or may not be connected to spalling.











Condition: Deformation/displacement

Definition: Shifting of stone surfaces out of plane by at least 1/2" due to movement or cracking. Can be forward (+) or backward (-).



Condition: Open joints

Definition: Loss of mortar at joint exposing joint to the elements. Also, displacement of unmortared joints greater than 1/8" exposing joint surfaces to the elements.

Graphic:

.....

Conditions Glossary (5)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Deteriorated mortar joint

Definition: Stone joints where the mortar is still present but eroded back  $\rm I/2$  inch or more in depth, or noticeably cracked, or separated from the stone



.....

Condition: Metallic staining

Definition: Colored staining derived from the weathering of metallic sources either intrinsic (a) or extrinsic (b). Typically yellow (iron) or green (copper)



Condition: Encrustation

Definition: Gray to black crusts, darker and denser than typical soiling patterns, formed in sheltered areas.













Conditions Glossary (6)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Repointing
Definition: Non-original mortar joint or joint displaying
non-original mortar
Graphic:
Territory Filled cracks
Definition: Filled cracks
Definition: Repairs to cracks executed at any time.
Graphic:
Territory Territ

Condition: Tooling marks

Definition: Marks caused by the original working of the stone, often in the form of parallel striations. Presence of these marks indicate a preserved original surface devoid of substantial weathering.





Conditions Glossary (7)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Composite repairs Definition: Mortar or resin-based system used as a surface repair for areas greater than 3/4 inch in width, excluding crack repairs. Graphic: Condition: Stone redressing Definition: Tooling marks that indicate the selective redressing of stone to address surface deterioration. Graphic: Condition: Defective mechanical features Definition: Building hardware that, by its condition, is affecting the deterioration of the stone. Graphic:

Conditions Glossary (8)

Note: Description of conditions sourced from Matero (2004): *Documentation and Conditions Survey of the Exterior Marble Masonry. The Second Bank of the United States*, pp. 78–107

Condition: Microflora

Graphic:

Graphic:

Condition: Paint coating

stone, regardless of condition.

Definition: Areas of biological growth of algae, fungi or lichens, showing as a black, green, or brown deposition on the surface in areas susceptible to moisture accumulation.

Definition: Layers of paint applied as a finish over the





Condition: Condition unique

Definition: Conditions not listed above are cited with a number and description on the condition survey.





# **Appendix 3: Condition Survey Drawings**

















Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37

# **CFOI - FOLIATION PLANES (I)** Author: Alberto Calderón-González

 $(\mathsf{D})$ 

IOft 0

Key:

Edge-Oriented Horizontal
Edge-Oriented Vertical
Edge-Oriented Diagonal
Face-Oriented

-





# Mechanics' National Bank

22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

CF02 - FOLIATION PLANES (2)

Author: Alberto Calderón-González



<u>o \_\_\_\_\_ioft</u>



### Key:

Edge-Oriented Horizontal	
Edge-Oriented Vertical	

- Edge-Oriented Diagonal
- Face-Oriented

















### | Mechanics' National Bank

22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

### COI - EXTERIOR

Author: Alberto Calderón-González



loft

# Key: Mineral inclusions Network cracking ----- Moderate cracking ---- Major cracking Friability/flaking Differential erosion Contour scaling Incipient spalling Dimensional loss +-Deformation/displ. ----- Open joints ----- Deteriorated mortar joint Metallic staining (ext./int.) Encrustation Repointing ----- Filled cracks Tooling marks Composite repairs Stone redressing Defective mech. features Microflora Paint coating 🛈 Graffiti Incised marks





### Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37

Co2 - Pronaos interior

Author: Alberto Calderón-González



<u>o \_\_\_\_\_ioft</u>

Key:
Mineral inclusions
Network cracking
Moderate cracking
Major cracking
Friability/flaking
Differential erosion
Contour scaling
Incipient spalling
Dimensional loss
+- Deformation/displ.
Open joints
Deteriorated mortar joint
Metallic staining (ext./int.)
Encrustation
Repointing
Filled cracks
Tooling marks
Composite repairs
Stone redressing
Defective mech. features
Microflora
Paint coating
1 Graffiti
Incised marks



Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37
<b>C03 - EAST ELEVATION</b> Author: Alberto Calderón-González
<u>o5tt</u>
Key:
Mineral inclusions
Mederate cracking
Maior cracking
Friability/flaking
Differential erosion
Contour scaling
Incipient spalling
Dimensional loss
+- Deformation/displ.
+++++ Open joints
HINH Deteriorated mortar joint
Metallic staining (ext./int.)
Encrustation
Filled cracks
T Tooling marks
Composite repairs
Stone redressing
Defective mech. features
Microflora
Paint coating
1 Graffiti
Incised marks





### Mechanics' National Bank 22–24 S 3rd St, Philadelphia, PA 19106

William Strickland, 1836–37

### Co4 - N and S Elevations

Author: Alberto Calderón-González



\_\_\_\_\_5ft

0\_\_\_\_

## Key: Mineral inclusions Network cracking ----- Moderate cracking ---- Major cracking Friability/flaking Differential erosion Contour scaling Incipient spalling Dimensional loss +-Deformation/displ. +++++ Open joints HIHH Deteriorated mortar joint Metallic staining (ext./int.) Encrustation HIHH Repointing Filled cracks Tooling marks Composite repairs Stone redressing Defective mech. features Microflora Paint coating 🛈 Graffiti Incised marks



Mechanics' National Bank 22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37	
<b>Co5 - Pronaos, W Elevation</b> Author: Alberto Calderón-González	
<u>o5tt</u>	
Key:	
Mineral inclusions	
Network cracking	
Moderate cracking	
Major cracking	
Friability/flaking	
Differential erosion	
Contour scaling	
Incipient spalling	
Dimensional loss	
+- Deformation/displ.	
me Open joints	
Motallic staining (ovt /int.)	
Encrustation	
HIHH Repointing	
Filled cracks	
Tooling marks	
Composite repairs	
Stone redressing	
Defective mech. features	
Microflora	
Paint coating	
G Graffiti	
Incised marks	



Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37
Co6 - PRONAOS, E ELEVATION Author: Alberto Calderón-González
<u>o5tt</u>
Key:
Minoral inclusions
Network cracking
Moderate cracking
Major cracking
Contour scaling
Incipient spalling
Dimensional loss
+- Deformation/displ.
+++++ Open joints
HINN Deteriorated mortar joint
Metallic staining (ext./int.)
Encrustation
+++++ Repointing
Stope redressing
Defective mech. features
Microflora
Paint coating
1 Graffiti
Incised marks



| Mechanics' National Bank

22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37

Co7 - Pronaos, N and S









### | Mechanics' National Bank

22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

### Co8 - Plans

Author: Alberto Calderón-González







Co9 Horizontal cornice

### | Mechanics' National Bank

22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

### Co9 - Entablature

Author: Alberto Calderón-González



\_\_\_\_\_ 5ft

0\_\_\_\_

Key: Mineral inclusions Network cracking ----- Moderate cracking ---- Major cracking Friability/flaking Differential erosion Contour scaling Incipient spalling Dimensional loss +-Deformation/displ. +++++ Open joints HIHH Deteriorated mortar joint Metallic staining (ext./int.) Encrustation Filled cracks Tooling marks Composite repairs Stone redressing Defective mech. features Microflora Paint coating Graffiti Incised marks













CII South Pilaster

CII North Pilaster



# Mechanics' National Bank

22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37

CII – PILASTER CAPITALS

Author: Alberto Calderón-González



<u>o\_\_\_\_\_\_ift</u>

West

Key:
Mineral inclusions
Network cracking
Moderate cracking
— Major cracking
Friability/flaking
Differential erosion
Contour scaling
Incipient spalling
Dimensional loss
+- Deformation/displ.
Open joints
- Deteriorated mortar joint
Metallic staining (ext./int.)
Encrustation
—— Filled cracks
Tooling marks
Composite repairs
Stone redressing
Defective mech. features
Microflora
Paint coating
1 Graffiti
<ul><li>Graffiti</li><li>Incised marks</li></ul>

# Appendix 4: Non-Destructive Testing



Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37
<b>TMOI – MAGNETOMETRY I</b> Author: Alberto Calderón-González
<u>o5tt</u>
Кеу:
Point metallic element
<ul> <li>Linear metallic element</li> <li>Inferred elements in inacc. areas</li> </ul>
Extent of testing





Mechanics' National Bank 22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37
TM02 – MAGNETOMETRY III Author: Alberto Calderón-González
<u>o5tt</u>
Кеу:
Point metallic element
Linear metallic element
O Inferred elements in inacc. areas
Extent of testing



Mechanics' National Bank 22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37
<b>TPOI – PERCUSSIVE SDG. I</b> Author: Alberto Calderón-González
<u>o5tt</u>
Key:
Ringing sound - healthy stone Muffled sound - loss of cohesion
Hollow sound - incipient spalling


















### Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106

22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

TROI - RILEM LOCATIONS I

Author: Alberto Calderón-González

<u>o \_\_\_\_\_ioft</u>

Key:

Test (Horizontal Surface)
 Test (Vertical Surface)







## Mechanics' National Bank 22-24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836-37

TR02 - RILEM LOCATIONS II





<u>o \_\_\_\_\_ loft</u>



Key:

Test (Horizontal Surface)
Test (Vertical Surface)

# **Appendix 5: Sample Locations**











N Elevation



| Mechanics' National Bank 22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

TSOI - SAMPLE LOCATIONS I Author: Alberto Calderón-González

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loft 0

Key	
\$	SS - Stone Sample
•	MS - Mortar Sample
<b>\$</b>	PS – Paint Sample







11002



**PS01** 

## Mechanics' National Bank 22–24 S 3rd St, Philadelphia, PA 19106 William Strickland, 1836–37

**TSO2 - SAMPLE LOCATIONS II** Author: Alberto Calderón-González







Key:
SS - Stone Sample
MS - Mortar Sample
PS - Paint Sample

Appendix 6: Petrographic Thin Section Photographs



**NOTES:** Surface at area with encrusted soiling. Texture is granoblastic. Soiling only thin layer on grains, with some weathering of grains but no evidence of gypsum crust. Medium-sized subhedral and anhedral grains, equant to subelongate. No intra- or intergranular cracking and no damage at cleavage planes. Irregular boundaries between grains with few triple junctions.



**NOTES:** Surface at area with encrusted soiling. Primary mineral calcite/dolomite evidenced by rhombohedral cleavage and high order birefringence cream colors.



**NOTES:** Interior of sample. Texture is granoblastic. Medium-sized subhedral and anhedral grains, equant to subelongate. No intra- or intergranular cracking and no damage at cleavage planes. Irregular boundaries between grains with few triple junctions.



SAMPLE SS03 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: XPL

**NOTES:** Interior of sample. Primary mineral calcite/dolomite evidenced by rhombohedral cleavage and high order birefringence cream colors. Some large grains of accessory minerals including probable microcline feldspar evidenced by hatched twinning (top left).



SAMPLE SS03 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

Imaging: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 10x

Light Type: XPL

Light Source: Halogen

NOTES: Surface showing soiling layer and alteration of crystals.



SAMPLE SS03 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 10x

Light Type: XPL

NOTES: Accessory mineral with undulose extinction (possible feldspar).



SAMPLE SS03 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: PPL

Light Source: Halogen

NOTES: Large grain of accessory mineral with severe weathering making identification difficult.



**NOTES:** Large grain of accessory mineral with severe weathering making identification difficult.

#### SAMPLE SS03 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: XPL



**NOTES:** Grain of same mineral showing simple twinning in XPL which suggests it may be feldspar.



SAMPLE SS04 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: PPL

**NOTES:** Surface at interface with mortar M02. Texture is foliated. Sample too small and fragmented to observe microstructure.



**NOTES:** Surface at interface with mortar M02. Primary mineral calcite/dolomite evidenced by rhombohedral cleavage and high order birefringence cream colors. Some small grains of accessory minerals including quartz evidenced by high relief and lower first order gray color (center left) and mica laths (extreme left).



SAMPLE SS04 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 20x

Light Type: XPL

Light Source: Halogen

**NOTES:** Detail of platy micaceous lath, probably muscovite (bottom) and intragranular crack (top) with lenticular crystals in crack that suggest possible formation of gypsum.



#### SAMPLE SS04 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 20x

Light Type: XPL

NOTES: Detail of very small quartz grain.



**NOTES:** Interior of sample. Texture is granoblastic to foliated. Medium to large-sized subhedral grains, equant to subelongate. Severe intergranular cracking following foliation planes of rock and intragranular cracking at cleavage planes. Boundaries between grains less irregular than SS03, with a few triple junctions.



**NOTES:** Interior of sample. Primary mineral calcite/dolomite evidenced by rhombohedral cleavage and high order birefringence cream colors. Some small grains of accessory minerals, esp. at cracks.



**NOTES:** Interior of sample (2). Texture is granoblastic to foliated. Medium to large-sized subhedral grains, equant to subequant. Intergranular cracking following foliation planes of rock and intragranular cracking at cleavage planes. Boundaries between grains less irregular than SS03, with a few triple junctions.



#### SAMPLE SS04 (White) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: XPL

**NOTES:** Interior of sample (2). Primary mineral calcite evidenced by rhombohedral cleavage and high order birefringence cream colors. Some medium-to-large grains at center show simple twinning and undulose extinction, suggesting possible orthoclase feldspar.



**NOTES:** Detail showing crack in calcite/dolomite grain along cleavage planes. Surface alteration along spall surface visible at right, indicating the spall was exposed for some time.



**NOTES:** Small crystal of opaque mineral at crack. Mineral not identified but may be graphite, as suggested by common presence as accessory mineral in marble and identification by Kimmel (1996).



**NOTES:** Crystals at intergranular crack. Small quartz grain at center (evidenced by high relief and lower first order gray color) and large, platy micaceous lath (probably muscovite) showing splitting. Crystal growth inside splitting lath suggests crystallization of unidentified soluble salts, such as gypsum, causing the splitting.



#### SAMPLE SS04 (White) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 10x

Light Type: XPL

**NOTES:** Calcite crystal with polysynthetic twinning showing unidentified circular structure filled in by another calcite crystal. This could be a metamorphosed onlith or similar fossil remain,



**NOTES:** Surface. Texture is granoblastic to foliated. Medium-sized, mostly subhedral grains, subequant to elongate. intergranular cracking but little intragranular cracking and no damage at cleavage planes. Boundaries between grains less irregular than SS03 and SS04 with some triple junctions.



**NOTES:** Surface. Primary mineral calcite/dolomite evidenced by rhombohedral cleavage, polysynthetic twinning along cleavage and high order birefringence cream colors. Small micaceous laths, probably muscovite (center top right) and some crystal growth within cracks (left).



**NOTES:** Interior close to surface. Texture is granoblastic to foliated. Medium-sized, mostly subhedral grains, subequant to subelongate. Small amount of intergranular cracking. Boundaries between grains less irregular than SS03 and SS04 with some triple junctions.



**NOTES:** Interior close to surface. Primary mineral calcite/dolomite evidenced by rhombohedral cleavage, polysynthetic twinning along cleavage and high order birefringence cream colors.



**NOTES:** Interior. Texture is granoblastic to foliated. Small to medium-sized, mostly subhedral and some anhedral grains, equant to subelongate. No inter- or intragranular cracking. Boundaries between grains less irregular than SS03 and SS04 with some triple junctions.



SAMPLE SS05 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: XPL

**NOTES:** Interior. Primary mineral calcite/dolomite evidenced by rhombohedral cleavage, polysynthetic twinning along cleavage and high order birefringence cream colors.



SAMPLE SS05 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 10x

Light Type: XPL

Light Source: Halogen

**NOTES:** Surface showing weathering of calcite to a shallow depth. Note also small cracking along cleavage planes (right) and a very small quartz grain (center left).



SAMPLE SS05 (Blue) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 20x

Light Type: XPL

**NOTES:** Crystal growth inside cracks suggests crystallization of unidentified soluble salts, such as gypsum, causing the splitting.



**NOTES:** Mortar 1 was the original pointing mortar. Small and deteriorated sample allows little information to be extracted about the microstructure.



**NOTES:** XPL shows a carbonated lime mortar (evidenced by brown-colored binder) with very little aggregate in small subangular particles.



SAMPLE SS04 (M02) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: PPL

Light Source: Halogen

**NOTES:** Mortar 2 was the first repointing campaign. Opaque binder suggests Portland cement. Large well-graded aggregate, sub-rounded to sub-angular, in an approx. 1:1 binder-aggregate ratio. Cracking of binder may be related to drying or, more likely, be mechanical cracking associated with the movement of the joint.



#### SAMPLE SS04 (M02) Thin Section

**Origin**: Mechanics' Bank **Taken**: March 2018

**Imaging**: Nikon DS-Fi1 camera with NIS Elements BR software

**Microscope**: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x Objective Mag: 4x

Light Type: XPL

NOTES: Aggregate appears to be composed primarily of quartz grains with some feldspar grains (center left).



SAMPLE SS04 (M03) **Thin Section** 

Origin: Mechanics' Bank Taken: March 2018

Imaging: Nikon DS-Fi1 camera with NIS Elements BR software

Microscope: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x **Objective Mag**: 4x

Light Type: PPL

Light Source: Halogen

NOTES: Mortar 3 was the second pointing campaign. Opaque binder suggests Portland cement. Small well-sorted aggregate, sub-angular to angular, in an approx. 1:2 binder-aggregate ratio.



Thin Section

**Origin**: Mechanics' Bank Taken: March 2018

Imaging: Nikon DS-Fi1 camera with NIS Elements BR software

Microscope: Olympus CX31 Petrographic Microscope

Ocular Mag: 10x **Objective Mag**: 4x

Light Type: XPL

NOTES: Aggregate appears to be composed primarily of quartz grains.

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