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Conservation Plan for the Suddards-Manuel-Clark Funerary Monument, The Woodlands Cemetery, Philadelphia, PA

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A thesis in Historic Preservation Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE IN HISTORIC PRESERVATION, 2009.

Conservation Plan for the Suddards-Manuel-Clark Funerary Monument, The Woodlands Cemetery, Philadelphia, PA

Abstract
The Suddards-Manuel-Clark is one of the oldest, largest and most significant structures of the Woodlands Cemetery, one of the country's early rural garden cemeteries. This vault was constructed during the main period of development of the Cemetery and has remained greatly intact over its more than 150-year history. This research develops a conservation plan for the monument, focusing on a study of the design, weathering and performance issues of the sandstone structure. Although little is known about the families interred therein or about the construction of the monument, it is clear that there was considerable attention paid to the architectural style and design of the monument as well as to the selection of high quality building materials that have endured decades of a harsh environment. Despite its alternate function as a retaining wall to the bank of a hill, the tomb has withstood constant moisture and structural loads on three sides and numerous decay mechanisms at its façade. A conditions glossary specific to this monument has been created and a conditions survey has been completed. The conditions of the monument were assessed in relation to the design and environment of the site and in relation to each other. Pilot cleaning was carried out and recommendations are made for appropriate future conservation treatments as part of a conservation and management plan for the site.

Comments
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CONSERVATION PLAN FOR

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Elise S. Kemery

A THESIS

in

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2009

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CHAPTER 4

1. INTRODUCTION

1.1 PROJECT JUSTIFICATION

The Suddards-Manuel-Clark funerary monument is one of the earliest, largest and most prominent tombs at The Woodlands Cemetery. This vault was constructed during the main period of development of the Cemetery and has remained mostly intact over its more than 150-year history. This research develops a conservation plan for the monument, focusing on a study of the design, weathering and performance issues of the sandstone structure. Funerary monuments such as the Suddards-Manuel-Clark tomb are the ideal subject for the study of historic building materials. The monument is of a scale that is accessible for study, and this particular monument has not yet been the subject of any historical or conservation investigation.

The monument displays almost every possible type of deterioration and weathering that can be observed in sandstone. A glossary of these conditions was created, and a detailed conditions assessment was conducted on the monument's façade. The interior of the tomb is currently inaccessible, and there are very limited viewports to the interior. The central sections of each third of the monument that would have served as entrances to the three families' crypts have all been sealed in recent years. What is accessible and visible exhibits several different forms of weathering, most of which have led to disfigurement and instability. These deterioration mechanisms appear to be active, and loss has been visible over the period of nine months since photos were taken at the outset of this research.

Development of a conservation plan begins with understanding the design and construction of the monument and its significance. Significance lies within the values of the monument; values are based on the physical properties of the object as well as its non-material aspects, which are often determined by stakeholders. The Suddards-Manuel-Clark monument has architectural and aesthetic value because of its distinctive Gothic Revival design and use of brown sandstone. The monument may well be among only a handful of architect-designed tombs that were conceived during the early years of the cemetery's planning. The sheer size of the monument and its assiduous craftsmanship augment its value, as does the use of sandstone, uncommon at The Woodlands Cemetery and in cemetery monument design in general which are dominated by granite and marble. The utility of the monument as a funerary vault necessarily gives it use value, and its legacy as such gives the monument commemorative value as well. Historical value of the vault is derived from its role within the development of The Woodlands Cemetery Company and from the significance of the individuals and families associated with the monument. Cemetery visitors find the vault to be an object of interest, and stewards of the Cemetery such as the staff and Board of Trustees value it as an historical and architectural treasure.

A conservation plan is not intended to serve as the impetus for any particular action; rather, it is the precursor to any action taken toward the management or toward the amendment of management of cultural heritage. This conservation plan is to be used by the stewards of The Woodlands Cemetery to address those conservation issues that interfere with the preservation of the monument in its ideal state. Each step taken within the methodology of this research works toward the conservation plan, beginning with historical research (understanding the monument and its significance), conditions assessment (determining the threats to the monument's significance) and, finally, pilot tests of treatment and selection of best practices.

1.2 CONSERVATION PLANS AND CONSERVATION METHODOLOGY

The conservation plan is a tool used by stewards of built heritage to ensure the retention of significance of a particular site or structure. The first step to the creation of a conservation plan is to come to understand the subject of the plan and then to define that site's significance. This assessment is followed by identification of the threats to that significance and establishment of policy or measures to preserve the site's significance. According to one source, "Conservation Plans are about managing change, not resisting it. But doing so in an informed, planned, and sensitive way, taking account of all the interest involved and adding value to the heritage and to its surroundings."[1] Conservation plans provide understanding of the site, its value, its threats and options for thwarting any loss of value of the site.

For larger structures, buildings with multiple uses and sites with multiple structures, conservation plans have been described as documents that describe a site's significance and "how that significance will be retained in any future use, alteration, development or management."[2] For the purposes of this research, the same definition applies despite that future use, development and management will remain unchanged. Often conservation plans are written when significance is thought to be "vulnerable" to loss; in the case of the Suddards-Manuel-Clark monument, a large part of the value of the monument lies in the material itself, which is the component of significance most vulnerable in its current state.

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[1] Clark, Kate, ed. *Conservation Plans in Action: Proceedings of the Oxford Conference*. London: English Heritage, 1999, 6.
[2] Clark, Kate. *Informed Conservation: Understanding historic buildings and their landscapes for conservation*. London: English Heritage, 2001, 62.

Organizations and individuals who manage and/or own historic sites or cultural heritage follow a decision-making process before making any change or adjustment, whether it is a simple of strengths, weaknesses, opportunities and threats or is a complex assessment based on quantitative data. Decision-making methodology for cultural heritage must always take into account the value and significance of the site or object. Conservation planning proactively reconciles significance with change, and "understanding must be the first step in any repair programme." [3] The development of a conservation plan for the Suddards-Manuel-Clark monument follows the systematic methodology as described in Applebaum's *Conservation Treatment Methodology:*[4]

1. Characterize the site
2. Reconstruct a history of the site
3. Determine the *ideal state* for the site
4. Decide on a *realistic goal* of treatment
5. Choose the treatment methods and materials
6. Prepare pre-treatment documentation
7. Carry out the treatment
8. Prepare final treatment documentation

The conservation plan process does not need to be modified to correspond with this methodology; the conservation treatment methodology merely breaks the conservation plan down into more explicit stages. This methodology takes into account the physical-material and assignable-intangible characteristics of cultural heritage, which, in the case of the Suddards-Manuel-Clark monument, both contribute to its significance. In the case

[3] Clark, *Conservation Plans in Action: Proceedings of the Oxford Conference,* 4.
[4] Applebaum, Barbara. *Conservation Treatment Methodology*. Oxford: Butterworth-Heinemann, 2007.

of this research, pilot treatments, rather than full treatment of each condition, are carried out. What follows a conservation plan is a management plan that puts the conservation plan into action through budgeting, feasibility assessments and administrative and organizational tools. The goal of the conservation plan is to equip The Woodlands Cemetery Company with the means to conceive a resultant management plan.

Critical to the implementation of conservation plan-based actions is an ethical conservation philosophy.[5] Conservation treatments should only be undertaken when absolutely necessary to ensure preservation of the significance of the site. Non-intervention is a defensible preference when the site lacks structural issues and deteriorating mechanisms that threaten the preservation of the site. Any conservation treatment should only be the minimum action required to reach the ideal state and goals of treatment. Conservation treatment should also be retreatable so as not to preclude or inhibit any future conservation treatment that may be necessary in the future. It is not uncommon that part of conservation includes "extraordinary maintenance" and that treatments may have to be carried out multiple times.[6] Materials selected for conservation treatments and techniques used to carry out conservation treatments should be respectful to original fabric. Incompatible materials or treatments undermine the value and significance of cultural heritage.

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[5] Charola, A. Elena. "Ethical Criteria in Conservation Interventions." University of Pennsylvania, Philadelphia. 31 March 2009.
[6] Charola, "Ethical Criteria in Conservation Interventions."

2. HISTORY AND DESIGN

2.1. THE WOODLANDS AND THE RURAL GARDEN CEMETERY

Located at 4000 Woodland Avenue in Philadelphia, The Woodlands Cemetery and its Company were founded between 1840 and 1843 after the purchase of the declining Hamilton estate, a several-hundred acre gentleman's plantation developed beginning in 1766 by William Hamilton.[7] After several failed development plans and with the changing needs of the neighborhood, Thomas Mitchell, a developer who had purchased the property from the Hamilton family, partnered with a group of investors whose plan was to found a new cemetery. The property included Hamilton's Federal style mansion and outbuildings and the landscaped park-like grounds, which were filled with various species of plants and trees. Although it is difficult to imagine now, the site of the Hamilton estate was at the time in a rural area of Philadelphia that overlooked the Schuylkill River. Following the lead of the Laurel Hill Cemetery Company, the investors decided that it was the ideal site to plan a rural garden cemetery in West Philadelphia.

The concept of the rural garden cemetery was brought to the United States from Europe in the early nineteenth century, and among the first of these was Mount Auburn Cemetery, near Boston, in 1831 and the nearby Laurel Hill Cemetery in Philadelphia, which was founded in 1835.[8] Mount Auburn Cemetery was greatly influenced by the English garden as well as Paris's celebrated Père Lachaise Cemetery; the effect of Mount

[7] Wunsch, Aaron V. *Woodlands Cemetery*. Historic American Landscape Survey. Washington, D.C.: National Park Service, United States Department of the Interior, 2000, 3.
[8] Morgan, Keith N. "The Emergence of the American Landscape Professional: John Notman and the Design of Rural Cemeteries." *Journal of Garden History* 4.3 (1984): 270.

Figure 2.1 The Woodlands Cemetery; view looking southwest along Mansion Avenue (Source: Historic American Landscape Survey, 2003)

Auburn was a "garden of graves" that "mixed urbanity with isolation."[9] The rural garden cemetery was a planned and landscaped park-like setting for a cemetery, meant to serve as a pastoral haven for the families and friends of the deceased outside of the urban activity of the city. "The new cemetery which would console rather than frighten," was designed to "allow the cemetery to join nature itself."[10] The rural garden cemetery often included manicured greenery, specially selected trees, winding paths, attractive views and prominent cemetery entrance gates (Figs. 2.1, 2.2). William Hamilton was not only meticulous with the design of his classical villa, but he also took a great interest in botany and had planted over "10,000 plants and trees, many imported from foreign lands and cultivated in his greenhouse."[11] Consequently, Hamilton's contribution to the landscape eventually became the foundation for the transformation of his estate into a rural garden cemetery.

1839-1878 was the main period of development of The Woodlands Cemetery; through the 1840s however lot sales were slow because of the "enduing preference for churchyard burial" and much of the development at this time was landscape improvements and updating of buildings on the property.[12] The rural garden cemetery would usher in the era of individualized funerary monuments and uncongested burial grounds. By the 1850s, the purchase of lots at The Woodlands Cemetery became increasingly popular. The cemetery's entrance gate was also designed by John McArthur and constructed during this period. The growth of lot sales was most likely as a result of

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[9] Wunsch, *Woodlands Cemetery*, 97.
[10] Etlin, Richard. "Landscapes of Eternity: Funerary Architecture and the Cemetery, 1793-1881." *Oppositions* 8.4 (Spring 1977): 18.
[11] *The Woodlands: Historic Mansion, Cemetery & Landscape.* Philadelphia: The Woodlands.
[12] Wunsch, *Woodlands Cemetery*, 47.

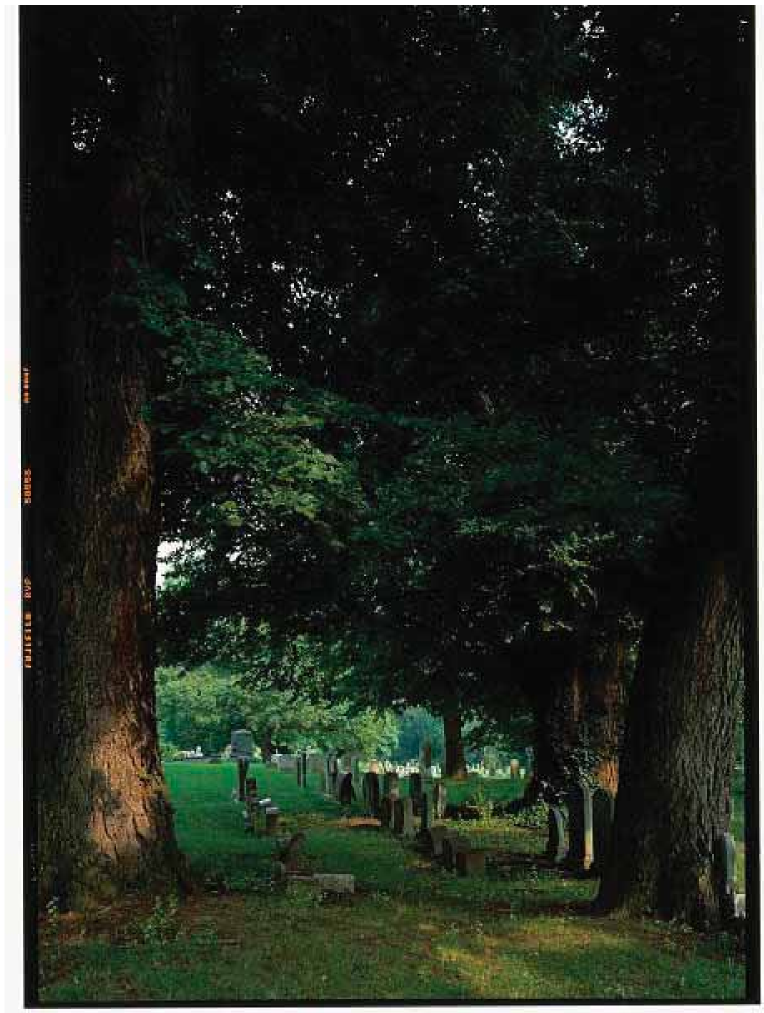

Figure 2.2 The Woodlands Cemetery; view up Larch Avenue looking north from Section F (Source: Historic American Landscape Survey, 2003)

the efforts of the cemetery company to bring status to The Woodlands by interring "local worthies" and "military heroes" in the cemetery; the practice of "dignify[ing] their grounds" in this way was "an established rural-cemetery strategy."[13] One of these dignitaries was General Thomas Robinson; Robinson was one of the first burials at The Woodlands, and his body was eventually "accompanied by those of his grandchildren and other relatives, creating that all-important fixture of rural cemeteries: the hallowed family lot."[14] The Suddards-Manuel-Clark monument was likely built during this time and would come to be one of the grandest and most authoritative of family lots.

Today 54 central acres of the several hundred acres that once comprised Hamilton's estate have been preserved as The Woodlands Cemetery. Thousands of new trees have been planted, and the property now includes "seven aged but magnificent English elms and fifteen trees that qualify for State Champion status."[15] The Woodlands estate was designated a National Historic Landmark in 1967, and The Woodlands Cemetery was added in 2006 to establish a National Historic Landmark District.[16]

2.2 THE SUDDARDS, MANUEL AND CLARK FAMILIES

The monument, which stands in Section E, Lots 171, 173 and 175 of the cemetery, can be divided into three segments, both by variations in design and by family. The west (left) section, Lot E-171, belonged to the Suddards family. In the early developmental stages of The Woodlands Cemetery, the cemetery company devised a scheme to boost its lot sales. The cemetery company partnered with local parishes to sell

[13] Ibid., 48.
[14] Ibid.
[15] *The Woodlands: Historic Mansion, Cemetery & Landscape.*
[16] Ibid.

lots to their congregations. By early 1845, despite having negotiated partnerships with five churches, only Grace Church, located at Twelfth and Cherry Streets, had "done anything towards promoting burials in The Woodlands."[17] Reverend William Suddards purchased Lot E-171 from Grace Church, who owned several lots in the cemetery, in 1857. Suddards family members were buried in the vault beginning in 1862 up until 1947. The vault contains the remains of thirteen members of the family, not including those of two other family members who were interred in 1907 and then removed to West Laurel Hill Cemetery three years later.[18] Reverend Suddards was a well respected member of the Protestant Episcopal community and the rector of Grace Church from 1834 to 1881.[19] Upon his retirement in 1881, Reverend Suddards was honored as rector emeritus.[20] Suddards was a native of England and was the editor of *The Episcopal Reader* and *The British Pulpit*; he had also published several of his sermons and was "one of the most influential clergymen of the diocese."[21]

The central section of the monument, Lot E-173, belonged to John and Joseph Manuel. There is little historical information about the Manuel family; however, there is a connection between the Suddards and Manuel families through Rowland Evans, Jr., the son-in-law of Charles A. Suddards and also the executor for the estate of John Manuel.[22] Manuel family members were buried in the vault beginning in 1851 up until 1958. The vault contains the remains of twenty-one members of the family. The east (right) section, Lot E-175, belonged to James G. Clark. There was no connection found between the

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[17] Wunsch, *Woodlands Cemetery*, 47.
[18] Woodlands Cemetery Lot Cards.
[19] Scharf, John Thomas and Thompson Westcott. *History of Philadelphia, 1609-1884*. Philadelphia: L. H. Everts, 1884, 1352.
[20] Ibid.
[21] Ibid.
[22] Woodlands Cemetery Lot Cards.

Suddards and Manuel families and the Clark family. Clark family members were buried in the vault beginning in 1858 up until 1884.

2.3 DESIGN AND CONSTRUCTION

While monument and marker design was limited greatly to marble tablets and simple obelisks in the 1840s, lot owners began to see their lots as real estate and to design more elaborate monuments into the 1850s.[23] Obelisks were embellished, figural sculpture was integrated, and architectural styles (Gothic, French, Egyptian, Greek Revival, Renaissance Revival) began to be applied to tomb design. Laurel Hill Cemetery published a guidebook to its grounds and policies in 1844. The cemetery company expressly stated that the rural garden cemetery was meant to be "a *toute ensemble*" and that marker and monument design should be carefully considered; owners were instructed to inquire with the cemetery before ordering their monuments to ensure that "monotony" and "dull uniformity" would not preside over the landscape.[24] Laurel Hill also offered design guidance in the form of drawings that could be adapted should an owner find "too frequent imitation" in more austere markers.[25]

The lot holders of The Woodlands Cemetery also understood that monument design could communicate individuality, wealth and status. Richard Etlin states, "In the nineteenth century, the families of "the well-off class of society" constructed their world as much in the city of the dead as in that of the living."[26] Among those families whose

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[23] Wunsch, *Woodlands Cemetery*, 66.
[24] Laurel Hill Cemetery. *Guide to Laurel Hill Cemetery, near Philadelphia*. Philadelphia: C. Sherman, 1844.
[25] Ibid.
[26] Etlin, 26.

funerary monuments at The Woodlands Cemetery are as imposing and highly crafted as the Suddards-Manuel-Clark monument are the McDaniel, Burns-Detre and Drexel families. Not only was size and design a factor in expression of prosperity and taste, but topography and site of lots was conscious and intentional. The centrality of lots corresponded with social class, and also those lots at the highest points of the landscape were more expensive.[27] Lots nearest to the mansion were also considered desirable, and the planned concentric "Center Circle" area was reserved for only the most prominent and celebrated of Philadelphia families. The Drexel mausoleum conveys the importance and wealth of the Drexel family through its substantial size, architectural design and close proximity to the Hamilton mansion.

The Suddards-Manuel-Clark monument is located in Section E, south of the Center and South Circles. The Gothic Revival vault is built into a bank; bank lots were more affordable as only one side of the dimensional monument could be viewed and had to be designed.[28] The monument curves along the cemetery's Vault Avenue and is located at the juncture of Vault Avenue and Cypress Avenue, with the full panorama of the vault visible as visitors amble north up Cypress (Figures 2.3, 2.4). The monument abuts the E. A. Warne vault to the west and two sets of sandstone steps to the east that give access to the top of the monument and bank. The Suddards section of the vault is approximately 18 feet long and nine feet high at its highest point. The central Manuel

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[27] Wunsch, Aaron V. "The Woodlands Cemetery." The Woodlands Cemetery Company Offices, Philadelphia. 17 March 2009.
[28] Wunsch, *Woodlands Cemetery*, 142.

Figure 2.3 The Woodlands Cemetery (Source: Google Earth, 2009)

Figure 2.4 The Woodlands Cemetery (Source: Google Earth, 2009)

section is approximately 22 feet long and thirteen feet high at its highest point. The Clark section of the vault is approximately 17 feet long and eight feet, eight inches high at its highest point. The entire monument is 57 feet long. There is a shallow slate and granite courtyard in front of the Suddards section of the monument. Granite curbing follows the façade of the vault and shows evidence of a stone or metal railing that must have been removed at some point. A granite base supports almost the entirety of the monument, becoming less prominent from the west to the east end of the vault where it disappears under the central panel of the Clark section. Because the ground under the vault is not level, it slopes up from west to east, the granite base may have been designed to level the monument to some extent. It is not clear how far into the vault the granite slab extends because of the restricted access to the vault's interior.

The monument is in essence a stone fronted retaining wall to the bank and vaults within. The elevation is a tripartite design with a central pavilion and two flanks. Each section is three bays wide. The tomb is constructed of very large masonry units to give the appearance of a cohesive, jointless façade. The Suddards section of the vault alternates wide, flat piers with smaller piers flanking the marble panels where the names of those there interred are inscribed (Fig 2.7). The flat Gothic arches of the marble tablets are echoed with sandstone panels above with a row of smaller Gothic arches. These arched pieces are carved out of one single sandstone block. The small piers have simple capitals from which the blind arcaded panels spring. The larger piers support a simplified entablature, which carries a continuous crenellated parapet. The central

Figure 2.5 Suddards-Manuel-Clark monument; view from south (Source: E. Kemery, 2009)

Figure 2.6 Suddards-Manuel-Clark monument; view from east (Source: E. Kemery, 2008)

Figure 2.7 Suddards-Manuel-Clark monument, Suddards (west) section (Source: E. Kemery, 2009)

Figure 2.8 Suddards-Manuel-Clark monument, Manuel (central) section (Source: E. Kemery, 2009)

marble tablet, which is wider than those to its left and right, would have served as a door; there is a small key hole on the left side. Vandals had forced open the door of the Suddards section of the vault on at least two different occasions, so the cemetery company had it sealed off in 1974.[29]

The Manuel section of the vault is the most architecturally complex of the three families' sections (Figure 2.8). Like the Suddards section of the vault, wide piers punctuate the façade, but the piers in the Manuel section are carved with eave-like projections. The piers are carved of a single block of sandstone. Two outer coved towers are topped with the blind arcade motif and crenellations and at one point held marble statuary.[30] What once would have likely been a marble panel door similar to that of the Suddards section is now simply an opening filled with concrete masonry blocks between the two piers. The lot card for the section indicates that the vault was sealed in this manner in 1960. Above the central door is a carved sandstone bust of a male figure with a long beard and mustache and a furrowed brow, possibly a personification of Father Time The marble panels on either side of the central door are narrower than those of the Suddards section. Above the simplified entablature of the central section is a carved marble panel featuring a cherub and an inscription that is no longer legible due to erosion of the marble. What is still legible reads, "ENTRUST…UNTO THE LORD." This panel is topped with a pedimented entablature and crenellations.

The Clark section of the vault is similar in scale and design to the Suddards section of the vault, visually balancing the entire monument (Figure 2.9). The Clark

[29] Woodlands Cemetery Lot Cards.
[30] Wunsch, *Woodlands Cemetery*, 66.


Figure 2.9 Suddards-Manuel-Clark monument, Clark (east) section (Source: E. Kemery, 2008)

section has the same wide piers, simplified entablature and crenellations of the other two sections. Again, the central section that likely would have been a marble panel door has been subject to more recent interventions. The entire panel has been covered with a cementitious material; it is actually not certain whether or not the original marble panel still exists beneath this material. The two flat Gothic arched sections on either side of the central door differ from those of the Suddards and Manuel sections in that they are divided by a third column creating two thin, separate arched marble panels. It does not appear that any of these four panels were ever inscribed. The motif of the two smaller pointed arches within the larger pointed arch leaves a diamond-shaped opening that may have been left for ventilation purposes.

The façade is entirely of a brown sandstone with the exception of the white marble panels. While marble and granite are the predominant materials of markers and monuments in the cemetery, there was a short period when sandstone was popular in the mid-nineteenth century.[31] The areas of the monument visible on each side and the coping of sections that rise a few inches above the ground on the top of the monument are also sandstone (Figure 2.10). Although not much is known about the interior of the monument, the interior sub-grade structure is predominantly brick, which can be seen in exposed areas where the sandstone has cracked and been lost or where soil has eroded away. The sandstone appears to be fine-grained, very dense and without visible bedding. Tooling marks are visible in areas that were not meant to be viewed, but the finish on the dressed surface of the stone is rubbed smooth to a sanded finish (Figure 2.11). Many of

[31] Wunsch, "The Woodlands Cemetery."

Figure 2.10 Suddards-Manuel-Clark monument, top of the monument view looking south east (Source: E. Kemery, 2009)

Figure 2.11 Toolmarks visible on east wall open joint (Source: E. Kemery, 2009)

the mortar joints have weathered out, but where mortar is visible, it appears that original joints were thin and that the pointing was brown in color and recessed to give the appearance of dry-laid masonry (Fig 2.12).

There is no record the monument's design or date of construction. Each of the three sections of the vault also has slight variations in design, indicating that the entire monument was probably not built at the same time. The earliest date of interment of the Manuel family is 1851. The earliest dates of interment of the Suddards and Clark families are 1862 and 1858, respectively, but Reverend Suddards purchased the lot in 1857. Hand-measured drawings of the monument indicate minor differences in dimensions of the stone blocks that make up the structure. While crenellations of the Suddards and Clark sections are very similar in dimension, about 19 inches long for each individual crenellation, those of the Manuel section are 9 and 12 inches long. The wide, flat piers of the Suddards and Clark sections are about 14-½ inches wide, and the piers of the Manuel section are about 11 ¾ inches wide. The piers of the Manuel section are not only narrower than those of its neighbors, but they are architecturally dissimilar and include a carved moulding. It is likely that the central Manuel section of the vault was constructed around 1851, before the flanking Suddards and Clark sections. The Suddards and Clark sections could have been constructed between 1851 and 1858, or separately, before 1858 (Clark) and before 1862 (Suddards). If the central Manuel section was built before the other two sections, it would have still been symmetrical and could have been interpreted as a complete monument of its own. Open joints at the junctures of the

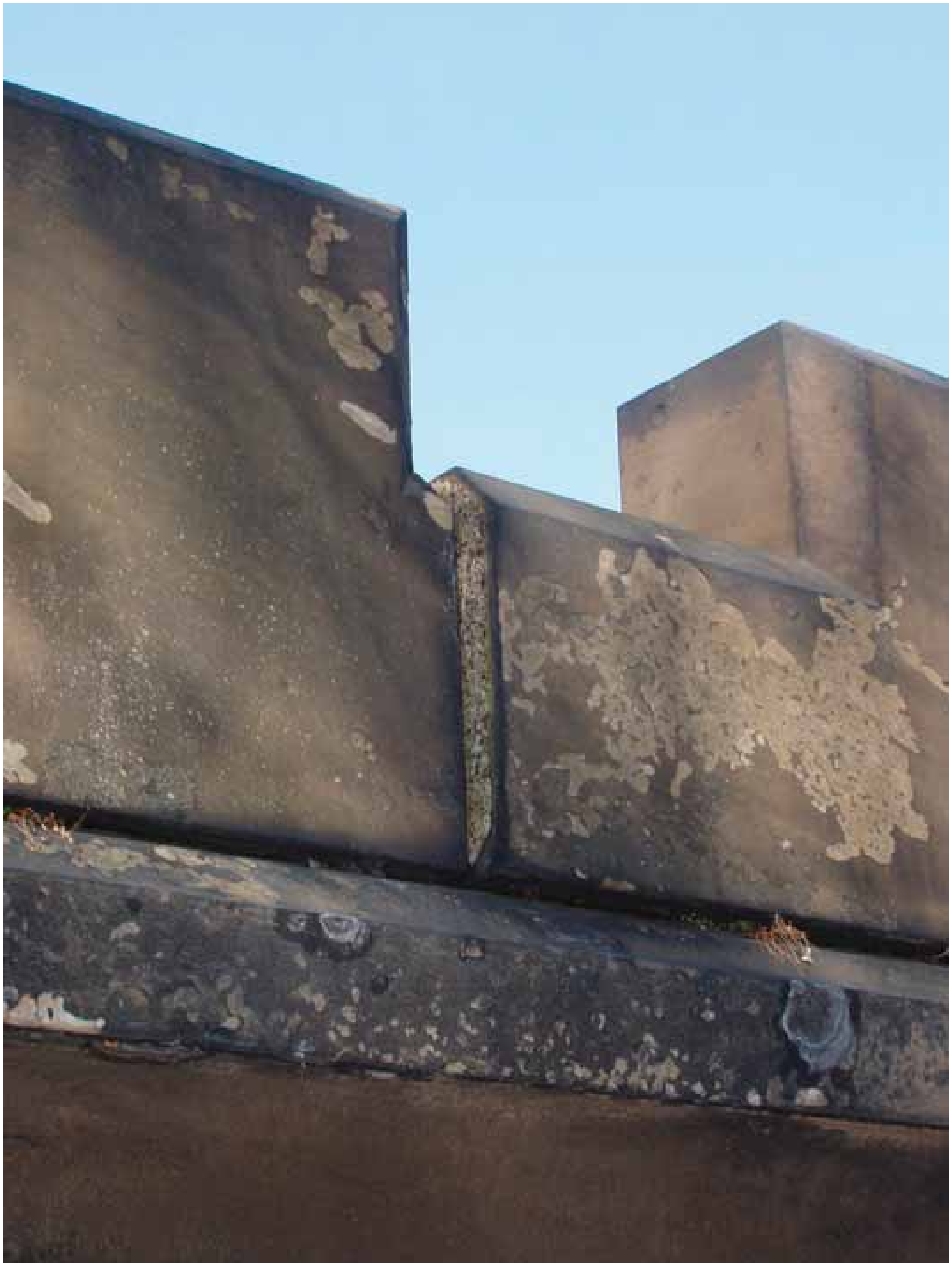

Figure 2.12 Recessed mortar joint on displaced crenellation (Source: E. Kemery, 2009)

Suddards and Manuel sections and the Manuel and Clark sections suggest that all three sections were not originally constructed as one.

There are records of the architects of some of the monuments at The Woodlands, especially those that are larger or more prominent; in some cases, designers even signed the monuments they constructed. Unfortunately, there is no record of the mason, designer or architect of the monument. Not only could status be evoked through scale, location and design of a monument, but "an existential bond" or "a special and close relationship between the architect and the client" would also have signified position in society.[32] While there is no documentation of the designer of the Suddards-Manuel-Clark vault, it is clear that there is an architectural awareness and skill in the design that could be attributed to any one of several architects. One of the benefits of the rural garden cemetery "for architects was the commission for sepulture monuments. Tomb plans were not beneath the skill of Philadelphia's major architects, including John Strickland, Thomas U. Walter and John Notman, who actively designed these monuments."[33]

John Notman was the planner and architect of the Laurel Hill Cemetery grounds and its entrance gate; it was his first commission after coming to America from Scotland, and his "Scottish training had provided an exposure to numerous historical styles and to the natural or picturesque landscape."[34] Not only did Notman design the plan and entrance gate for Laurel Hill, but he also designed several monuments in the "Gothic, Egyptian and Greek Revival styles."[35] While he was not by any means as active at The Woodlands Cemetery, Notman was asked to compete for the commission of The

[32] Etlin, 28.
[33] Morgan, 281.
[34] Ibid., 272.
[35] Ibid., 281.

Woodlands' entrance gate, and, being so familiar with the rural garden cemetery context, he may have designed monuments for The Woodlands' clientele as well.

There exist some striking similarities between some of the monuments Notman designed at Laurel Hill Cemetery and the Suddards-Manuel-Clark monument. The Gothic marble monument of J. A. Brown, Esq. and family is featured on the cover of and in three other instances of the 1844 *Guide to Laurel Hill Cemetery, near Philadelphia* (Figure 2.13). The drawings for the guidebook were prepared by Notman himself, and he must have been proud of his work on this monument. The Brown monument has panels similar to those of the Clark section: three small columns with two small and one large Gothic arch topped with a blind arcade of Gothic arches. The corresponding Gothic elements aside, there is one particular design detail that is common in both monuments. The pier with projecting moulding carved from one single block of stone is also present in Notman's Brown monument (Figure 2.14). The skill and design of this piece is unusual and exceptional. Notman was also the designer of Laurel Hill Cemetery's *Old Mortality*, which the cemetery considers their "signature monument."[36] *Old Mortality* is a sculptural group by sculptor James Thom, which is housed in an arched sandstone structure with crenellated turrets at each corner (Figure 2.15).[37]

The Ripka monument in Laurel Hill Cemetery's Section I, designed by Notman, has the very similar motif of the small blind arch arcade found on the Suddards-Manuel-Clark monument. However, the tomb of Dr. Horace Evans, Laurel Hill Section A1-4,

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[36] "The Restoration of Old Mortality." *Laurel Hill Cemetery.* 2009. < http://www.thelaurel hillcemetery.org/index.php?m=6>.
[37] Ibid.

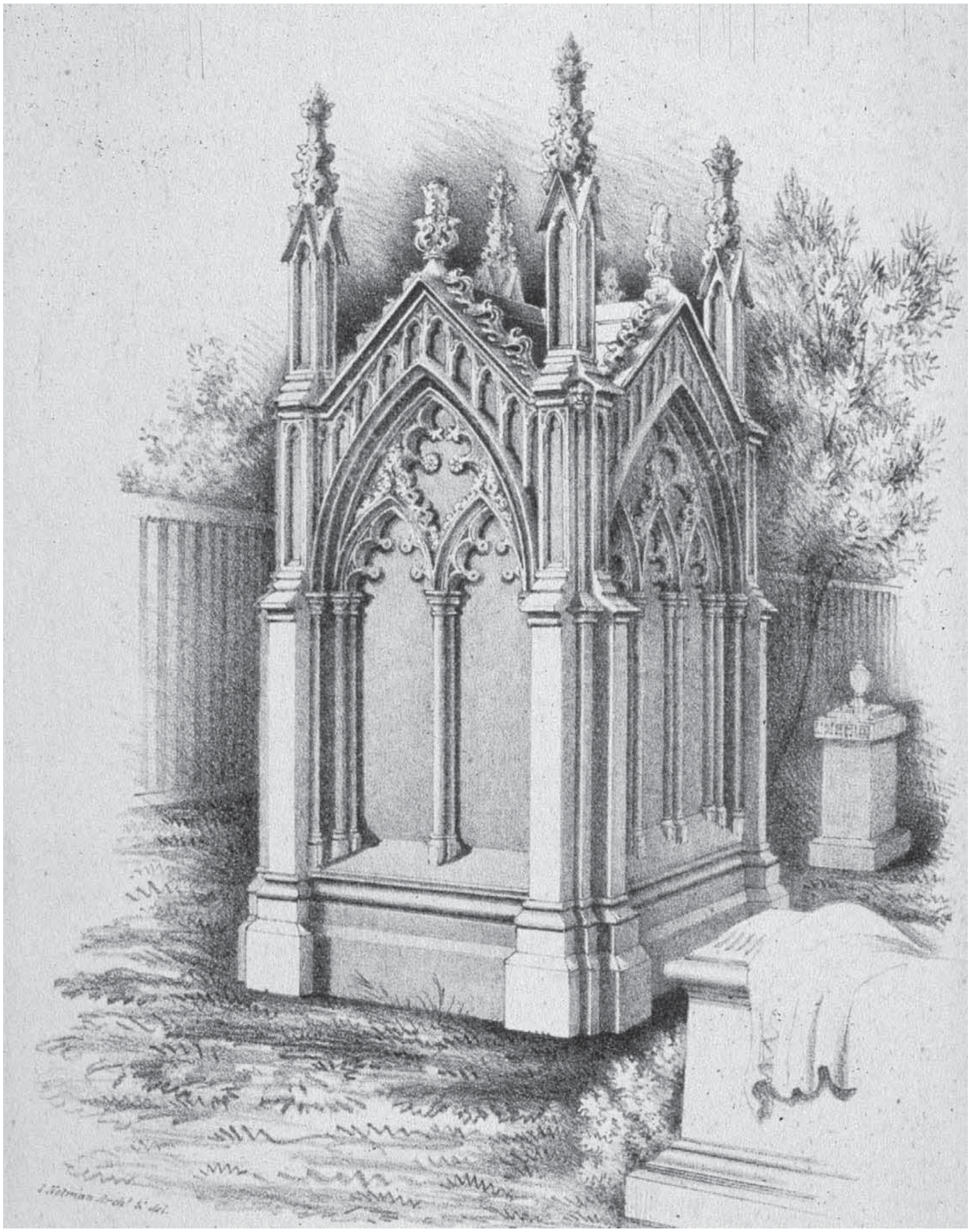

Figure 2.13 Gothic Revival tomb of J. A. Brown at Laurel Hill Cemetery, designed by John Notman; drawing by John Notman in *Guide to Laurel Hill Cemetery, near Philadelphia*, 1844 (Source: University of Pennsylvania, Fine Arts Library Image Collection)

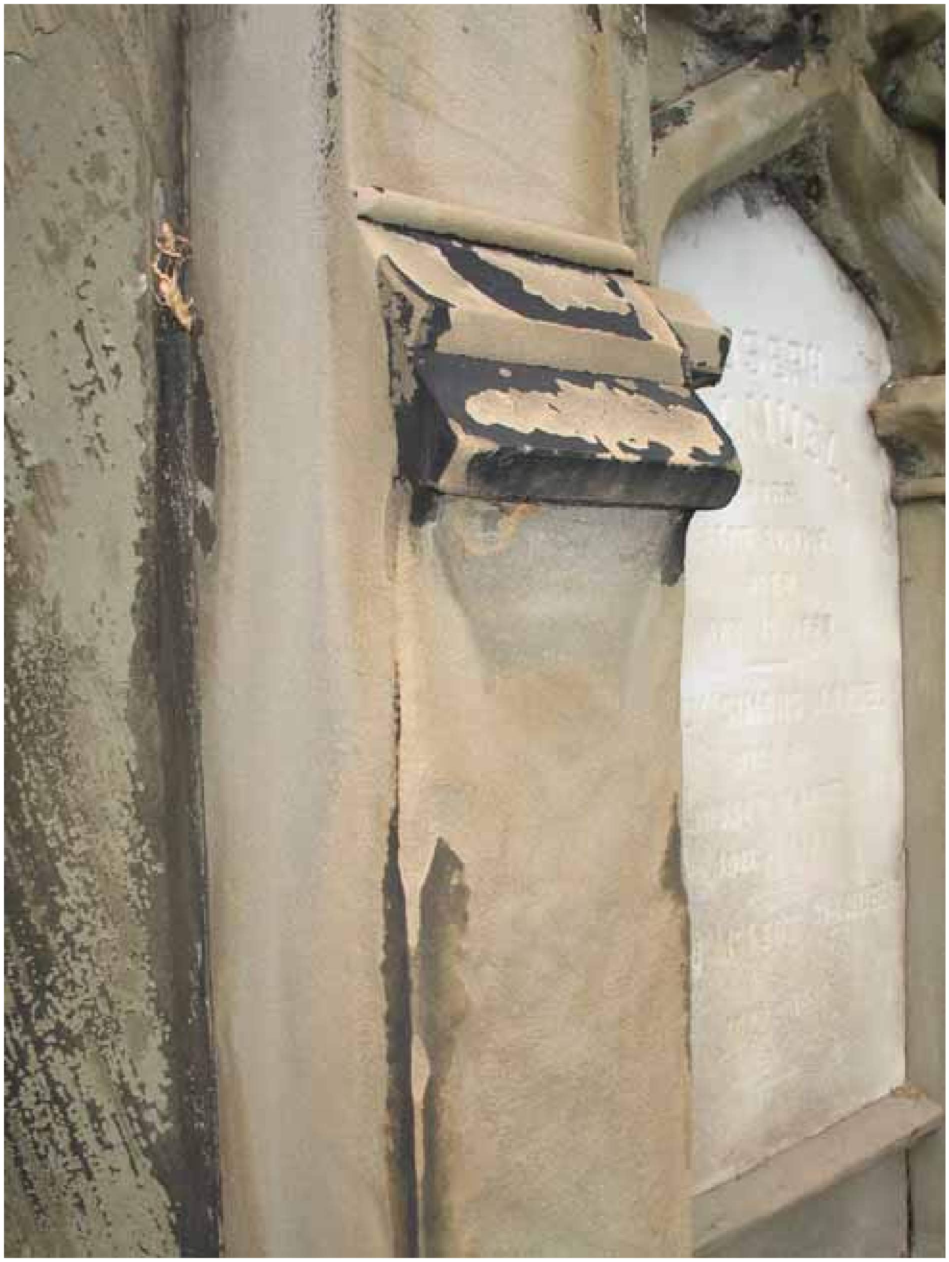

Figure 2.14 Pier of the Suddards-Manuel-Clark tomb with unique moulding feature (Source: E. Kemery, 2008)

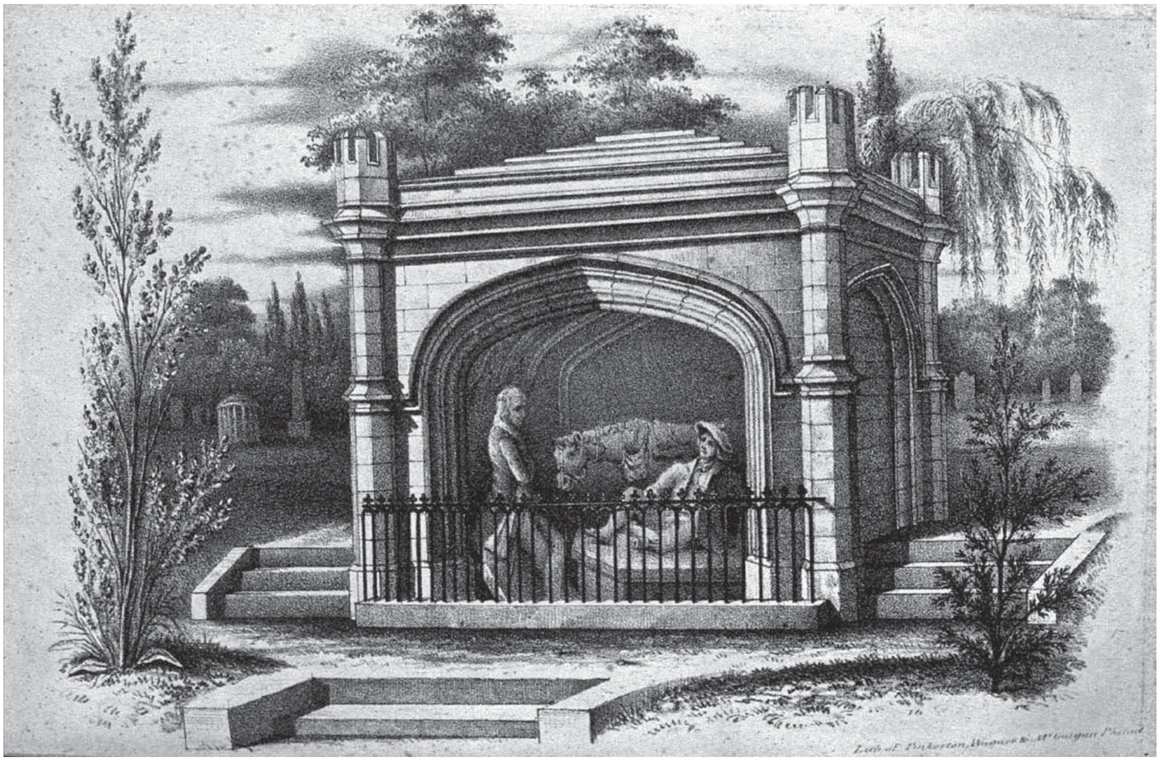

Figure 2.15 Monument to Old Mortality and Sir Walter Scott at Laurel Hill Cemetery, designed by John Notman, drawing by John Notman in *Guide to Laurel Hill Cemetery, near Philadelphia*, 1844 (Source: University of Pennsylvania, Fine Arts Library Image Collection)

Figure 2.16 Tomb of Dr. Horace Evans at Laurel Hill Cemetery, designed by J. Struthers & Son (Source: University of Pennsylvania, Fine Arts Library Image Collection, date unknown)

which was designed by mason J. Struthers & Son also carries this same motif (Figure 2.16). Records indicated that Struthers may have designed and/or built the Robert Swift monument in 1862 and the J. Barlow Reynolds monument, both at The Woodlands Cemetery.[38]

Stephen D. Button was an architect active in Philadelphia beginning in 1848; he worked in the firm Hoxie and Button until it was dissolved in 1852.[39] In 1855, Button designed the entrance gate and gatehouse of the Mount Moriah Cemetery, also located in Philadelphia.[40] Like the Suddards-Manuel-Clark monument, the Mount Moriah entrance gate is Gothic Revival in style and constructed of a red-brown sandstone (Figure 2.17). It is monumental in size and is topped with large crenellations and rounded and stepped parapets with stone urns. Not only is the choice of material very similar to that of the vault at The Woodlands, but the entrance gate also shares the crenellations and a simplified form of the blind arcade gothic arches. Button's design for Mount Moriah is much more elaborate than the design of the Suddards-Manuel-Clark monument, but highly crafted was the norm for cemetery entrance gates. One of the most significant differences in the design aesthetic between the two structures is that the Mount Moriah entrance gate is so large that the individual masonry blocks are distinguishable, whereas the individual masonry blocks of the vault at The Woodlands Cemetery have been carefully crafted to conceal superfluous joints and lines that would break up the unified

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[38] Wunsch, *Woodlands Cemetery*, 18.
[39] Moss, Roger W. "Button, Stephen Decatur (1813-1897)." *American Architects and Buildings*. 2009 < http://www.philadelphiabuildings.org/pab/app/ar_display.cfm/ 22852>.
[40] "Mount Moriah Cemetery Gatehouse, 6299 Kingsessing Avenue, Philadelphia, Philadelphia County, PA." Historic American Buildings Survey. Washington, D.C.: National Park Service, United States Department of the Interior, 1975.

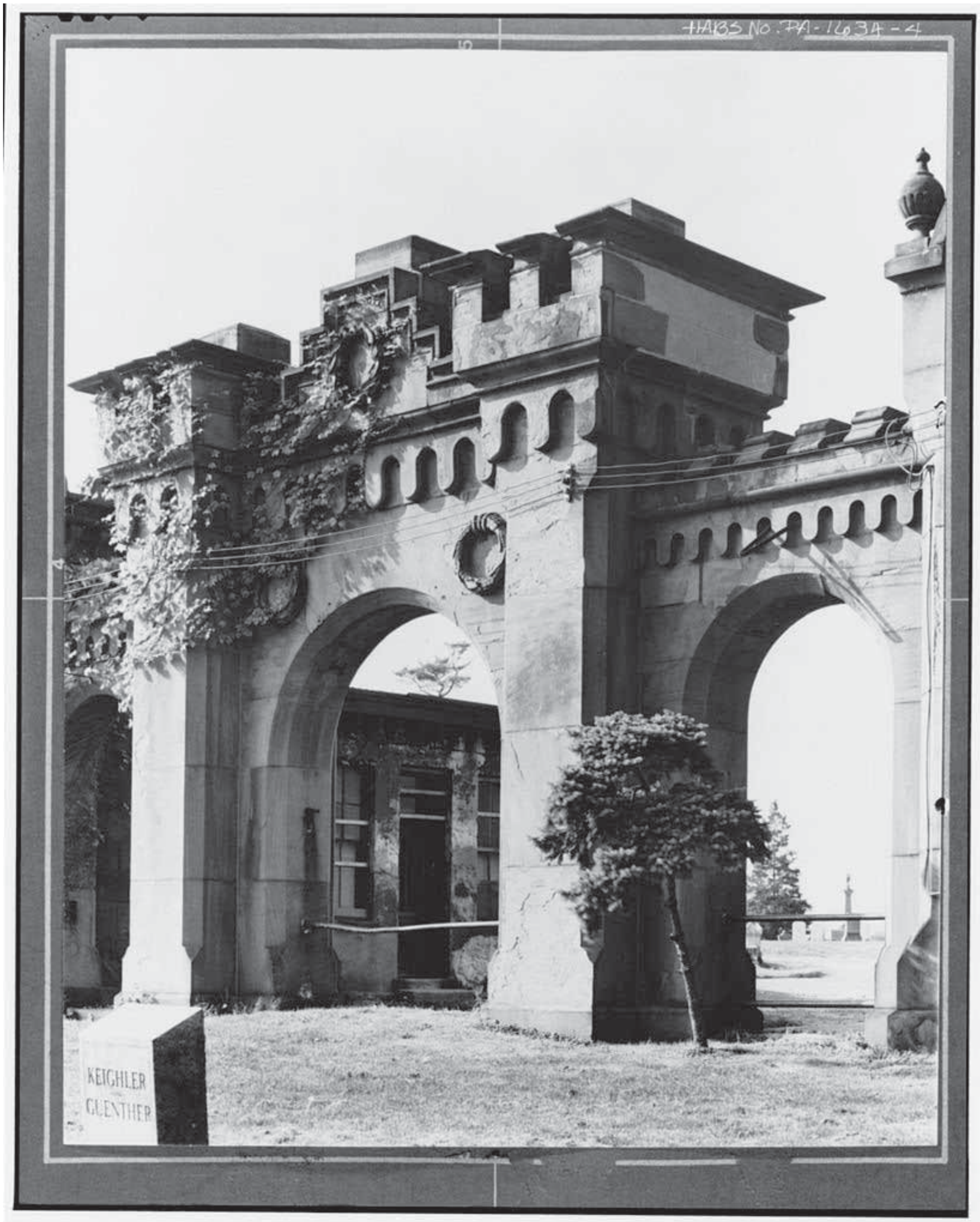

Figure 2.17 Gothic Revival entrance gate to Mount Moriah Cemetery, designed by Stephen D. Button (Source: HABS, 1975)

façade. Button is also not among those listed as architects associated with the construction and design of either The Woodlands Cemetery or individual monuments of the cemetery.[41]

[41] Wunsch, *Woodlands Cemetery*, 18.

3. LITERATURE REVIEW

3.1 LITERATURE PERTAINING TO THE SUDDARDS-MANUEL-CLARK MONUMENT

Archival research in The Woodlands Cemetery records provides names and dates of those buried inside the tomb from lot cards and lot ownership information from the cemetery's register of deeds. The lot files for the tomb contain almost no other information except correspondence connecting two otherwise ostensibly unrelated families through Rowland Evans, Jr. As Suddards is a less common name than Manuel or Clark, early sources such as the *Journal of the Proceedings of the Bishops, Clergy and Laity of the Protestant Episcopal Church* and Scharf and Westcott's *History of Philadelphia*, both from the second half of the 19th century, refer to Reverend William Suddards.

Although little is known about the Suddards, Manuel and Clark families or about the designer of the vault, Aaron V. Wunsch recently completed the Historic American Landscape Survey of The Woodlands Cemetery. Little else is specifically revealed about this particular monument, but Wunsch examines the history, construction and development of the cemetery. Potential architects can be found in the list of architects associated with the design and development of the cemetery.[42] While much of the historical literature pertaining to Philadelphia cemeteries focuses on Laurel Hill Cemetery, the study of Laurel Hill Cemetery can inform the design of the Suddards-Manuel-Clark vault.

[42] Wunsch, *Woodlands Cemetery*, 14-17.

3.2 LITERATURE PERTAINING TO SANDSTONE AS A BUILDING MATERIAL

Early twentieth century texts by George Perkins Merril (1910), Frederick P. Spalding (1921) and Robert John Schaffer (1932) are seminal works concerning the use of stone as a building material. These texts discuss composition and properties of stone, describe tools used in masonry construction and illustrate use of stone and design of stone structures. Schaffer acknowledges the concept of bedding planes and emphasizes that "faulty craftsmanship" in laying stone can lead to decay. Almost every text from this point on, whether on the subject of properties, weathering or conservation, highlights the effect of bedding on performance. There is very little literature from the 1940s through the 1960s on the subject of sandstone. This can be attributed to stone's decreasing popularity as a building material; it appears that no new testing or information was being investigated or presented. Harley J. McKee's *Introduction to Early American Masonry* (1973) revisits the quarry and describes the working and finishing of stone. Much of the literature of the 1970s and 1980s on stone as a building material, including McKee's book, is concerned with stone walls. McKee's book touches on deterioration and marks the beginning of the investigation of stone decay.

There is a wealth of petrological data written on the subject of sandstones and its material properties that inform their performance as building materials. Sandstone is a sedimentary rock, and the sandstone used for the construction of the Suddards-Manuel-Clark monument is a clastic or detrital rock. Clastic sediments differ from chemical sediments in that clastic sediments are formed by accumulation of mechanically disintegrated rock and mineral fragments, and chemical sediments are formed through precipitation or evaporation.[43] While many sedimentary rocks have bedding from deposition of sediment in layers, the sandstone used for this monument generally does not have discernible bedding. Sandstones are composed of quartz, feldspar, silicates, mica, hornblende and clay minerals that are cemented with siliceous or carbonate/calcite cement.[44] Sandstone cemented with silica cement have great properties; Winkler compares “very high strength” of siliceous cement to “sufficient strength and durability” calcite cement.[45] Weathering and performance of sandstone depend greatly on the porosity and permeability of the material, which are derived from the arrangement of minerals, clays and cementing material in the stone.

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[43] Winkler, Erhard M. *Stone in architecture: properties, durability*. 3rd ed. Berlin: Springer, 1994, 9.
[44] Ibid., 14.
[45] Ibid., 15.

3.3 LITERATURE PERTAINING TO SANDSTONE DECAY

Schaffer in 1932 is one of the earliest works to cite atmospheric pollution and acid gases as causes for soiling and deterioration of stone. From the late 1970s on, works by Ashurst, Matero, Teutonico, Weiss and Winkler are the main texts pertaining to stone decay. Lynch and Higgins (1982) identify the types of decay specific to sandstone as exfoliation, blind exfoliation, blistering, cracking and detachment. This is later refined by Snethlage and Wendler (1997) to include flaking, scaling, disintegration and erosion. Much of the literature of the 1990s and 2000s regarding decay focuses on salts, acid rain and air pollution, the two latter of these becoming ever greater a threat, especially in urban areas like Philadelphia. The chemistry behind these phenomena is also more greatly explored from the 1990s on and continues to be investigated and updated.

Literature of the 1970s and 1980s also begins to explore the sources of stone decay and the necessary and sufficient factors which lead to decay problems. Vos (1973) and Massari (1985) discuss the effect of moisture on structures and on stone. Massari is a particularly important text that examines capillary action, humidity and a structure's environment and micro-climate. Understanding of moisture and environment is fundamental to the study of decay; moisture is the vehicle for pollution, salts and minerals, moisture and environment are the source of freeze-thaw cycling, moisture and temperature provide hospitable environments for biological organisms and moisture can break down the cementing/binding material in stone such as sandstone. Sources of deterioration not related to moisture include solar and ultraviolet radiation, cooling and heating loads and structural issues.

Weathering and deterioration can either be chemical or mechanical, and factors leading to decay can be inherent to the material or dependent on outside forces and factors. These external factors can be fabrication of the masonry system, design of the masonry system, environment/site or non-original intervention. In the case of the Suddards-Manuel-Clark monument, weathering to a great degree is related to the environment and site of the monument with the design of the structure and the material properties of the stone itself accelerating or intensifying the decay mechanisms. Moisture, salts and air pollution are the contributing factors of the environment and site of the monument, and the material properties of the stone promote decay by interacting with these factors. Snethlage and Wendler (1997) and Winkler (1997) give thorough discussions of moisture, related decay mechanisms and resulting conditions, and Charola (2000) focuses on salt weathering and resulting conditions.

Fitzner, Heinrichs and Kownatzki (1995) discuss the forms that decay mechanisms take as major categories of loss, discoloration/deposit, detachment and fissures/deformation. These categories are then illustrated and broken down into more specific weathering forms, for example, pitting (loss), soiling by pollutants from the atmosphere (discoloration/deposit), flaking (detachment) and bending/buckling (fissures/deformation).[46] What Fitzner et al. created here was a glossary of conditions of building stone deterioration. The most recent of these glossaries was published in 2008 by ICOMOS.[47] While the glossaries themselves present very little information on the

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[46] Fitzner, B., K. Heinrichs and R. Kownatzki. "Weathering Forms – Classification and Mapping." *Natursteinkonservierung in der Denkmalpflege*. Ed. Rolf Snethlage. Berlin: Verlag Ernst & Sohn GmbH, 1995. 41-88.

[47] ICOMOS-ISCS: Illustrated Glossary on Stone Deterioration Patterns. Monuments and Sites XV. Paris: ICOMOS-ISCS, 2008.

sources of these conditions, they can be used in conjunction with works like Snethlage and Wendler (1997), Winkler (1997) and Charola (2000) to give a full picture of decay.

3.4 LITERATURE PERTAINING TO THE CLEANING OF SANDSTONE

Most of the literature on cleaning of sandstone that does not specifically focus on laser cleaning was published in the 1980s and 1990s. Early cleaning methods included water washing, dry abrasive cleaning, wet abrasive cleaning and chemical cleaning. Abrasive cleaning techniques experimented with various materials such as sand, glass beads, glass powder, corn- or seed-husk grit, assorted slurries and poultices. Grimmer's 1988 publication is a succinct explanation of types of soiling and methods for cleaning employed by the National Park Service. Grimmer emphasizes that selection of cleaning method should be the "gentlest means possible."[48] Grimmer presents water cleaning, chemical cleaning and poulticing but stipulates testing, specifications, precautions and minimization of hazards to the historic structure, environment and project personnel.

Mansfield's "Sources of building soiling and a review of the stone cleaning industry" (1991) in Webster's *Stone cleaning and the nature, soiling and decay mechanisms of stone* shows that only 27% of individuals/organizations surveyed who had their stone structure cleaned did so for preservation purposes.[49] 42% cited appearance as their reason for cleaning, 5% to decrease long term maintenance costs, 4% to increase the value of the property and 2% as an alternative to painting. Through the 1990s and 2000s, as there is an emphasis on materials conservation, cleaning techniques are improved and

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[48] Grimmer, Anne E. *Keeping it clean: removing exterior dirt, paint, stains and graffiti from Historic Masonry Buildings*. Washington, D.C.: United States Department of the Interior, National Park Service, Preservation Assistance Division, Technical Preservation Services, 1988, 29.

[49] Webster, Robin G. M., ed. *Stone cleaning and the nature, soiling and decay mechanisms of stone*. London: Donhead, 1992, 90.

those found to have been detrimental to the material are discouraged. Research and experimentation to advance chemical cleaning are continually being carried out. Laser cleaning was first studied in the 1970s by Asmus et al, and Asmus has continued to make strides in laser cleaning through the 2000s.[50] New products for cleaning are constantly emerging, and even technical journals cannot always keep up with them.

Cleaning of masonry should always precede any other conservation treatments. There are four main categories for masonry cleaning as defined by Ashurst (1994):

> 1. Water-based methods (principally for limestone and marble): fine sprays (mists), water sprays with and without pressure, hot or cold water, steam.
> 2. Chemical methods (principally for sandstones, brick, terracotta, granite but also for limestones): acidic and alkaline solutions.
> 3. Poultices and packs (most substrates): acid, alkaline and neutral pastes.
> 4. Air abrasive and mechanical methods: wet and dry abrasive, micro-abrasive, surface redressing.[51]

For sandstone, chemical cleaners are greatly more effective than water washing, even pressure or steam washing, because the material to be removed by cleaning is not limited to soluble material, soiling and dust. Chemical hydrofluoric acid-based cleaning, alkali-based cleaning and alkali-acid cleaning can be used in low concentrations to remove heavy soiling on sandstone. In all chemically-based cleaning, even application and pre-wetting of the surface to be cleaned are required, and pH should be tested regularly at the site of the application through the cleaning process.[52] Plain clay-based aqueous poultices are effective in removing soluble salts, and aqueous clay-based alkaline poultices to remove soiling. Micro-abrasive and wet or dry abrasive cleaning have proven effective for cleaning of sandstone surfaces as well. Micro-abrasive methods can use "aluminum

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[50] Asmus, John F., Walter H. Munk and Carl G. Murphy. "Studies on the Interaction of Laser Radiation with Art Artifacts." *Developments in Laser Technology II: 17th Annual Technical Meeting, seminar-in-depth, August 27-29, 1973, San Diego, California.*. Ed. Ralph F. Wuerker. Palos Verdes Estates, CA: Society of Photo-optical Instrumentation Engineers, 1974. 19-26.; Webster, 278.
[51] Ashurst, Nicola. *Cleaning Historic Buildings*. London: Donhead, 1994, 1.
[52] Ashurst, N., 10.

oxide, sodium bicarbonate, silicon carbide, glass beads and crushed glass" have historically been used as abrasives, and more recently proprietary systems have begun to use specialized materials as abrasives.

No matter what method is used, cleaning is not retreatable and should therefore be carefully undertaken. Specifications must be followed, and manufacturers datasheets for products should be consulted. For historic buildings, the ideal state of the stone must be determined; in some cases, the ideal state is not for pristine, like-new surfaces. In general, "proper definition of cleaning parameters" must be decided before cleaning begins.[53] For chemical cleaners, important parameters include dwell time, concentration and pre-wetting and rinsing procedures; for abrasive cleaners, important parameters include "size distribution and nature of the [abrasives], the size of the nozzles, the working distance, the air/water pressure."[54] Because of the possible harmful effects if completed improperly, cleaning should be performed by trained practitioners and trained operators of machinery should certain equipment be necessary. In revisiting buildings in urban areas cleaned ten to fifteen years earlier, Ashurst (1985) discovered re-soiling, damage, "over-clean[ing]" and discoloration, which he attributed in many cases to "inexpert" application.[55] Sandstone buildings that had been cleaned by sand-blasting were pitted and showed "medium-fast" re-soiling, and sandstone buildings that had been acid-cleaned showed some streaking and staining but were in generally "good"

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[53] Vergès-Belmin, V. "Towards a Definition of Common Evaluation Criteria for the Cleaning of Porous Building Materials: A Review." *Science and Technology for Cultural Heritage* 5.I (1996): 79.
[54] Ibid.
[55] Ashurst, John. "Cleaning and Surface Repair: Past Mistakes and Future Prospects." *APT Bulletin* 17.2 (1985): 39.

condition.[56] Cleaning can often cause damage to or loss of the surface of a material, deposit and leave chemicals in the pores of stone and precipitate both soluble and insoluble salts.[57] The effects of cleaning will vary depending on the material cleaned and its physical properties. Only the gentlest and least intrusive means necessary to achieve the goals of cleaning for a particular site or building should be used.

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[56] Ibid., 40.

[57] Pombo Fernandez, S., K. Nicholson and D. Urquhart. "Removal and Analysis of Soluble Salts from Chemically Cleaned Sandstones." Eds. Melanie S. Jones and Rachel D. Wakefield. *Aspects of stone weathering, decay and conservation: Proceedings of the 1997 Stone Weathering and Atmospheric Pollution Network Conference*. London: Imperial College Press, 1999. 77-89.

3.5 LITERATURE PERTAINING TO THE CONSERVATION OF SANDSTONE

Much of the literature pertaining to the conservation of sandstone comes from conferences and congresses on the conservation of stone. Also, stone conservation appears to have been a studied extensively in the *APT Bulletin* from the late 1970s to the early 1990s. The literature focusing on consolidants and hydrophobic treatments outweighs that on mechanical repair. This imbalance may be due to the fact that consolidants, grouts and coatings are constantly being altered, improved and new created, while there has been little change in pinning with the exception of adhesive formulation or in dimensional stone replacement or composite repair. The trend seen in the 1990s and 2000s was for research and conferences on stone conservation to be based in England and Scotland. Winkler cites a study carried out by Clarke and Ashurst of 24 public buildings in England that were treated with consolidants; examined after 20 years of natural exposure to the buildings' environment, the performance of the consolidants was "not satisfactory."[58] While weathering can now be much more replicated in the laboratory, there are few other studies of treatments carried out and then left to be examined at a later date. More often, they are tested for initial performance. The most recent literature deals mainly with experimentation of chemical variation in consolidants.

Consolidation treatments have been documented since Roman times, and the earliest consolidants were often waxes, oils, hide glues and lime water[59]. From antiquity to the nineteenth century, various paints, waxes and treatments were used to protect the surface of monuments and buildings and to repel water, but "in the later part of the

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[58] Winkler, *Stone in architecture: properties, durability*, 273.
[59] Foulks, William G., ed. *Historic Building Facades: The Manual for Maintenance and Rehabilitation*. New York: Wiley, 1997, 55.

nineteenth century, emphasis shifted towards consolidation of the stone rather than its protection".[60] In his history of "Chemical Treatments for Masonry," Norman Weiss notes the first use of ethyl silicate as a consolidant in 1861; Polish scientist Domaslowski applied epoxies as consolidants in 1967, and shortly after in 1972, S. Z. Lewin effectively applied ethyl silicate in-situ for treatment of sandstone, limestone and concrete.[61] Consolidants were relative newcomers to the scene of masonry conservation, and as early as 1982, in a handbook that explained mechanical repair, composite patching and cutting and resurfacing of architectural sandstone, it was written that consolidation was not recommended because "none of the consolidants currently marketed in the United States has proven successful for large-scale architectural use."[62] Ethyl silicate had been used as a consolidant in Europe, and the company ProSoCo, Inc. began to market ethyl silicate as Conservare OH and Conservare H in the mid-1980s.[63]

Just as there were few consolidants on the market in the 1980s, there were little to no accepted methodologies for testing, selection and application of consolidants. Considering the irreversibility of most consolidants and "the rush to consolidate" seen over the next decade, many architectural conservators and conservation scientists began to establish models for use of consolidants. Winkler was the first in 1985; he outlined testing of consolidant-treated samples to help the user determine which consolidant would be best for his/her project. Charola (1995) and Searls and Wessel (1995) followed, not only with testing, but with guidelines for selection, preparation, application and

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[60] Charola, A. Elena. "Water-Repellent Treatments for Building Stones: A Practical Overview." *APT Bulletin* 26.2/3 (1995): 10.
[61] Weiss, Norman R. "Chemical Treatments for Masonry: An American History" *APT Bulletin* 26.4 (1995): 13.
[62] Lynch, Michael F. and William J. Higgins. *The Maintenance and Repair of Architectural Sandstone*. New York: New York Landmarks Conservancy, 1982, 3.
[63] Weiss, "Chemical Treatments for Masonry: An American History," 13.

maintenance and with philosophies for consolidation of stone. One of the main concepts emphasized by not only these but by several of the authors below is that consolidation can only be successful if the stone deterioration source and problem are resolved.

Much of the literature from 1995 on focuses on reexamining cases where consolidants have been used and exploring new options for consolidants. These articles and papers re-evaluate ethyl silicates and epoxy resins to determine how they have performed and investigate various other polymers, monomers, silanes, acrylics and emulsions. Many questions about consolidants still exist; "little is known about the bonding, if any, that takes place between a consolidant and the substrate" and "little may be known, either, about the molecular structure of the polymer that is deposited within the stone."[64] The more recent work includes testing removal of consolidants that were thought to be irreversible and development of non-destructive testing to evaluate performance of consolidants.

Consolidation is the reestablishment of intergranular cohesion of stone. Consolidants are often fluid solutions that are pulled into the surface of the stone through capillary action. Consolidants either form "adhesive bridges between and among loose mineral grains" or saturate the spaces between loose mineral grains "mechanically locking mineral grains in place."[65] While consolidants must be fluid and have low viscosity in the application process, they must solidify and reinforce once they are within the substrate material. This setting process can happen in one of three ways: a consolidant that is fluid at a high temperature can be applied and allowed to cool and

[64] Price, Clifford A. *Stone Conservation: An Overview of Current Research*. Santa Monica, CA: Getty Conservation Institute, 1996, 17.
[65] Foulks, 55.

harden; a consolidant that is dissolved in a solvent can be applied and is left when the solvent evaporates; or a low-viscosity consolidant can be applied that "undergoes a chemical reaction in situ to give a solid product."[66] Although thought of as a surface treatment because consolidants are applied to the surface of a material, saturation and penetration into the substrate are vital to the success of the consolidant. Consolidants can be brushed or sprayed on, injected, absorbed by capillary rise or, if the object to be conserved is small enough, it can be immersed in the consolidant.

The goal of consolidation is to reestablish the intergranular cohesion of stone, however consolidants used for conservation of historic materials must also possess other important properties derived from a conservation methodology of retreatability and compatibility. An "ideal" consolidant will "fill up the grain structure from the narrowest pores (good penetration and deposition in micropores) and should extend up to the macropores."[67] No matter how they are applied, consolidants enter the surface of the stone through capillary absorption; therefore a consolidant must have appropriate viscosity and surface tension in order to penetrate the material to which it is applied. In order to perform properly and in its highest capacity, the consolidant must "penetrate at least through the weathered layers of stone into sound stone."[68] If the depth of penetration does not reach solid stone, grains are only re-adhered to each other; although beneficial, this will only temporarily succeed or give the appearance of achievement of full consolidation.

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[66] Price, 17.
[67] Sasse H. R. and R. Snethlage. "Evaluation of Stone Consolidation Treatments." *Science and Technology in Cultural Heritage* 5.I (1996): 87.
[68] Searls, Carolyn L. and David P. Wessel. "Guidelines for Consolidants." *APT Bulletin* 26.4 (1995): 43.

The granular disintegration of stone weakens the stone structurally, and consolidants are used to strengthen and reinforce stone. While many materials could be used as stone strengtheners, suitable and effective consolidants mimic the hygric and hydric behaviour of the stone to which they are being applied. Consolidants should not alter other physical properties or performance of the stone; for example, consolidated stone should have a "[similar] coefficient of expansion to the untreated stone."[69] Not only should consolidants not alter the performance of the stone, but the appearance of the treated stone should not differ from that of untreated or original stone, especially when applied to historic fabric. Some of the most successful consolidants in strengthening stone produce the worst aesthetic effects. Finally, although consolidation may be a part of a regular maintenance or conservation plan for a site, after treatment, the stone "should retain the improved properties for an extended period of time."[70] When used incorrectly, consolidants are one conservation treatment that can have deleterious effects to the material to which they are applied.

The main types of consolidants and water-repellent treatments appropriate for use on sandstones are acrylic resins and alkoxysilanes. Other consolidants can only be used with calcareous stones, and still others, such as epoxy resins, which are not UV stable, have proven to be ineffectual in retaining all of the above properties that consolidants should possess. Alkoxysilanes are a class of organic resins that crosslink with silicon in the stone and therefore need a "quartzose rock to become and remain effective."[71] The alkyl group is often a methyl or ethyl group and can be a butyl, propyl or octyl group.

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[69] Ibid.
[70] Ibid.
[71] Winkler, *Stone in architecture: properties, durability,* 270.

The hydrophobicity of the consolidant or water repellent is dependent on this alkyl group, which is attached to the silane, siloxane or silicone.[72] Methyltrimethoxysilane, methyltriethoxysilane and ethyl silicate are among these consolidants. Ethyl silicate has the widest use historically according to the literature, but modified alkoxysilanes with varied chemical structures as well as various solvents, carriers, primers and pre-treatments have been more recently tested and applied. Acrylic resins are copolymers of acrylates and methacrylates, which are also appropriate for consolidation but are often more effective at imparting hydrophobic properties to substrates.

Before treatment, informed selection of the appropriate product is critical and may be achieved through testing. A great majority of the recent journal publications and conference papers on consolidation deal with selection of consolidants and water-repellant treatments and laboratory testing of these products to determine their performance properties. Charola and Rodrigues give a method for assessment of water-repellent treatments, which is also somewhat applicable to consolidation treatments. Effectiveness (absorption, depth of impregnation), harmfulness (change in color, water vapor permeability, hygric dilation and moisture retention) and durability (temperature, UV, air pollution, salts, wetting and drying, and freezing and thawing) should be assessed.[73] Effectiveness, harmfulness and durability of a treatment whenever possible should be tested on samples of the substrate on which it is to be used. All tests show comparison of treated and untreated samples. There is at least one test that can be carried

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[72] Charola, A. Elena. "Water Repellents and Other 'Protective' Treatments: A Critical Review." *Hydrophobe III, 3rd International Conference on Surface Technology with Water Repellent Agents*. Freiburg: Aedification Publishers, 2001, 6.

[73] Charola, A. E. and J. Delgado Rodrigues. "Discussions and Conclusions of the Round-Table on Water-Repellent Treatments." *Science and Technology for Cultural Heritage* 5.I (1996): 113.

out in the laboratory for every property a consolidant or water-repellent treatment should have. Any test that could be run on untreated stone to determine its properties, for example, water absorption by total immersion, could be run on a treated sample.

While some of the literature emphasizes and other literature neglects to mention it, cleaning should always be carried out prior to conservation treatments, and conservation treatments and interventions will ultimately be ineffective or even more harmful if the source of the decay mechanism being treated is not first managed.

4. LABORATORY ANALYSIS

4.1. Sampling and Testing Methodology

Samples and laboratory testing were selected to inform the weathering conditions and decay mechanisms of the Suddards-Manuel-Clark façade. Three spalls were taken as samples, one small sample from the corner of a pier of the Suddards section, one small sample from a pilaster capital and one large sample from the lower step at the top of the monument on the east wall. The small samples were both about 5 centimeters by 2 centimeters by 2 centimeters; the large sample is triangular in shape, and measures about 26 centimeters by 18 centimeters by 2 centimeters. The spall from the pier was sent to American Petrographics Inc. in Roslyn Heights, New York for creation of a thin section for examination of stone structure. The large spall was used for pilot cleaning tests and for mortar matching. The spall from the pilaster capital and four other samples of various conditions manifest on the façade were utilized for identification of components of the stone and various weathering byproducts (Figs. 4.1, 4.2). All sampling and testing was carefully selected and carried out in order to investigate the composition and structure of the sandstone. All testing, laboratory work and microscopy was carried out at the Architectural Conservation Laboratory of the University of Pennsylvania.

Figure 4.1 Sample area of flaking (Source: E. Kemery, 2009)


Figure 4.2 Sample area of blisters (Source: E. Kemery, 2009)

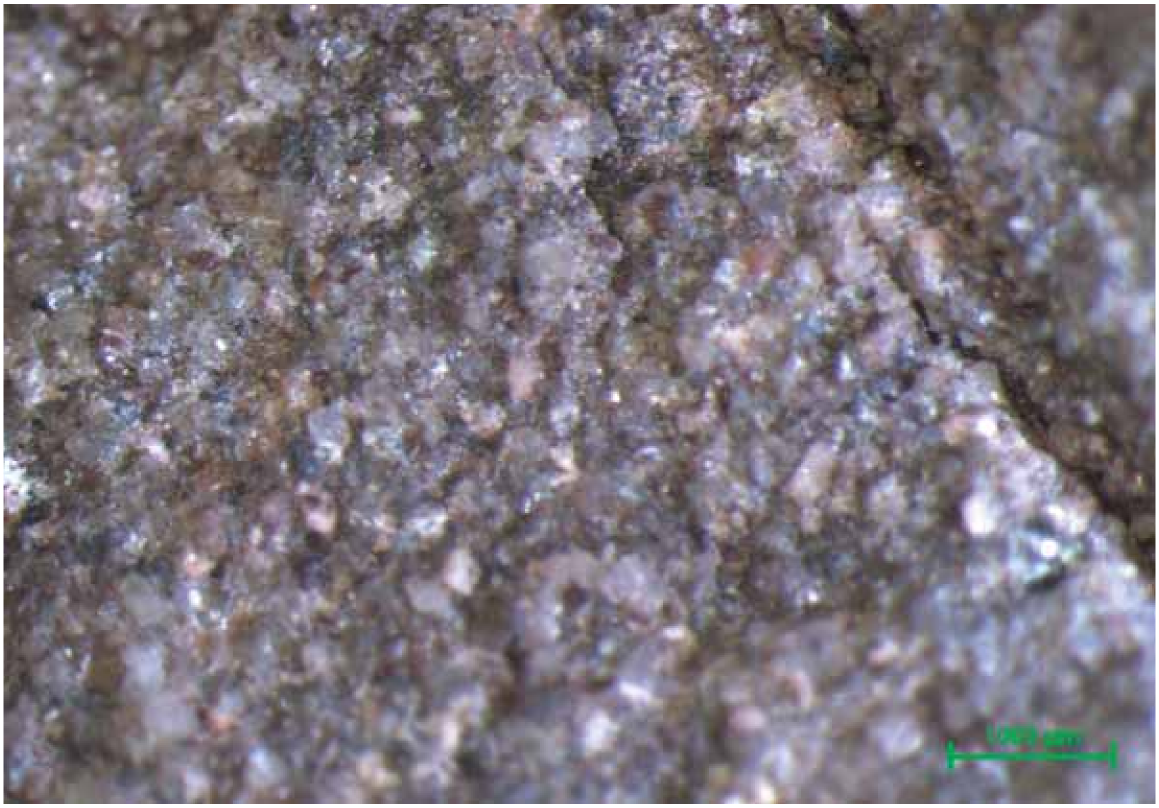

Figure 4.3 Sandstone spall used for petrographic thin section, 50x, Leica MZ16 stereomicroscope, reflected light (Source: E. Kemery, 2009)

4.2. Petrographic Thin Section

4.2.1. Objective

Petrographic thin sections show the grain structure and mineralogical composition of a sample. Examination and analysis of a petrographic thin section is "the most generally useful technique" for sandstone petrology.[74] The purpose of thin section examination is to observe micro-structure so that it can be correlated to performance. Presence of minerals can be determined by shape and size under plane polarized light and by color and extinction properties under cross-polarized light. Grain size, grain distribution and grain contact affect pore structure, and pore structure is "the main factor influencing water transport."[75] Pore radius and network determine capillarity and liquid moisture and moisture vapor transport.

4.2.2. Procedure

A small spall was sent to Leonard Cannone at American Petrographics, Inc. for creation of a thin section. Thin-section samples are about 0.03 mm thick; they are cut with a diamond blade saw and are made thin and even through fine polishing and grinding.[76] This thin section sample was examined with a Nikon Optiphot 2-Pol microscope in polarized and cross polarized light. The illumination source is a 12V-100W long life halogen lamp. Photomicrographs were taken of with the Nikon DSFil color digital camera. Particles were measured using the NIS Elements BR software to

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[74] Blatt, H. *Sedimentary Petrology.* 2nd ed. New York: W.H. Freeman & Co., 1992, 119.

[75] Bourgès, A., K. T. Fehr, S. Simon and R. Snethlage. "Correlation Between the Micro-Structure and the Macroscopic Behaviour of Sandstones." *International Journal for Restoration of Buildings and Monuments* 14.3 (2008): 158.

[76] Nesse, William D. *Introduction to Optical Mineralogy*. 2nd ed. New York: Oxford University Press, 1991, 303.

Figure 4.4 Petrographic thin section, 25x, Leica MZ16 stereomicroscope, reflected light (Source: E. Kemery, 2009)

determine an average particle size in a sample area of 2.60 mm. Percent area of quartz grains and percent area pore space were also calculated in the same sample area.

4.2.3. Results

Particle	Length (µ)	Particle	Length (µ)	Particle	Length (µ)	
1	5.04	17	95.57	33	71.1	
2	10.44	18	141	34	83.51	
3	78.66	19	68.25	35	91.12	
4	217.53	20	87.01	36	59.51	
5	143.35	21	131.43	37	53.36	
6	135.74	22	133.45	38	29.45	
7	272.78	23	213.35	39	36.03	
8	96.11	24	88.15	40	94.1	
9	95.17	25	83.51	41	67.87	
10	366.77	26	97.09	42	100.69	
11	83.08	27	190.5	43	88.22	
12	43.69	28	85.19	44	15.43	
13	63.77	29	151.24	45	130.26	
14	56.95	30	101.24	46	38.2	
15	155.87	31	100.55	47	89.94	
16	42.07	32	57.03		**116.69**	**Average**

Table 4.1 Average particle size

	Percentage of Pores	Sample Size	Percentage of Quartz	Sample Size
	16.02%	2705	70.79%	206
	14.85%	3808	74.84%	288
	16.01%	3275	78.54%	216
	15.52%	3216	78.40%	210
	15.92%	2832	78.94%	240
Average	**15.66%**	3167.2	**76.30%**	232

Table 4.2 Component percentages

Under plane polarized light, quartz crystals are colorless to very pale brown-gray. The quartz crystals are large and angular and appear tightly packed. A few feldspar crystals can be seen, and what appears to be a crystal of biotite was found in one area.

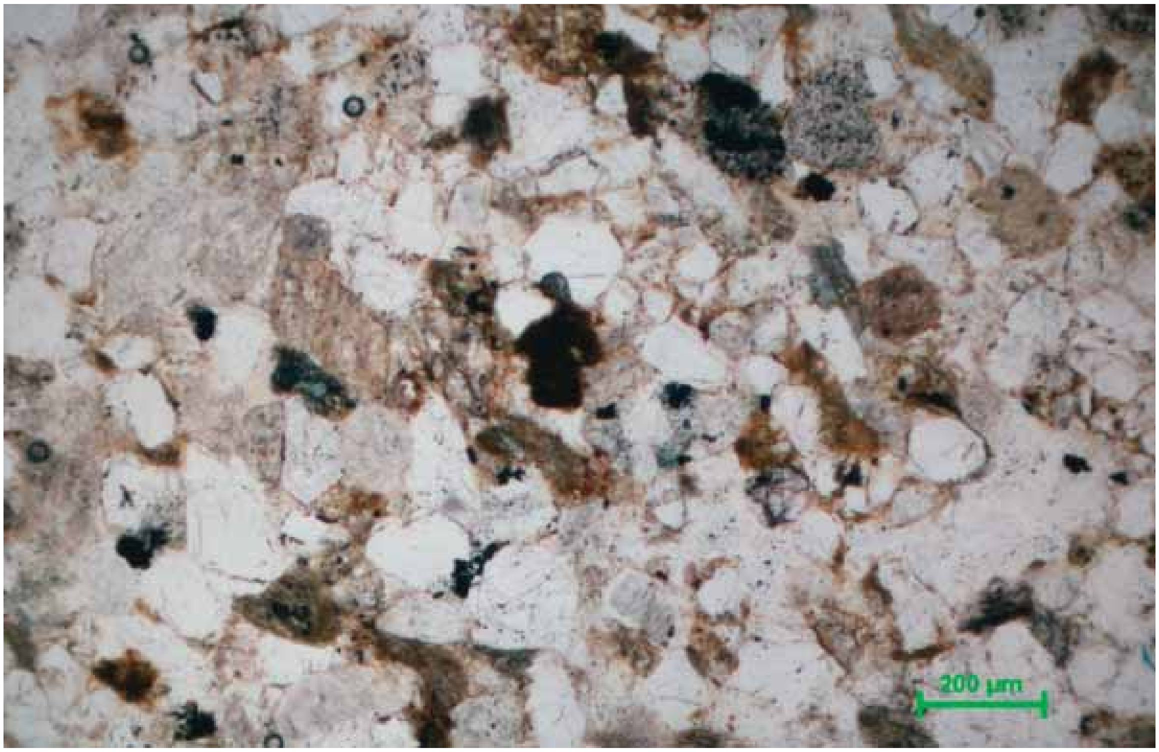

Figure 4.5 Thin section in plane polarized light, 50x, Nikon Optiphot 2-Pol Microscope (Source: E. Kemery, 2009)

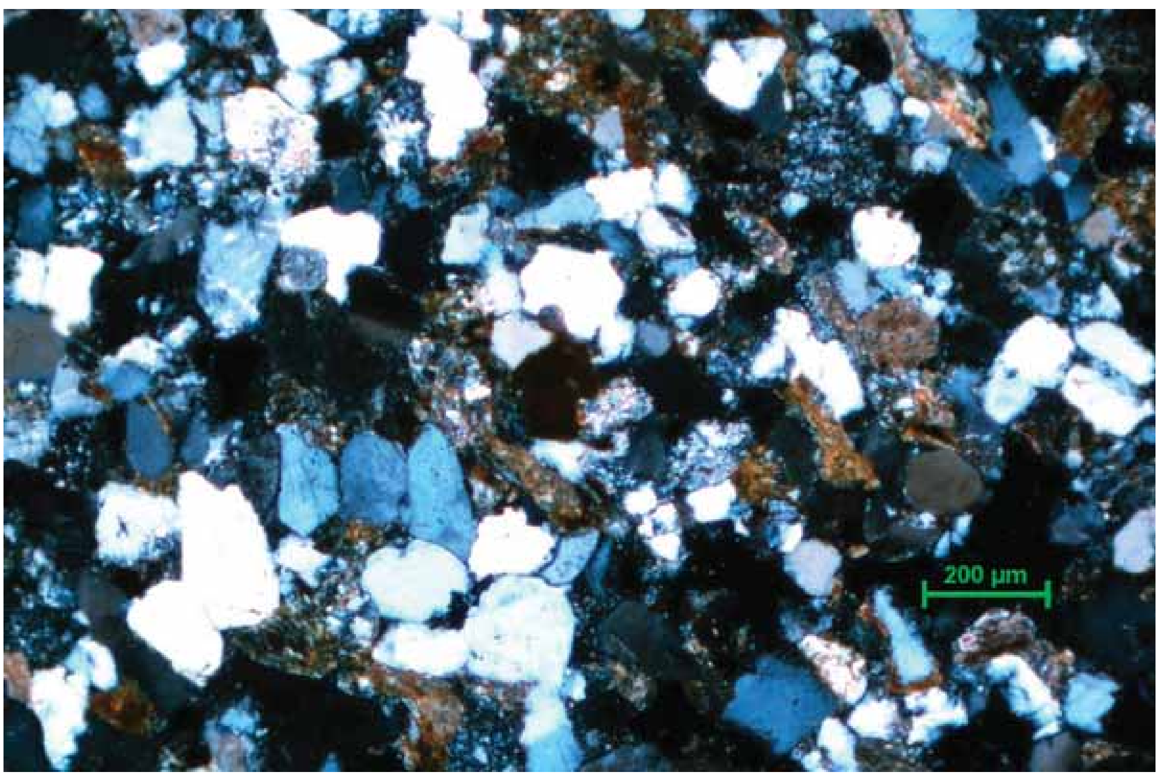

Figure 4.6 Thin section in cross-polarized light, 50x, Nikon Optiphot 2-Pol Microscope (Source: E. Kemery, 2009)

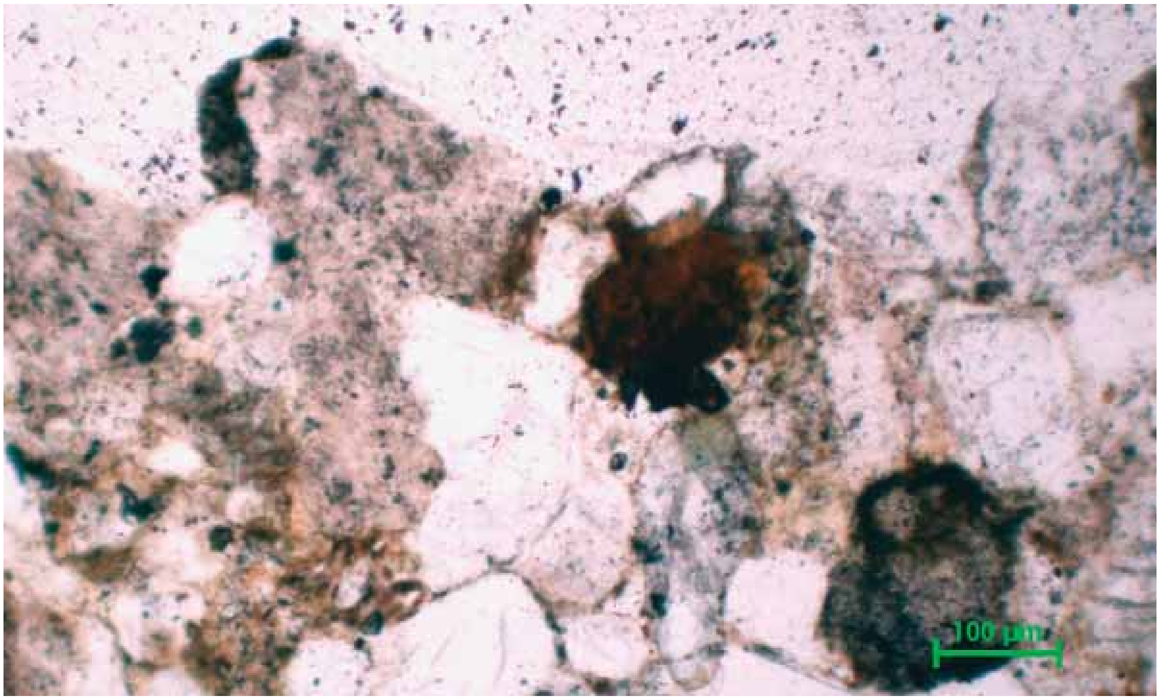

Figure 4.7 Sandstone surface; thin section in plane polarized light, 100x, Nikon Optiphot 2-Pol Microscope (Source: E. Kemery, 2009)

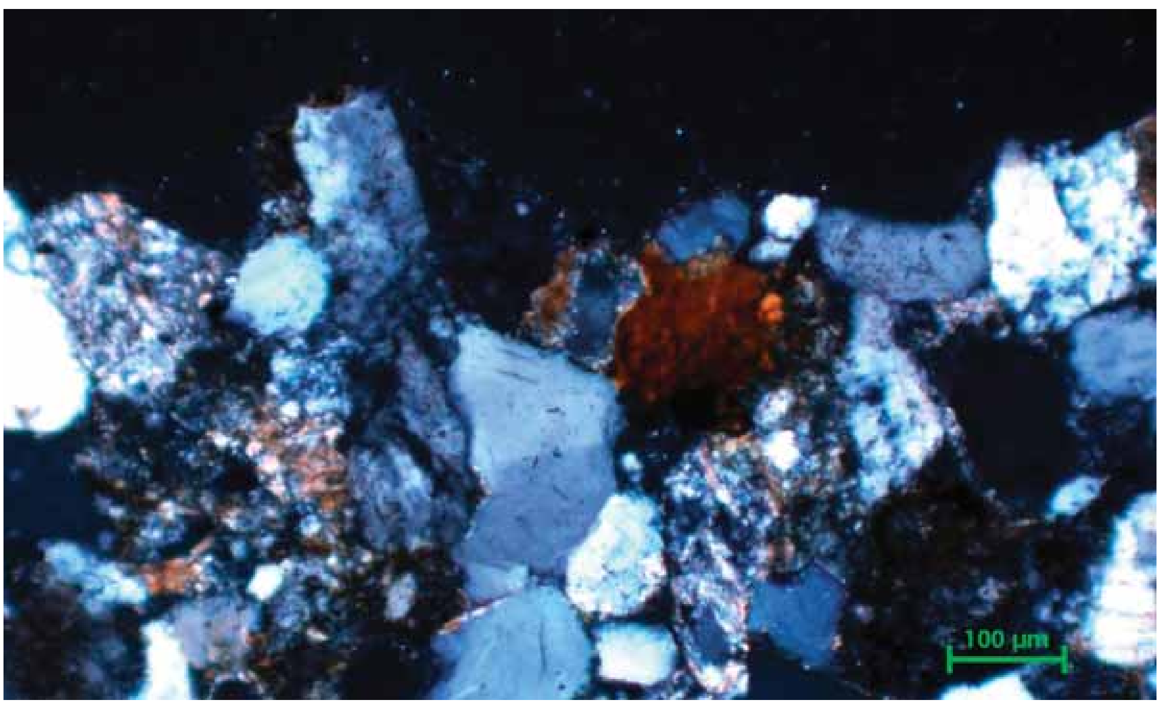

Figure 4.8 Sandstone surface; thin section in cross-polarized light, 100x, Nikon Optiphot 2-Pol Microscope (Source: E. Kemery, 2009)

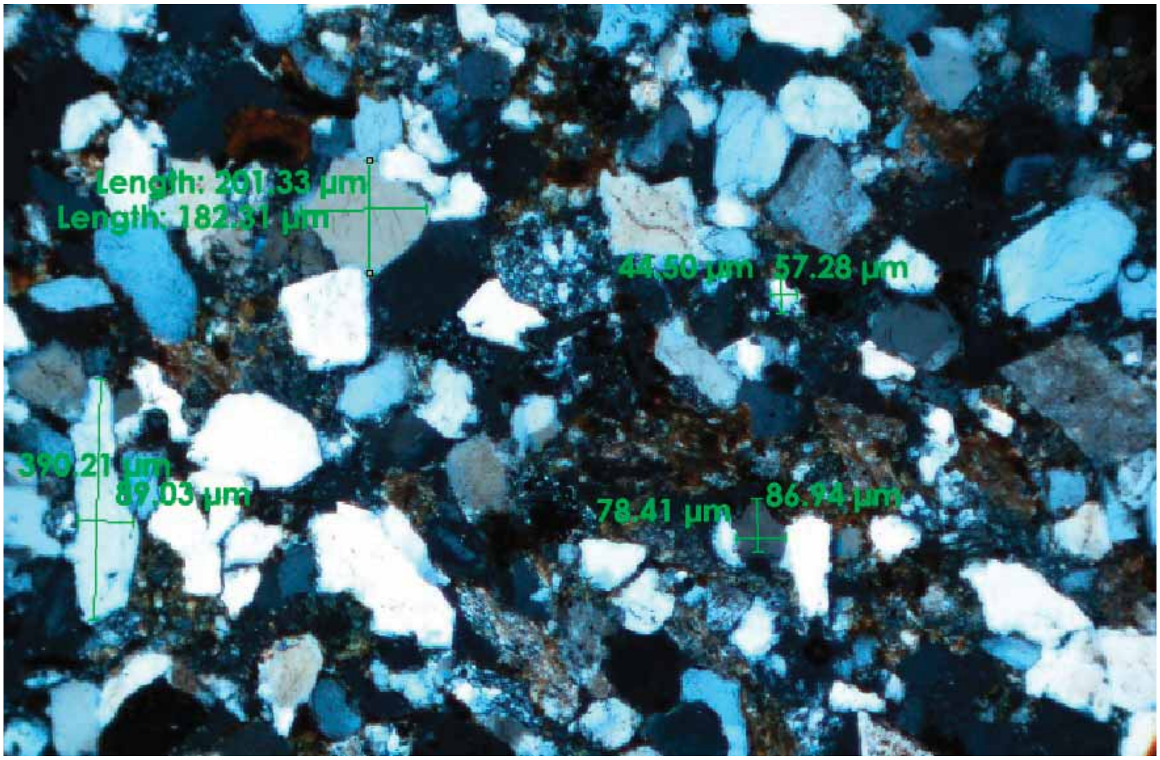

Figure 4.9 Thin section in cross-polarized light with dimensions of three quartz particles, 50x, Nikon Optiphot 2-Pol Microscope (Source: E. Kemery, 2009)

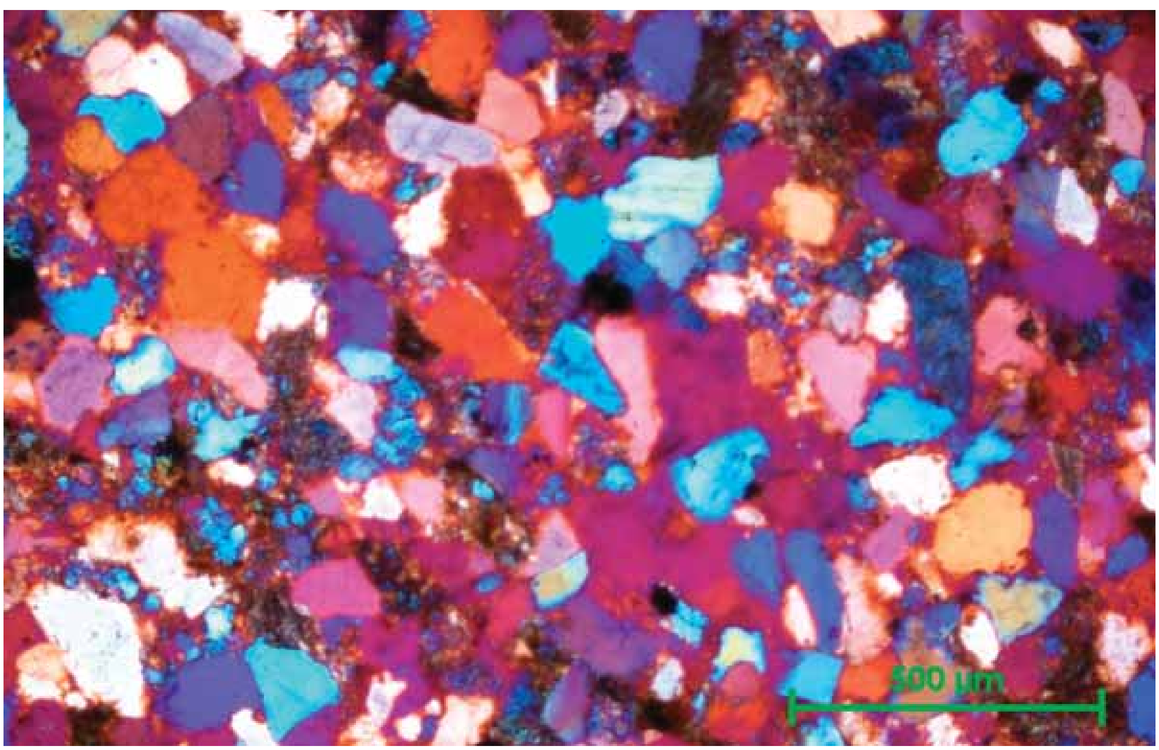

Figure 4.10 Thin section in cross-polarized light with sensitive tint plate (540nm) engaged, 50x, Nikon Optiphot 2-Pol Microscope (Source: E. Kemery, 2009)

Examination of the surface of the sample shows where grains of quartz have been lost. Under cross-polarized light, quartz crystals appear gray to blue. They exhibit extinction but are not very birefringent. Calcite, though difficult to detect, is gray in plane polarized light. When viewed under crossed-polars, it exhibits "mostly pale pinks and greens," which were very intermittent but still visible.[77] When measured, the percent area of pores to quartz grains of five sample areas averaged 15.66% to 76.30% respectively. While this is a relatively high percentage of quartz, there exist sandstones with even higher pore to grain ratios.[78] This low porosity is what gives this sandstone that gives it its strength and resistance to weathering. It is a very high quality stone that is sound and in relatively good condition. Surface alteration is largely related to surface hardening from mineral transport resulting in a case-hardened crust, increasing or decreasing the porosity of the stone respectively. Error in these calculations is solely based on the limitations of the NIS Elements BR software. The software differentiates between components by their color threshold, counts the objects and then calculates their total area percentage of the sample.

[77] MacKenzie, W. S. and A. E. Adams. *A Color Atlas of Rocks and Minerals in Thin Section*. New York: John Wiley & Sons, Inc., 1994, 126.
[78] Bourgès, Fehr, Simon and Snethlage, 158.; Blatt, 106-107.

4.3. Surface Water Permeability

4.3.1. Objective

Testing of surface water permeability is a measurement of water absorption under low pressure. This experiment was carried out on five different sample areas, two in situ, and three in the lab. Comparison of the volume of water absorbed informs relative permeability, which has an immense effect on how porous materials weather. Permeability is dependent on interconnectedness of pores within the stone; these pores and inter-pore connections hold liquid moisture and moisture vapor. Moisture can be damaging to porous materials in several ways, and increased permeability can lead to increased deterioration.

4.3.2. Procedure

This experiment involves the use of a RILEM tube, a pipe-like column for water with "a flat, circular brim" that is affixed to the surface of the porous material with putty. The tube is engineered so that the height of the column of water inside the tube is 9.8 centimeters, which "corresponds to a pressure of 961.38 pascals (approximately 0.14 psi), or a dynamic wind pressure of 142.6 kilometers per hour (approximately 88.5 mph)."[79] After the tube is fastened to the surface of the stone with the putty, deionized water is gently poured into the tube until it reaches the 0 gradation mark. Measurements were taken and recorded every five minutes for the period of one hour. The top of the column of water moves down the pipe indicating that water has been absorbed into the surface of the stone. The reading is taken at the bottom of the meniscus of the column of water using the gradations on the tube. This process was carried out on a differentially eroded

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[79] Gale, Frances. "Measurement of Water Absorption." *APT Bulletin* 21.3/4 (1989): 8.

surface and on a case-hardened and soiled surface of the Suddards-Manuel-Clark façade in situ (Figure 4.11). In the laboratory, the same process was carried out on the interior face of the large sample from the monument (Figure 4.12).[80] This sample had been kept in a desiccator at 23% humidity prior to the experiment and was used as the control. Two other materials were chosen to compare with the Suddards-Manuel-Clark sandstone, a brownstone and a quartzite. These materials were chosen because it was conjectured that the brownstone would have a similar permeability to the sandstone and that the quartzite would have a much lower permeability than the sandstone.

4.3.3. Results

	Case-hardened/ soiled S-M-C sandstone, in situ	**Quartzite**	**Brownstone, parallel to bedding plane**	**S-M-C Sandstone control**
Time (min)	**Water absorbed (cm^3)**			
0	0	0	0	0
5	0	0	0.08	0.3
10	0	0	0.15	0.35
15	0.01	0.02	0.2	0.4
20	0.02	0.05	0.2	0.45
25	0.02	0.05	0.25	0.5
30	0.02	0.05	0.25	0.55
35	0.03	0.06	0.3	0.6
40	0.03	0.07	0.4	0.7
45	0.04	0.08	0.5	0.7
50	0.04	0.08	0.6	0.75
55	0.05	0.09	0.7	0.8
60	0.05	0.1	0.75	0.85

Table 4.3 RILEM tube surface water permeability testing

[80] Pilot cleaning tests had been carried out on the exterior surface of this sample; it was unknown how this treatment might have affected the data collected in the RILEM tube experiment, so the interior surface of the stone was used as the control.

Figure 4.11 RILEM tube testing in situ on a case-hardened surface (Source: E. Kemery, 2009)

Figure 4.12 RILEM tube testing in the lab on sandstone control sample (Source: E. Kemery, 2009)

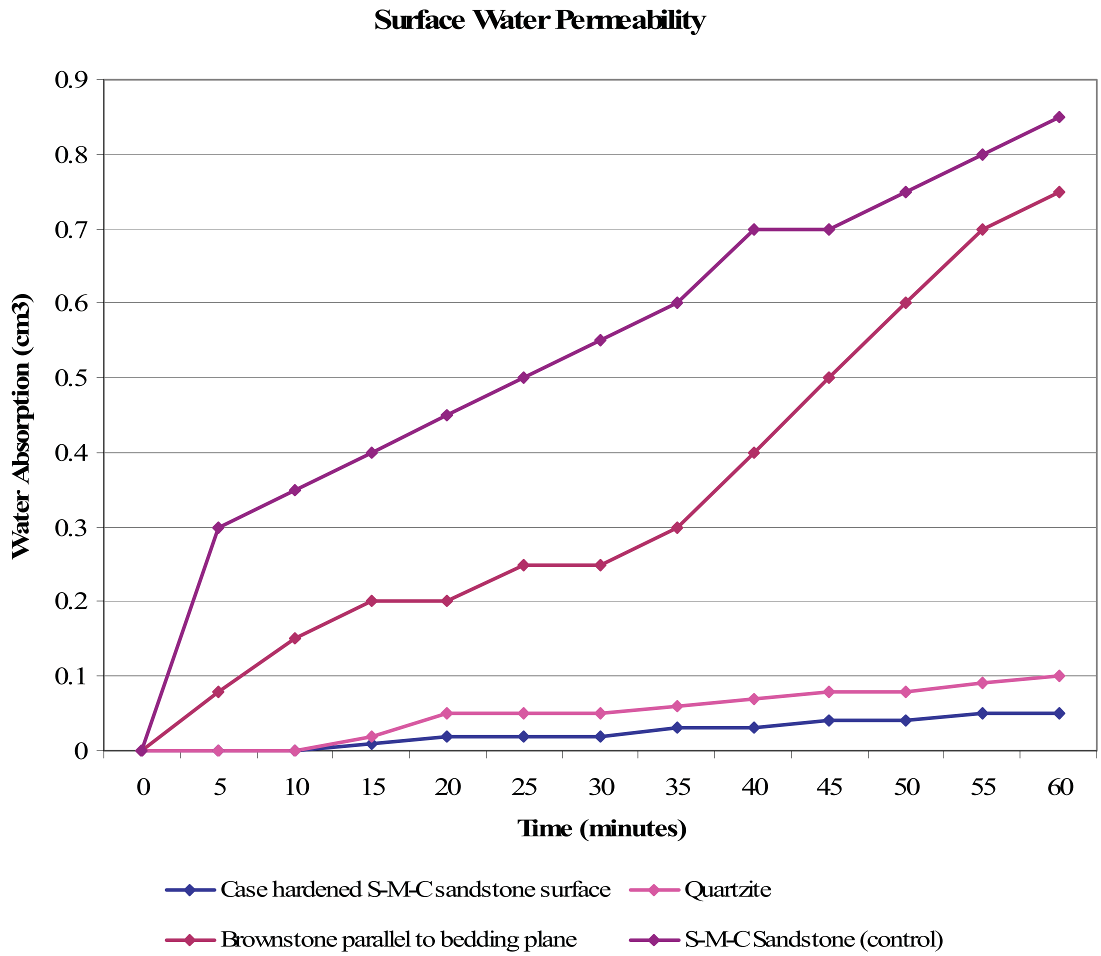

Figure 4.18 Water absorption (cm^3) as a function of time (min) in surface water permeability testing

In situ, application of RILEM tubes to various weathered surfaces was tested. The putty did not affix the tube to the surface of flaking or blistered areas, and although it adhered to a differentially eroded surface, which began to absorb water, it failed at 8 minutes and fell off (Figure 4.13). For the time that it did remain on the surface of the stone, more water was absorbed (0.02 cm^3) than the other in situ testing area, a case-hardened and soiled sandstone surface. Data collected shows that this case-hardened surface absorbed even less water than the quartzite; the action of case hardening and/or

Figure 4.13 Failed RILEM tube testing in situ on a differentially eroded surface (Source: E. Kemery, 2009)

soiling caused a change in the permeability of the stone at its surface. This suggests that pore diameter or pore volume of the black crust is less than that of the original stone surface that has not had surface enrichment. These areas of case hardening eventually begin peeling and then spall off. While similar in permeability to the brownstone, the sandstone control sample absorbed even more water. The relatively high permeability of the Suddards-Manuel-Clark sandstone as compared to the other samples tested confirms that the permeability of the stone is directly related to susceptibility to weathering. As can be seen in the survey of conditions on the façade of the monument, several of the decay mechanisms require water and use pores to transport salts and minerals through the stone.

Sources of error in this test include inaccuracy inherent in the apparatus itself; the RILEM tubes used lacked intermediate gradations, so error in reading of measurements is possible. The test also is inaccurate if water leaks between the surface of the stone, as in the case of the differentially eroded surface. If putty is squeezed inward and obstructs the surface area in contact with the water, the measured absorption will be reduced and will not be consistent between tests on various materials.

4.4. Moisture and Soluble Salt Content

4.4.1. Objective

Porous materials contain moisture vapor and liquid water within their pores. For porous materials, especially like the Suddards-Manuel-Clark sandstone that are deteriorating due to moisture and salts, moisture and soluble salt content can be very significant indicators of decay mechanisms. For this experiment, the spalled capital sample (referred to in the data as "Sandstone"), flakes, blisters and the two types of peeling were tested for moisture content and soluble salt content.

4.4.2. Procedure

To determine moisture content, samples were weighed and then put in a 110ºC oven for more than 24 hours. They were cooled in a dessicator at 23% humidity, and cycled between the oven and dessicator until a steady dry weight was reached. Where w_e is the weight of the sample before drying, and w_d is the weight of the dry sample, moisture content is expressed as:

$$\% \text{ Moisture content (w/w)} = \frac{(w_e - w_d) \times 100}{w_d}$$

To determine soluble salt content, the samples were then ground in an agate mortar until broken down into a coarse to fine powder. The powdered samples were weighed and then put in a 110ºC oven for more than 24 hours. They were cooled in a dessicator at 23% humidity, and cycled between the oven and dessicator until a steady dry weight was reached. After drying, samples were transferred to individual beakers and covered with enough deionized water to dissolve soluble salts. Beakers were stirred for 2 hours with a magnetic stirrer bar; the stirrer bar was then removed, and the samples were allowed to settle for several hours. Samples were then filtered through Whatman No. 1 Qualitative filter paper. Solid sample left on the filter paper was transferred to a 110ºC oven for more than 24 hours. After oven drying, the samples were cooled in a dessicator at 23% humidity, and cycled between the oven and dessicator until a steady dry weight was reached. Where w'_d is the dry weight of the crushed sample and w_{dryf} is the weight of the dry solid that was left on the filter paper, soluble salt content is expressed by:

$$\% \text{ Soluble Salt content (w/w)} = \frac{(w'_d - w_{dryf}) \times 100}{w'_d}$$

4.4.3. Results

Sample Name	Sample #	w_e	w_d	Moisture Content
Sandstone	1-0	15.93 g	15.64 g	1.85%
Flakes	1-1	5.33 g	5.21 g	2.30%
Blisters	1-2	4.99 g	4.43 g	12.64%
Peeling	1-3	3.93 g	3.89 g	1.03%
Peeling, Opaque	1-4	10.66 g	10.58 g	0.76%

Table 4.4 Moisture content of samples

Sample Name	Sample #	w'_d	w_{dryf}	Soluble Salt Content
Sandstone	1-0	15.62 g	14.93 g	4.42%
Flakes	1-1	5.16 g	4.71 g	8.72%
Blisters	1-2	4.40 g	3.43 g	22.05%
Peeling	1-3	3.88 g	3.80 g	2.06%
Peeling, Opaque	1-4	10.44 g	9.89 g	5.27%

Table 4.5 Soluble salt content of samples

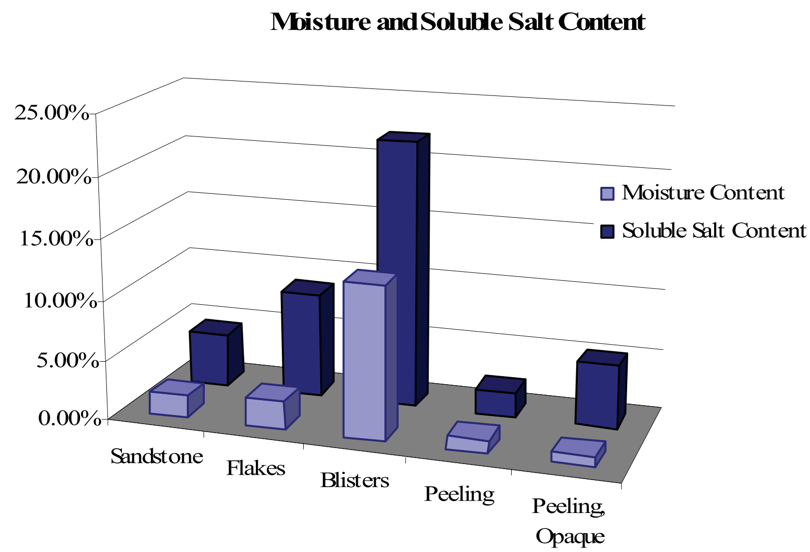

Figure 4.21 Moisture and soluble salt content of samples

The moisture content in the samples is related to the relative humidity of their environment and the pore structure of the material. Blisters collected from protected areas beneath the blind arcades have both the highest moisture content and soluble salt content. The blisters are also very often located with visible efflorescence and subflorescence. The sandstone spall that was tested should give a somewhat representative moisture and soluble salt content for the Suddards-Manuel-Clark stone; however, the sample was located in close proximity to blistering, which may have attributed to its soluble salt content. The moisture content of the sandstone is lower than that of the flakes. This disparity could have easily been predicted as flaking is detachment of non-original surface; where original surface has been lost, it is not unexpected that porosity and permeability would be greater. The face of the stone beneath hardened crusts is often weaker in strength than both the crust and the sound stone behind it. The flakes also often occur in conjunction with subflorescence which pushes the flakes from the surface of the stone; these salts are further indication of the soluble salt content in the flakes. Both types of peeling had low moisture content and low soluble salt content. The case hardening that is occurring in areas of peeling is much less permeable than the original surface and therefore results in lower moisture content. Although peeling is sometimes found in occurrence with subflorescence, there is little soluble salt in the peeling because lower permeability indicates that salts in solution are not entering into the material as easily as in other places. Sources of error in this experiment result loss of material or hygric gain during grinding, transfer from container to container and filtering.

4.5. Ion Test Strips for Semiquantitative Concentration Determination

4.5.1. Objective

Soluble salt content by semiquantitative concentration determination of sulfate SO_4^{2-}, chloride, Cl^- and nitrate, NO_3^- ions was performed using commercially available testing strips. Identification of ions present in soluble salt solutions can point to what salts, like $NaSO_4$, $CaSO_4$, $NaNO_3$, NaCl, are cycling in these materials.

4.5.2. Procedure

Merck's Merckoquant® test strips were used: the EM Quant Sulfate (SO_4^{2-}) #10019-1 test strip, Chloride (Cl^-) #10079-1 test strip and Nitrate (NO_3^-) #10020-1 test strip. One of each strip was dipped into a separate beaker of each salt solution. After dipping the test strip in the solution for one second, excess solution was shaken off. Chloride and nitrate test strips were left to develop their color readings for one minute, and sulfate test strips were left to develop their color readings for a period of two minutes. After this short period, colors developed on the strip due to interaction with the ions present were compared to the keys located on each package. Sensitivity of sulfate strips ranged from 0-1600+ mg/L. Sensitivity of chloride strips ranged from 0-3000+ mg/L. Sensitivity of nitrate strips ranged from 0-500+ mg/L.

4.5.3. Results

Sample Name	**Sample #**	w_{sample}	**Soluble Salt Content**	SO_4^{2-}	Cl^-	NO_3^-
Sandstone	1-0	15.62 g	4.42%	3.20-6.40%	0%	0.20-0.40%
Flakes	1-1	5.16 g	8.72%	4.65-6.20%	0%	0.10%-0.19%
Blisters	1-2	4.40 g	22.05%	more than 6.36%	0%	0.20-0.40%
Peeling	1-3	3.88 g	2.06%	1.55-3.09%	0%	0.19-0.39%
Peeling, Opaque	1-4	10.44 g	5.27%	0.34-0.67%	0%	0%

Table 4.6 Semiquantitative concentration determination of salts

Blisters had the highest soluble salt content, and the highest content of sulfate ions. These ions are most likely components in gypsum as $CaSO_4 \cdot 2H_2O$. Other salts such as magnesium sulfate or sodium sulfate may also be present. Magnesium sulfate and sodium sulfate can both originate from groundwater, and magnesium sulfate can also be deposited by pollutants.[81] The case-hardened black crust is pollutant ion-related, which may contain magnesium sulfate. None of the samples tested positive for any concentration of chloride ions. Mortar is often the source of magnesium chloride, and deicing salts often leave calcium chloride and sodium chloride in masonry buildings. All of the samples except the opaque peeling contain similar concentrations of nitrates. Calcium nitrate and sodium nitrate are both transported through groundwater, and nitrates often indicate biological activity. Sources of error in this experiment can result from any error in the creation of the solutions and from subjective reading and color matching of the test strips to the key. Analysis is only semiquantitative because each color correlates with a range of possible concentration.

[81] Winkler, *Stone in architecture: properties, durability,* 161.

4.6. Qualitative Test for Carbonate Reaction

4.6.1. Objective

The reaction of calcium carbonate with hydrochloric acid results in the evolution of carbon dioxide gas in the reaction $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$. To determine whether or not there is a carbonate fraction (calcite, dolomite) in the sandstone of the Suddards-Manuel-Clark monument, a simple qualitative test based on the principles of the more comprehensive and quantitative ASTM D3042 Standard Test Method for Insoluble Residue in Carbonate Aggregates. Carbonate rocks react differently to atmospheric pollution than purely silicate rocks. Formation of gypsum crusts would only be possible with some calcareous content in the stone.

4.6.2. Procedure

A small sample taken from the large triangular spall was ground into a medium fine powder in an agate mortar. Samples of flakes, blisters and both types of peeling were also ground for testing. One or two drops of 2M HCl were released onto each crushed sample, and if bubbles were produced upon contact of the hydrochloric acid with the sample, carbon dioxide was released indicating the presence of calcium/magnesium carbonate.

4.6.3. Results

Sample Name	Sample #	Reaction
Stone	1-0	moderate reaction
Flakes	1-1	none
Blisters	1-2	slight reaction
Soiled Peeling	1-3	very slight reaction
Soiled Peeling, matte	1-4	slight reaction

Table 4.7 Observations of evolution of carbon dioxide gas

The reaction of the crushed stone sample with hydrochloric acid indicates that the sandstone of the Suddards-Manuel-Clark monument is slightly calcareous. This was confirmed by the thin section examination where microcrystalline calcite was observed under polarized light microscopy. This suggests that the lower reactivity in the surface blisters, flakes and peeling in combination with the presence of sulfates may be due to the formation of gypsum. An important concept revealed to apply to this sandstone is the susceptibility of the stone to different types of weathering than if it did not have a calcareous component. While gypsum "is soluble in hydrochloric acid" it will not "effervesce or gelatinze."[82] The hydrochloric acid reacts with calcium carbonate to release carbon dioxide, and gypsum is calcium sulfate. Sources of error in this experiment are inconsequential because the analysis is only qualitative; observation of effervescence is subjective depending on the observer.

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[82]Stone, Ralph Walter. *Gypsum Deposits of the United States*. US Government Printing Office, 1920.

5. METHODOLOGY

5.1. Conditions Glossary

To record and assess the masonry conditions of the monument, it was necessary to create an illustrated glossary of the current conditions. Terminology was derived from the 2008 *ICOMOS-ISCS: Illustrated Glossary on Stone Deterioration Patterns*, from the University of Pennsylvania's Architectural Conservation Laboratory and Research Center's *The Pennsylvania Blue Project: Documentation and Conditions Survey of the Exterior Marble Masonry* and from the writings of Bernd Fitzner.[83] Each glossary term is illustrated with one or two representative photographs of the condition and with corresponding graphic symbology in AutoCAD. The location of the area where each photograph was taken is indicated on the photomontage below. Glossary definitions are greatly based on terminology from the ICIMOS-ISCS publication but are tailored to apply specifically to the Suddards-Manuel-Clark monument, its sandstone and its unique construction.

[83] Fitzner, Heinrichs and Kownatzki, "Weathering Forms – Classification and Mapping;" Fitzner, Bernd and Kurt Heinrichs. "Damage Diagnosis on Stone Monuments – Weathering Forms, Damage Categories and Damage Indices." Understanding and Managing Stone Decay: Proceedings of the International Conference Stone Weathering and Atmospheric Pollution Network (SWAPNET) 2001. Eds. R. Prikryl and H. A. Viles. Prague: The Karolinum Press. 11-56.; Fitzner, B., K. Heinrichs and R. Kownatzki. "Weathering damage on Pharaonic sandstone monuments in Luxor-Egypt." *Building and environment* 38.9-10. (2003): 1089-1103.

Figure 5.1 Suddards-Manuel-Clark monument rectified photomontage

MASONRY CONDITIONS GLOSSARY

CONDITION

Crack

SYMBOLOGY

DEFINITION

An individual fissure, generally 0.5 to 2 millimeters in width but clearly visible to the naked eye, resulting in partial (a) or full (b) separation of the masonry unit

(a)

(b)

MASONRY CONDITIONS GLOSSARY

CONDITION

Incipient spall

SYMBOLOGY

DEFINITION

Planar or lens shaped detachments that have become partially separated from the stone unit

MASONRY CONDITIONS GLOSSARY

CONDITION

Dimensional loss

SYMBOLOGY

DEFINITION

Complete (a) or partial (b) absence of masonry units resulting in significant incompleteness of form

(a)

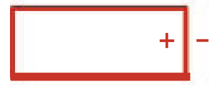
(b)

MASONRY CONDITIONS GLOSSARY

CONDITION

Displacement

SYMBOLOGY



DEFINITION

A significant deviation from the plane of the masonry generally due to post-construction settlement

MASONRY CONDITIONS GLOSSARY

CONDITION

Open joint

SYMBOLOGY

DEFINITION

Absence of bedding mortar and/or widening of joint between masonry units after construction

MASONRY CONDITIONS GLOSSARY

CONDITION

Biological growth, macro

SYMBOLOGY

DEFINITION

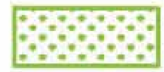
Presence of higher plant forms, including their root remnants

MASONRY CONDITIONS GLOSSARY

CONDITION

Biological growth, micro

SYMBOLOGY



DEFINITION

Presence of microflora, such as (a) fungi, (b) algae or (c) lichens

(a)

(b)

(c)

MASONRY CONDITIONS GLOSSARY

CONDITION

Peeling

SYMBOLOGY

DEFINITION

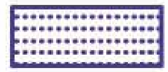
Thin, dark detachments of original stone surface of a roughly uniform in thickness that reveal a lighter, friable suface below; not related to bedding.

MASONRY CONDITIONS GLOSSARY

CONDITION

Flaking

SYMBOLOGY



DEFINITION

Areas of thin, irregular detachments from the surface of the stone that are roughly of uniform thickness; does not include original surface of the stone

MASONRY CONDITIONS GLOSSARY

CONDITION

Blistering

SYMBOLOGY

DEFINITION

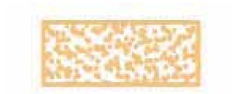
Localized areas of separated, raised hemispherical elevations resulting from the detachment and deformation of the surface of the stone; does not include original surface of the stone; located in protected areas

MASONRY CONDITIONS GLOSSARY

CONDITION

Granular disintegration

SYMBOLOGY



DEFINITION

Detachment of single grains or aggregates of grains producing a sugar-like debris; does not include original surface

MASONRY CONDITIONS GLOSSARY

CONDITION

Differential erosion

SYMBOLOGY

DEFINITION

Localized areas of surface loss, resulting in (a) partial loss of detail or (b) planar contours

(a)

(b)

MASONRY CONDITIONS GLOSSARY

CONDITION

Efflorescence

SYMBOLOGY

DEFINITION

White powdery or whisker-like salt crystals on the surface of the stone that may be soluble or insoluble

MASONRY CONDITIONS GLOSSARY

CONDITION

Previous repair

SYMBOLOGY

DEFINITION

Subsequent alterations made for structural, aesthetic or functional reasons

5.2. Photodocumentation

Color photographs were taken with a six mega-pixel Olympus C-60Z digital camera. Photographs for the photomontage elevation were taken with the camera mounted on a tripod with the camera lens parallel to the façade of the monument. Because the monument follows the curve of the Cemetery's radiating circular arc plan, photographs were not always taken from an exact distance from the façade of the monument but at approximately two meters away. Detail photographs were also taken for conditions descriptions. Measurements were taken of the monument and some of its architectural features for creation of a measured drawing in AutoCAD. The photographs to be photomontaged were uploaded to a Toshiba Satellite A70 computer, and rectification and photomontage were completed using Photoshop CS (Figure 5.1).

5.3. Conditions Assessment

The finished photomontage was printed in color on 11x17 inch paper and placed in acetate sheet covers. The completed conditions glossary was brought into the field for reference, and the conditions assessment took place over four site visits. All recording was conducted from the ground and from the top of the monument when necessary. Conditions were studied and recorded carefully onto acetate sheets. In order to draw the conditions in AutoCAD, the photomontage was scaled to the measured drawing of the monument's façade. The fourteen acetate sheets with recorded conditions were used to reproduce weathering forms digitally, some from the hard copy acetate drawings and some from scanned images of the acetate recordings. Detail photographs taken of the entire monument after the conditions assessment were used to ensure conditions were recorded in the correct locations. Non-linear conditions were drawn as polygons and were hatched with the corresponding symbology of the conditions glossary. Each condition was drawn in a separate layer in AutoCAD so that each could be analyzed separately and in relation to the other mechanisms and associated features as well.

6. CONDITIONS

6.1 DESCRIPTION OF THE CURRENT CONDITIONS

The weathering mechanisms exhibited on the façade of the Suddards-Manuel-Clark monument and inventoried in the conditions glossary are all the result of the response of the sandstone to mechanical and chemical processes. The sources of these processes may be intrinsic, that is inherent in the material or extrinsic, relating to the design, fabrication or environment of the vault. The sandstone used to construct this monument was well chosen; the material itself is dense and fine-grained with moderate porosity and has weathered reasonably well. However, its calcareous binder accounts for some of these deterioration mechanisms. The monument is built into a bank and acts essentially as a retaining wall. Much of the condition of the vault can be attributed to this design as well as to the extrinsic factors of site and climate. The conditions themselves are often interrelated and causal as well.

Conditions of the façade of the vault are discussed in detail below; the interior is inaccessible, and through limited visual examination, a few conclusions can be made about the conditions within the vault that may have some effect on the façade. Photographs of the Clark section of the monument taken through what were likely designed as vents give some degree of view of the vault interior. The brick structure of the vault can be seen as well as a render covering the brick on some surfaces. This render is cracked in areas and has been lost and exposes the brick backer wall in other areas. The walls and the ceiling of the vault display what appears to be black microbiological

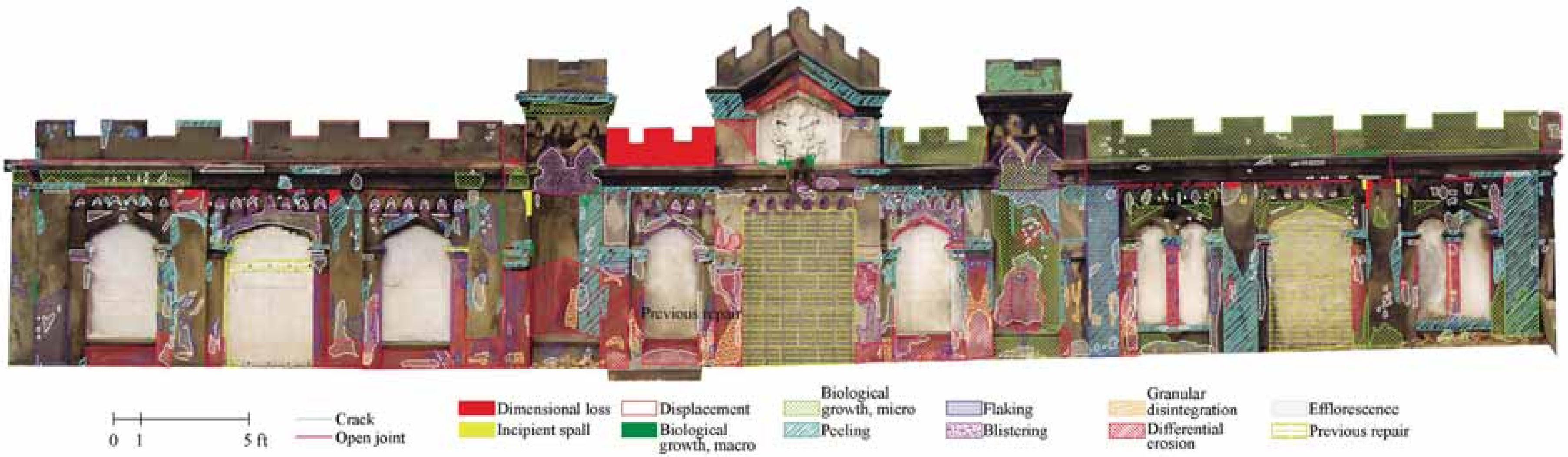


Figure 6.1 All conditions of the Suddards-Manuel-Clark monument

colonization, indicating that conditions of moisture and temperature are hospitable to biological growth. Efflorescence is also present on the walls and the ceiling and is especially concentrated at joints.

Photographs taken both when liquid water was present on the walls and ceiling of the monument and when no liquid water was visible show both soluble salts and insoluble salts. When liquid water is present either due to groundwater entering into the monument or vapor condensation, soluble salts go into solution, and heavy deposits of insoluble salts remain. Also prominent in photographs are stalactites that have formed from horizontal areas within the vault. These stalactites range in length, width and concentration. The calcium carbonate in these formations may come from the sandstone, brick, mortar or render; not enough is known about the construction of the interior to rule out any of those sources.

Photographs of the interior of the Clark section of the monument show that the walls and ceiling of the vault may become saturated with water. Water is entering into the monument through various transport and wetting processes. Because the vault is built into a bank, all sides of the vault except the façade are in contact with earth, and there is a thin mound of grass and soil on the top of the monument as well as slate paving stones at the west end of the monument, which certainly have an effect on groundwater transport. Stone gutters at the north and south corners of the monument's east wall would have once diverted water collected at the top of the monument. Unfortunately these gutters were designed to be too short to have alleviated entry of liquated water; water collected in these gutters would have been diverted only a few inches away from the east wall of the

Figure 6.2 Interior of Suddards-Manuel-Clark vault showing brick sub-grade structure and white marble tablet (Source: E. Kemery, 2009)

Figure 6.3 Interior of Suddards-Manuel-Clark vault showing black biological colonization (Source: E. Kemery, 2009)

Figure 6.4 Interior of Suddards-Manuel-Clark vault showing stalactites and calcite buildup (Source: E. Kemery, 2009)

Figure 6.5 Interior of Suddards-Manuel-Clark vault showing efflorescence (Source: E. Kemery, 2009)

Figure 6.6 Top of the Suddards-Manuel-Clark monument, note slate paving stones in foreground and ventilation sources at center (Source: E. Kemery, 2009)

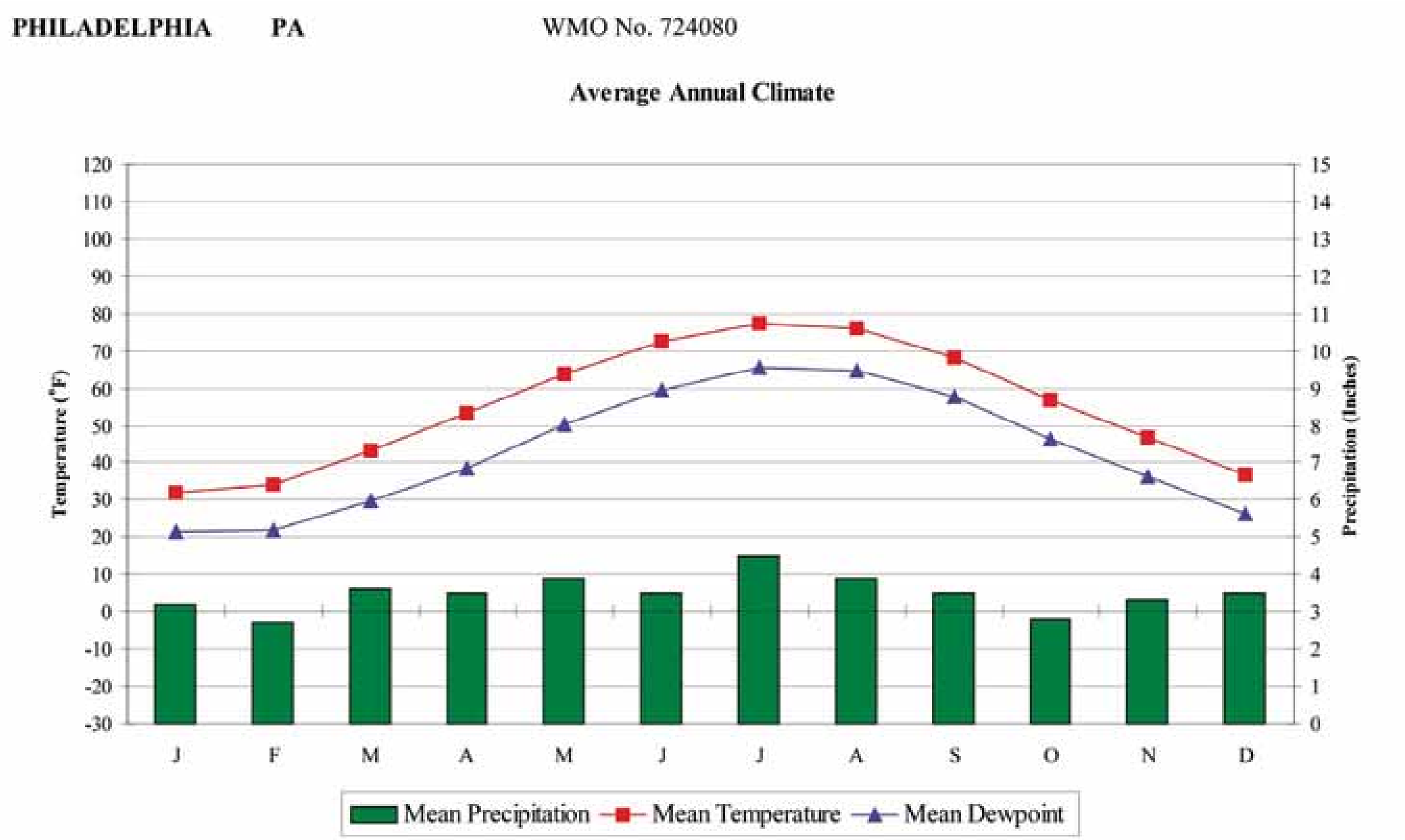


Figure 6.7 Average Annual Climate for Philadelphia, PA (Source: Engineering Weather Data, 1996)

Figure 6.8 Interior of Suddards-Manuel-Clark vault under dry conditions (Source: E. Kemery, 2009)

Figure 6.9 Interior of Suddards-Manuel-Clark vault under wet conditions (Source: E. Kemery, 2008)

monument, and furthermore, erosion and changes in topography at the top of the tomb have almost completely obviated these gutters' efficacy. The source of liquid water is groundwater which is being transported by gravity from above and transported greatly through rising damp via capillarity. Vapor is also being transported through the walls on all sides through convection; in the summer months when the groundwater temperature/the temperature inside the monument is lower than the dew point, condensation occurs.[84] Vapor transport is therefore not only occurring at the outer surface of the stone, but vapor is also transported through the stone into the interior.

On the façade of the monument, moisture vapor and liquid moisture are likewise either the source of or related to the surficial conditions. The surficial deterioration mechanisms outnumber structural conditions, which can be greatly explained in relation to each other.

[84] Engineering Weather Data, Philadelphia, PA. National Climatic Data Center. United States Department of Commerce.

6.1.1 CRACK

A crack is an individual fissure, generally 0.5 to 2 millimeters in width but clearly visible to the naked eye. A crack results in partial or full separation of the masonry unit. Cracking in the Suddards-Manuel-Clark monument is very limited. Cracks that have formed at the base of one of the piers of the Suddards section are most likely compression cracks. Cracks in three other areas at the tops of piers, one in each family section, are accompanied by an incipient spall. These cracks and incipient spalls are located at the outer edges of these piers and may also be associated with compression cracking due to this location. Two very fine lateral cracks appear in areas of original stone surface loss below the crenellations of the west tower. The cracks are located on an exposed and protruding area of the tower and are most likely the result of thermal cycling. Although these cracks are the most minimal in width, they have the potential to result in incipient spall followed by dimensional loss after further cycling, especially considering their location in a projecting area.

The largest of the cracks of the vault's façade is located on the wide flat face of the second pier of the Suddards section. Unlike the other cracks in the piers it is neither vertical nor parallel to the length of the pier. This crack cuts across almost the entire face of the pier and curves downward becoming narrower from west to east (left to right). While the structural reason behind this crack is unclear, it may be an inherent flaw in this particular masonry unit or from quarrying, salts in and at the edges of the crack are visible. The presence of salts also indicates that water has entered into the crack; both moisture and salts can aggravate and deteriorate this crack over time, which could lead to a large dimensional spall or structural problem should the crack fracture the entire face of the pier.

Figure 6.10 Crack

6.1.2. INCIPIENT SPALL

An incipient spall is a planar or lens shaped detachment that has become partially separated from the stone unit. It is often bounded by a joint, as is the case with the incipient spalls of the Suddards-Manuel-Clark vault. There is very little incipient spalling on the monument's façade. All but one of the areas of incipient spall are located directly below the simplified entablature that runs across the entire façade of the monument. Three of these incipient spalls are located on the wide flat piers, one in each family section; one is located at the end of a blind arcade. An incipient spall by definition is always accompanied by at least one crack but usually more are present. The spalls appear to be the result of compression cracking. They are small, ranging from about 1-1/8 inches long by 2-1/4 inches wide to about 6 inches long by 1-1/4 inches wide. One of the areas of incipient spall is located on the capital of one of the small piers. The area that projects most on this capital has been subject to blistering and flaking. Blisters and flakes were lost as was much of the cementing material, and what has been left behind is a system of fine cracks, some incipient spalling and some dimensional loss. This case differs from the others in that it is likely the result of thermal cycling and loss of cementing material rather than as a result of compression stresses.

The largest of these incipient spalls is about 10-3/4 inches long by 3-1/2 inches wide. This area of cracking and incipient spall is located directly under one of the masonry blocks that supports the west tower. The line of the bounding crack can be followed almost directly from the outer edge of this tower, and because it is a very narrow area that supports the tower, it can be assumed that a combination of compression and ensuing shearing is the cause of the cracking and spall. Spalls also eventually lead to dimensional loss.

Figure 6.11 Incipient Spall

6.1.3. DIMENSIONAL LOSS

Dimensional loss is complete or partial absence of masonry units resulting in significant incompleteness of form. In only one area is an entire masonry unit absent, which is where a crenellation is missing between the west tower and central pedimented segment of the Manuel section. This crenellation and its pair are the smallest unit blocks of crenellations. The Suddards-Manuel-Clark monument has a history of vandalism, and this loss is certainly a product of human force rather than natural forces.[85] The missing crenellation block remains at the base of the façade where it fell from the parapet.

The other areas of dimensional loss are only partial absence of masonry units. Like the cracks and incipient spall of the monument, dimensional losses are relatively few and small in size, and they exhibit the same pattern of occurring below the joint at the base of the simplified entablature. Some but not all losses abut incipient spalls and cracks; in most case, dimensional losses would follow cracks and incipient spalls. Like the incipient spalls, dimensional losses are often located at the corners of the wide flat piers of the monument's façade. In two areas, there are dimensional losses of projecting features. At least four if not more of the dimensional losses of the monument are related to the weathering of the joint under the entablature that runs the length of the façade. In the two areas where there are mid-entablature breaks in the masonry units, differential erosion has occurred from water running down the joint between the two stone blocks. The combination of differential erosion, dissolution of cementing material and the locus of water carving its way down the face of the flat pier beneath has led to dimensional loss

[85] Woodlands Cemetery Lot Cards.

as well as erosion. Other areas of dimensional loss appear to be related to inherent flaws in the stone.

Figure 6.12 Dimensional Loss

Figure 6.13 Crack, incipient spall and dimensional loss

6.1.4. DISPLACEMENT

Displacement of a masonry unit is the significant deviation of the unit from the plane of the masonry resulting after construction. Displacement is often due to post-construction settlement, which is a possibility in the crenellations of the Suddards-Manuel-Clark monument. All of the vault's crenellations have been displaced except the western-most crenellation. The smallest of these crenellations stands between the pedimented central bay and the east tower of the Suddards section. Its pair has been disengaged through vandalism and remains lying at the foot of the monument. It is highly unlikely that the remaining small crenellation has been shifted out of plane as much as it is simply by mechanical forces; it is more likely that the attempt to shove the crenellation from its position failed but left it somewhat misaligned.

For the larger parapet sections that have been displaced more subtly, the cause is most likely a natural physical mechanism. The crenellations act as a parapet to the vault and are some of the few masonry units that are above grade. They rise from the top of the monument and are exposed on all sides whereas most of the other individual masonry blocks are bounded either by soil or by the tomb's interior. These blocks are therefore more susceptible to heating and cooling and have greater head loads than the other stone blocks of the masonry system. Their exposure to heating and cooling causes greater expansion and contraction, enough to create a ratcheting effect, which, over time, could cause the amount displacement displayed in three of these parapet blocks. The massiveness of the individual blocks used in the design of the monument gives it a unified and cohesive appearance but may have affected the condition of displacement. The design of the long blocks of these three crenellations, about 9-1/2, 7-1/2 and 9-1/4 feet in length to a comparatively short alternating height of 10 and 17 inches, increases their susceptibility to more fluctuations in temperature. This ratcheting effect would have ground down mortar leading to partial or total mortar loss, which only exacerbates the potential for movement of these crenellations.

The smaller easternmost crenellation is a single block that has been displaced. This displacement is likely the result of settlement. This block has moved both laterally east-west and north-south, having shifted outward away from the rest of the façade to the east (right) and north, backward from the plane of the façade. There is also evidence that a thick, wide strap, most likely metal, once tied this block to the adjacent long crenellation. Loss of mortar can be seen in the widening of the joint between the two stone units. In all cases of displacement here, the condition of displacement is obviously accompanied by the condition of open joint as displacement widens spaces between masonry units in at least one direction

Figure 6.14 Displacement

Figure 6.15 East corner of the Suddards-Manuel-Clark monument, gutter drain hole and evidence of a strap that held these two blocks together (Source: E. Kemery, 2008)

6.1.5. OPEN JOINT

An open joint is the absence of bedding and/or widening of the joint between masonry units after construction. In the case of the Suddards-Manuel-Clark monument, there are several causes behind the condition of open joints. While some of these open joints are from settlement, many correspond to displacement of masonry units resulting in deviations of the stone from the plane of the façade. Where masonry units have been displaced, there are open joints at the edges, and expansion and contraction due to heating and cooling grind down mortar leading to loss over time. While not much is known about the construction history of the monument itself, open joints on either side of the Manuel section towers may correspond to the construction sequence if the Suddards and Clark sections were constructed after the central Manuel section. While settlement is possible, open joints may also be a result of construction of the tombs and vaults in close proximity to the Suddards-Manuel-Clark vault. The large vault inscribed "E. A. Warne" directly to the west of the monument was constructed c.1863, and a large tomb with crypt directly to the north of the monument was constructed c.1852.[86] Five other tombs in close proximity to the north of the vault have dates ranging from 1870 to 1921. Construction of these tombs, especially the vault and crypt, is likely to have structurally affected the monument and may have had some effect on the formation of open joints, but construction processes are undocumented so it there is no way to be sure.

A few of the open joints are related to differential erosion, where erosion occurring around the joints has caused areas of stone to weather away, leaving an opening and allowing the weathering out of mortar. Several of the openings have also

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[86] Ibid.

been created by thick growth of mosses, woody stems and roots and correspond with the condition of macrobiological growth.

Figure 6.16 Open Joint

6.1.6. BIOLOGICAL GROWTH, MACRO

The condition of macrobiological growth is the presence of higher plant forms, including their root remnants. Every incidence of macrobiological growth on the monument is in a joint. In some, but not all areas, this joint can be an open joint. Macrobiological growth can be sustained by "nutrients from simple plants, like bacteria and algae, on and between stone blocks" and take root "especially in areas of ample moisture supply."[87] Macrobiological growth has caused open joints in some cases, and in other cases, open joints have allowed for macrobiological growth. Areas of large macrobiological growth are usually in the form of woody stems and roots, which can be living or root remnants. "The pressure of a growing plant root…is surprisingly high," and this type of growth is what has widened joints.[88] Areas of individual macrobiological growth are usually in the form of thick areas of moss growth and small green plants. Colonization of biological growth is concentrated along the joint under the crenellations of the Suddards section of the monument and in areas under the crenellations of the Clark section of the monument. This joint is at grade, providing macrobiological growth in these areas with moisture and nutrients from the soil.

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[87] Winkler, *Stone in architecture: properties, durability*, 226.
[88] Ibid.

Figure 6.17 Biological growth, macro

6.1.7. BIOLOGICAL GROWTH, MICRO

The condition of microbiological growth is the presence of microflora, such as fungi, algae and lichens. Conditions mapping illustrates a visible pattern of microbiological growth. Microbiological growth is greatly concentrated on the east half on the monument. This concentration is the result of the site of the monument; two large trees grow just south of the monument and hang close to the façade. A small leafy tree also grows on the top of the vault. Light blocked by these trees prevents moisture evaporation from this area of the façade. Because the monument is south-facing, there is less microflora than if it were north-facing; the west half of the monument is as such greatly free from microbiological colonization. In areas where microflora is present on the west half of the monument, it follows a secondary pattern that also applies on the east half of the monument. Microbiological colonization occurs in coved areas, such as the carved pilaster capitals and entablature.

Microbiological growth in the form of algae is the most prevalent type of growth. It is located in coved areas, such as the entablature and the statuary cove of the east tower, and in recessed or covered areas, such as the triangular insets above the arched bays and areas below the arches of the bind arcades. These areas are moist, cool, dark and hospitable to biological colonization. Algae are also located at the base of the wide, flat piers of the Clark section of the monument as well as in the areas below the marble panels. Algal growth on sandstone has been found to be exponentially greater than non-algal growth.[89] The presence of fungi and lichens is much less manifest. Fungi and

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[89] Young, M. E. and D. Urquhart. "Algal and Non-Algal Soiling Rates of Some Scottish Building Sandstones." Eds. Melanie S. Jones and Rachel D. Wakefield. *Aspects of stone weathering, decay and*

lichen can be found in joints between masonry units and are generally spread across the crenellations of the east half of the vault. Various fungi, lichen and algae form beneath the surface of peeling, flaking and blistered areas, although they are not visible until accelerating peeling, flakes and blisters are removed. In some cases, this growth has the effect of causing peeling, flakes or blisters to spall from the surface of the stone. Both microbiological and macrobiological growth also can have the effect of holding moisture on or in the stone and can secrete organic acids.[90]

Microbiological colonization can also be a factor in chemical decay of stone. Certain bacteria are "nitrogen-fixing," and can convert calcium carbonate to calcium nitrate.[91] The sandstone of the Suddards-Manuel-Clark monument is a slightly calcareous sandstone. The chemical process "carried out by nitrifying bacteria" is[92]:

$$2CaCO_3 + (NH_4)_2SO_4 + 4O_2 = Ca(NO_3)_2 + CaSO_4 + 2CO_2 + 4H_2O$$

Not only is calcium nitrate produced, but calcium sulfate is produced in this reaction as well. While atmospheric interaction can form gypsum in protected areas, nitrogen-fixing bacteria can explain formation of gypsum on unprotected stone surfaces. Samples taken of flakes and blisters and from areas of peeling were tested for presence of ions, and were found to contain NO_3^- and SO_4^{2-}, which are likely in the form of the salts $Ca(NO_3)_2$ and $CaSO_4$. Presence of nitrates is often an indicator of biological activity.

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conservation: Proceedings of the 1997 Stone Weathering and Atmospheric Pollution Network Conference. London: Imperial College Press, 1999, 123.

90 Winkler, *Stone in architecture: properties, durability*, 222.

91 Ibid., 218.

92 Ibid., 219.

Figure 6.18 Biological growth, micro

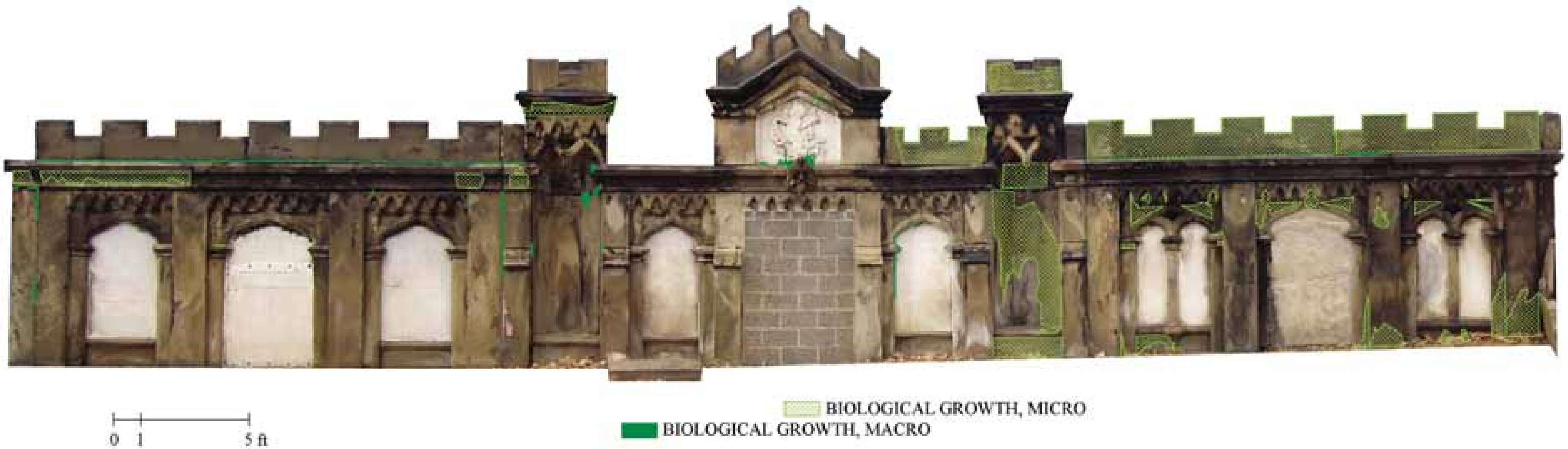

Figure 6.19 Macrobiological and microbiological growth

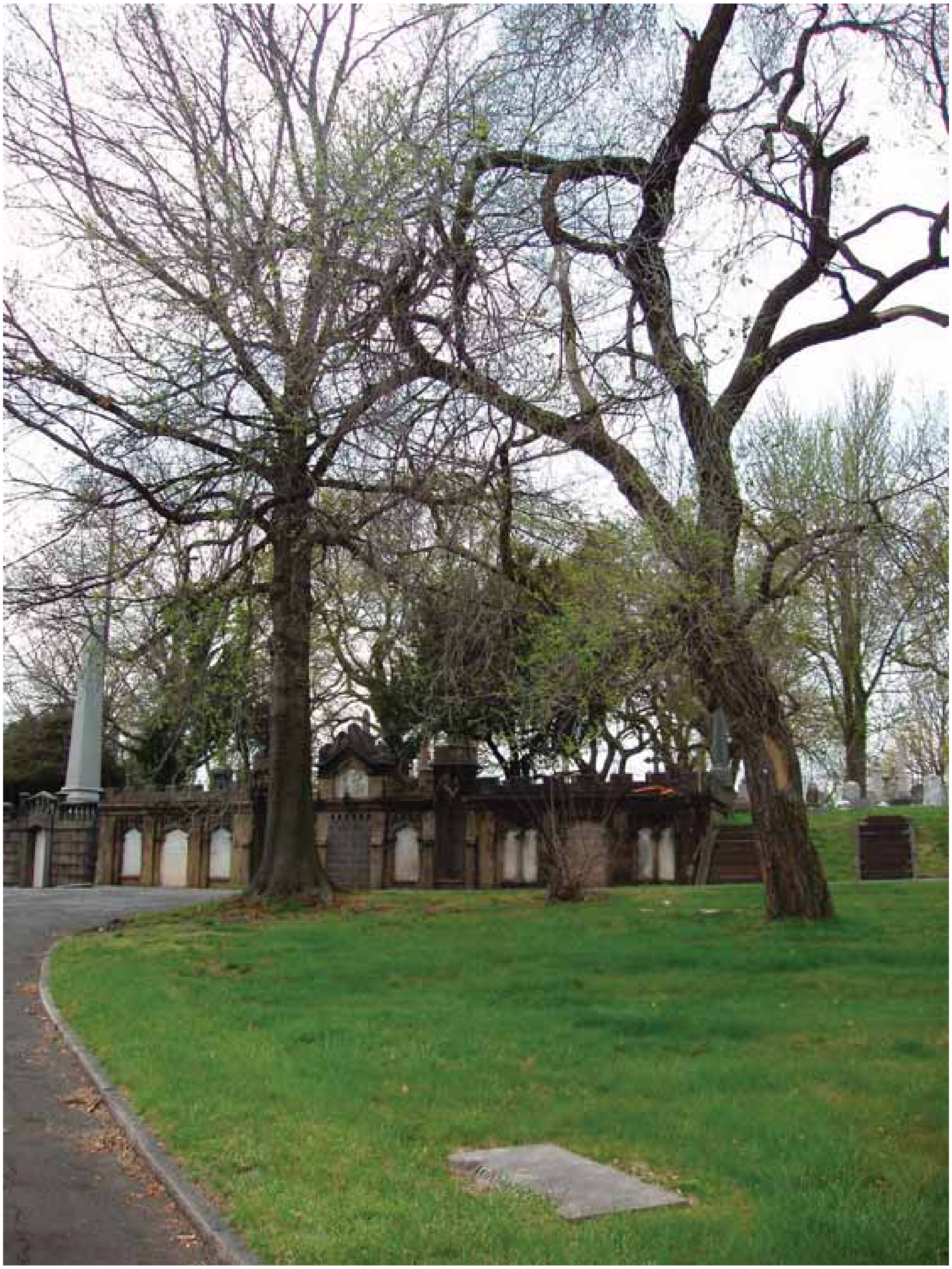

Figure 6.20 View from south of the monument; note overhanging trees (Source: E. Kemery, 2009)

Figure 6.21 Microbiological colonization beneath blisters (Source: E. Kemery, 2009)

Figure 6.22 Microbiological colonization beneath peeling on crenellations (Source: E. Kemery, 2009)

6.1.8. PEELING

Peeling is thin detachments of original surface from the stone of a roughly uniform thickness that reveal a lighter colored surface below. Peeling is characterized by a dark gray to black color; however, not all areas of dark gray to black stone were recorded as peeling. Only those surfaces that are actively detaching from the dimensional masonry units are considered peeling. At first it was unclear if the darkening of the stone was as a result of soiling or of microbiological growth. Cleaning with Cathedral Stone ® Products D/2 Biological Solution, which eliminates algae, bacteria, fungi and lichen, successfully removed algae from cleaned areas but had no effect on the darkened areas. It was therefore decided that this darkening was a result of case hardening and atmospheric soiling. In some areas, peeling is opaque, matte and darkened. Both structurally and chemically, the opaque peeling is different from the more commonly-occurring peeling, which is simply darkened.

The opaque peeling is generally darker than the common peeling and has a smoother texture. The more common peeling ranges in color from only slightly darker than the interior stone surface to as dark as the opaque peeling in a few areas. Generally, it takes on the texture of the stone and is slightly to moderately rougher than the opaque peeling. Samples of each type of peeling were taken and examined with a Leica MZ16 stereomicroscope in reflected light with Volpi Intralux 5000 fiber optic illumination. Photomicrographs were taken with a Nikon DSFil color digital camera at both 50x and 100x showing this textural difference between the two types of peeling.

The peeling is most likely the result of gypsum formation and the dissolution and migration of calcite to the surface of the stone. This case-hardened layer a densification of the surface, which separates from the parent stone in thin detachments, leaving friable flaking stone beneath. A thin black crust is also visible where blackening is…even more superficial."[93] This is usually found in sandstones with calcareous binding cement" like the sandstone of the Suddards-Manuel-Clark monument. While the sampled opaque peeling was found to contain little SO_4^{2-} and no NO_3^-, the sampled common peeling contained levels of NO_3^- similar to the rest of the samples and a high concentration of SO_4^{2-}. Confirmatory analysis of the peeling samples in the form of an SEM dot map would show whether the detachments are composed of sulfur or silica. Silica that has "leached from the fine clay fraction" can be "redeposited to form a dense surface layer" in a different type of case hardening process.[94] The two types of peeling also react differently to qualitative carbonate testing with hydrochloric acid; the opaque peeling was slightly more reactive to the hydrochloric acid than the common peeling, though both samples released very minute amounts of carbon dioxide. The reason for this chemical difference probably relates to the degree of sulfation. Silica that has "leached from the fine clay fraction" is in this case hardening process "redeposited to form a dense surface layer.

Active thin detachments of darkened surface occur all over the façade with no particular pattern. Evidence of areas where peeling has already occurred is clearly identifiable by the lighter color of these areas. Peeling occurs on wide flat surfaces like the piers of the façade but not on the wide flat surfaces of the crenellations. Peeling is

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[93] Robinson, D. A. and R. B. G. Williams. "The Weathering of Hastings Beds Sandstone Gravestones in South East England." Eds. Melanie S. Jones and Rachel D. Wakefield. *Aspects of stone weathering, decay and conservation: Proceedings of the 1997 Stone Weathering and Atmospheric Pollution Network Conference*. London: Imperial College Press, 1999, 5.
[94] Ibid.

also found on carved elements like many of the small pilaster capitals and projecting mouldings of the Manuel section but not on the carved arcades. Thicker detachments on water-protected areas such as pilasters under mouldings may be due to slow gypsum formation while thinner black peeling can be found in exposed areas. Where peeling has already been largely lost, if case hardening is left, it remains at the outer edges and on corners. On long rounded and projecting areas like the mouldings of the entablature, the thin detaching crusts have split lengthwise. While peeling is occurring in larger areas on the east half of the monument, it is occurring in more small patches on the west half of the monument. In a few areas, removed peeling shows subflorescence beneath the peeling surface and in other areas, removal of peeling reveals colonization of microflora. Insects also create habitats between the stone surface and the areas of peeling and leave behind organic byproducts.

Figure 6.23 Peeling

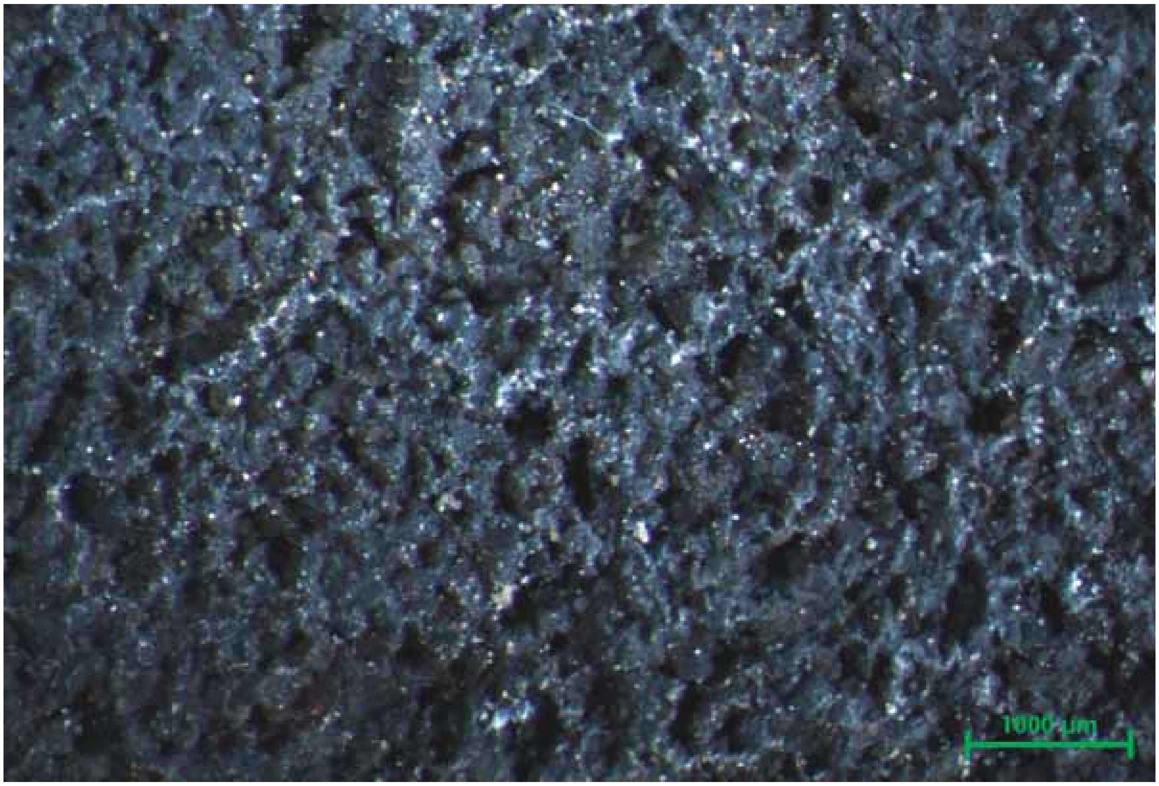

Figure 6.24 Surface detail of peeling surface, 50x, Leica MZ16 stereomicroscope, reflected light (Source: E. Kemery, 2009)

Figure 6.25 Surface detail of opaque peeling, 50x, Leica MZ16 stereomicroscope, reflected light (Source: E. Kemery, 2009)

6.1.9. FLAKING

Flaking consists of areas of thin, irregular detachments from the surface of the stone that are roughly of uniform thickness. While flaking and peeling are very similar conditions, peeling is the detachment of original surface, and flaking is the detachment of the surface that is left after peeling has occurred. Flaking is not nearly as extensive of a condition as peeling, and it is more concentrated on the west half of the monument, as the east half of the monument retains more of its original surface. Flaking and peeling occur together in a few areas where both original and new stone surface are detaching concurrently. Flaking can occur both as areas of multiple small flakes or as areas of single large detachments. Although the stone does not have discernable bedding, flakes come off in laminar units, and in a few areas, areas are visible where flakes that have spalled are actively re-flaking. Flaking can also be the result of newly formed gypsum on freshly exposed stone after peeling.

In many instances, efflorescence also accompanies flaking, and removal of flakes sometimes reveals subflorescence. Salt weathering is the cause of flaking in these areas. Almost all occurrences of flaking are on flat, vertical surfaces of the façade. These flat, vertical surfaces have moderate drying rates, and salt solutions will remain in “the surface zone, so that the liquid front will not withdraw into the stone.”[95] Salt cycling, when salts alternate recrystallization and return to solution, on the surface of the stone in areas of moderate drying rates will create flakes of detachment. In areas of low drying rates, salt cycling instead causes granular disintegration.

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[95] Snethlage, R. and E. Wendler. “Moisture Cycles and Sandstone Degradation.” *Report of the Dahlem Workshop on Saving Our Architectural Heritage: The Conservation of Historic Stone Structures Held in Berlin 3-8 March 1996.* Ed. N.S. Baer and R. Snethlage. Chichester: John Wiley & Sons, 1997, 18.

Figure 6.26 Flaking

Figure 6.27 Flaking and efflorescence

6.1.10. BLISTERING

Blistering is localized areas of separated, raised hemispherical elevations resulting from the partial detachment and deformation of the surface of the stone. Like the condition of flaking, blistering does not apply, nor does it occur, on the original surface of the stone. Blisters can be thin, friable and flake-like or dense and crust-like; blisters range in color from the color of the stone to darkened tones similar to those of peeling. Individual blisters can range in size from a few millimeters to three or four inches. Blistering is only located in protected or recessed areas, and it almost always accompanied by efflorescence. The most severe areas of blistering appear inside the upper coved areas of the two towers of the Manuel section. Other blisters have formed in recessed bays between piers, especially in the areas under the arches of the blind arcades. Blisters in the areas under the arches of the blind arcades are the most dense and hemi-spherical and some of the darkest in color.

A sample of blisters had a moisture content much higher than other samples taken from the monument (spall, flakes, opaque peeling and common peeling). Testing for presence of ions also showed the highest concentrations of both NO_3^- and SO_4^{2-} as compared to the other samples taken. These levels of SO_4^{2-} as well as the location of blisters in sheltered areas suggest the presence of $CaSO_4 \cdot 2H_2O$, gypsum. The sandstone of the Suddards-Manuel-Clark monument is slightly calcareous, and the calcite in the sandstone reacts with the SO_2 air pollutants to form gypsum. Because gypsum is soluble in water, "rain-washed…surfaces rarely accumulate" gypsum crusts, which explains why blisters are only located in covered areas of the stone.[96] Darkened areas are gypsum

[96] Winkler, *Stone in architecture: properties, durability*, 194.

blisters that have trapped soiling during formation. Thicker and denser blisters are crusts that have built up over several years of dry and wet deposition of pollutants. One source notes:

> Blistering may occur simply as a result of gypsum crust growth, where volume increases and thermal conductivity differences between the crust and underlying stone cause the crust to begin to spall away…soluble salts may accumulate beneath the crust, aiding blister development through crystallization processes….Studies of a series of photographs have revealed that blisters grow irregularly over time, and may continue to develop even after air pollution has declined, suggesting that other processes may be contributing to their development.[97]

The spalling of blisters from the Suddards-Manuel-Clark stone often reveals both subflorescence and biological colonization, which may also contribute to the very elevated levels of NO_3^- and SO_4^{2-} ions. Salts and microflora contribute to the loss of blisters and likely contribute to the buildup of blister crusting as well.

[97] Goudie, Andrew and Heather Viles. *Salt Weathering Hazards*. New York: Wiley, 1997, 189-190.

Figure 6.28 Blistering

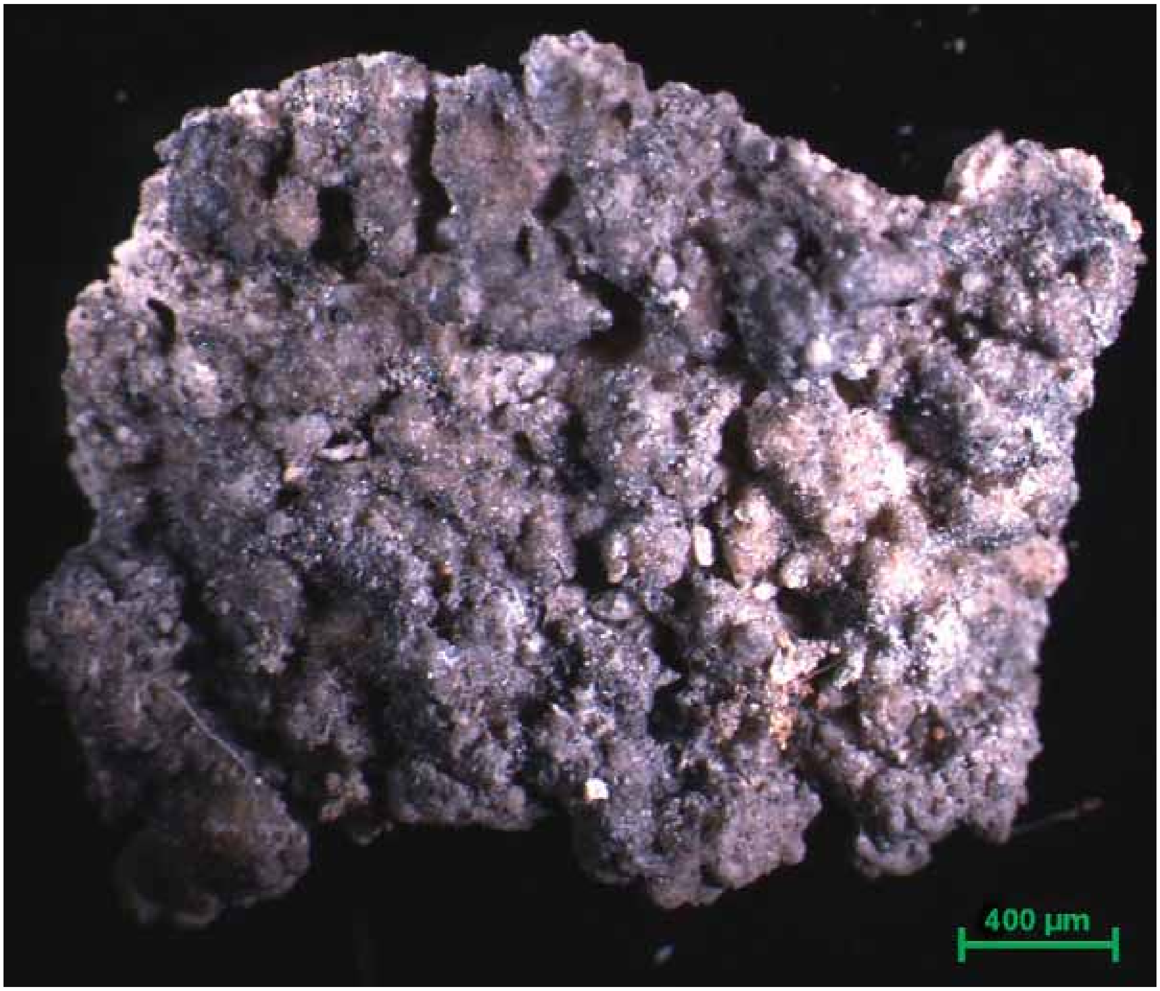

Figure 6.29 Sample of blistering, 20x, Leica MZ16 stereomicroscope, reflected light (Source: E. Kemery, 2009)

6.1.11. GRANULAR DISINTEGRATION

Granular disintegration is the detachment of single grains or aggregates of grains, producing a sugar-like debris. Like the conditions of flaking and blistering, granular disintegration does not occur on areas of original surface. While granular disintegration occurs infrequently on the façade of the Suddards-Manuel-Clark monument, it develops in specific areas and is related to other conditions that are manifest. Granular disintegration is often accompanied by efflorescence and/or differential erosion. Just as efflorescence can be named as a cause of granular disintegration, granular disintegration can be named as a source of differential erosion. Granular disintegration on the monument's façade occurs in areas with low drying rates. These "zone[s] of maxim moisture content, which [are] necessarily the zone[s] of the salt precipitation" are generally located in the lower half of the monument and in many cases very close to the ground.[98] These areas remain moist due to capillary rise and are sometimes even visibly and tactilely wet. Where salt precipitation is "located on the surface, the damage type that forms will be sanding off," or granular disintegration.[99] Crystallization of salts in pores of the sandstone cause individual grains to push off or loosen from the face of the stone. When liquid moisture or moisture vapor become present again, and salts return into solution, loose grains are left as debris. While some of this debris is left positioned precariously on the surface of the stone, other loose grains can be washed away by liquid water or blown from the face of the stone. Accordingly, relatively little granular disintegration can be seen on the façade of the Suddards-Manuel-Clark monument, when compared with other surficial conditions. While the presence of loose grains is what has

[98] Snethlage and Wendler, "Moisture Cycles and Sandstone Degradation," 17.
[99] Ibid.

been recorded as the condition of granular disintegration, the absence of these grains that has intensified over time is the condition of differential erosion.

Figure 6.30 Granular Disintegration

6.1.12. DIFFERENTIAL EROSION

Differential erosion is characterized by localized areas of surface loss, resulting in a partial loss of detail or planar contours. There appear to be three different causes of differential erosion on the façade of the Suddards-Manuel-Clark monument: (1) uneven loss of flakes, peeling and blisters, (2) erosion by water washing, and (3) erosion by dissolution of salts and minerals. Differential erosion by uneven loss of stone material and deterioration byproducts is only a minimal source of erosion. Differential erosion by water washing is primarily occurring below the joint under the vault's entablature. Here, differential erosion is dissolution of the matrix and resultant surface reduction. This joint is constantly wet because it is at grade. It is filled with microflora and macrobiological growth that hold moisture in the joint, and groundwater moisture runs into this joint and seeps onto the façade of the monument. In two of the areas of a joint between the masonry blocks of the entablature, this condition is even more manifest as water is also washing from the vault's soil cap down these joints. In a few areas below the entablature, erosion has been severe enough to cause full spalling.

Most of the differential erosion, however, is related to moisture cycling. Areas of differential erosion due to dissolution of salts and minerals occur in conjunction with areas of granular disintegration and efflorescence. As stated above, efflorescence causes granular disintegration, and granular disintegration leads to differential erosion. Repeated dissolution and crystallization of salts on the surface of the stone in various areas causes the loosening of grains of the stone. This kind of cycling causes repeated loss of these grains, which weather away unevenly, leaving a contoured, sometimes rippled, surface. Like granular disintegration, differential erosion is concentrated at the base of the monument and can extend up to the height of the capillary fringe. In some areas, differential erosion from salt cycling has been so severe that it has caused loss of sharp corners and even partial loss of carved detail.

Figure 6.31 Differential Erosion

Figure 6.32 Granular disintegration, differential erosion and efflorescence

6.1.13. EFFLORESCENCE

Efflorescence is the presence of white powdery or whisker-like salt crystals on the surface of the stone. These salts may be soluble or insoluble; soluble salts have been transported through the stone or onto the stone surface by moisture. Images of the Suddards-Manuel-Clark monument taken during cooler months when salts have crystallized on the surface of the façade can be compared with images of the vault during warmer months with higher humidity when salts have entered into solution, and white efflorescence appears to have faded away. Salts may come from chemical reactions with pollutants in the air, from deicing salts at the base of the monument, from groundwater or from previous interventions, or they may be inherent in the stone. Not only is groundwater a major source of salts, but groundwater is among one of the greatest sources of moisture for salt weathering; the others are dew, fog and rain.[100] Efflorescence that is located in large patches in areas within the capillary fringe can be attributed to transport of salts in solution through rising damp. Crystallization of salts due to rising damp occurs at different heights according to differing solubility.[101] Condensation can also "introduce, or reintroduce, surface salts" into stone.[102]

As explained above, salt cycling is very damaging to the fabric of stone, causing critical loss of material. Crystallization pressure and hydration pressure are the main mechanisms of salt damage. When the pore volume of a material is less than the volume of a supersaturated salt solution and the crystals precipitating from that solution,

[100] Goudie and Viles, 79.
[101] Charola, A. Elena. "Salts in the Deterioration of Porous Materials: An Overview." *Journal of the American Institute for Conservation* 39 (2000): 330.
[102] Ibid., 329.

"hydrostatic crystallization pressure" is created.[103] This can cause flaking, granular disintegration and alveolar erosion, and crystallization pressure increases with decreasing pore size, so the low porosity of the Suddards-Manuel-Clark sandstone augments decay by crystallization pressure.[104] "Surface crust," like the soiled, case-hardened crusts of the monument, "has a higher number of smaller pores, and hence the higher crystallization pressures should lead to its flaking."[105] Hydration pressure is the increase of volume of a solution when salts solublize and can swell; this hydration and dehydration cycling through the pores of the stone systematically leads to significant material loss over time.[106]

Efflorescence as recorded on the façade of the Suddards-Manuel-Clark monument does not occur in any specific pattern. Salts are present on all three sections of the monument, and it must be remembered that only those salts that had crystallized on the surface of the stone the day the condition of efflorescence was recorded are documented herein. Not only does salt cycling greatly affect the weathering of stone, but presence of salts can also encourage chemical weathering. When salt solutions have high pH levels, from pH of 9 up to pH of more than 11, "silica mobility tends to be greatly increased" because the "solubility of silica increases exponentially above pH 9."[107] Microbiological growth can also "precipitate sulphates and oxalates, and thus may be active in creating

[103] Ibid., 332.
[104] Ibid.
[105] Ibid., 333.
[106] Ibid.
[107] Goudie and Viles, 151.

salts which then cause damage to rocks."[108] In these ways, salts can even indirectly cause weathering by accelerating other conditions and forms of deterioration.

[108] Ibid., 157.

Figure 6.33 Efflorescence

6.1.14. PREVIOUS REPAIR

If not the result of material, design, fabrication or environment, deterioration can often be traced to previous interventions. While some of the previous interventions carried out on the Suddards-Manuel-Clark monument have been documented, others have not; however, there do not appear to be more than three major areas of repair up to this point. Because vandals had forced open the door of the Suddards section of the vault on at least two different occasions, the cemetery company sealed the door in 1974.[109] In the central Manuel section of the vault, what once would have likely been a marble panel door similar to that of the Suddards section is now simply an opening filled with concrete masonry units between the two piers. The lot card for the section indicates that the vault was sealed in this manner in 1960.[110] Additionally, the central door to the Clark section of the monument has been entirely covered with a cementitious material; it is actually not certain whether or not the original marble panel still exists. Although incompatible and inappropriate, it is unclear if the materials used to seal the three doors of the vault have stimulated any further deterioration in the stone. The cementitious repair material may have increased the amount of salts present in the stone of the monument, but efflorescence is so pervasive that it is difficult to be completely sure of the sources of the salts.

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[109] Woodlands Cemetery Lot Cards.
[110] Ibid.

Figure 6.34 Previous Repair

6.2. SUMMARY CONCLUSIONS

The Suddards-Manuel-Clark monument is in good condition with high integrity and little loss of fabric. Cracking, incipient spall and dimensional loss are in most cases related conditions but are generally very minimal. Displacement and open joints are also associated conditions and can be repaired through resetting of masonry blocks and repointing of joints. Macrobiological and microbiological growth are pervasive throughout the façade, though microbiological growth is highly concentrated on the east side of the monument due to tree cover. Pervasiveness of biological activity in the form of higher plant forms, microflora and living insects/insect byproducts indicates that moisture and temperature are hospitable to living organisms. Peeling is a crust surface enrichment that can be identified by its dark color and because it only affects the original surface of the stone. Flaking, blistering and granular disintegration are surficial conditions that only affect the surface of the stone beneath the original peeling surface. Flaking and blistering appear to be related to gypsum formation, while granular disintegration is associated with differential erosion and efflorescence. Differential erosion is the result of the loss of surface partially due to flaking but greatly due to granular disintegration. Efflorescence is found in all areas of the façade and leads to loss of material through salt cycling. Previous repairs are an aesthetic issue rather than a deterioration mechanism; they have not to this point manifested in introduction of soluble salts.

7. TREATMENT

7.1 Pilot Cleaning Tests

As cleaning is the first step to be taken before any conservation treatment is begun, pilot cleaning tests were carried out first on the large sandstone sample in the laboratory and then in situ on the monument. PROSOCO, Inc. Sure Klean® Heavy Duty Restoration Cleaner, a hydrofluoric acid based cleaner, was diluted 1 part cleaner to 3 parts water and 1 part cleaner to 6 parts water. After pre-wetting, the cleaner was applied, left for a three minute dwell time, scrubbed gently with a brush and then rinsed off. This cycle was repeated three times. After three cycles, the 1:6 cleaner had lightened soiling and cleared much biological growth, and the 1:3 cleaner had lightened the soiling greatly and cleared all biological growth from its teat area.

In situ cleaning was carried out with Cathedral Stone® Products, Inc. D/2 Biological Solution. Equal parts of cleaner and water were mixed and applied to surfaces with different types and degrees of soiling and biological attack. After a three minute dwell time, each surface was scrubbed gently with a brush, left on the surface for another five minutes and then scrubbed again. This cycle was repeated a second time on all surfaces with variable results. The D/2 Solution had no cleaning effect on the case-hardened surfaces except to bring out or deposit soluble salts. Areas of algal and lichen growth were cleaned quite successfully with no residual salt crystallization.

Figure 7.1 Pilot cleaning tests with PROSOCO, Inc. Sure Klean® Heavy Duty Restoration Cleaner; control (left), 1:3 cleaner to water solution (middle), 1:6 cleaner to water solution (right) (Source: E. Kemery, 2009)

Figure 7.2 Areas cleaned with D/2 Solution

Figure 7.3 Section of the Suddards-Manuel-Clark monument to be cleaned, before cleaning with Cathedral Stone ® Products D/2 Biological Solution (Source: E. Kemery, 2009)

Figure 7.4 Cove after first cycle of Cathedral Stone ® Products D/2 Biological Solution application (Source: E. Kemery, 2009)

Figure 7.5 Section of opaque peeling/case-hardened crust during cleaning with Cathedral Stone ® Products D/2 Biological Solution; D/2 Solution had no effect on case-hardened surfaces (Source: E. Kemery, 2009)

Figure 7.6 Cove area after cleaning with Cathedral Stone ® Products D/2 Biological Solution (Source: E. Kemery, 2009)

Figure 7.7 D/2 Solution did not remove soiling from case-hardened areas; note efflorescence post-cleaning (Source: E. Kemery, 2009)

Figure 7.8 D/2 Solution removed biological growth in this area but did not remove other soiling (Source: E. Kemery, 2009)

7.2 Repair Mortar Formulation

Samples of two mortars were removed from open joints, one thick mortar joint from a wide joint and one thinner mortar joint. These mortars, although both slightly different in color and composition, were clearly meant to closely match the sandstone of the Suddards-Manuel Clark monument. In order to formulate a repair mortar, a sand was first selected that was closest in overall color to the stone. Three sands from the Architectural Conservation Laboratory's sand library were chosen for matching: Schooley Caldwell Associates Circleville OH Sand 75, Watrous Sand 87 and Hanson Aggregates Inc. C-144 Mason Sand. The first of these, Sand 75, was the closest in color, and formulations were based on one part St. Astier Natural Hydraulic Lime 3.5 to three parts sand plus masonry pigment. Dry formulations of various amounts and combinations of pigments were colormatched in northern daylight to the clean sandstone sample. Mock-ups of five samples of different formulations were mixed and left to dry overnight. Where 1 part by volume for natural hydraulic lime and sand was 15 milliliters:

1 NHL 3.5 + 3 Sand (control)
1 NHL 3.5 + 3 Sand + 0.95 g Lime Proof Brown
1 NHL 3.5 + 3 Sand + 1.00 g Van Dyke Brown
1 NHL 3.5 + 3 Sand + 0.70 g Lime Proof Brown + 0.73 g Van Dyke Brown
1 NHL 3.5 + 3 Sand + 0.35 g Lime Proof Brown + 1.01 g Van Dyke Brown

After drying overnight, the mortar samples were compared in northern daylight to the clean sandstone sample, and while several of the samples were close in color to the stone, the formulation of 1 NHL 3.5 + 3 Sand + 1.00 g Van Dyke Brown was the closest match.

Figure 7.9 Colormatching of dry mortar formulations before creation of mortar samples; clockwise from bottom left: sand; original mortar sample in weighing boat; original mortar sample in weighing boat; stone sample with various dry lime, sand and pigment formulations for matching; mixing bowl with dry mortar formulation (Source: E. Kemery, 2009)

Figure 7.10 Stone sample and original mortar sample from a narrow joint (Source: E. Kemery, 2009)

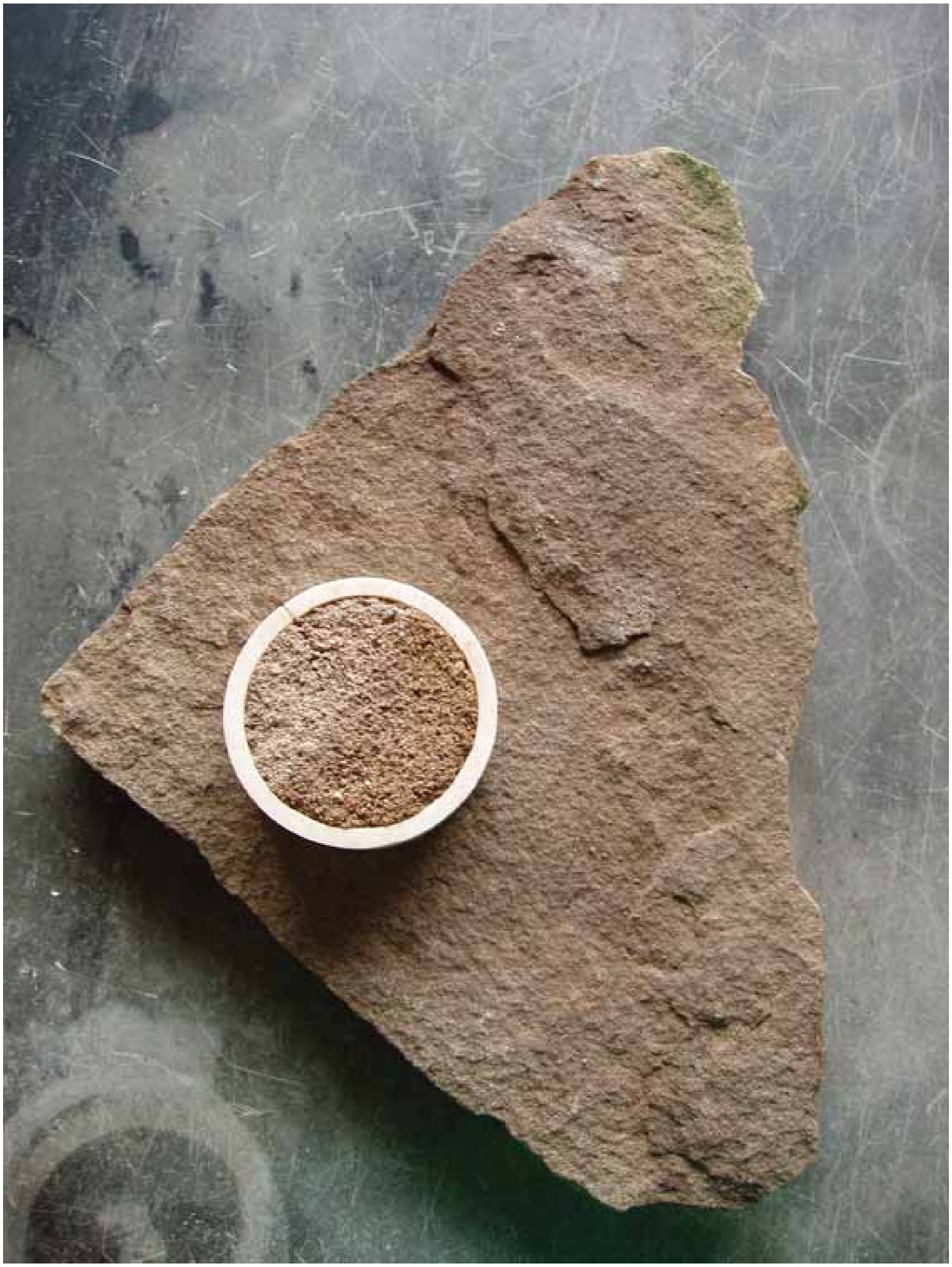

Figure 7.11 Repair mortar formulation 1 NHL 3.5 + 3 Sand + 1.00 g Van Dyke Brown (Source: E. Kemery, 2009)

7.3 Proposed Treatments

7.3.1 Resetting and Resurfacing of Masonry Units

For those masonry units that have been displaced and are out of plane with the façade of the Sudddards-Manuel-Clark monument, the only solution for repair is to reset the blocks. This will not only halt displacement but will ameliorate open joints and circumvent future dimensional loss. For severely peeling, flaking and differentially eroded surfaces, the only means of leveling or smoothing the façade is to resurface these blocks.

7.3.2 Repointing and Composite Repair

Before cleaning, the monument must be repointed so that moisture does not enter into the monument through open joints. This mortar can be a temporary one, to be replaced after conservation treatment, or it can be intended for a normal service life of mortar. Repointing will be necessary if masonry units are reset, and even if the choice is made not to reset the displaced blocks, there remain open joints not related to displacement. The mortar formulation created should be used if the sand proves to be available. In the case that Sand 75 is no longer available, the same mortar matching process should be followed for the other two sands to come up with a comparable match. The mortar used for repointing can also be used for small composite repair in areas that have spalled. It is important to note that the original intention of the masonry system was for the monument to appear as a whole and unified façade without joints; this is the reason that both the original and the repair mortars are so close in color to the sandstone.

A recessed joint was used originally and should be used for repointing to ensure that mortar joints are visually deferential to the stone.

7.3.3 Cleaning and Desalination

Blisters, flaking and peeling should be removed before cleaning or consolidation. It is important to note that flaking and peeling are *active* conditions, therefore areas that remain sound and attached that only have the appearance of flaking and peeling (i.e. soiled encrustation) should not be forcibly removed. Gypsum blisters can be removed with water washing or can be removed mechanically. Cleaning of biological growth was successful with D/2 Solution, and the cleaner should act as a biocide for at least one year from application as well. Areas of microbiological growth can be cleaned with D/2 Solution using the method described above. All other areas can be cleaned with Sure Klean® Heavy Duty Restoration Cleaner using the method described above. Desalination using poultices will be critical to the treatment of the monument as much of the decay is due to salt weathering. A dry abrasive cleaning method such as SpongeJet would also be ideally suited to the Suddards-Manuel-Clark monument; however, limitations of site and budget exist that would make the use of SpongeJet difficult.

7.3.4 Consolidation and Grouting

Alkoxysilanes have been found to be most effective on sandstones, and ethyl silicate has been widely used for decades. Areas of microflaking, differential erosion and granular disintegration should be consolidated to prevent further loss of stone surface. An alkoxysilane should be used, preferably a methyltriethoxysilane (MTEOS), for example, Silbond® 40. Methyltriethoxysilanes have some water-repellent properties as well. Areas where blisters and partially-detached peeling and flaking several centimeters wide and long have begun to disengage from the face of the stone, injection grouting may be used to re-adhere these areas to prevent loss of thick layers of stone surface. These areas may be detected by tapping lightly on the surface of the stone and listening for audible change that indicates detachment from the sound stone.

8. CONCLUSION AND RECOMMENDATIONS

The Suddards-Manuel-Clark is one of the oldest, largest and most significant structures of The Woodlands Cemetery, one of the country's early rural garden cemeteries. Although little is known about the families interred therein or about the construction of the monument, it is clear that there was considerable attention paid to the architectural style and design of the monument as well as to the selection of high quality building materials that have endured decades of a harsh environment. Despite its alternate function as a retaining wall to the bank of a hill, the tomb has withstood constant moisture and structural loads on three sides and numerous decay mechanisms at its façade. A conditions glossary specific to this monument has been created and a conditions survey has been completed. These two tools can be used to monitor and record conditions as they develop over time.

Future work should include testing of selected conservation treatments. Testing can be done on mortar sample mock-ups in the laboratory for strength and hydric and hygric behaviour. Samples of the stone for testing consolidants would be optimal; if this is not possible, then consolidation should be undertaken with very explicit specifications. Also it must not go unsaid that consolidation and other conservation treatments will only be temporarily effective if the sources of decay mechanisms are not managed. Conservation treatments can even be detrimental if the causes and locus of moisture are not addressed. The vault cannot be removed from its site, so calculated measures must be taken to solve conditions issues in situ. In many areas, desalination will be essential to preventing weathering. Where capillary rise is the locus of moisture, a barrier system may be necessary to avoid further material loss through granular disintegration and differential erosion after consolidation. Resetting of masonry units is critical to both structural and aesthetic objectives for the monument. Resurfacing of stone would be by and large an aesthetic treatment and would necessitate further loss of the sandstone, but it may be considered. Investigation of the interior of the vault would be enormously invaluable to the study of the Suddards-Manuel-Clark monument. It would give a greater and more accurate understanding of moisture entry and weathering mechanisms as well as to design and construction.

The Woodlands Cemetery and its users are fortunate to have an exemplary mid-nineteenth century Gothic Revival bank tomb. The materials, most notably the dense and handsome sandstone, used to construct this monument have performed considerably well, and the site retains high integrity. Conservation treatments and maintenance will ensure that the Suddards-Manuel-Clark vault will continue to be studied and enjoyed by future generations of Woodlands Cemetery visitors.

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Woodlands Cemetery Lot Cards

Woodlands Cemetery *Register of Deeds*

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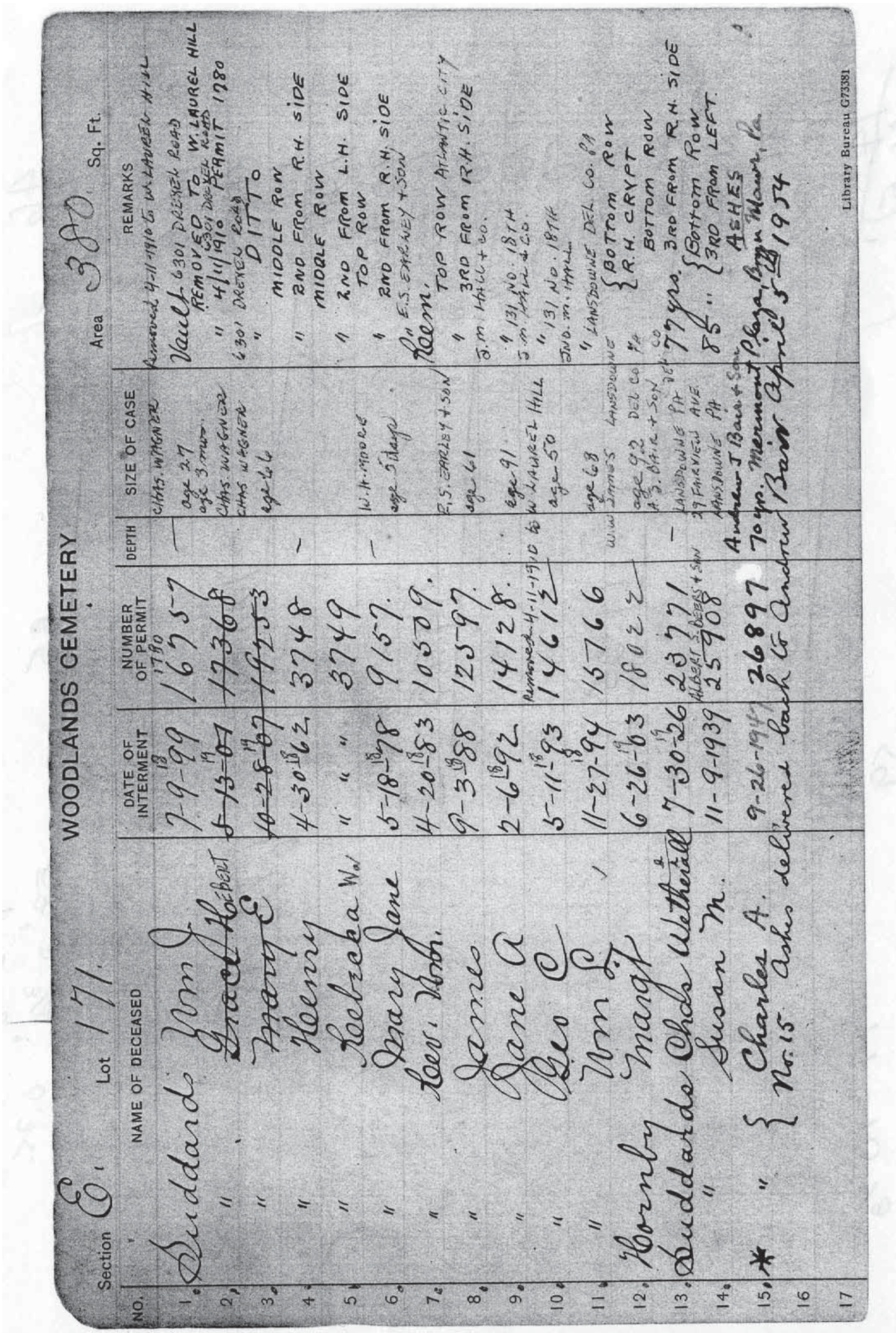
APPENDIX A: WOODLANDS CEMETERY LOT CARDS

LOT E 171 SUDDARDS



WOODLANDS CEMETERY

Section E. Lot 171. Area 380 Sq. Ft.

NO.	NAME OF DECEASED	DATE OF INTERMENT	NUMBER OF PERMIT	DEPTH	SIZE OF CASE	REMARKS
1.	Suddards Wm J	7-9-1899	1780 16757	—	Chas. Wagner age 27	Removed 4-11-1910 to W. Laurel Hill; Vault 6301 Drexel Road
2.	" ~~Grace~~ Hebert	~~8-13-1901~~	~~17368~~		age 3 mos. Chas. Wagner	Removed to W. Laurel Hill " 4/11/1910 6301 Drexel Road Permit 1780
3.	" ~~Mary E~~	~~10-28-1907~~	~~19253~~		Chas Wagner age 66	6301 Drexel Road " Ditto
4.	" Henry	4-30-1862	3748	—		Middle Row " 2nd from R.H. side
5.	" Rebecca Wd	" " "	3749			Middle Row " 2nd from L.H. side
6.	" Mary Jane	5-18-1878	9157.	—	W.H. Moore age 5 days	Top Row " 2nd from R.H. side
7.	" Rev. Wm.	4-20-1883	10509.			" E.S. Earley + Son Reem.
8.	" James	9-3-1888	12597.		E.S. Earley + Son age 61	Top Row Atlantic City " 3rd from R.H. side
9.	" Jane A	2-6-1892	14128.		age 91	J.M. Hall + Co. " 131 No. 18th
10.	" Geo C	5-11-1893	Removed 4-11-1910 to W Laurel Hill 14612		age 50	J.M. Hall + Co. " 131 No. 18th
11.	" Wm L	11-27-1894	15766		age 68	Jno. M. Hall " Lansdowne Del. Co. PA
12.	Hornby Margt	6-26-1903	18022		W.W. James Lansdowne age 92 Del Co PA	{Bottom Row R.H. Crypt
13.	Suddards Chas Wetherill	7-30-1926	23771	—	A.S. Bair + Son Del Co Lansdowne PA	77 yrs. Bottom Row 3rd from R.H. side
14.	" Susan M.	11-9-1939	Albert S. Beers + Son 25908		29 Fairview Ave. Lansdowne PA	85 " {Bottom Row 3rd from Left
15.	* " {Charles A.	9-26-1947	26897		Andrew J Bair + Son 70 yrs. Mermont Plaza, Bryn Mawr, Pa.	Ashes
	{No. 15 Ashes delivered back to Andrew Bair April 5th 1954					
16						
17						

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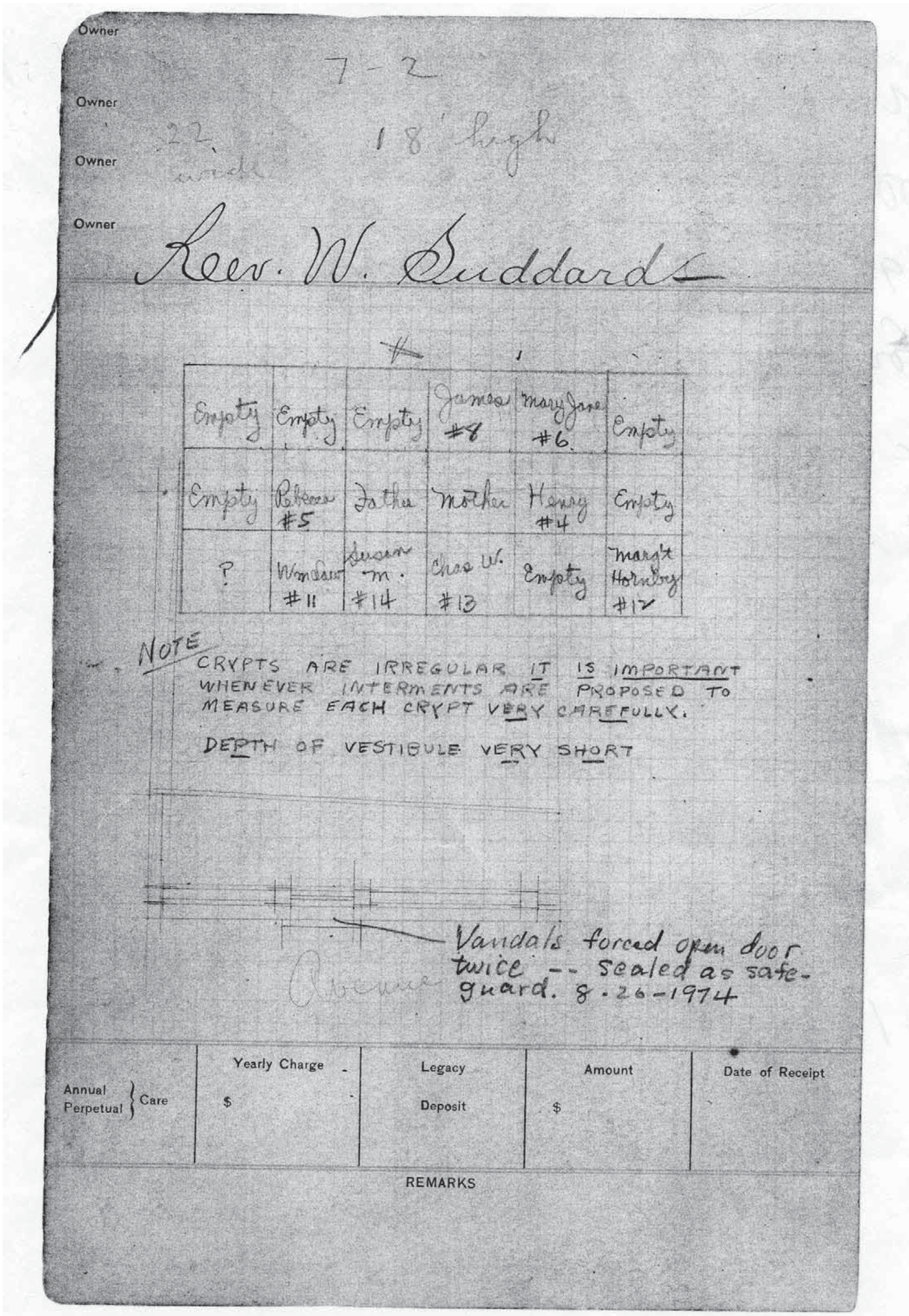
APPENDIX A: WOODLANDS CEMETERY LOT CARDS



Owner 7-2

Owner 22' wide 18' high

Owner

Owner Rev. W. Suddards

Empty	Empty	Empty	James #8	Mary Jane #6	Empty
Empty	Rebecca #5	Father	Mother	Henry #4	Empty
?	Windsor #11	Susan M. #14	Chas W. #13	Empty	Marg't Hornby #12

NOTE CRYPTS ARE IRREGULAR IT IS IMPORTANT WHENEVER INTERMENTS ARE PROPOSED TO MEASURE EACH CRYPT VERY CAREFULLY.

DEPTH OF VESTIBULE VERY SHORT

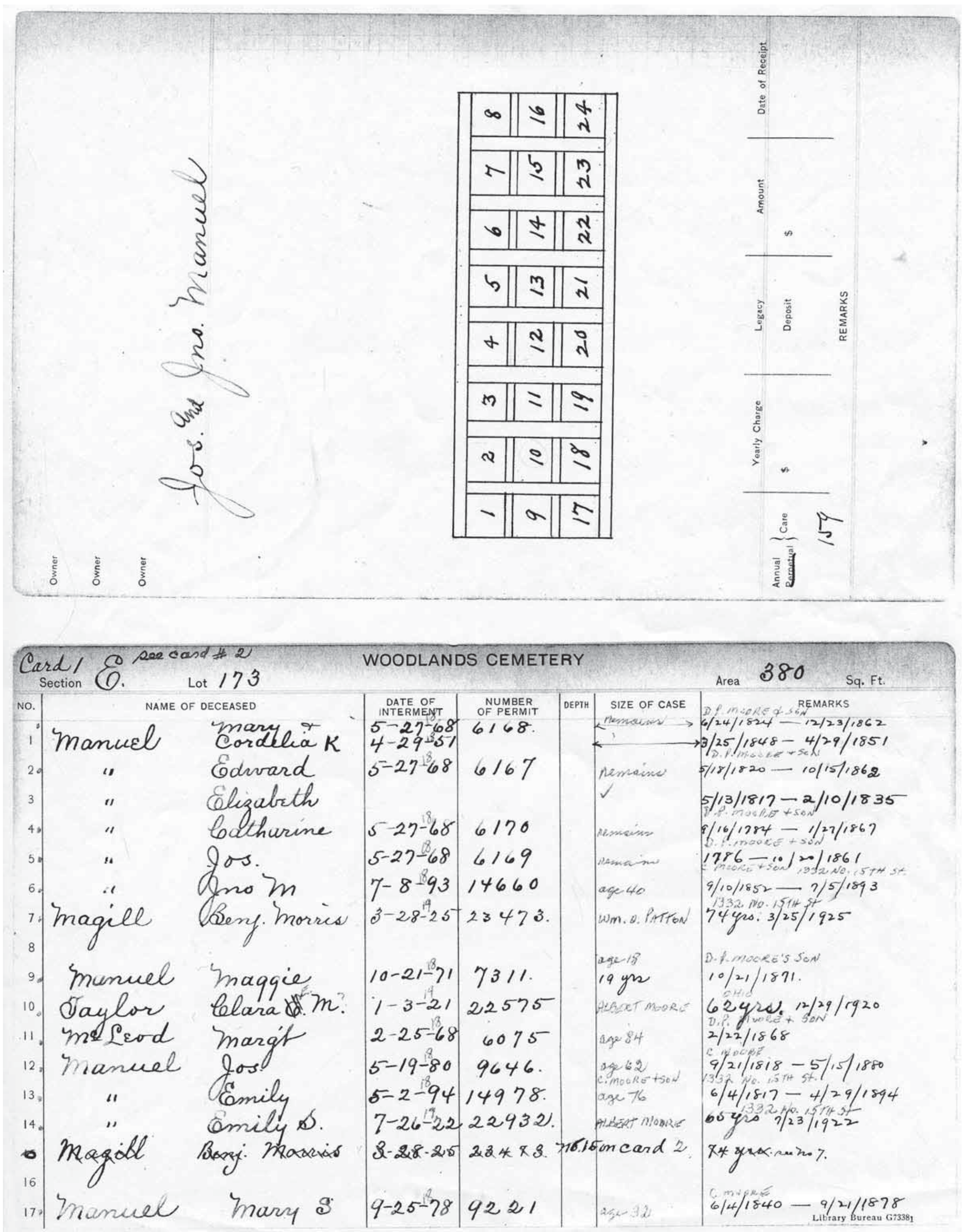
Vandals forced open door twice -- sealed as safe-guard. 8-26-1974

Annual / Perpetual Care	Yearly Charge	Legacy Deposit	Amount	Date of Receipt
	$		$	

REMARKS

APPENDIX A: WOODLANDS CEMETERY LOT CARDS

LOT E 173 MANUEL



Owner Jos. and Jno. Manuel
Owner
Owner

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Annual / Perpetual } Care 159
Yearly Charge $
Legacy
Deposit $
Amount
Date of Receipt
REMARKS

Card 1 see card # 2
WOODLANDS CEMETERY
Section E. Lot 173 Area 380 Sq. Ft.

NO.	NAME OF DECEASED		DATE OF INTERMENT	NUMBER OF PERMIT	DEPTH	SIZE OF CASE	REMARKS
1	Manuel	Mary & Cordelia K	5-27-(18)68 4-29-(18)51	6168.		Remains ← →	D.P. Moore & Son 6/24/1824 — 12/23/1862 3/25/1848 — 4/29/1851
2	"	Edward	5-27-(18)68	6167		Remains	D.P. Moore + Son 5/18/1820 — 10/15/1862
3	"	Elizabeth				✓	5/13/1817 — 2/10/1835
4	"	Catharine	5-27-(18)68	6170		Remains	D.P. Moore + Son 8/16/1784 — 1/27/1867
5	"	Jos.	5-27-(18)68	6169		Remains	D.P. Moore + Son 1786 — 10/20/1861
6	"	Jno M	7-8-(18)93	14660		age 40	C. Moore + Son 1332 No. 15th St. 9/10/1852 — 7/5/1893
7	Magill	Benj. Morris	3-28-(19)25	23473.		Wm. D. Patton	1332 No. 15th St 74 yrs. 3/25/1925
8							
9	Manuel	Maggie	10-21-(18)71	7311.		age 18 19 yrs	D.P. Moore's Son 10/21/1871.
10	Taylor	Clara E. M.	1-3-(19)21	22575		Albert Moore	Ohio 62 yrs. 12/29/1920
11	McLeod	Marg't	2-25-(18)68	6075		age 84	D.P. Moore + Son 2/22/1868
12	Manuel	Jos.	5-19-(18)80	9646.		age 62	C. Moore 9/21/1818 — 5/15/1880
13	"	Emily	5-2-(18)94	14978.		C. Moore + Son age 76	1332 No. 15th St. 6/4/1817 — 4/29/1894
14	"	Emily S.	7-26-(19)22	22932.		Albert Moore	1332 No. 15th St 65 yrs 7/23/1922
○	Magill	Benj. Morris	3-28-25	234?3.	716.15	on card 2	74 yrs. see no. 7.
16							
17	Manuel	Mary S	9-25-(18)78	9221		age 32	C. Moore 6/4/1840 — 9/21/1878

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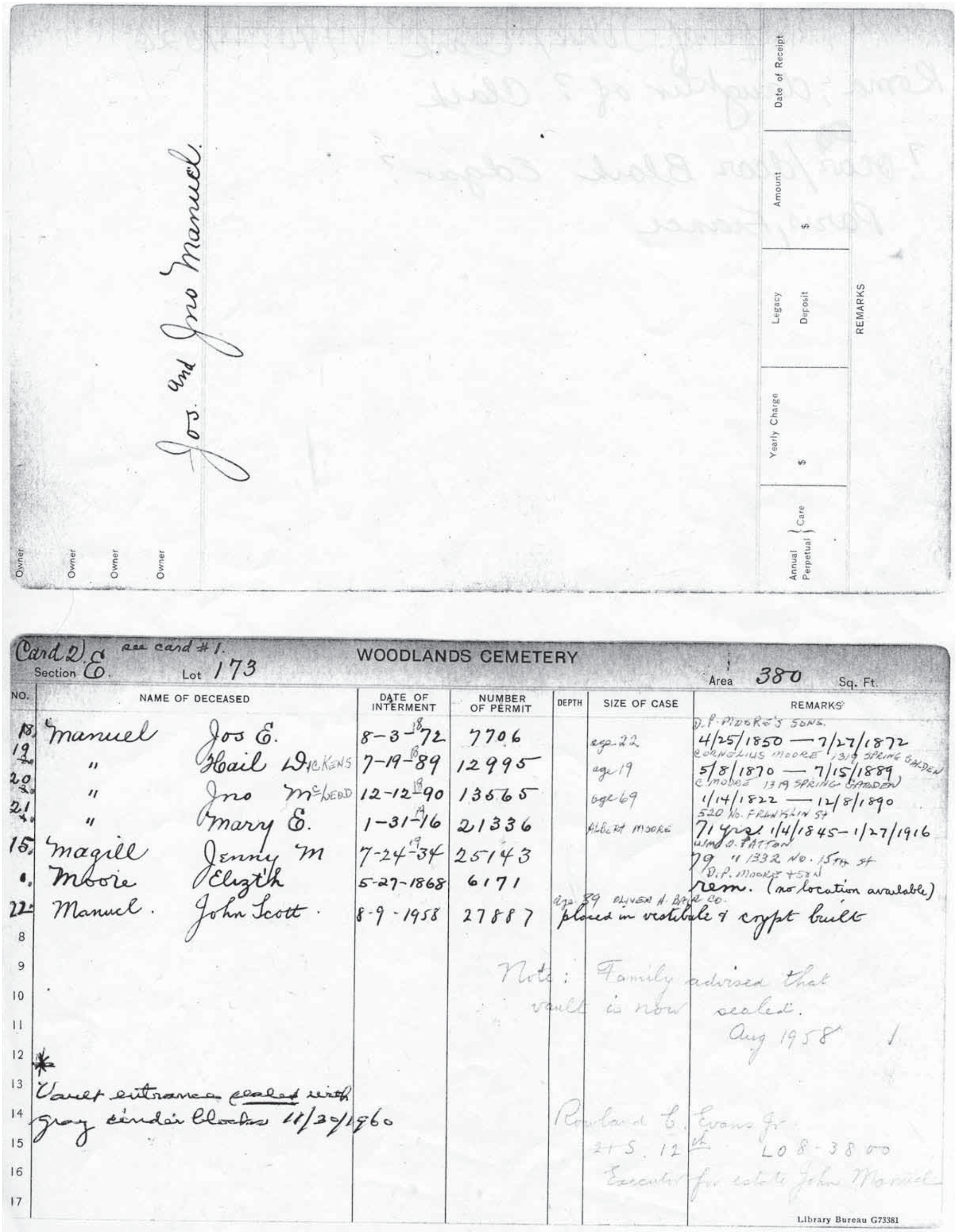
APPENDIX A: WOODLANDS CEMETERY LOT CARDS



Owner Jos. and Jno Manuel.

Owner

Owner

Owner

Annual / Perpetual { Care | Yearly Charge $ | Legacy / Deposit | $ Amount | Date of Receipt

REMARKS

Card 2) see card #1.

Section E. Lot 173 WOODLANDS CEMETERY Area 380 Sq. Ft.

NO.	NAME OF DECEASED		DATE OF INTERMENT	NUMBER OF PERMIT	DEPTH	SIZE OF CASE	REMARKS
18	Manuel	Jos E.	8-3-1872	7706		age 22	D. P. Moore's Sons. 4/25/1850 — 7/27/1872
19	"	Hail Dickens	7-19-1889	12995		age 19	Cornelius Moore 1319 Spring Garden 5/8/1870 — 7/15/1889
20	"	Jno McLeod	12-12-1890	13565		age 69	C. Moore 1319 Spring Garden 1/14/1822 — 12/8/1890
21	"	Mary E.	1-31-1916	21336		Albert Moore	520 No. Franklin St 71 yrs. 1/4/1845 – 1/27/1916
15	Magill	Jenny M	7-24-1934	25143			Wm D. Patton 79 " 1332 No. 15th St
6	Moore	Elizth	5-27-1868	6171			D. P. Moore + Son rem. (no location available)
22	Manuel.	John Scott.	8-9-1958	27887	age 89 Oliver H. Bair Co. placed in vestibule & crypt built		
8							
9							
10							
11							
12	*						
13	Vault entrance sealed with						
14	gray cinder blocks 11/20/1960						
15							
16							
17							

Note: Family advised that vault is now sealed. Aug 1958

Rowland E. Evans Jr
21 S. 12th LO 8-3800
Executor for estate John Manuel

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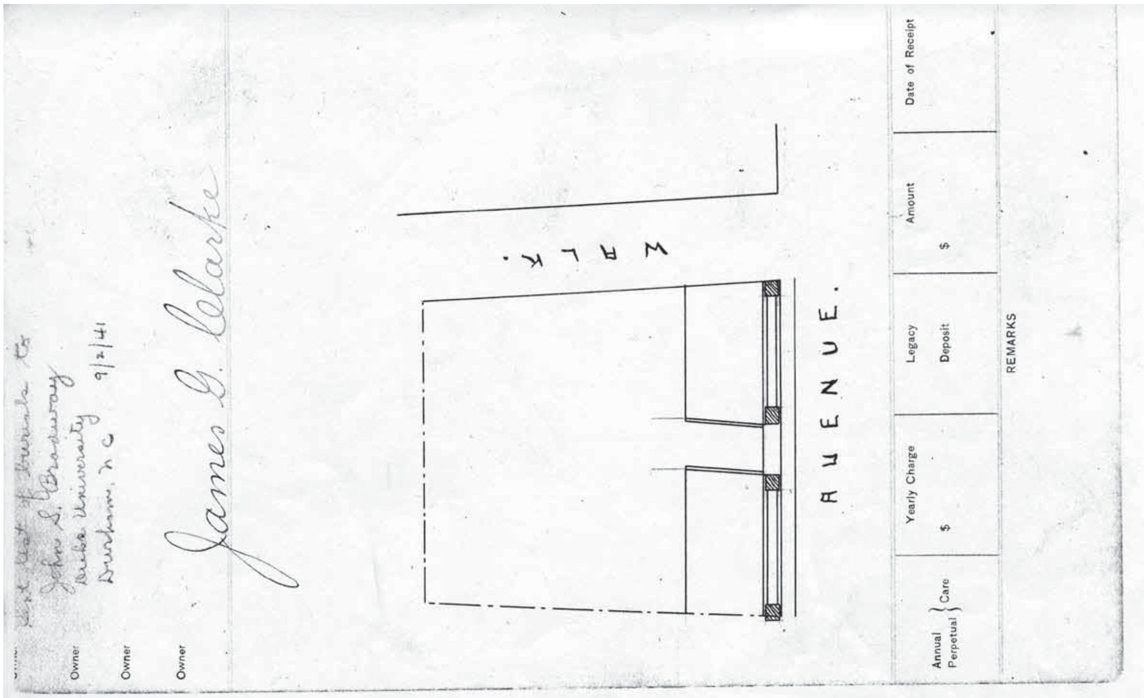
APPENDIX A: WOODLANDS CEMETERY LOT CARDS

LOT E 175 CLARK



Section #1 E. Lot 175 WOODLANDS CEMETERY CARD #1 Area 360. Sq. Ft.

No.	NAME OF DECEASED	DATE OF INTERMENT	NUMBER OF PERMIT	DEPTH	SIZE OF CASE	REMARKS
1.	England L. C. (could be same as #3)	4-11-1858 / 12-28-1859	2492 / 2945		age 23	L. Fayette Ir. Moved from 274-F; Reem Family Vault
2.	" Sarah T. (same as #14)	10- -1860	3203			" "
3.	" Lewis C (could be same as #1)	10- -1860	3205			"
4.	Gibson Franklin Peale	3-9-1868	6087		age 2 1/8	"
5.	Irwin Wm H.	9-17-1874	8292		age 43	Moore Bros. "
6.	Clark Jas G.	5-11-1883	10531		age 87	R.R. Bringhurst & Co. 1716 Race St "
7.	" Lydia	1-22-1884	10743		age 79	R.R. Bringhurst 1716 Race St "
8.	Bonsall Lydia	10-13-1866	5598		age 24	"
9.	Clarke (Clark) Elizth, ~~Jos E.~~ Jesse, ~~Ann Eveline~~ Ann Eveline & Emma	12-~~25~~-1859	2945			Reem See Card #2
10	Clarke Jos	10- -1860	3200		Remains	" "
11	" Ann Eveline	10- -1860	3201		Remains	"
12.	Clark Harriet G	7-28-1880	9706.		age 80	Robt Bringhurst "
13.	Clark Rebecca	9-1-1880	9734		age 73	Robt Bring Hurst "
14.	~~England Sarah T.~~ (same as #2)	~~12-25-1859~~	~~2945~~	—	Remains	"
15.	Clark Harriet B.	11-3-1884	11009		age 70	R.R. Bringhurst Broad St. Station West Chester
16.	Gill Mary. M.	1-16-1883	10409		age 73	R.R. Bringhurst
17.	Tonkin Edwd	7-25-1884	10940	—	age 87	A. J. Simmerman Woodbury N.J.

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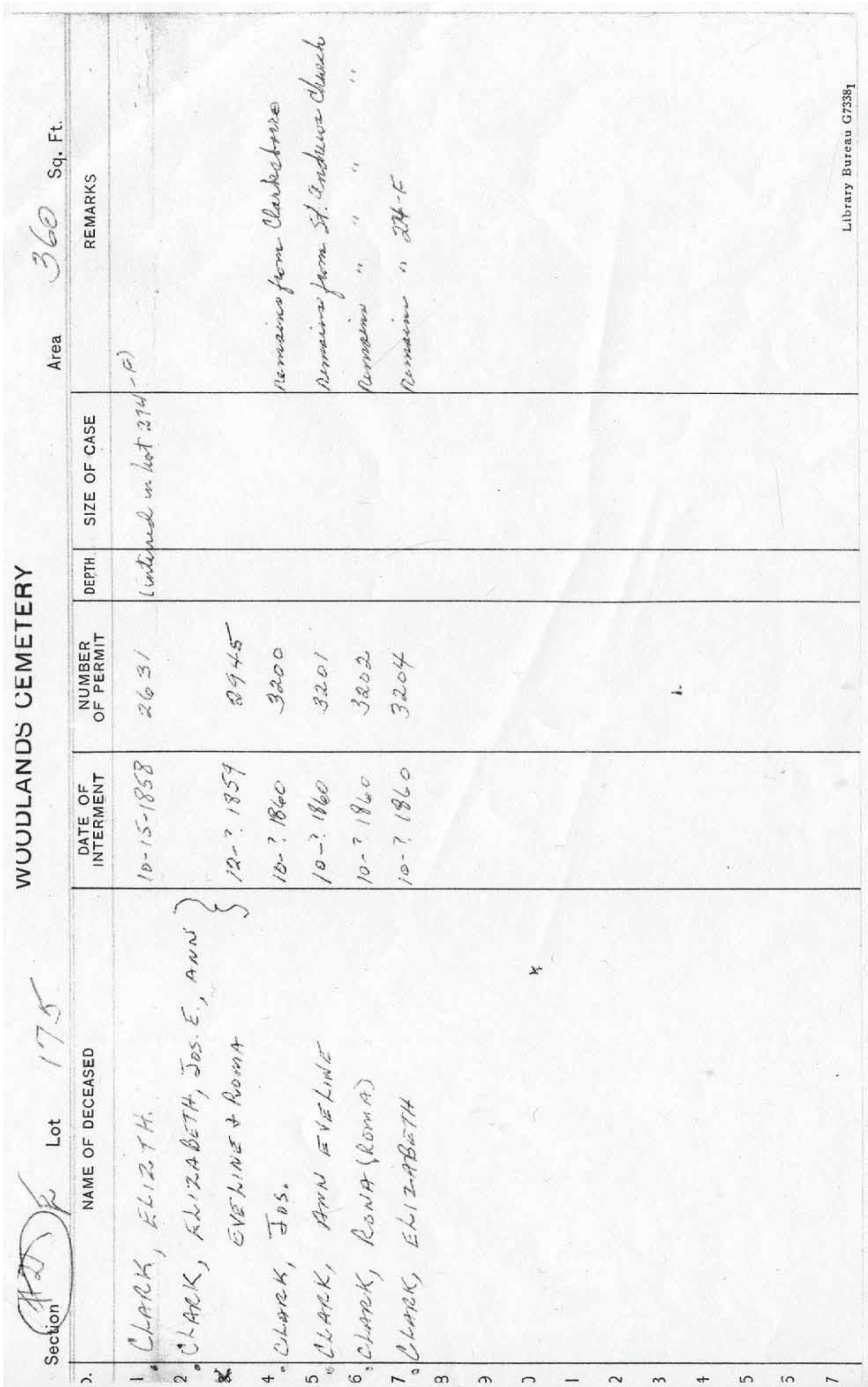
APPENDIX A: WOODLANDS CEMETERY LOT CARDS



WOODLANDS CEMETERY

Section (#21) F Lot 175 Area 360 Sq. Ft.

No.	NAME OF DECEASED	DATE OF INTERMENT	NUMBER OF PERMIT	DEPTH	SIZE OF CASE	REMARKS
1	CLARK, ELIZ'TH.	10-15-1858	2631	(interred in lot 274-F)		
2	CLARK, ELIZABETH, JOS. E., ANN					
3	EVELINE & ROMA	12-?-1859	2945			
4	CLARK, JOS.	10-?-1860	3200			remains from Clarksboro
5	CLARK, ANN EVELINE	10-?-1860	3201			remains from St. Andrews Church
6	CLARK, RONA (ROMA)	10-?-1860	3202			remains " " "
7	CLARK, ELIZABETH	10-?-1860	3204			remains " 274-F
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						

Library Bureau G7338

APPENDIX B: MANUFACTURERS DATA SHEETS AND MATERIAL SAFETY DATA SHEETS

Cathedral Stone ® Products D/2 Biological Solution

D/2 Biological Solution

D/2 Biological Solution is a safe, easy to use liquid that removes a broad spectrum of biological deposits from hard environmental surfaces. A contact time of only 1 to 2 minutes will loosen most fungal and algal deposits with manual scrubbing and is typically sufficient for excellent results.

Growth of bacteria, fungi, algae, lichens, and mosses contributes significantly to the degradation of many types of construction materials, and can be disfiguring. D/2 can be utilized to control this problem on outdoor sculpture, monuments, decorative fountains, gravestones, and tombs. Biological growth found on some individual building features (such as parapets and zones of ground contact) or materials (such as stucco) can also be treated with D/2, although it is not a general purpose architectural cleaner.

Features and Benefits

- **Fast Acting:** 1 to 2 minute contact time for great results.
- **Keeps Surfaces Clean for a Minimum of 1 year**
- **Safe for Landscape Plantings and Grass**
- **No Detrimental Effects on Masonry**
- **Non-Toxic and Biodegradable:** No special precautions required for handling and storage.

Application Procedures

No Scrub/No Rinse Method

1. Apply D/2 Biological Solution with a brush or pump sprayer to a dry surface. Do not pre-wet the surface. 2. Allow to dry. Repeat if there are heavy biological deposits. D/2 works with the elements and results occur within one week to one month depending on severity of growth and weather conditions. The surface will become cleaner over time as the subsurface biological growth dies and releases.

Immediate Result Method

1. Apply D/2 Biological Solution with a brush, roller or pump sprayer to a dry surface. Do not pre-wet the surface. 2. After waiting 2-5 minutes, scrub surface with a non-metallic, short bristle scrub brush. 3. Allow the undiluted D/2 to remain on the surface 5-10 minutes longer. 4. Apply additional D/2 to maintain a wet surface and continue scrubbing. 5. Rinse with clean water.

Heavy biological deposits should first be loosened using a low pressure washer (300 to 600 psi), or by mechanical scraping using wood or plastic tools. Follow removal with one or more applications of D/2 as stated above. The surface will become cleaner over time as the subsurface biological growth dies and releases.

Light biological deposits may be removed with a D/2 dilution of water from 1:1 to 1:4 parts water by volume. Perform tests to determine effectiveness of various dilutions. Follow testing with application of D/2 as stated above.

Safety Information

D/2 Biological Solution is non-mutagenic, and contains no carcinogenic compounds as defined by NTP, IARC, or OSHA. It is considered essentially non-toxic by swallowing, as it has an oral LD50 of greater than 5.0 g/kg of body weight. No special ventilation is required during use.

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Packaging and Coverage

D/2 Biological Solution is available in 32 ounce spray bottle, 1 gallon and 5 gallon containers, and 55 gallon drums.

The area that can be treated with one gallon of D/2 will vary considerably as a function of the nature and extent of biological deposits, as well as the physical characteristics of the surface.

Typical coverage to remove medium deposits will vary from 250 to 350 square feet per gallon.

Cathedral Stone® Products, Inc. 7266 Park Circle Drive, Hanover Maryland 21076
(800) 684-0901 FAX: (410) 782-9155 WEBSITE: www.cathedralstone.com

Cathedral Stone ® Products D/2 Biological Solution

D/2 Biological Solution
Page 2

Technical Data

Physical Form . . . . Transparent, low viscosity liquid
Color . . . . Almost colorless
pH 9.5
Specific Gravity 1.01g/cc
Solubility in Water . . . . Complete
Vapor Pressure . . . . 25 mm Hg @ 20°C

Notice: The information contained herein is based on our own research and the research of others, and it is provided solely as a service to help users. It is believed to be accurate to the best of our knowledge. However, no guarantee of its accuracy can be made, and it is not intended to serve as the basis for determining this product's suitability in any particular situation. For this reason, purchasers are responsible to make their own tests and assume all risks associated with using this product.

11/2008

Cathedral Stone® Products, Inc. 7266 Park Circle Drive, Hanover Maryland 21076
(800) 684-0901 FAX: (410) 782-9155 WEBSITE: www.cathedralstone.com

APPENDIX B: MANUFACTURERS DATA SHEETS AND MATERIAL SAFETY DATA SHEETS

Cathedral Stone ® Products D/2 Biological Solution

Material Safety Data Sheet: **D/2 BIOLOGICAL SOLUTION**
Version No. 24005 Date of Issue: March 2008 *ANSI-Z400.1-2003 Format*

Section 1: PRODUCT & COMPANY IDENTIFICATION

Product Name: D/2 Biological Solution

Exclusively Distributed By:
Cathedral Stone® Products, Inc.
7266 Park Circle Drive
Hanover, MD 21076
Telephone: 410-782-9150
Fax: 410-782-9155

Manufactured By:
Sunshine Makers, Inc.
15922 Pacific Coast Highway
Huntington Harbour, CA 92649
Telephone: 800-228-0709
Fax: 562-592-3830

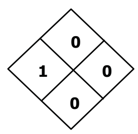
Emergency Phone: Chem-Tel 24-Hour Emergency Service: 800-225-3924

Use of Product D/2 Biological Solution is an easy-to-use liquid that aids in the removal of a broad spectrum of soils. It is designed for use on outdoor sculpture, monuments, decorative fountains, stone, brick, terra cotta, concrete, stucco, and other architectural surfaces.

Section 2: HAZARDS IDENTIFICATION

D/2 Biological Solution is a colorless liquid with a very faint detergent-like odor. It is non-flammable, non-combustible, non-explosive, and non-reactive.

Hazard Rating (NFPA/HMIS)
Health = 1* Reactivity = 0
Fire = 0 Special = 0
* Mild eye irritant, non-mutagenic and non-carcinogenic



Rating Scale
0 = Minimal 1 = Slight 2 = Moderate
3 = Serious 4 = Severe

Eye Contact: Eye Irritant.

Skin Contact: Prolonged skin contact with D/2 Biological Solution may irritate the skin. Repeated daily application to the skin without rinsing, or continuous contact of D/2 Biological Solution on the skin may lead to irritation.

Ingestion: Essentially non-toxic. May cause stomach or intestinal upset if swallowed.

Inhalation: No adverse effects expected under typical use conditions. Adequate ventilation should be present when using D/2 Biological Solution over a prolonged period of time. Open windows or ventilate via fan or other air-moving equipment if necessary. Mucous membranes may become irritated by concentrate mist.

Carcinogens: No ingredients are listed by OSHA, IARC, or NTP as known or suspected carcinogens.

Medical Conditions: No medical conditions are known to be aggravated by exposure to D/2 Biological Solution.

Section 3: COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients	CAS Number	OSHA PEL ACGIH TLV
Surfactants	Proprietary	None established
Wetting Agents	Proprietary	None established
Buffers	Proprietary	None established

Section 4: FIRST AID MEASURES

If in Eyes: Immediately rinse the eye with large quantities of cool water; if present, contact lenses should be removed after 5 minutes of rinsing; continue rinsing 10-15 minutes more. Both upper and lower lids should be lifted to facilitate thorough rinsing.

If on Skin: Minimal effects, if any, from diluted product; rinse skin with water, rinse shoes and launder clothing before reuse. -Reversible reddening may occur in some dermal-sensitive users; thoroughly rinse area.

If Inhaled: Use in well-ventilated area, or use adequate protection from inhaling mist during spray applications. Prolonged exposure of workers to concentrate-mist during spray application may cause mild irritation of nasal passages or throat. If this happens, relocate workers to fresh air.

If Ingested: Give several glasses of milk or water to dilute; do not induce vomiting. If stomach upset occurs, consult physician.

Material Safety Data Sheet: D/2 BIOLOGICAL SOLUTION

APPENDIX B: MANUFACTURERS DATA SHEETS AND MATERIAL SAFETY DATA SHEETS

Cathedral Stone ® Products D/2 Biological Solution

Material Safety Data Sheet: **D/2 BIOLOGICAL SOLUTION**
Version No. 24005 Date of Issue: January 2007 *ANSI-Z400.1-2003 Format*

Section 11: TOXICOLOGICAL INFORMATION

Toxicity Data: Available from relevant laboratory testing of ingredients or similar mixtures.

Acute Toxicity:	Oral LD_{50}: >2.0 g/kg body weight Dermal LD_{50}: Not estimated
Eye Irritation:	With or without rinsing with water, the irritation scores in rabbits at 24 hours did not exceed 17 (mild irritant) on a scale of 110 (extremely irritating); all scores were normal at seven days.
Dermal Irritation:	In a standard test on rabbits, mild irritation was found at 72 hours; well-defined reddening was observed at 7 and 14 days after exposure.
Dermal Sensitization:	No allergic reactions occurred in guinea pigs treated with D/2 Biological Solution.
Carcinogenicity:	D/2 Biological Solution contains no carcinogenic compounds as defined by the National Toxicology Program (NTP), the international Agency for Research on Carcinogens (IARC), or the Occupational Health and Safety Administration (OSHA).

Section 12: ECOLOGICAL INFORMATION

Biodegradability:	All components are inherently biodegradable.
Ecotoxicity:	Not Tested.

Section 13: DISPOSAL CONSIDERATIONS

Unused Product:	* Dilute with water 1:10 (1 part D/2 Biological Solution to 10 parts water) and dispose by sanitary sewer.
Used Product:	*Used product may be hazardous depending on the cleaning application and resulting contaminants.
Empty Containers:	*Triple-rinse with water and offer for recycling if available. Otherwise, dispose as non-hazardous waste.

*Dispose of used or unused product, and empty containers in accordance with the local, State, Provincial, and Federal regulations for your location. Never dispose of used degreasing rinsates into lakes, streams, and open bodies of water or storm drains.

Section 14: TRANSPORT INFORMATION

IATA Proper Shipping Name: Detergent solution Hazard Class: Non hazardous

Section 15: REGULATORY INFORMATION

*Reportable components: None. The U.S. Environmental Protection Agency (EPA) has determined that propylene glycol ethers are not included within the listed category "glycol ethers" under either EPCRA §313 Toxic Release Inventory or Clean Air Act §112 Hazardous Air Pollutants (both lists include only ethylene glycol ethers). Nor are propylene glycol ethers included in the various EPA Resource Conservation and Recovery Act, and Clean Water Act lists, nor the California Proposition 65 lists.

All components are listed on: EINECS and TSCA Inventory
No components listed under: Clean Air Act Section 112

RCRA Status:	Not a hazardous waste.	CERCLA Status:	No components listed
TSCA TRI Reporting:	Not required / Not listed	CA PROP. 65 Status:	No components listed

Section 16: OTHER INFORMATION

For Safety Information, Sales Applications and Availability contact:

CATHEDRAL STONE® PRODUCTS, INC.
7266 Park Circle Drive, Hanover, MD 21076
Telephone: 410-782-9150 Fax: 410-782-9155

DISCLAIMER: All information appearing herein is based upon data obtained by the manufacturer and recognized technical sources. Judgments as to the suitability of information herein for purchaser's purposes are necessarily purchaser's responsibility. Therefore, although reasonable care has been taken in the preparation of this information, Sunshine Makers, Inc. or its distributors extends no warranties, makes no representations and assumes no responsibility as to the suitability of such information for application to purchaser's intended purposes or for consequences of its use.

APPENDIX B: MANUFACTURERS DATA SHEETS AND MATERIAL SAFETY DATA SHEETS

PROSOCO, Inc. Sure Klean® Heavy Duty Restoration Cleaner

SURE KLEAN®

PROSOCO
SINCE 1939

Heavy Duty Restoration Cleaner

concentrated carbon & pollution remover

DESCRIPTION AND USE

Sure Klean® Heavy Duty Restoration Cleaner is a concentrated acidic cleaning compound for the removal of heavy atmospheric staining from unpolished masonry. Used properly, Heavy Duty Restoration Cleaner dissolves heavy carbon and many other stains commonly found on masonry buildings in highly polluted areas. Dilute with water to produce a cost-effective, general-purpose restoration cleaner for brick, granite, sandstone, slate, terra cotta and many other masonry surfaces.

ADVANTAGES

- **Cost-effective concentrate reduces shipping, storage and container disposal costs.**
- **Proven effective for cleaning the dirtiest buildings.**
- **Safer than sandblasting. Will not damage masonry when properly used.**

Limitations

- Repeated application, or use when diluted with less than three parts fresh water, may damage some masonry surfaces. Use Sure Klean® Light Duty Restoration Cleaner or Sure Klean® Restoration Cleaner where possible.
- Not for interior use. Use Sure Klean® Light Duty Restoration Cleaner.
- Not suitable for polished stone surfaces. Use Sure Klean® Light Duty Restoration Cleaner.

Heavy Duty Restoration Cleaner is recommended for these substrates. Always test. Coverage is in sq.ft./m. per gallon of concentrate.

Substrate	Type	Use?	Coverage
Architectural Concrete Block	Burnished	no	NA
	Smooth	no	
	Split-faced	no	
	Ribbed	no	
Concrete	Brick	no	NA
	Tile	no	
	Precast Panels	no	
	Pavers	no	
	Cast-in-place	no	
Fired Clay	Brick	**yes**	125-400 sq.ft. 28-47 sq.m.
	Tile	**yes**	
	Terra Cotta	**yes**	
	Pavers	**yes**	
Marble, Travertine, Limestone	Polished	no	NA
	Unpolished	no	NA
Granite	Polished	no	NA
	Unpolished	**yes**	100-175 sq.ft. 9-16 sq.m.
Sandstone	Unpolished	**yes**	100-175 sq.ft. 9-16 sq.m.
Slate	Unpolished	**yes**	100-175 sq.ft. 9-16 sq.m.

Repeated applications may damage some surfaces.
Always test to ensure desired results. Coverage estimates depend on surface texture and porosity.

TYPICAL TECHNICAL DATA

FORM: Clear liquid
SPECIFIC GRAVITY: 1.132
pH: 2.2 @ 1:3 dilution
WT/GAL: 9.42 lbs.
ACTIVE CONTENT: NA
TOTAL SOLIDS: NA
FLASH POINT: NA
FREEZE POINT: ND
SHELF LIFE: 3 years in tightly sealed, unopened container

PREPARATION

Protect people, vehicles, property, plants and all nonmasonry surfaces from cleaner, rinse, fumes, and wind drift. Protect and/or divert auto and pedestrian traffic. This product is corrosive, etches glass and architectural aluminum and is harmful to wood, painted surfaces and foliage.

Complete cleaning before installing windows, doors, hardware, light fixtures, roofing materials and any other nonmasonry items. If such fixtures have been installed, protect before application of cleaner. All caulking and sealant materials should be in place and thoroughly cured before cleaning begins.

Avoid exposing building occupants to fumes. On occupied buildings, cover all windows, air intakes and exterior air conditioning vents. Shut down air handling equipment during cleaning and until surfaces are thoroughly dry. Fumes attack glass, metal and all other acid-sensitive surfaces.

Surface and Air Temperatures

Cleaning when temperatures are below freezing or will be overnight may harm masonry. Best cleaning results are obtained when air and masonry surface temperatures are 40°F (4°C) or above. If freezing conditions exist prior to application, let masonry thaw.

Equipment

Apply using an acid-resistant brush or low-pressure airless spray equipment with a maximum 50 psi. Equipment should be fitted with acid-resistant hoses and gaskets to avoid discoloration. Pressure spray above 50 psi drives the chemicals deep into the surface, making it difficult to rinse completely, and may result in staining.

APPENDIX B: MANUFACTURERS DATA SHEETS AND MATERIAL SAFETY DATA SHEETS

PROSOCO, Inc. Sure Klean® Heavy Duty Restoration Cleaner

Rinse with enough water and pressure to flush spent cleaner and dissolved soiling from the masonry surface and surface pores without damage. Inadequate rinsing leaves residues which may stain the cleaned surface.

Masonry-washing equipment generating 400-1000 psi with a water flow rate of 6-8 gallons per minute is the best water/pressure combination for rinsing porous masonry. Use a 15-45° fan spray tip. Heated water (150-180°A; 65-82°C) may improve cleaning efficiency. Use adjustable equipment for reducing water flow-rates and rinsing pressure as needed for sensitive surfaces.

Rinsing pressures greater than 1000 psi and fan spray tips smaller than 15° may permanently damage sensitive masonry. Water flow-rates less than 6 gallons per minute may reduce cleaning productivity and contribute to uneven cleaning results.

Storage and Handling
Store in a cool, dry place with adequate ventilation. Always seal container after dispensing. Do not alter or mix with other chemicals. Published shelf life assumes upright storage of factory-sealed containers in a dry place. Maintain temperature of 45-100°A (7-38°C). Do not double stack pallets. Dispose of unused product and container in accordance with local, state and federal regulations.

APPLICATION

Before use, read "Preparation" and "Safety Information."

ALWAYS TEST each type of surface and stain before overall application to ensure suitability and desired results. Test using the following application procedures. Let test area dry thoroughly before inspection and approval.

Dilution
Heavy Duty Restoration Cleaner must be diluted with fresh water before application. Aailure to dilute may result in bleaching of the masonry's natural color. When diluting, always pour cold water into bucket first, then carefully add product. Acidic materials will attack metal. Use polyethylene or polypropylene buckets only.

For porous masonry, dilute one part concentrate to 3 parts water, depending on test results.

For nonporous masonry (glazed brick, terra cotta), dilute one part concentrate to 4 to 6 parts water, depending on test results.

Application Instructions
1. Working from the bottom to the top, prewet the surface with clean water.
2. Apply the cleaner using a brush or low-pressure spray.
3. Let the cleaning solution stay on the surface for 3 to 5 minutes. Reapply. Gently scrub heavily soiled areas. Do not let cleaner dry on the surface. If drying occurs, lightly wet treated surfaces with fresh water and reapply in a gentle scrubbing manner.
4. Rinse with low-pressure flood rinse to remove initial acidic residue with minimum risk of wind drift.
5. Rinse thoroughly using high-pressure spray, from the bottom of the treated area to the top covering each section of the surface with a concentrated stream of water. NOTE: To avoid streaking, keep wall below wet and rinsed free of cleaner and residues.

Cleanup
Clean tools and equipment using fresh water.

SAFETY INFORMATION

Sure Klean® Heavy Duty Restoration Cleaner is a concentrated, acidic cleaner designed and labeled for professional use. This product may damage glass and a variety of common construction materials and has safety issues common to corrosive materials. Use appropriate safety equipment and job site controls during application and handling. Read the full label and MSDS for precautionary instructions before use.

First Aid
Ingestion: If conscious, give large amounts of milk or water and call a physician, emergency room or poison control center immediately. Do not induce vomiting.

Eye Contact: Rinse eyes and under lids thoroughly for 15 minutes. Get immediate medical assistance.

Skin Contact: Remove contaminated clothing and rinse thoroughly for 15 minutes. Immerse exposed area in 0.13% Zepharin Chloride or apply 2.5% Calcium Gluconate gel if available. Get medical attention. Launder contaminated clothing before reuse.

Inhalation: Remove to fresh air. Give artificial respiration if not breathing. Get immediate medical attention.

24-Hour Emergency Information: INFOTRAC at 800-535-5053

WARRANTY

The information and recommendations made are based on our own research and the research of others, and are believed to be accurate. However, no guarantee of their accuracy is made because we cannot cover every possible application of our products, nor anticipate every variation encountered in masonry surfaces, job conditions and methods used. The purchasers shall make their own tests to determine the suitability of such products for a particular purpose.

PROSOCO, Inc. warrants this product to be free from defects. **Where permitted by law, PROSOCO makes no other warranties with respect to this product, express or implied, including without limitation the implied warranties of merchantability or fitness for particular purpose**. The purchaser shall be responsible to make his own tests to determine the suitability of this product for his particular purpose. PROSOCO's liability shall be limited in all events to supplying sufficient product to re-treat the specific areas to which defective product has been applied. Acceptance and use of this product absolves PROSOCO from any other liability, from whatever source, including liability for incidental, consequential or resultant damages whether due to breach of warranty, negligence or strict liability. This warranty may not be modified or extended by representatives of PROSOCO, its distributors or dealers.

CUSTOMER CARE

Factory personnel are available for product, environment and job-safety assistance with no obligation. Call 800-255-4255 and ask for Customer Care - technical support.

Factory-trained representatives are established in principal cities throughout the continental United States. Call Customer Care at 800-255-4255, or visit our web site at www.prosoco.com, for the name of the Sure Klean® representative in your area.

APPENDIX B: MANUFACTURERS DATA SHEETS AND MATERIAL SAFETY DATA SHEETS

PROSOCO, Inc. Sure Klean® Heavy Duty Restoration Cleaner

MATERIAL SAFETY DATA SHEET **PROSOCO, Inc.**

I PRODUCT IDENTIFICATION

MANUFACTURER'S NAME AND ADDRESS:	PROSOCO, Inc. 3741 Greenway Circle Lawrence, KS 66046	**EMERGENCY TELEPHONE NUMBERS:** **8:00 AM – 5:00 PM CST Monday-Friday:** **NON-BUSINESS HOURS (INFOTRAC):**	 785-865-4200 800/535-5053

PRODUCT TRADE NAME: **Sure Klean® Heavy Duty Restoration Cleaner**

II HAZARDOUS INGREDIENTS

CHEMICAL NAME	(COMMON NAME)	CAS NO.	NFPA CODE	ACGIH TLV/TWA	OHSA PEL/TWA
Glycolic Acid	(Hydroxyacetic Acid)	79-14-1	3,0,0,-	Not listed	Not listed
Hydrofluoric Acid	(Hydrogen Fluoride)	7664-39-3	4,0,1,-	3 ppm	3ppm
Nonionic Surfactant	(Nonionic Surfactant)	*	3,1,0,-	Not listed	Not listed
Orthophosphoric Acid	(Phosphoric Acid)	7664-38-2	3,0,1,-	1 mg/m^3	1 mg/m^3
B-Hydroxy-Tricarboxylic Acid, 2 Hydroxy	(Citric Acid)	77-92-9	Unknown	Not listed	Not listed

* Exact chemical identity withheld as Trade Secret pursuant to OSHA regulations.

III PHYSICAL DATA

	BOILING POINT (°F)	VAPOR PRESSURE (mm Hg)	VAPOR DENSITY (Air = 1)	EVAPORATION RATE (Butyl Acetate = 1)
Glycolic Acid	234°F	17.5 (68°F)	1.7	N/A
Hydrofluoric Acid	224°F	27 (70°F)	2.21 @ 70°F	N/A
Nonionic surfactant	360°F	< 0.01 (36°F)	> 1	< 0.01
Orthophosphoric Acid	243°F	0.0285 (36°F)	N/A	N/A
B-Hydroxy-Tricarboxylic Acid, 2 Hydroxy	> 212°F	N/A	N/A	< 1

	SPECIFIC GRAVITY	SOLIBILITY IN WATER	APPEARANCE AND ODOR
Heavy Duty Restoration Cleaner	1.132	Complete	Clear liquid with irritating odor.

IV FIRE AND EXPLOSION HAZARD DATA

EMERGENCY OVERVIEW

Sure Klean® Heavy Duty Restoration Cleaner is a highly corrosive material that may cause damage to skin, eyes and mucous membranes. Burns from this product may not be immediately painful or evident. Exposures to large skin areas may be fatal. Wear proper safety equipment to avoid exposure. Wash immediately after exposure. Exposures require fluoride specific treatment.

FLASH POINT (METHOD): Not applicable.

FLAMMABLE LIMITS: No applicable information found.

EXTINGUISHING MEDIA: No applicable information found.

PROSOCO, Inc. Sure Klean® Heavy Duty Restoration Cleaner

SPECIAL FIRE FIGHTING PROCEDURES: Wear NIOSH/MSHA approved self-contained breathing apparatus with a full face piece operated in pressure demand or other positive pressure mode and full body protective clothing when fighting fires. Generates heat upon addition of water with possible spattering. Water may be used to keep fire-exposed containers cool until fire is out. Water or foam may cause frothing which can be violent and endanger the life of the fire fighter, especially if sprayed into containers of hot, burning liquid.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Reacts with most metals to release hydrogen gas which can form explosive mixtures with air. Flammable and explosive mixtures are unlikely except in poorly ventilated or confined areas.

V HEALTH HAZARD DATA

PRIMARY ROUTES OF EXPOSURE: Skin, eyes, inhalation.

CARCINOGEN INFORMATION: Not listed (OSHA, IARC, NTP).

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: No applicable information found.

EFFECTS OF OVER EXPOSURE: Causes severe damage to eyes. Causes burns to skin. Breathing of mist or dust can damage nasal and respiratory passages. Swallowing results in damage to mucous membranes and deep tissue; can result in death on penetration to vital areas. Bronchitis, pulmonary edema and chemical pneumonitis may occur from inhalation of vapors or mists.

EYE CONTACT: Liquid or concentrated vapors can cause eye irritation, severe burns and permanent damage.

SKIN CONTACT: Vapors, mists and liquid are corrosive to the skin. Vapors will irritate the skin. Liquid and mists will burn the skin. Prolonged liquid contact will burn or destroy surrounding tissue. Exposure to large skin areas can cause potentially fatal hypocalcaemia. Burns from this product may be delayed as long as 24 hours after initial exposure.

INHALATION: Vapors and mists are corrosive to the nose, throat, and mucous membranes. Bronchitis, pulmonary edema, and chemical pneumonitis may occur. Irritation, coughing, chest pain, and difficulty in breathing may occur with brief exposure. Prolonged exposure may result in more severe irritation and tissue damage.

INGESTION: Vapors, mists, and liquid are corrosive to the mouth and throat. Swallowing the liquid burns the tissues, causes abdominal pain, nausea, vomiting and collapse. Ingestion can cause death.

EMERGENCY AND FIRST AID PROCEDURES:

EYE CONTACT: Irrigate eyes for 15-30 minutes with water, keeping eyelids apart and away from eyeballs during irrigation. Get medical attention immediately, preferably an eye specialist. If a physician is not immediately available, apply 1 or 2 drops of 0.5% Pontocaine® Hydrochloride solution followed by a second irrigation for 15 minutes. Do not use the solution described for skin treatment.

Irrigate with 1% calcium gluconate in normal saline for 1 to 2 hours to prevent or lessen corneal damage.

SKIN CONTACT: Immediately place under a safety shower or wash the burned area with a water hose. Remove all contaminated clothing while washing continuously. Keep washing with large amounts of water for 15 to 20 minutes. After washing, the burned area should be immersed in a solution of 0.13% Zephiran® Chloride. If immersion is not practical, towels should be soaked with the above solution and used as compresses for the burned area. The compresses should be changed every 2 minutes and continue until pain is relieved, up to 4 to 6 hours. Alternatively, 2.5% calcium gluconate gel may be promptly and continuously massaged into the burned area until the pain is relieved. Seek medical attention immediately for all burns.

INHALATION: Immediately remove to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration, but **NOT** mouth-to-mouth.

INGESTION: Drink large amounts of water to dilute. **DO NOT** induce vomiting. Several glasses of milk or several ounces of milk of magnesia may be given for their soothing effect. Seek medical attention.

NOTE TO PHYSICIAN: For larger burns, if pain is not relieved by soaking in Zephiran® or by calcium gluconate gel, inject sterile 5% aqueous calcium gluconate solution subcutaneously beneath, around, and in the burned area. Initially use no more than 0.5 cc per square centimeter and do not distort appearance of skin. If pain is not completely relieved, additional treatment is indicated. (5% calcium gluconate solution may be prepared by mixing equal parts of 10% calcium gluconate solution with normal saline. For burns of large skin areas, (greater than 25 square inches), for ingestion and for significant inhalation exposure, severe systemic effects may occur. Monitor and correct for hypocalcemia, cardiac arrhythmias, hypomagnesemia and hyperkalemia. In some cases renal dialysis may be indicated. For certain burns, especially of the digits, use of intra-arterial calcium gluconate may be indicated. Use of local anesthetics is not recommend, as effectiveness of treatment is indicated by cessation of pain.

VI REACTIVITY DATA

STABILITY: Stable.

CONDITIONS TO AVOID: Contact with strong bases (alkali), can cause violent reaction generating large amounts of heat. Avoid heat, sparks, or open flame.

INCOMPATIBILITY (MATERIALS TO AVOID): Alkaline materials, metals, oxidizing materials, cyanides, sulfides, combustible materials, organic peroxides, strong reducing agents, carbides, chlorates, nitrates, picrates, fulminates and reducing materials.

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS: Carbon monoxide, carbon dioxide, hydrogen when in contact with metal. May release sulfur dioxide, hydrogen cyanide, or hydrogen sulfide.

VII SPILL OR LEAK PROCEDURES

SPILL, LEAK, WASTE DISPOSAL PROCEDURES: Provide adequate ventilation. Evacuate immediate area where concentrated fumes are present. Cleanup personnel must wear proper protective equipment. Contain spilled material with dikes, etc., and prevent runoff into ground and surface waters or into sewers.

Dilute spilled product with water to reduce fuming during cleanup work and from reaction with neutralizing substances. Spills and leaks should be neutralized by pouring dry soda ash or lime over the affected area to absorb as much liquid as possible. Allow powdered material to remain on spill for five to ten minutes and flush thoroughly with water. Neutralized material, both liquid and solid, must be recovered for proper disposal.

WASTE DISPOSAL METHODS: Recovered solids or liquids may be disposed of in a permitted waste management facility. Neutralized materials may be discharged to a sanitary sewer with approval of the receiving treatment plant. Typical pH range of 6-10 is generally considered appropriate for discharge. Consult federal, state, and/or local authorities for approved procedure. For additional information regarding handling and disposal of rinse-water, please review Technical Bulletin 200-CW “Controlled Handling of Cleaning Wastewater”. Empty containers must be triple rinsed before disposal in a permitted sanitary landfill. Check local restrictions.

VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: If you notice irritation or if air monitoring indicates concentrations above the TLV for hydrogen fluoride, wear a NIOSH approved half-mask respirator with acid vapor cartridges. Exposures to phosphoric acid above its TLV is unlikely because of its low vapor pressure. Supplied air is required for phosphoric acid exposures in excess of the TLV. A dust/mist respirator should be worn to avoid exposure to mists generated during application or removal of this product.

VENTILATION: Provide sufficient general and/or local exhaust ventilation to maintain exposure below the TLV.

PROTECTIVE CLOTHING: Wear acid-resistant neoprene or PVC rain suit and rubber boots with protective pants outside.

PROTECTIVE GLOVES: Rubber gloves with gauntlets.

EYE PROTECTION: Chemical splash goggles and/or full face shield. Do not wear contact lenses because they may contribute to the severity of an eye injury.

OTHER PROTECTIVE EQUIPMENT: An eyewash and safety shower should be nearby and ready for use.

IX SPECIAL PRECAUTIONS

WORK PRACTICES: Proper work practices and planning should be utilized to avoid contact with workers, passersby, and non-masonry surfaces. Do not atomize during application. Beware of wind drift. Wind-drift hazards may be diminished by pre-rinsing with low-pressure water before pressure washing. Divert pedestrian traffic around work areas. See the Product Data sheet and label for specific precautions to be taken during use. Smoking, eating and drinking should be discouraged during the use of this product. Wash hands after handling or use.

PROSOCO, Inc. Sure Klean® Heavy Duty Restoration Cleaner

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Use proper safety equipment (see section VIII) when handling. Store in a cool, well-ventilated area. Separate from oxidizing agents, nitric acid, alkalis, chlorates, sulfides, etc. (see section VI). Store in proper acid-resistant containers such as rubber-lined steel, glass, or plastic. Emptied containers retain product residues (vapor, liquid, and/or solid). All hazard precautions given in this data sheet must be observed.

OTHER PRECAUTIONS: Do not get in eyes, on skin or on clothing. Can cause injury or blindness. Avoid breathing mist or vapor. Provide ventilation sufficient to limit employee exposure below OSHA permissible limit. Do not take internally. Wash thoroughly after handling. Empty containers should be treated as if they were full.

X REGULATORY INFORMATION

SHIPPING: The proper shipping description for this product is: **UN2922, Corrosive Liquid, Toxic, N.O.S. (Hydrofluoric and Phosphoric Acid), 8(6.1), II** when shipped in its original factory packaging. This product and packaging combination is not allowed in air transport. Special packaging is required for shipping by small parcel carriers and is limited to 1 quart per package. Call PROSOCO's Regulatory Department for additional information.

NATIONAL MOTOR FREIGHT CLASSIFICATION: 45615 Sub 5 Class Rate: 92.5

SARA 313 REPORTABLE:

CHEMICAL NAME	CAS	UPPERBOUND CONCENTRATION % BY WEIGHT
Hydrogen Fluoride	**7664-39-3**	**20%**

CALIFORNIA PROPOSITION 65: **This product contains no chemicals listed under California's Proposition 65.**

XI OTHER

MSDS Status:

Date of Revision: April 10, 2007

For Product Manufactured After: N/A – no product formulation change

Changes: Update Shipping Description (Section X) for Compliance with DOT Regulations

Item #: 20032

Approved By: Regulatory Department

DISCLAIMER:

The information contained on the Material Safety Data Sheet has been compiled from data considered accurate. This data is believed to be reliable, but it must be pointed out that values for certain properties are known to vary from source to source. PROSOCO, Inc. expressly disclaims any warranty express or implied as well as any liability for any injury or loss arising from the use of this information or the materials described. This data is not to be construed as absolutely complete since additional data may be desirable when particular conditions or circumstances exist. It is the responsibility of the user to determine the best precautions necessary for the safe handling and use of this product for his unique application. This data relates only to the specific material designated and is not to be used in combination with any other material. Many federal and state regulations pertain directly or indirectly to the product's end use and disposal of containers and unused material. It is the purchaser's responsibility to familiarize himself with all applicable regulations.

DATE OF PREPARATION: April 10, 2007

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